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POST-DISRUPTION SUPPLY CHAIN RECOVERY FOLLOWING A DISRUPTION IN AN EPIDEMIOLOGICAL CONTEXT: MERGING DIMENSIONS OF RESILIENCE AND SUSTAINABILITY IN SUPPLY CHAIN – A CASE STUDY INSPIRED BY THE MOROCCAN CONTEXT

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Abstract. The resilience between practitioners and academics is a central concern of policy makers worldwide. Currently, the context driven by the occurrence of disruptive low-occurrence, high-severity hazards has accelerated investment in resilient mitigation and adaptation programmes with spillover effects on low-certainty contexts. To ensure continuity in the management of flows, research programmes are attempting to model and simulate the effect of systemic risks on the resilience of supply chains that experience large variations in their lead times and delivery. The present study looks at the capabilities to improve recovery times in the presence of systemic risks before and during the occurrence of the Covid19 context. Then 35 systemic risk events are identified and prioritised using the Fuzzy AHP method and sequentially simulated using Fuzzy TOPSIS to assess the ability of the resilient and sustainable dimensions to mitigate and reduce the propagation of disruptive risks.

Keywords: Supply chain resilience; supply chain sustainability; spillover effect; systemic risks; Fuzzy AHP analytical hierarchy; Fuzzy TOPSIS ideal solution similarity order execution technique.

Résumé : La résilience, tant chez les praticiens que chez les universitaires, est au cœur des préoccupations des décideurs politiques du monde entier. Actuellement, le contexte marqué par la survenue de risques perturbateurs, peu fréquents mais d'une grande gravité, a accéléré les investissements dans des programmes de résilience axés sur l'atténuation et l'adaptation, avec des retombées sur des contextes présentant un faible degré de certitude. Afin d'assurer la continuité de la gestion des flux, des programmes de recherche tentent de modéliser et de simuler l'effet des risques systémiques sur la résilience des chaînes d'approvisionnement confrontées à d'importantes variations dans leurs délais de livraison et leurs livraisons. La présente étude examine les capacités à améliorer les délais de reprise en présence de risques systémiques avant et pendant la crise du Covid-19. Ensuite, 35 événements de risque systémique sont identifiés et classés par ordre de priorité à l'aide de la méthode AHP floue, puis simulés séquentiellement à l'aide de la méthode TOPSIS floue afin d'évaluer la capacité des dimensions de résilience et de durabilité à atténuer et à réduire la propagation des risques perturbateurs.

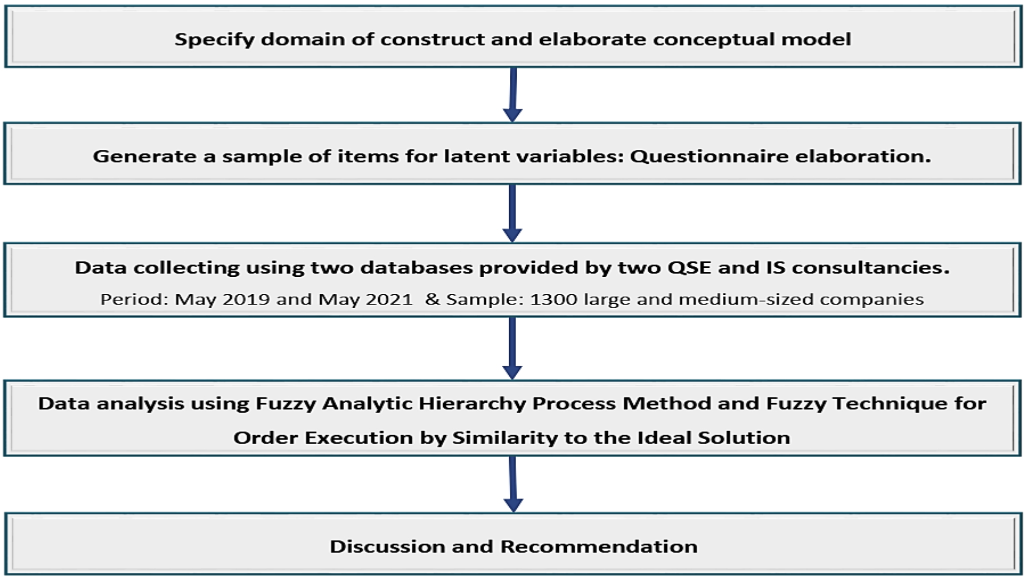
Mots-clés : Résilience de la chaîne d'approvisionnement; durabilité de la chaîne d'approvisionnement; effet de contagion; risques systémiques; hiérarchie analytique floue AHP; technique d'exécution de l'ordre de similarité des solutions idéales Fuzzy TOPSIS.

1. Introduction

Today's supply chains are characterised by complex designs that aim to align with customer trends (Pettit et al, 2010; Colicchia and Strozzi, 2012). Furthermore, the ability of supply chains to fulfil these strategic directions is dictated by their levels of understanding of the disruptions and vulnerabilities that prevail in their business contexts (Blackhurst et al., 2008; Lavastre et al., 2012). Often the form of response adopted by practitioners is to develop individual risk mitigation mechanisms and strategies unsuited to industrial supply chain contexts that remain ineffective in reducing and monitoring disruptive risks (Ponomarov and Holcomb 2009; Gligor and Holcomb 2012). In order to fill this gap, new areas of thinking are emerging that focus on developing resilient supply chain strategies that assess, reduce, mitigate, monitor, control and respond in the most efficient and cost-effective manner (Melnyk et al., 2010; Pettit et al., 2013; Abdel-Basset et al., 2019).

The present work is initiated by a systemic analysis of the existing literature review to assimilate the concepts, mechanisms, approaches and techniques of resiliencies, vulnerabilities and sustainability of supply chains to consolidate their competitive positions (Pettit et al., 2010; Ponis and Koronis, 2012). And on the other hand to review the homogeneity of the conceptual framing due to the divergent development of the theory and the multidisciplinarity of their application areas (Tukamuhabwa et al., 2015; Hohenstein et al., 2015; Hosseini et al., 2016; Datta, 2016; Ribeiro and Povoa, 2017; Macdonald et al., 2017; Kochan and Nowicki, 2018). Certainly, research on risk management and supply chain sustainability has experienced subsequent growth since the 2000s, with the potential to converge on theories specific to industrial contexts (Datta, 2016; Ribeiro and Povoa, 2017; Macdonald et al., 2017; Kochan and Nowicki, 2018). That explanatory and synthetic systems studies (Tranfield et al., 2003; Rousseau, 2008) with a contribution to the issues of risk propagation through the synergy offered by the complementarity of both resilient and sustainable capabilities remain a persistent concern in today's contexts of high uncertainty and complexity (Dolgui et al., 2019; Ivanov et al., 2019). So to frame future trends and directions leading to understanding the support of resilient and sustainable measures to absorb the effect of disruptive risks and vulnerabilities factors on the sustainable performance of supply chains that represent in the authors' sense (Tranfield et al., 2003; Rousseau, 2008; Soni and kodali 2011) the outcome of the framework explaining for any context their causes, contexts and consequences (Christopher & Peck, 2004; Chowdhury & Quaddus, 2017).

In this sense we find some literary research programs in question for the last two decades (Hosseini et al., 2015; Hohenstein et al., 2015; Ribeiro and Povoa, 2017; Macdonald et al., 2017). So through a literature review of 67 papers between 2000 and 2013, (Hohenstein et al, 2015) proposed for each stage of ex-ante and ex-post disturbance appropriate yield control measures based on proactive or reactive strategies. (Hosseini et al., 2015) out of 139 papers from 2000 to 2015 examined the quantification of resilience on engineering systems with a focus through a classification of qualitative and quantitative approaches. On a rather interesting program (Datta, 2016) studied through a literature review between 1996 and 2016, the possible proposals in linking the factors of vulnerabilities translated by the uncertainty and complexity of the environment to the resilience conditions of supply chains. On 2009 and 2016 the authors (Ribeiro and Povoa, 2017) drew attention to the lack of conceptualization works according to holistic frameworks that address the characteristics and elements of resilience of supply chains. And most recently a systemic analysis of a literature base of 228 articles between 2000 and 2017 (Kochan and Nowicki, 2018) proposed a typological framework of the content of the supply chain resilience literature. Indeed, this research programme aims to conduct an extensive review of the literature on supply chain resilience, vulnerability and sustainability between 1978 and 2020 to cover the full range of issues related to the assessment of the nature and location of systemic risk propagations, approaches to quantifying environmental uncertainty factors, resilience capacities and recovery measures in supply chains with high uncertainty and interrelated complexity (Blackhurst et al, 2017; El Abdellaoui and Pâché, 2019; Ivanov and Dolgui, 2019).



2. Literature review

2.1. Systemic disruptive risks and logistics performance as perceived by decision makers in industrial and service companies

2.1.1. Micro supply risk

Less serious incidents that have an impact on supply or logistics chains occur frequently. Examples include a heavy truck getting stuck in traffic while delivering goods to several stores, a sudden warehouse strike impeding factory supplies, a general failure in a supplier's information system impeding the planning of customer orders, and the list goes on and on. For instance, a buyer may get dissatisfied if a product they ordered online from an e-retailer becomes unavailable. Over 20 years ago, the problem of supply chain vulnerability first surfaced, especially in relation to the idea of resilience to external shocks at specific times (Sheffi and Rice, 2005; Ganguly et al., 2018). However, it is unclear how disruptive events affect supply chains' ability to compete. These occurrences can have a mild, severe, or even catastrophic impact on logistics performance. In order to best handle disruptive events, it is essential to establish a specialized strategy for managing supply chain operations risks (Blackhurst et al., 2017; El Abdellaoui and Pâché, 2019).

For many researchers, the phenomenon of risk and uncertainty remains a central concern for policy makers, as changes in the design and configuration of global supply chains make them potentially susceptible to systemic risk disruptions (Blackhurst et al., 2017) but at the same time a factor in competitive, value-creating competitiveness (Christopher et al, 2011; Gurnani and Gupta, 2014). Certainly this structural change increases the efficiency of supply chain operations through tight, dependent interconnections allowing for secure continuity in the steering of flows that result in balanced levels of performance and customer perceived value (Craighead et al, 2007). While this synergy relies on inter-organisational coordination, collaboration, integration and sharing approaches, it also relies on frameworks for dealing with, assessing and, above all, mitigating risks in supply chains with high levels of uncertainty (Trkman and McCormack, 2009; Olson et al., 2010; Zhao et al., 2013; Pettit et al., 2013). Yet, supply market uncertainties are seen as a source of vulnerability that generates financial loss, making sources of supply completely unavailable and varying with disruption times and the complex design of supply chain structures (Hendricks and Singhal, 2005; Manuj 2013; Yu and Goh, 2014; Chowdhury et al, 2017). Consequently impacts on the performance and logistical resource of all partners at different levels and interfaces of supply chains (Pettit et al, 2013; Lee and Pierson, 2011; Blackhurst et al, 2017).

Risks to supply chain efficiency that affect the logistics performance of partners are a major concern for decision makers. All risks pose the threat of disruptions that can have considerable economic and financial repercussions in terms of customer and/or shareholder value (El Abdellaoui and Moflih, 2017). It is therefore logical to highlight in the same framework of ideas (Davis, 1993; Wagner and Bode, 2008; William ho et al., 2015) the importance of addressing and evaluating the consequences of disruptive events and their propagations on normal performance levels in a cost-effective manner (Hosseini et al., 2019). In light of these theoretical advances, the assumption of the dynamic and systemic nature of supply chain disruptive risks and that the effects of micro and macro risks negatively impact logistics performance must always be assessed and prioritised by decision makers in order to successfully integrate their resilient strategies based on absorptive, adaptive and restorative capacities (Hosseini et al., 2019; El Abdellaoui and Pâché, 2020). We operationalise upstream risk through disruptive events related to the buyer-supplier interface, the structure, constraints and environment of supply markets, capacity constraints related to the product and supplier (Giunipero and Eltantawy, 2004; Christopher and Peck 2004; Gaudenzi and Borghesi 2006; Manuj and Mentzer 2008; Wagner and Bode 2008; Zsidisin, 2010; Thun and Hoenig 2011; Hahn and Kuhn 2012; Samvedi and Chan 2013)

2.1.2. Micro demand risk

As supply chains become more intricate and globalized, businesses are working to become more agile in both their internal operations and their utilization of outside resources in order to remain competitive. Their susceptibility to disruptive occurrences tends to rise as a result. One of the most important occurrences is connected to final demand, which is unpredictable due to the extremely volatile nature of consumer behavior on the one hand and a policy of hypersegmentation and product differentiation adopted by businesses on the other (Blackhurst et al., 2017). Given that it has become increasingly difficult to predict consumer needs across several months or even weeks, the most obvious effect is an increase in supply chain disruption at the very downstream end of the supply chain (Jüttner, 2005). This is compounded by the dramatic shortening of the product life cycle, which has led to unprecedented instability in the final demand profile (Ghadge et al., 2012; Roberta et al., 2014). And that this results in a potential loss of commercial capacity for companies, resulting in increased inventory levels due to unreliable sales projections, and extremely difficult to control transport flows along the supply chain. Even more so, disruptive events are interrelated and that a low impact incident from a first tier supplier or secondary service provider potentially affects the perceived value to customers after its propagation along the supply chain (Wieland and Wallenburg, 2012; Blackhurst et al, 2017).

Therefore, downstream risk might significantly hinder logistical performance. This is mostly caused by failures associated with issues with product quality, the frequently challenging sharing of electronic data, and the extremely delayed development of collaboration and confidence. This outcome is consistent with a discovery in the purchasing and supply management literature that has been incorporated into the matrix proposed by (Kraljic, 1983; Bier et al., 2020). Demand risk is seen as being equally crucial to logistical success. Therefore, the ability of supply chain participants to organize logistics operations efficiently is significantly impacted by the end demand's more erratic and unpredictable nature. The supply chain decision-makers have been dealing with a series of major occurrences or those that are obviously the product of a hypersegmentation business plan for a number of years, which reflect this. The capacity of downstream supply chains to manage risk, in contrast, is to better position themselves and their competitors to alter disruption levels and vulnerability variables through efficient risk management programs to stabilize typical performance levels. Our ability to adapt to challenges posed by downstream logistics operations, the unpredictability of customer forecasts and trends, and intrinsic factors related to product, quality, cost, and value are how we operationalize downstream micro risk (Zsidisin 2003; Chopra and Sodhi 2004; Rao and Goldsby 2009; Tang and Musa, 2011; Ghadge et al., 2012; Wagner and Bode, 2012).

2.1.3. Micro infrastructure risk

For efficient communication and sharing of information flows, members of the supply chain need a technological infrastructure that facilitates exchange. This infrastructure can of course be subject to disruptions that hamper the efficiency of the supply chain with repercussions on time, quality and cost (El Abdellaoui, 2018). For a very long time, the infrastructural dimension has favored investments in roads, ports, and airports to promote trade, especially from the standpoint of the transport economy. The focus currently is on the informational components associated to the monitoring of flows, even though this feature is still present and crucial for the growth of emerging nations. Thus, disruptive events that influence data transmission and the secure processing of information flows pose a clear threat to Industry 4.0's links between processes and businesses (Chopra and Sodhi, 2004; Pfohl et al., 2010; Kachi and Takahashi, 2011).

In addition, several researchers have analysed the capacity of integrated information flows to improve demand visibility and consequently the whip effect on downstream logistics chains. According to (Smaros et al., 2003), it can improve the efficiency of production and inventory control if demand visibility is partially improved. Others are interested in the ability of cyber attacks to potentially threaten all interfaces of supply chains. Building on this (Durowoju et al., 2012), it has been argued that the disruption in information flows in the case of collaborative sharing of production facilities, processes and operations creates unpredictable uncertainties and costs of retention. For example, the institutional sanctions on Huawei technology in 2019 and 2020 to use substances and solutions developed by US companies caused a 12% drop in business and 22% losses compared to the same first quarter of the previous year on its mobile and network solutions subsidiaries in China. This time, at the national level, US and French automakers doing business in Morocco in 2017 experienced significant data theft and were refused access to their IT infrastructures, which caused a complete halt to production and customer deliveries for many days. The proliferation of infrastructure concerns finally shows the supply chain's fundamental weakness, contradicting the reputation of huge corporations as experts in managing massive volumes of data (Manners-Bel 2017). The primary goal of international supply chains is also to invest in the privacy and security of their data (Craighead et al., 2007; Colicchia & Strozzi, 2012; Das, 2017).

In terms of logistics performance, disruptive incidents that compromise flow management are likewise viewed as dramatic. It is hardly unexpected that modern supply chains are more vulnerable to information systems given how dependent they are on technology. Big data management is increasingly important to Industry 4.0's success, therefore any downtime for IT systems will have a significant impact on lost production capacity and, more generally, will have a long-lasting impact on supply chain agility (Dolgui et al., 2018). As a result, the perceived sensitivity of logistics performance to transport risk is another facet of flow control that is primarily concerned with critical incidents related to product transport. And as noted by (Blackhurst et al., 2017; Ivanov and Dolgui, 2019), systemic disruptive events generate upstream and downstream spillover effects, thus compromising the ongoing efficiency of the supply chain. We therefore operationalise the concept of infrastructure risk through disruptive incidents related to the massive theft of infrastructure data and capabilities (Davis, 1993; De Oliveira et al., 2017; Deng et al., 2019; El Abdellaoui et al., 2022).

2.1.4. Micro transport and distribution risk

In order to consistently fulfill the requirements of guaranteeing continuity of flows at sufficient levels of service quality and timeliness in line with market expectations, product delivery plays a crucial role in logistics performance (Christopher and Holweg, 2011; Roberta et al., 2014). However, if disruptive events paralyze flows for varied lengths of time, transportation could also pose a problem (Wilson, 2007; Schoenherr and Harrison, 2008; Wagner and Neshat, 2010). And according to Chopra and Sodhi, 2004, any disruptions whose source does not include those of an external nature prevent the efficient flow of physical flows between different partners in a supply chain, thus generating potential losses of capacity and resources if they occur (Braunscheidel and Suresh, 2009; Blackhurst et al., 2011; Dolgui et al., 2020).

2.1.5. Macro ecological and socio-economic risk

En raison de la pression des coûts et des avantages concurrentiels, les entreprises adoptent des stratégies d'internationalisation, ce qui rend les chaines logistiques plus complexes, plus étendues mais plus lean aux risques venant de leurs environnements externes, vue que les capacités de production et les infrastructures logistique leurs sont très vulnérables. Ce type de risque désigne toutes les menaces de nature macroéconomique, notamment en matière politique, catastrophe naturelle, sociopolitique, culturelle, énergétique ou terroristes dont les effets sont dévastateurs pour les chaînes logistiques complexes de forte degré d'incertitude (Rudolf et Pâché, 2016 ; Levner et Ptuskin 2018). S'il y a une conclusion à laquelle la majorité des chercheurs et praticiens en gestion des risques de la chaîne logistique sont conscients, c'est que la capacité destructive des risques perturbateurs, externe ou macro de faible probabilité d'occurrence mais de forte degré d'impact en cas de leurs survenances peuvent faire disparaitre des chaines de valeurs mondiales et mettre dans des cas extrêmes l'économie mondiale en quarantaine (Fan et Svensson, 2018; El Abdellaoui, 2018; Hosseini et al., 2019).

Thus, the intense pressure on supply chains to meet their upstream and downstream challenges in terms of on-time delivery, distribution channel and storage optimisation as well as technological changes remains a persistent concern through further acceleration of decision making processes by ensuring dynamic flow management in accordance with (Faisal, 2009; Christopher et al, 2011; Tang et al., 2012). levels of inventory and sales. We also concur with findings (Jung et al., 2012) that show a strong relationship between industrial organization choices, long-term transportation costs, and the function of transportation in logistics performance in general. Despite the fact that the necessity of adding transportation and carriers in the definition of physical distribution services for consumers, as well as the detrimental impacts of service disruption brought on by disruptive events, such at the macro level (McKinnon, 2006). However, infrastructure risk is operationalised through incidents of failure of transport and distribution modes and choices and the integration and efficiency of service providers (McKinnon, 2006; Sawik, 2008; Olson and Wu 2010).

The current context helps to illustrate this observation, for example the chemical explosion in 2015 in Tianjin directly impacted the global automotive equipment chains of the seven leading manufacturers with a financial effect of 8 billion dollars in the medium term (BCI, 2017; Kumar et al., 2020). Similarly, wars and terrorist acts in Libya, Syria and Iraq as well as political crises with the departure of the United Kingdom from the European Union or economic sanctions in Iran and Turkey have weakened the national currencies with a loss of 20% of their exchange value and a negative impact on their trade balances (Khan et al. 2018). Another example is the failure of Egyptian currency liberalization and its critical effects on upstream and downstream supply chains. And most recently, the pandemic wave (SARS-CoV-1 and 2), which is characterised by long-term disruption and high uncertainty, requiring a three-year reserve of more than $50 trillion to revive the global economy. These examples show that the supply chain macro-environment generates disruptive events that have two different types of effects: (1) on the ability of supply chains to fully deploy strategic action over the long term and (2) on their capacity to recover from external shocks over the short to medium term (Sheffi and Rice, 2005; Mensah and Merkuryev, 2013). This necessitates a fresh conception of the supply chain sustainability decision environment (El Abdellaoui, 2017; Ivanov and Dolgui, 2020).

2.2. Complementarity between the interfaces of sustainability and resilience of supply chains

When designing supply chains, a special effort should be made to increase the level of control over their complexity and to detect potential causes of failure early (Skilton and Robinson, 2009; Scheibe and Blackhurst, 2018). Again, the nature of the failures and the structure of the systems represent unexpected but common faults of out-of-control operation resulting from the interplay of the dependency of the different interfaces and the interactive complexity of the supply chains (Wolf 2001). In this sense, efforts to design sustainable supply chains taking into account certain sustainability measures to increase the reliability of system safety are of great importance due to the inherent ability of supply chain structures and complexity to prevent failure detection and control (Skilton and Robinson, 2009; Weick and Sutcliffe, 2001).

This idea is of crucial importance as sustainable and resilient practices focused on efficiency offer a certain balance between their resilient capabilities that guarantee more reliability and their vulnerability factors due to the complexities and dynamic nature of disturbances influencing the validity of risk management tools. Therefore, this sustainability (Pettit et al, 2013; Ivanov et al, 2017) synonymous with safe system reliability will improve the detectability of failures, and the controllability of potential new sources of risk due to interactive complexity or dependence on other system interfaces. This somehow reduces uncertainty in the decision-making process as well as sustaining the sustainability of the competitive advantage that guides strategic action across the entire logistics system (Barney, 1991; Christopher, 2010; Camman and Guieu 2013; Calvi et al, 2014).

2.2.1. Supply chain performance

By posing the question of variation or control of supply chain performance when assessing the ability of sustainable and resilient measures to mitigate the propagating conditions and vulnerabilities of supply chains, one arrives exclusively at the theory of high reliability systems and complex systems. Certainly, the definitional framework we have chosen to form our concept is based on economic, ecological, operational and social aspects. This complex framework in the sense of the Triple Bottom of Line theory follows the reasoning adopted on our holistic conceptual model which requires a wider dimension of the variables that compose it. Therefore, the assessment of the interfaces of resilience and sustainability has been subject to both the combined typology of risks, the vulnerable environment overlay and of course the fundamental field of supply chain performance. This complementary homogeneity was also accompanied by five interrelated but complementary theoretical fields to capture the specificity of the framework and context studied. To better appreciate the controllability and coherence of complex supply chains in uncertain contexts, they need to adopt dynamic capability designs that are both responsive and adaptive to systemic disturbances causing loss of time, resources and goal attainment (Pâché and Paraponaris, 2006; William ho et al., 2015; El Abdellaoui & Paché, 2020).

Then the performance assessment has been enriched by the divergence of methods and measures selected and results generated through general or partial frameworks for the validation of theoretical reflections at industrial levels (Melnyk, Zobel et al., 2014; Song et al., 2018; Naoui et al., 2023). In this sense the resilience performance of logistics networks has been simulated by an inclusive probability and severity risk measure, before after a disruption context (Dixit et al., 2020). While organizational performance namely environmental, social, operational and competitiveness performance have been studied from the dimension of sustainable practices (Debadyuti Das, 2017) or the proactive dimension and resilient design quality to predict the operational vulnerability of dynamic supply chains. The authors (Hallikas et al., 2015; Brandenburg et al., 2016) have configured the overall financial, operational and environmental performance to discuss the issues of dynamic design of sustainable supply chains with economic and environmental risk reduction considerations. Similarly, variation in the performance of downstream supply chain operations has been analysed by the reactive and flexible ability to control changes in turnover speed and transaction cost (Ivanov et al., 2014; Schmidt 2015).

However, the absorptive capacity or resilient zone in the sense (Ambulkar et al., 2015; Pettit et al., 2015) allow for a reduction in the sensitivity of supply chains to systemic disruptions through a focus on organisational behaviour and knowledge management (Evrard Samuel, 2013; El Abdellaoui & Pache, 2019).

However, we operationalise the concept of supply chain performance according to a combined measurement scale that takes into account operational, social, ecological and economic aspects to broaden the scope of resilient and sustainable measures on specific supply chain structures. Thus, this scale encompasses: delivery time and reliability; customer order capacity; on-time delivery; flexibility of delivery plans; quality of products delivered; order fulfilment capacity and flexibility; integration of information systems; stock turns; logistics cost reductions; consolidation and size of warehouses; environmentally friendly product, packaging and process; and customer satisfaction (Gunasekaran et al, 2004; Rodrigues et al, 2004; Gunasekaran and Ngai, 2005; Kim et al, 2006; Green et al, 2008; Panayides and Venus Lun 2009; Hsiao et al, 2010; Darling and Wise, 2010; Gallmann and Belvedere, 2011; Forslund, 2012; Richardson, 2012; Roy and Beaulieu, 2013; Melnyk, Zobel et al, 2014).

2.2.2. Supply chain resilience

Our reasoning remains largely incubated by the foundations (Chopra and Sodhi 2004; Ponomarov and Holcomb, 2009) that envisage that today's highly uncertain environment requires capabilities that enable supply chains to survive, adapt, grow and recover quickly from disruptions. These capacities of absorption, mitigation and especially recovery remain exclusive to the resilient supply chain. It is defined as a preventive and reactive capacity acting before, during and after a disruption on the causes by reducing their probability of occurrence through active and early detection. And proactive during a disruption acting on the consequences by reducing their severity by maintaining the conditions of protection, safeguard, control and adjustment necessary for the continuity of operations for progressively sustainable levels of stability (Chopra & Sodhi, 2004; Chopra & Sodhi, 2014; El Abdellaoui et al., 2022).

Numerous studies use resilient techniques to lessen the impact of interruptions, manage risk factors, and determine the kind of tools that can be used to address upstream sources of risk while enhancing supply chain efficiency downstream (Mishra et al., 2016). While others prefer integrative frameworks that combine resilient measures like cooperation and integration, adaptability and anticipation, capacity and security, efficiency and visibility, response and recovery, robustness and responsiveness, information sharing, and sustainability in order to quantify their quantified on an uncertain environment (Soni et al., 2014; Dabhilkar et al., 2016; Ribeiro et al., 2017). The performance aspect has been extensively studied from a balance or flexibility perspective with frameworks that emphasize factors for enhancing and reducing both proactive downstream resilience and vulnerability (Bogataj & Bogataj, 2007; Jüttner and Maklan, 2011).

We recall that the majority of studies on resilient supply chains only explore the conceptualization of a limited number of their measures, failing which the present conceptual model attempts to address this concern with an advanced level of understanding of the phenomena of systemic risks by nature; source; causes and consequences of their propagations on contexts of high uncertainty. And thus focuses on another alternative rarely raised by researchers in the management of logistics operations by introducing high reliability systems and complexity theories as theoretical frameworks. To this end, we operationalise the concept in question according to a scale of measurement that is complementary to that of sustainable measures and that encompasses: flexibility and supply capacity; execution of distribution and transport operations; efficiency and visibility; adaptability and anticipation; dispersion and velocity; collaboration and integration; security; response and recovery; robustness and knowledge transfer (JPettit et al, 2015; Barroso et al, 2015; Brusset and Teller, 2016; Ivanov et al, 2017)

2.2.3. Supply chain sustainability

Supply chain sustainability as a field of thought has developed remarkably over the last two decades (Seuring and Gold, 2013; Fahimnia et al, 2015) with a particular focus on the sustainable design of operations and supply chains. Currently, the issue of adaptability and complementarity in the design of sustainable and resilient supply chains remains an interesting new research avenue for deploying more viable chains in which performance, sustainability and resilience remain stable in the face of disruptions, also balanced translated by resilient capabilities to keep vulnerability at manageable thresholds (Golicic and Smith, 2013; Cutter, 2013; Pettit et al, 2015; Gunasekaran et al., 2015; Ivanov et al, 2017). One of the issues justified in our study is the interconnectedness of performance, risk management and sustainability in our research area (Aqlan and Lam 2015; Ivanov, Tsipoulanidis and Schönberger 2017) and which we wish to assess the possible causal links between the concepts of risk, vulnerability, resilience and sustainability by arguing that sustainability ensures continuity of operations and reduces long-term risks (Fahimnia and Jabbarzadeh 2016; Giannakis and Papadopoulos 2016).

Indeed, to measure sustainability in supply chains we have framed it through the capacities of health and hospital institutions to ensure sustainable collaboration with their partners and patients, as well as the selection of distribution centres and sustainable partners adapting their systems to greener supply strategies. Consideration has also been given to the establishment of formalised risk management approaches and learning from experience processes as part of the contingency plans needed to capitalise on business continuity guidelines in the event of potential disruptions. Indeed, this theoretical perspective allows us to operationalise the concept in question through, orientation and business continuity; sustainable collaboration; product and process integration; green practices; risk management culture; coordination and trust; learning and knowledge transfer; ecological practice and technological progress (Morali and Searcy 2013; Beske et al, 2015; Alexander et al, 2014; Norazlan et al 2014; Hendrik and David 2016; Esfahbodi et al, 2016; Julia et al, 2016; Paulraj et al, 2017; Rajeev et al, 2017; Hong et al, 2017; Debadyuti Das 2017; Ivanov, 2017).

2.2.4. Resilience, vulnerability, risk, performance and sustainability

Therefore, resilience remains relevant, when conventional risk management fails to provide decision-makers with the dynamic means to deal with the uncertainty of their business contexts (Pettit et al., 2013; König and Spinler, 2016). Among these contributions (Heckmann et al., 2015) have analysed the ability of resilient strategies to reduce the consequences of disruptive incidents by considering risk as much as a primary dimension while vulnerability and resilience are aggregated to the impacts of systemic risks while improving the downstream performance of complex and tightly coupled supply chains (Perrow, 2004; Mishra et al., 2016) Furthermore, effective assessment of the impact of risks on supply chain performance helps decision makers to better design resilient supply chains based on insights gained through their perceptions of the disruption-sensitive environment (Juttner and Maklan, 2011; Ambulkar et al., 2015). The authors (Cardoso et al., 2015) studied the design of resilient supply chains allowing for a mitigation of downstream disruptive risks as well as an improvement of their performance over contexts of high uncertainty. By comparing supplier resilience levels, resilient performance criteria or supply chain resilience factors while assessing the ability of reactive and proactive strategies to control spillover conditions (Adtiya, 2014; Soni et al., 2014; Rajesh, 2015; Ivanov et al., 2015).

Other frameworks have looked at the optimal location or zone of balanced resilience where exposure and sensitivity to disturbances are controlled by the ability of resilient measures to keep them within acceptable thresholds designed by decision makers (Spiegel et al, 2012; Nikookar et al, 2014; Ambulkar et al, 2015). While the quantification and assessment of resilient and vulnerable factors have been empirically analysed on the issues of resilient supply chain design and planning, vulnerability assessment through cost, performance as well as environmental overlay indicators on low certainty contexts (Wagner et al, 2012; Vlajic et al, 2012; Chen et al, 2013; Ivanov and Dolgui, 2019).

Furthermore, when considering vulnerability, resilience and sustainability from a supply chain viability perspective, how and when disruptions propagate, ultimately affect supply chain performance conditioned by the design of sustainable resilient supply chains (Ivanov et al., 2018; Jabbarzadeh et al., 2018). In this sense, (Dabhilkar et al., 2016; Jain et., 2017) argue that the combinatorial adoption of resilient-sustainable practices in a dynamic way enhances the strengthening of resilience and management of disruptions under different highly complex and uncertain circumstances. Thus (Ivanov and Sokolov, 2019; Dubey et al., 2019) highlighted that information sharing, data analysis, organisational flexibility support proactive resilience of supply chains for effective proactive management of both systemic risks, operational complexities and internal vulnerabilities (Braunscheidel & Suresh, 2009; Brandon-Jones et al., 2014).

2.3. Towards delineating the contextual and disruptive factors of sustainable supply chains: Mediating and moderating variables in exploratory and confirmatory research models

Recently, researchers are devising new decision analysis frameworks based on the integrity and viability of supply chains to ensure sustainable resilience to the overlaying conditions of their internal environment and catastrophic degree of disruption of the external one (Ivanov and Dolgui, 2020). By keeping potential disruptions and contextual vulnerabilities to manageable thresholds, extreme cases of covid-19, for example, replace the concepts of individual robustness, collaboration, and coordination with those of sustainability, in which resilience, durability, and performance remain unchanged at acceptable levels (El Abdellaoui et al, 2022). And consequently reduces uncertainty in decision-making processes and guides adaptive strategic action on highly disrupted logistics networks (Datta, 2016). Sustainably resilient supply chains with a high capacity to adapt, absorb and recover are best maintained to survive and grow incrementally in critical contexts because of their structures designed to continue to operate with acceptable levels of performance (Carvalho et al., 2012; Fahimnia et al., 2015; El Abdellaoui, 2018).

The resilient measures of flexibility, collaboration, responsiveness and communication sharing ensure the continuity of operational programmes, which are sustained by the incorporation of sustainable ones. So this dual competence of resilient and sustainable capabilities is both complementary and constructive, and in our view improves the structural capacity of supply chains to control and monitor potential sources of systemic risk and, above all, to balance levels of performance with changes in their environments (El Abdellaoui et al., 2020). The design of our research model is designed to provide insights into our central question of how resilient and sustainable measures can help to keep the levels of risk, vulnerability and performance of supply chains within manageable limits. So the assessment of the mediation of supply chain performance allows us to understand the how, while the assessment of the moderation of supply chain resilience and vulnerability informs us of the why and the conditions that need to come together to explore and confirm the relationship between systemic disruption and sustainability in the supply chain (Viswanadham & Samvedi, 2013; Fiksel, 2015; Vishnu et al., 2019).

3. Approaches and modelling

3.1. Fuzzy analytic hierarchy process method and fuzzy technique for order execution by similarity to the ideal solution

As part of the approaches and methods related to multi-criteria decision making or multi-criteria decision analysis (MCDM or MCDA) that are frequently used to address the decision making concerns of identifying, analysing and classifying problems related to the steering of logistics operations (Yoon, 1995; Nadabana et al., 2016). That methods such as fuzzy analytic hierarchy process and the technique of order execution by similarity to the ideal solution (Fuzzy AHP & TOPSIS) are chosen to cope with the uncertainty and contextual as well as structural sensitivity of intertwined supply chains (Cardoso et al., 2015; Elleuch et al., 2016). Providing decision makers with a form of agile management in which information transfer and sharing becomes a competitive factor (Mandal, 2012; Chen et al., 2013; Giannakis & Papadopoulos, 2016).

Although the extension of fuzzy set theory approaches has resulted in methods capable of analysing incomplete and uncertain data via criterion weighting or retained fuzzy weights (Saaty, 1980; Wu et al., 2009). As part of the approaches and methods related to multi-criteria decision making or multi-criteria decision analysis (MCDM or MCDA) that are frequently used to address the decision making concerns of identifying, analysing and classifying problems related to the steering of logistics operations (Yoon, 1995; Nadabana et al., 2016). That methods such as fuzzy analytic hierarchy process and the technique of order execution by similarity to the ideal solution (Fuzzy AHP & TOPSIS) are chosen to cope with the uncertainty and contextual as well as structural sensitivity of intertwined supply chains (Cardoso et al., 2015; Elleuch et al., 2016). Giving decision makers a form of agile management in which information transfer and sharing becomes a competitive factor (Yates & Stone, 1992; Mandal, 2012; Chen et al., 2013).

Although the extension of fuzzy set theory approaches has resulted in methods capable of analysing incomplete and uncertain data via criterion weighting or retained fuzzy weights (Saaty, 1980; Wu et al., 2009). At this level, the construction of the fuzzy pair comparison matrix starts with the assignment of fuzzy numbers to linguistic variables, which often take the form of triangular, Gaussian or trapezoidal comparisons to reflect the subjective perception of the decision maker in a quantitative way, in order to calculate the fuzzy normalisation weights needed to identify, analyse and evaluate a data structure (Bellman, 1970; Nadabana et al., 2016). Another approach has been based on the mechanism that the alternative must trace the shortest and furthest distances to the ideal solution to a decision making problem by introducing a vertex method to compute the one between two triangular fuzzy numbers (Dagdeviren et al., 2009; Zavadskas et al., 2014; Kahraman et al., 2015). Thus, given the simplicity and efficiency of their mathematical approaches the two above-mentioned approaches are adopted and implemented in various fields related to supply chain management (Palczewski and Sałabun, 2019) and their formulation and execution procedures will be seen in more detail on the following title

3.2. Classification and prioritisation according to the FUZZY AHP method

Elt	Sum criteria weight value (a)	Criteria weight value (b)	© = (SCW)/CW)	Lmax = ©/n	Consenstency index (CI) = LM-n/n-1	Random index (RI)		Consenstency ratio (CR) = CI/RI
SMR01	3,097	0,102	30,427	29,981	0,26004	1	0,3591	
SMR02	2,825	0,091	30,929			2	0,3793	
SMR03	2,610	0,081	32,239			3	0,5245	
SMR04	2,373	0,073	32,714			4	0,8815	
SMR05	2,160	0,066	32,547			5	1,1086	
SMR08	2,145	0,066	32,527			6	1,2479	
SMR09	1,741	0,055	31,701			7	1,3417	
SMR11	1,587	0,051	31,193			8	1,4056	
DMR01	1,471	0,048	30,809			9	1,4499	
DMR02	1,346	0,044	30,465			10	1,4854	
DMR03	1,260	0,039	32,012			11	1,5141	
DMR06	1,132	0,037	30,543			12	1,5365	

DMR07	0,972	0,033	29,088	13	1,5551	
DMR10	0,888	0,029	30,459	14	1,5713	0,15686795
MTR01	0,801	0,026	30,935	15	1,5838	
MTR02	0,724	0,023	30,846	16	1,5978	
MTR03	0,662	0,023	28,445	17	1,6086	
MIR02	0,600	0,022	27,525	18	1,6181	
MIR03	0,527	0,019	27,178	19	1,6265	
MIR04	0,465	0,017	26,955	20	1,6341	
MIR05	0,416	0,015	26,928	21	1,6409	
MAC01	0,376	0,014	27,218	22	1,6470	
MAC02	0,336	0,012	27,927	23	1,6526	
MAC03	0,335	0,012	27,934	24	1,6577	

Table 1. Hierarchisation of supply chain risk incidents using the AHP multi-criteria Analytical prioritisation method

To begin our analysis, one of the main constraints of decision making in logistics systems is the identification, prioritization and analysis of disruptive systemic risks that impact both the continuity and performance of logistics operations management programs. Therefore, we align ourselves with the contextual and structural facts related to the economic environment of Moroccan logistics chains by recognizing the multidimensional and multi-interface effect of systemic propagations of retroactive and cyclical nature perceived by decision makers (Blackhurst et al., 2017). At this level, such an observation requires a decisional approach in Fuzzy AHP simulation in order to classify the risk events linked to industrial and service logistics chains by their degrees of severity and occurrence while reducing the subjective perception or the uncertainty of judgement of the decision-makers which leads to a certain degree of uncertainty in case of comparison (Saaty, 1980; Chaghooshi et al., 2014; William ho et al., 2015). We recall that today's context of high uncertainty requires capabilities to survive, adapt, grow and recover ex-post disruption by acting on the causes by decreasing their probability of occurrence through reactive detection. And proactive during the time of disruption acting on the consequences reducing their severity while maintaining the protective conditions necessary to sustain yield levels (Ponomarov and Holcomb, 2009; Gligor & Holcomb, 2012; Golicic & Smith, 2013)

However, this study suffers from some methodological limitations such as a complex algorithm lacking a triangular fuzzy number scale assigned to the comparison matrices and an overestimation of the uncertainty rank also explained by the informational risk when projecting the judgement made by the decision makers (Hwang and Yoon, 2012; Karczmarczyk et al., 2018). These two sources can lead to a degradation of the quality of the results of our analysis by a rank inversion mostly related to the correct identification, classification of the main disruptive risks related to supply chains (Craighead et al., 2007; Blackhurst et al., 2011). In order to effectively assess, manage, and track the drag-out effect on interconnected designs and extreme disruption scenarios, the supply chain risk management system must first be activated at the individual supply chain risk identification stage (Ivanov et al., 2014; Ivanov and Das, 2020; Ivanov, 2020). At this level, the identification and analysis concentrated on low likelihood occurrences with high effect that have significant ramifications for the supply networks under investigation (Kinra et al., 2019; Hosseini et al., 2019). This systemic propagation generates, in the sense of the authors Dolgui, Ivanov and their collaborators, a sharing of the profile of high-impact risks with low probability of occurrence with other types of risks by manifesting the spillover effect or synergy between interfaces in the term of Ambulkar et al., 2015. In the third section, we will see the resilient and sustainable measures taken to enhance the responsiveness of supply chains to risky events on contexts driven by extreme disturbances such as Covid19 or Sars-Cov2 evaluated using Fuzzy AHP & TOPSIS simulation (El Abdellaoui et al., 2022). This position remains a natural development of extreme phenomena occurring with sequential and cyclical implications for supply chains over a particularly uncertain geographical and temporal horizon (Hallikas et al., 2004; Gunasekaran et al., 2015; Heckmann et al., 2015).

At this level, the identification and analysis focused on low probability of occurrence events against a high degree of impact that present considerable repercussions for the investigated supply chains (Kinra et al., 2019; Hosseini et al., 2019). This systemic propagation generates, in the sense of the authors Dolgui, Ivanov and their collaborators, a sharing of the profile of high-impact risks with low probability of occurrence with other types of risks by manifesting the spillover effect or synergy between interfaces in the term of Ambulkar et al., 2015. In the third section, we will see the resilient and sustainable measures taken to enhance the responsiveness of supply chains to risky events on contexts driven by extreme disturbances such as Covid19 or Sars-Cov2 evaluated using Fuzzy AHP & TOPSIS simulation (El Abdellaoui et al., 2022). This position remains a natural development of extreme phenomena occurring with sequential and cyclical implications for supply chains over a particularly uncertain geographical and temporal horizon. We start our scanning process by constructing the fuzzy pair comparison matrix by assigning for each criterion a fuzzy number of a triangular nature with a measurement scale of 10 points, calculated in this way over four steps to reach the normalisation to prioritise the selected risks. Then the consistency and weight tests were generated using Excel 2016. Such a finding requires an evaluation of the articulation of alternatives, of the importance of the criteria by an equivalence between the numbers and weights of the attributes.

Linguistic terms relating to alternative ratings	Likert scale	Initial grade awarded in FN	Final grade awarded in FN
Very low impact	0 ou 1/2	(0, 0, 1)	(0,00; 0,00; 0,10)
Low impact	1	(1, 1, 3)	(0,10; 0,10; 0,30)
Significant impact	3	(1, 3, 5)	(0,10; 0,30; 0,50)
Meaningful impact	5	(5, 6, 7)	(0,50; 0,60; 0,70)
High impact	7	(7, 8, 9)	(0,70; 0,80; 0,90)
Very strong impact	9	(9, 10, 10)	(0,90; 1.00; 1.00)
Extreme impact	10	(10, 10, 10)	(1.00; 1.00; 1.00)

Table 2. Values and linguistic terms for alternative triangular fuzzy number notations

Step 1: Calculate the fuzzy pair comparison matrix

$$S_i = \sum_{j=1}^{n} \bar{a}_{ij} \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij} \right]^{-1}$$

- *Normalized pairwise comparison matrix = Initial attribute or criterion / Sum of initial attribute or criterion*

$$\sum_{j=1}^{n} \bar{a}_{ij} = A_1 \oplus A_2 = (a_1, b_1, c_1) + (a_2, b_2, c_2) + (a_3, b_3, c_3)$$

$$= (a_1, a_2, a_3) + (b_1, b_2, b_3) + (c_1, c_2, c_3)$$

- *Criteria weight = Pairwise normalized sum per line / Number of people*

$${\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij}}^{-1} = \frac{1}{a_1, a_2, a_3} + \frac{1}{b_1, b_2, b_3} + \frac{1}{c_1, c_2, c_3} = (l_1, m_1, n_1)^{-1} = \left(\frac{1}{n_1}, \frac{1}{m_1}, \frac{1}{l_1} \right)$$

- *Criteria weight value = Normalized pair attribute * Criteria weight*

$$S_i = \sum_{j=1}^{n} \bar{a}_{ij} \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij} \right]^{-1} = A_1 \oplus A_2 \times \left(\frac{1}{n_1}, \frac{1}{m_1}, \frac{1}{l_1} \right)$$

Step 2: Calculate the fuzzy synthetic range with respect to the ith alternative

- *Value of the weighted sum (a) = Sum per row of criteria*

$$\sum_{j=1}^{n} \bar{a}_{ij} = (L_1 + L_2) : \ (a_1, b_1, c_1) + (a_2, b_2, c_2) + (a_3, b_3, c_3)$$

$$= \ (a_1, a_2, a_3) + (b_1, b_2, b_3) + (c_1, c_2, c_3)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij}^{\ -1} = (a, b, c)^{-1} = \left(\frac{1}{c}, \frac{1}{b}, \frac{1}{a}\right)$$

$$S_i = \sum_{j=1}^{n} \bar{a}_{ij} \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij} \right]^{-1} = \ L_1 + L_2 \times \left(\frac{1}{c}, \frac{1}{b}, \frac{1}{a}\right)$$

Step 3: Calculate the degree of possibility

$$V(M_1 \geq M_2) = Sup\left(U_{m1(x)}, U_{max(y)}\right) = hgt\ (M_1 \cap M_2) = U_{m2(d)}$$

$$Avec \begin{cases} 1, if\ m_1 \geq m_2 \\ 0, l_1 \geq U_2 \\ \dfrac{(l_1 - u_1)}{(m_2 - u_2) - (m_1 - l_1)} \end{cases}$$

Step 4: Calculate the degree of possibility that a convex fuzzy number is greater than k convex

e. *Lamda max = Valeur de la somme pondérée (a) / Effectif*
f. *Indice de consistance (IC) = (Lamda max-n) / (n-1)*
g. *Random Index = données Statistique*
h. *Rapport de cohérence (CR) = Indice de cohérence (CI) Indice aléatoire /RI inférieur à 0,10*

$$V(S \geq S_1, S_2, \dots, S_k) = Min\, V(S \geq S_i); (i = 1, 2, \dots, k)$$
$$d'(A_i) = Min\, V(S_i \geq S_k); (i, k = 1, 2, \dots, n, k \neq 1)$$
$$p' = d'(A_1), d'(A_2), \dots, d'(A_n^T)$$

So to build the hierarchy of our alternatives from our normal distribution preference matrix and the reciprocal one, allowing to integrate all the criteria for each of the surveyed companies with the informational risk induced by the degree of uncertainty relative to the perception of the supply chain decision makers on the issues related to the taxonomies, identifications and analyses of the risks on their business contexts (Heckmann et al., 2015; William ho et al., 2015). At this level, we used the random matrix to neutralise the perceptual uncertainty of the decision makers to ensure that the level of uncertainty is low, which suggests that the reliability of our matrix is acceptable (Tang & Tomlin, 2008; Tang & Zhou, 2012; Tang et al., 2012).

ELT	Fuzzy geometric mean value (a)			Asymetrix Fuzzy geometric mean value (b)			Fuzzy weight (c) = (a)/(b)			Weight (w)	Normalised Weight (w')
SMR01	1,185	1,202	1,214	0,824	0,832	0,844	0,976	1,000	1,024	1,00019	0,04166778
SMR02	1,184	1,200	1,212	0,825	0,833	0,845	0,976	1,000	1,024	1,00019	0,04166767
SMR03	1,182	1,198	1,211	0,826	0,835	0,846	0,977	1,000	1,024	1,00019	0,04166756
SMR04	1,182	1,198	1,210	0,827	0,835	0,846	0,977	1,000	1,023	1,00017	0,04166702
SMR05	1,181	1,196	1,208	0,828	0,836	0,847	0,978	1,000	1,023	1,00017	0,04166689
SMR08	1,179	1,194	1,206	0,829	0,837	0,848	0,978	1,000	1,023	1,00017	0,04166675
SMR09	1,181	1,190	1,202	0,832	0,840	0,847	0,982	1,000	1,018	1,00010	0,04166413
SMR11	1,174	1,189	1,203	0,831	0,841	0,852	0,976	1,000	1,025	1,00020	0,04166818
DMR01	1,172	1,187	1,201	0,833	0,843	0,853	0,976	1,000	1,025	1,00020	0,04166809
DMR02	1,170	1,184	1,196	0,836	0,844	0,855	0,978	1,000	1,022	1,00016	0,04166637
DMR03	1,168	1,182	1,194	0,838	0,846	0,856	0,978	1,000	1,022	1,00016	0,04166635
DMR06	1,166	1,179	1,191	0,840	0,848	0,858	0,979	1,000	1,022	1,00015	0,04166612
DMR07	1,176	1,174	1,186	0,843	0,852	0,850	0,992	1,000	1,008	1,00002	0,04166063
DMR10	1,159	1,166	1,184	0,845	0,857	0,863	0,979	1,000	1,022	1,00015	0,04166619
MTR01	1,151	1,165	1,176	0,850	0,859	0,869	0,979	1,000	1,021	1,00015	0,04166592

MTR02	1,145	1,158	1,170	0,855	0,863	0,874	0,979	1,000	1,022	1,00016	0,04166627
MTR03	1,143	1,154	1,169	0,855	0,866	0,875	0,978	1,000	1,023	1,00017	0,04166679
MIR02	1,140	1,153	1,165	0,858	0,867	0,878	0,978	1,000	1,022	1,00016	0,04166649
MIR03	1,133	1,149	1,155	0,866	0,871	0,883	0,981	1,000	1,019	1,00012	0,04166482
MIR04	1,116	1,130	1,141	0,876	0,885	0,896	0,978	1,000	1,022	1,00016	0,04166650
MIR05	1,110	1,122	1,133	0,883	0,891	0,901	0,980	1,000	1,020	1,00014	0,04166540
MAC01	1,101	1,116	1,131	0,884	0,896	0,908	0,974	1,000	1,027	1,00024	0,04166959
MAC02	1,093	1,106	1,122	0,891	0,904	0,915	0,974	1,000	1,027	1,00023	0,04166941
MAC03	1,086	1,098	1,115	0,897	0,911	0,921	0,974	1,000	1,026	1,00022	0,04166908
Total	**27,677**	**27,989**	**28,293**	**20,373**	**20,594**	**20,826**	**23,478**	**24,000**	**24,534**	**24,00398**	

Table 3. Hierarchisation of supply chain risk incidents using the multi-criteria Fuzzy Analytical Hierarchy Method

3.3.Interest and application procedure of the fuzzy technique for order execution by similarity to the ideal solution

For the formulation of the problematic relating to the complementarity of the interfaces of sustainability and resilience of supply chains with n alternatives {a_1, a_2, a_3,…,a_n} assessed using n criteria {c_1, c_2, c_3,….,c_n}. And expressed thus by the decision matrix X with values at the ith alternative with respect to the jth weight criteria $Cj_{(1\leq j\leq n)}$, into numerical data for the decision value reflected by the vector Yj (Bellman, 1970; Nadabana et al., 2016). At this level, in order to assign an accurate scale with an alternative for the advised criteria special attention should be paid to both the evaluation of the alternatives by articulating the linguistic variables into triangular fuzzy numbers as well as the degree of importance to these criteria by ensuring equivalence between the fuzzy numbers and the weight of the chosen attributes (Hwang and Yoon, 2012; Karczmarczyk et al., 2018).

$$\boldsymbol{X} = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix}; \boldsymbol{Avec\ Y} = (\boldsymbol{y1}, \boldsymbol{y2}, \boldsymbol{y3}, \ldots\ldots, \boldsymbol{yn})$$

Thus the evaluation of the articulation of the alternatives, the importance of the criteria by an equivalence between the numbers and weights of the attributes is formulated by :

$$\widetilde{X} = \begin{bmatrix} \widetilde{X}_{11} & \cdots & \widetilde{X}_{1n} \\ \vdots & \ddots & \vdots \\ \widetilde{X}_{m1} & \cdots & \widetilde{X}_{mn} \end{bmatrix}$$

However, the Fuzzy analytic hierarchy process starts with the construction of the fuzzy pair comparison matrix where we assign for each criterion a fuzzy number of triangular nature, with X a decision matrix n2 where aij is the importance of the criterion Ci compared to that Cj. And whose fuzzy weight by normalization pi is calculated according to four stages by :

$$\widetilde{P} = \begin{bmatrix} (1,1,1) & \widetilde{a}_{12} \cdots & \widetilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \widetilde{a}_{n1} & \cdots & (1,1,1) \end{bmatrix} = \begin{bmatrix} (1,1,1) & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n} \\ (1,1,1)/\widetilde{a}_{12} & (1,1,1) & \ldots & \widetilde{a}_{2n} \\ (1,1,1)/\widetilde{a}_{1n} & (1,1,1)/\widetilde{a}_{2n} & \cdots & (1,1,1) \end{bmatrix}$$

$$\widetilde{p}_i = \widetilde{r}_i\,(\widetilde{r}_1 + \widetilde{r}_2 + \cdots + \widetilde{r}_n)^{-1}\ \boldsymbol{With}\ \widetilde{r}_i = (\widetilde{a}_{i1} \times \widetilde{a}_{i2} \times \widetilde{a}_{i3} \times \ldots \times \widetilde{a}_{in})^{\frac{1}{n}}$$

While the Fuzzy TOPSIS ideal solution similarity order execution technique is based on the idea that the selected alternative should be close to the positive ideal solution that minimizes the criteria related to the propagation and sensitivity of supply chains and eventually maximizes the criteria of the resilient and sustainable capacity of supply chains to improve their adaptation, control and recovery attitudes on potentially disrupted contexts (Atanassov and Gargov, 1989; Deepa and Sanjay, 2014; William ho et al. , 2015). And whose computational procedure is organized as follows:

a. Step 1: Calculate the aggregate fuzzy scores and weights for the criteria and alternatives

Then, we activate our computation procedure by assigning scores to the criteria and alternatives by a decision group noted G. At this level, the fuzzy notation of the Gème indicates the alternative criterion Ai (p.r.t) Ci and the criterion weight Cj expressed by :

$$\tilde{x}_{ij}^{k} = (a_{ij}^{k}, b_{ij}^{k}, c_{ij}^{k})$$

$$a_{ij} = min_{k}\{a_{ij}^{k}\} \; ; \; b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^{k} ; \; c_{ij} = max_{k}\{c_{ij}^{k}\}$$

$$\tilde{w}_{ij}^{k} = (w_{j1}^{k}, w_{j2}^{k}, w_{j3}^{k})$$

$$w_{j1} = min_{k}\{w_{j1}^{k}\} \; ; \; w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^{k} ; \; w_{j3} = max_{k}\{w_{j3}^{k}\}$$

Linguistic terms and values	Likert scale	Triangulation in FN (a_{ij})	Intuitionistic valued interval fuzzy weight
Very low impact	0	(0, 0, 1)	(0,00; 0,00; 0,10) (1.00; 1.00; 1.00)
Low impact	1	(1, 1, 3)	(0,10; 0,10; 0,30) (0,90; 1.00; 1.00)
Significant impact	3	(1, 3, 5)	(0,10; 0,30; 0,50) (0,70; 0,80; 0,90)
Significant impact	5	(3, 5, 7)	(0,50; 0,60; 0,70) (0,30; 0,30; 0,20)
High impact	7	(5, 6, 7)	(0,70; 0,80; 0,90) (0,10; 0,30; 0,50)
Very high impact	9	(7, 8, 9)	(0,90; 1.00; 1.00) (0,10; 0,10; 0,30)
Extreme impact	10	(9, 9, 10)	(1.00; 1.00; 1.00) (0,00; 0,00; 0,10)

Table 4. Linguistic values valued interval intuitionistic fuzzy weight

b. Second step: Calculation of the weighted normalized fuzzy decision matrix.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^{*}}, \frac{b_{ij}}{c_j^{*}}, \frac{c_{ij}}{c_j^{*}}\right) \text{ et } c_j^{*} = max_{i}\{c_{ij}\}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^{-}}{c_{ij}}, \frac{a_j^{-}}{b_{ij}}, \frac{a_j^{-}}{a_{ij}}\right) \text{ et } c_j^{-} = min_{i}\{a_{ij}\}$$

$$\tilde{V} = (\tilde{v}_{ij}) ; With\ \tilde{v}_{ij} = \tilde{r}_{ij} \times p_j$$

- Maximizing the criteria of the resilience and sustainability of supply chains to improve their adaptation, control and recovery attitudes in potentially disrupted contexts
- Minimizing criteria relating to the spread and sensitivity of supply chains

c. Third step: Calculation of the ideal positive and negative fuzzy solution and the distance of each alternative from them respectively.

d. $A^{*} = (\tilde{v}_1^{*}, \tilde{v}_2^{*}, \dots, \tilde{v}_n^{*})$, With $\tilde{v}_j^{*} = max_{i}\{v_{ij3}\}$

$$A^{-} = (\tilde{v}_1^{-}, \tilde{v}_2^{-}, \dots, \tilde{v}_n^{-}) , \tilde{v}_j^{-} = min_{i}\{v_{ij1}\}$$

$$d_i^{*} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_{ij}^{*}) \; ; \; d_i^{-} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-})$$

$$CC_i = \frac{d_i^{-}}{d_i^{-} + d_i^{*}}$$

3.3.1. Industrial and service sectors

We tried to analyse and evaluate the effect of five types of micro and macro risks on the logistics performance perceived by the decision-makers. In addition, respondents answered a questionnaire on different concepts related to supply chain risk management and logistics performance as perceived by decision makers. The data was collected by means of a survey conducted between January 2017 and May 2017 on a sample of 1300 large and medium-sized companies targeting senior management profits involved in steering logistics operations. The questionnaires were administered by email using two databases provided by two QSE and IS consultancies. This operation generated 592 observations of which 30 were discarded due to incompleteness and incompatibility of responses, thus 562 responses remain usable with a response rate of 43.2% significantly higher than (Ambulkar et al, 2015; Chowdhury et al., 2017) due to the availability of targeted profits, similar to other studies focusing on supply chain management as well as supply chain risk management (Tranfield et al., 2003; Tsai et al., 2008; Tummala & Schoenherr, 2011; Thun & Hoenig, 2011).

The data collected was statistically processed using SPSS 23.0 and SmartPLS version 3.2.7, constituting a heterogeneous sample of different natures and sectors (40.62% are industries, 48.42% are services and 10.72% are large and medium sized businesses) this had no impact on the weight of the results that were generated for this study. The figures below present the characteristics of the participating companies where 52% of the participating companies have a workforce between 300 and 1000, of which 51.5% have an annual turnover between 50 and 1000 million MAD. As for the profits interviewed, 78% are executives involved in supply chain operations, broken down as follows: 34% are supply and stock managers, 31% are purchasing and production managers and 22% are logistics managers. Therefore, our sample is still significant as more than half of them are large and medium-sized companies with an independent management or department in charge of supply chain operations (Kim, 2009).

Sectors	Frequency	Percentage	Cumulative
Automotive and Equipment Industry	90	16%	16%
Food and Energy	44	8%	24%
Construction and Metallurgy	62	11%	35%
Electronics and IT	45	8%	43%
Medical Equipment, Pharmaceuticals and Hospitals	112	20%	63%
Paper, Cardboard and Wood Industry	62	11%	74%
Rubber, Plastics and Textile Industry	62	11%	85%
Aeronautics and Defence	40	7%	93%
Logistics and Distribution	43	8%	100%
Total	**562**	**100%**	

Turnover in (Million MAD)	Frequency	Percentage	Cumulative
Less than 49 million MAD	104	18,53%	18,53%
Between 50 Million and 549 Million MAD	153	27,27%	45,80%
Between 550 Million and 999 Million MAD	132	23,43%	69,23%
Between 1.000 Million and 4.999 Million MAD	110	19,58%	88,81%
Between 5.000 Million and 7.999 Million MAD	43	7,69%	96,50%
Between 8.000 Million and 11.999 Million MAD	20	3,50%	100,00%
Total	**562**	**100%**	**100%**

Title of the offeror	Number of respondents	Number of respondents	Percentage cumulative
Logistics and SCM Manager	124	22%	22%
Purchasing and production manager	176	31%	53%
Procurement and stock managers	190	34%	87%
Controlling and other managers	73	13%	100%
Total	**562**	**100%**	**100%**

Table 5. Demographic characteristics of the sample for the industrial and service sectors

4. Conclusion

In order to identify supply chain disruptive causes and occurrences, we intended to add analytical frameworks that prioritize upstream, downstream, and internal EIRLs and FIRLs in automotive supply chains to the recent scientific literature on supply chain risk management. Our contribution thus entails the analysis of unpredictable events with variable degrees of likelihood and impact, as well as the ensuing effects on supply chains, using tools like the probability-impact matrix and hierarchy of criticality levels. The results in this regard imply that managers should concentrate on the sources of supply-side, internal, and demand-side risks, or FRLs: quality and customer/supplier relationships; structure, price, and capacity fluctuations in the supply and demand markets; logistics integration and production capacity failure; and not to forget the critical failure of the IT infrastructure (Hoffmann et al., 2013; Hong et al., 2018; Ivanov, 2020; Boubker et al., 2023).

At the end of this study, we paid particular attention to the three parts of our supply chain, with a special focus on the effects of internal disruptive events where we chose the risk of "critical infrastructure failure and massive incident of fraud or data theft" from the Global Risks Report 2017 to assess their consequences on the different links of the supply chains. At this level, our study in 2017 coincided with a wave of global cyber attacks that called into question the sensitivity of national supply chains to infrastructure risks. This attack was able to disrupt the Renault-Nissan group's production programmes, with losses estimated at up to one thousand cars not produced per day of production. Indeed, some points need to be raised concerning the subjective perception of decision-makers, which can be neutralised if we grant a probability of occurrence a frequency over a period of time at which at least one or more FRLs/ERLs occur in the event of a disruptive event (e.g.: a probability of occurrence x occurs α times over β months) generating, as an indication (e.g.: a degree of impact x is equivalent to a level of criticality α with a financial loss of π). Furthermore, in order to achieve a certain level of validity in our analyses of the spillover effect, we suggest retaining at least four types of impact to assess the different dimensions of risk in the service and industrial sectors in Morocco.

In contrast, when assessing the spillover effect associated with the influence of micro and macro systemic risks on the variability of logistics performance levels perceived by supply chain decision makers, the causal links that may exist between the different supply, demand, infrastructure, transport, distribution, socio-political and ecological risks were explored in our conceptual cause-consequence model. The causal links that may exist between the different risks of supply, demand, infrastructure, transport, distribution, socio-political and ecological risks were explored in our conceptual cause-consequence model. Although our results confirm that micro risks, with the exception of socio-political and ecological risks, show high levels of impact on logistics performance. This means that decision-makers minimise the impacts of socio-political and ecological risks on the macro-environment of supply chains, presumably because all supply chains operating in the same geographical area experience the same disruptive events. Therefore, the management knowledge held by individual decision-makers will not generate a sustainable competitive advantage, as all supply chains face the same socio-political situation. This is not the case for those of a micro nature where the know-how to manage these risks can differentiate companies to the extent that the reconfiguration of global supply chains is determined by highly competitive supply chains (Ivanov et al., 2016; Ivanov & Sokolov, 2019; Ivanov et al., 2019).

On the other hand, supply risk can drastically lower logistical performance. Failures connected to supplier product quality issues, the frequently challenging sharing of electronic data with suppliers, the extremely delayed development of a cooperative climate, and the extremely high reliance on external sources for crucial materials and components are the main causes of this. This outcome confirms an observation made in the literature on supply management and in particular in the matrix presented by (Kraljic, 1983; Chopra, 1987). Demand risk is therefore considered to be equally significant for logistical performance. The ability of supply chain participants to efficiently plan logistics operations is significantly impacted by the end demand's increasingly erratic and unpredictable nature. This leads to a string of serious incidents (recurrent stock-outs, increased inventories, unavailable transport infrastructure, etc.). Additionally, it is obvious that the disruptive occurrences are the outcome of a business strategy known as hypersegmentation, which supply chain decision-makers have been fighting for a number of years (Kraljic, 1983; Jüttner et al., 2003; Kleindorfer & Saad, 2005; Khan & Burnes, 2007).

Dramatic variations in logistics performance are also considered to be disruptive events that can impair flow monitoring. It is not surprising that modern supply chains are more vulnerable to information systems because they are typically just-in-time. Big Data management is a crucial component of Industry 4.0 success, thus any IT system outages will have a significant impact on lost production capacity and, more generally, will negatively affect the agility of supply chains (Dolgui et al., 2018). While another aspect of flow monitoring that primarily focuses on critical occurrences connected to product transport is the perceived sensitivity of logistics performance to transport risk. According to Blackhurst et al. (2017), disruptive events have systemic effects both upstream and downstream, which endanger the supply chain's continued efficiency. Disruptive occurrences have clear repercussions for every business involved in a supply chain's logistical operations. In fact, the interconnectedness, interaction, and reciprocal spread of upsetting occurrences were all taken into account during the systemic risk assessment step. Based on a methodical methodology and resilient and sustainable capacities, the data collected provide fertile ground for building scenarios that are suited for shortening recovery times (Lavastre & Spalanzani, 2010; Lavastre et al., 2012; Louis & Pagell, 2019; Macdonald et al., 2018). The majority of supply chain risk management research focuses on nations with geopolitically, economically, and legally stable environments. This tends to favor the application of universalist techniques, but it's critical to consider contextual specificities and to boost cultural research, particularly in Africa and the Middle East. Then, and only then, can we hope to formalize a conceptual model of integration that will highlight the many facets of risk management in a logistical setting that is exclusively African. Therefore, on the basis of this study some conclusions and managerial implications can be deduced:

- In the first instance, disruptive incidents have subsequent consequences in terms of impact on logistics performance and implicitly on overall business performance, so it makes sense to integrate new identification thinking that takes into account the degrees, ranges and dimensions of risk in supply chain risk management issues and processes. This will clarify their severity and initiate the process of integrating vulnerability and resilience into the supply chain in terms of assessment and control (Svensson, 2002; Stecke & Kumar, 2009; Talluri et al., 2010).
- Secondly, risks related to IT infrastructure are currently attracting attention due to the amplification of cyber attacks that have become more industrialised and automated. This unexpected event with an increasing frequency is prompting companies to strengthen their risk management framework through a new typology of uncertainties related to the information system factor (Ruel et al., 2017) and to secure their ecosystems through a dynamic of cyberagility and cyberresilience (March & Shapira, 1987; Mason-Jones & Towill, 2000; Manuj & Mentzer, 2008).
- Thirdly, despite the fact that logistics performance has an impact on financial and marketing performance, the study of the impact of supply chain risks must be carried out in an integrative logic with the sustainable performance of supply chains, in order to increase the explanatory capacity of the models (semi-partial with a rather more significant R2) (Munier, 2008; Nikookar et al., 2014)
- Fourth, future research could also analyse and assess the extent of supply chain risks in the context of emerging African economies through a comparative study in order to evaluate the risk management practices adopted by African firms. In this sense, most instrumentalization and quantification studies are related to economies characterized by a relatively stable political, legal, geographical and economic context and therefore the results are not always valid, hence the interest in studies that take into account all the specificities of the African context. It is also possible to think of an integrative conceptual model linking the dimensions of risk, including vulnerability and

resilience factors, with those of performance (logistical, operational) by integrating control variables (competence, training and experience) of the managers involved in supply chain operations and moderating variables such as risk mitigation practices including integration and collaboration upstream and downstream of the supply chain) (Behnezhad et al., 2012; Naoui et al., 2023; Mellouki et al., 2024).

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