Supply Chain Capabilities Using the FAHP Technique

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Supply chain resilience is one of the main aspects that enables manufacturers to cope with change and uncertainty; therefore, it is essential to develop the capabilities necessary to do so. The development of a Fuzzy Analytic Hierarchy Process (FAHP) model can assist in this process by providing a systematic framework for evaluating and prioritizing supply chain capabilities

supply chain resilience COVID-19 FAHP approach

1. Introduction

A supply chain can be understood as a system connecting a diverse range of specialists. This system starts with the supplier and ends with the last customer, encompassing both the service and manufacturing processes, with the aim of maintaining the flow of information and goods. This support helps organizations to sufficiently determine the best way to meet their business requirements [1]. Subsequently, businesses become globalized, and companies begin to follow novel strategies. These strategies may include excellent streamlined customer responses and rapid-response programs. In addition, the market becomes dynamic, thus increasing the requirements for changes within the supply chain [2]. These changes depend on an increase in the supply chain's complexity [3].

In the context of the COVID-19 pandemic, supply chains have become more unpredictable and unstable; in light of this, they face diverse challenges [4]. Epidemic outbreaks begin on a small scale but quickly increase in size and spread across numerous geographic areas with a considerable level of uncertainty. This makes it difficult to completely comprehend the effects of epidemic breakouts on supply chains and take the necessary precautions to respond to them [5]. There are different possible reasons for these disruptions within a supply chain, which have been illustrated by different practitioners and researchers within the literature. According to Pereira et al. [6] and Ghadge et al. [7], the short life cycle of a product, the high variability in demand because of changing requirements, and customers' expectations are the most probable reasons for such changes. The PricewaterhouseCoopers/Massachusetts Institute of Technology (PwC/MIT) Forum of Supply Chain Innovation conducted a global supply chain risk management survey that presented plans for business continuity, which included fluctuations in the prices of raw materials, fluctuations in currency, and market changes in risk areas [8]. The American Production and Inventory Control Society (APICS) supply chain council published a report in the year 2015, which discusses a natural disaster and a lack of information sharing. The report indicates that there are many disruptions within a supply chain. Such disruptions are due to a lack of visibility, insufficient information technology communication, cyberattacks, and loss of skills, according to the Business Continuity Institute (BCI) supply chain flexibility report (2017). If any disruption occurs in a supply chain, it can have a negative effect on the economic performance of an organization. Consequently, to sustain themselves within this scenario of a changing market, it is essential for organizations to have resilient supply chains. According to [9][10], capacity can be increased to respond to unanticipated influences, while also having the power to quickly return to the original position, being ready to respond once again. Moreover, the capacity increase can result in a cost-effective situation after responding to and facing the difficulty. In the present study, the capabilities of a supply chain are prioritized based on their importance in the context of the COVID-19 pandemic, aiming to ensure the resilience of the supply chain.

2. Supply Chain Resilience

Supply chain resilience has emerged as a topic of great concern for businesses due to the increasing frequency and severity of interruptions caused by multiple internal and external events [6]. The concept of resilience has been intensively researched in the field of supply chain management to understand how firms may more successfully prepare for and respond to crises [11]. There is no accepted definition of supply chain resilience. Yet, the expression is frequently used to describe a company's ability to withstand, recover from, and react to unanticipated disruptions while conducting business and meeting customer expectations [9][10]. A resilient supply chain is one that can adapt to changing conditions, whether those conditions are caused by pandemics, natural catastrophes, economic downturns, or other unpredictable circumstances [12]. After a significant series of disruptive events within global economies, several in-depth studies were carried out to improve our understanding of the ways that supply chains can more efficiently adapt to change [13][14][15]. When the term "resilience" appears in business vocabulary, researchers have investigated project attributes that contribute to supply chain disturbances as well as attributes that help enterprises to cope with and prevent those disturbances [16][17]. Resilience is also defined by the "four Rs"—robustness, recovery, review, and resourcefulness [18].

Resilience can be perceived from the perspectives of flexibility and redundancy, encouraging leaders to develop "flexibility DNA". This new DNA is developed during periods of distributed authority, communications, passion for the mission being pursued, conditioning to disruptions, and deferral from experience [15]. Even though these viewpoints are different, everyone differentiates resilience from conventional risk management [19]. The resilience concept, unlike traditional risk analysis, uses strategies that do not require exact quantification or whole enumeration to create possibilities or representative future assumptions [20]. Strategic resilience imperatives stimulate supply chains to become more adaptive and less brittle to change. This adaptability can refer to the visibility of changes in supply and demand throughout the supply chain and the design of the supply chain. Adaptabilities working to embed a resilient culture and to place focus on business procedure management for enhancing capabilities throughout the supply chain are other strategic resilience imperatives [21]. However, the authors of [20] recognized a research gap regarding linked vulnerabilities and threats against the strategies required to overcome them. The authors of [22] defined resilience as being derived from the foundations of life as well as the social sciences, and this definition is adapted by the Council on Competitiveness (2007) as "the capacity for an enterprise to survive, adapt and grow in the face of turbulent change". Resilience is understood as consisting of two constructs. The first construct is "vulnerabilities", which are the fundamental factors that render a project susceptible to disruptions, and the second construct is "capabilities", which are attributes that allow an enterprise to overcome and anticipate these disruptions [20]. The authors of [23] generated a methodology to develop the best disturbance management strategy according to many flexibility levels, derived from the fact that mitigation and contingency events are not free. In addition, Pettit et al. [13] developed capability and vulnerability constructs including 21 factors that contain 111 sub-factors. They proposed that these 21 factors can be estimated and used for the evaluation of a supply chain's current resilient state, and recommendations for resilience improvement can be prioritized through adjusting a company's capability portfolio by aligning the vulnerability pattern so that it remains within the Balanced Resilience Zone [23]. Responses to vulnerability are diverse and encompass capabilities throughout the entire enterprise, in addition to the synergistic or conflicting capabilities of supply chain members [24][25]. The aim of managers is to create capability portfolios that can balance the intrinsic vulnerabilities within the supply chain, resulting in a balanced form of resilience that is hypothesized to improve firm performance [13].

Reactive and proactive supply chain resilience (SCRE) capabilities can be understood through the lens of the Dynamic Capability View (DCV) [26]. Consistent with the DCV, firms must include capabilities for adapting, integrating, and reconfiguring their resources, in addition to capabilities for quickly addressing changes in environments. To accelerate similar changes, organizations must be proactive in scanning for environmental changes. They must also obtain the adaptability and flexibility that is essential for matching their proactive capability with their supply chain. This flexibility includes adapting to environmental changes to prevent potential vulnerabilities within the supply chain, according to the DCV. Successful companies working within the market ought to reconfigure their capabilities and resources quickly so as to recover competencies in turbulent times [26]. Moreover, supply chains must have the reactive capacity to reconfigure capabilities and resources in order to recover rapidly from disruptions. In their study, the authors of [13] outlined the "balanced resilience" concept, which is basically the balance between rising resilience capabilities and rising costs as a concept for controlling vulnerabilities. Ponomarov and Holcomb highlighted the significance of capability or resource specificity, in addition to their sufficient measurement, for sustaining profitability through the development of resilience balance [27]. According to the concept put forward by the authors of [13], it is important to balance managerial and supply chain vulnerabilities. Prioritizing robust capability factors in the textile sector, the authors of [28] discovered that readiness is the most crucial capability for resilience, followed by response and recovery. Government support has been one of the main causal elements aiding the global supply chain during the COVID-19 pandemic, and cost optimization is the main factor affecting the supply chain [29].

While the existing literature offers a framework for supply chain resilience capabilities, there exists a number of gaps in the literature, which lacks a comprehensive view of resilience capabilities, as well as studies being conducted in developing countries and those examining such capabilities empirically based on a pandemic such as the COVID-19 pandemic.

3. Fuzzy Analytic Hierarchy Process (FAHP) Method

Supply chain resilience has become increasingly important in the wake of the COVID-19 pandemic. To ensure that supply chains can continue to function effectively in the face of disruptions, it is important to identify and prioritize capabilities that are most critical for resilience. The development of a Fuzzy Analytic Hierarchy Process (FAHP) model can assist in this process by providing a systematic framework for evaluating and prioritizing supply chain capabilities [30]. Many studies have proved that the FAHP method is effective for many practical problems. In [31], Ooi et al. showed that FAHP achieved the best performance balance for criteria referring to various categories, including physicochemical properties, safety, health, and environmental aspects. The FAHP approach's assumption is that all involved criteria are independent from each other. Nevertheless, practically, the relationship between criteria is generally complex, and there might be interdependencies [32][33]. To control quality, a relevant element and method are required [34]. A fuzzy model can be used with different multi-criteria decision-making (MCDM) methods [35]. According to Chiu et al. [36], a FAHP model is a good reference for decision makers, as the fuzzy AHP method is applicable as a quality control method and is suitable for multi-criteria decision-making problems [37]. With the FAHP method, decision makers can make more realistic, flexible, and efficient decisions according to the available criteria and alternatives [38]. The most recent articles on multi-criteria decision-making tools, which primary focus is on resilience supply chain management, are included in **Table 1** below.

Table 1. Multi-criteria decision-making (MCDM) techniques for supply chain management.

Reference, Authors, and Year	MCDM Technique	Main Findings
[39] Gupta et al. (2019)	Fuzzy AHP, TOPSIS, MABAC, and WASPS	This study used a weighted sum and product model in WASPAS. The outcomes for choosing green suppliers were consistent across the three hybrid models (Fuzzy AHP and TOPSIS; Fuzzy AHP and WASPAS; and Fuzzy AHP and MABAC).
[40] Alkahtani et al. (2019)	Fuzzy AHP and TOPSIS	This study explored a mechanism for assessing the chosen approaches. The following aspects were taken into consideration when conducting the evaluation: group decision support, computational complexity, number of criteria, and alternative providers. The results show that AHP outperforms Fuzzy TOPSIS in terms of computational complexity, whereas Fuzzy TOPSIS is best suited for guaranteeing decision-making agility.
[41] Belhadi et al. (2022)	Fuzzy systems and wavelet neural networks	This study aimed to identify trends in AI approaches for creating various SCRes strategies. This paper offers an integrated multi-criteria decision-making (MCDM) strategy driven by AI-based algorithms, including fuzzy systems, wavelet neural networks (WNN), and evaluation based on the distance from the average solution (EDAS).
[42] Ayyildiz (2021)	Interval-valued intuitionistic FAHP	In this study, the importance of performance attributes was determined using the Fuzzy Analytic Hierarchy Process. The hierarchy levels were used to identify the most crucial performance attributes. The findings show that organizational characteristics are crucial for creating more

Reference, Authors, and Year	MCDM Technique	Main Findings
		resilient supply chains. For supply chain resilience, integrated systems are highly important.
[43] Murat et al. (2020)	AHP into VIKOR under intuitionistic fuzzy theory	The primary goal of this study was to use a quantitative approach to examine whether blockchain technology can be used in the logistics sector. A multi-criteria decision structure was provided, and AHP was integrated into VIKOR under the intuitionistic fuzzy theory. The study's conclusions imply that while security, visibility, and audit are the most crucial factors, transportation, material handling, warehousing, order processing, and fleet management are the most practical logistics operations for potential blockchain deployment.
[44] Wu et al. (2023)	Interval Type-2F-PT-TOPSIS	This study assessed the degree of robustness of the coal industrial chain and supply chain. An integrated method combining Interval Type-2 Fuzzy Prospect Theory and the Technique for Order Preference by Similarity to an Ideal Solution (Interval Type-2F-PT-TOPSIS) was proposed.
[45] Sathyan et al. (2023)	Fuzzy DEMATEL, Fuzzy AHP, and Fuzzy TOPSIS	The Fuzzy AHP–Fuzzy TOPSIS conclusion suggests that automakers should pay particular attention to management's commitment and strategic decision making, wait times for deliveries of vehicles, and demand forecasts. The suggested framework offers strategic objectives to direct various supply chain participants and decision makers in the automobile industry toward increased supply chain responsiveness.
[46] Giri et al. (2022)	Fuzzy DEMATEL	This study developed the DEMATEL approach based on Pythagorean fuzzy sets and used it to address the supplier selection issue in sustainable supply chain management. Based on information gathered from a group of professionals, the proposed method was mathematically presented.
[47] Sohrabi et al. (2022)	A combined metaheuristic-based robust fuzzy stochastic programming	To account for uncertainties in the real world, a hybrid resilient fuzzy stochastic programming approach was used in this study. The suggested model was put into practice for blood platelets. The outcomes demonstrate that the proposed RFSP model performs better than the Nominal model. In addition to lowering shortages and waste, it is also effective in minimizing overall system expenses and environmental damage.
[48] Rabbani et al. (2022)	Stochastic programming	In this study, a reactive strategy was modified to deal with network disruptions and failures, and a robust stochastic programming solution was extended and solved using a genetic algorithm to address uncertainties in the real world. A real-world case study was used to validate the model's efficacy and applicability. Additionally, the model's effectiveness and dependability were demonstrated according to its application in novel settings.

4. SC Resilience and COVID-19

Reference, Authors, and Year	MCDM Technique	Main Findings
[49] Shokouhifar et al. (2022)	A multivariate time-series deep learning model	[50] A multivariate time-series deep learning model based on long short-term memory is proposed in this paper to forecast blood donation/demand. The proposed model was used to achieve resilient blood inventory management so as to address the uncertainties that arose during the COVID-19 pandemic. The proposed method can be used to assist decision makers in managing blood supply chains during COVID-19 outbreaks and similar pandemics in the future by prioritizing blood transfusions.

in supply t SCs will emic and causes of tance [11]. od supply ience [30]. ch AI can improve supply chain resilience [51], while the authors of [52] used artificial intelligence to build supply chain resilience, enabling a supply chain to endure major disruptions such as COVID-19. The authors of [53] examined how changes resulting from the pandemic have impacted efforts to promote resilience, while [54] outlines the difficult situations that China's retail supply chains have had to address, evaluates the impact of the pandemic on supply chain resilience, and analyzes the pandemic's effects on SCs in terms of difficulties, concerns, actions, and solutions, with the aim of enhancing SC resilience. The authors of [12] also suggested using the combined ANP–TOPSIS framework to rank the answers based on these complex interrelationships.

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