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Supply chain risk assessment and mitigation under the global pandemic COVID-19

Ala H. Bani-Irshid [a1*], Mohammad M. Hamasha [a2], Lubna Al-Nsour [a3], Lana Mohammad [a4], Anfal Al-Dabaibeh [a5], Raya Al-Majali [a6], Hala Al-Daajeh [a7].

[a]Department of Industrial Engineering, Faculty of Engineering, The Hashemite University, Zarqa, Jordan.
[a1*] *alah@hu.edu.jo;* [a2] *mhamasha@hu.edu.jo*

Abstract:

Supply chain (SC) disruptions were massive in 2020, with many manufacturers forced to close their operations temporarily. The coronavirus pandemic (COVID-19) has changed the way enterprises perceive risks and the potential effect on their supply chain. Many enterprises are now very dependent on third-party services, so it is necessary to adapt to sustainability challenges. This paper aims to provide a detailed review of research related to risk assessment and mitigation of the SC under lockdown due to COVID-19. Then, it identifies risks associated with supply chains (SCs) during the pandemic using the Failure Mode Effect Analysis. Finally, it suggests improvements to have a fully resilient supply chain. In addition, it explored Supply Chain Resilience (SCR), its phases, and strategies by examining an enterprise that managed COVID-19 pandemic disruptions and turned their potential losses into revenue. Furthermore, we discussed a case study where the enterprise increased its total income by nearly $1 million.

Key words:

COVID-19, Supply Chain Management, Supply Chain Risk Management, Supply Chain Resilience, Supply Chain Risk Assessment.

1. Introduction

With the advent of Industry 4.0, initiated in Germany, there's an increasing shift towards this new industrial phase. Zhou et al. (2021) discussed the transition from Industry 3.0 to 4.0, and Germany has formulated an implementation strategy focused on networking, smart factories, and intelligent production. However, many SMEs globally struggle with automation, let alone transitioning to Industry 4.0. Additionally, companies are now more focused on managing unforeseen crises like COVID-19.

2020 was a challenging year due to the impact of COVID-19. It had many ups and downs in numerous aspects and many uncertainties. Although the first case of COVID-19 was identified in Wuhan, China, in December 2019, most countries did not take any action until the first lockdown of Wuhan. This lockdown was followed by the spread of the disease worldwide, and the number of cases increased exponentially. Finally, with the Wuhan lockdown turning out to be a success as announced, countries have gradually started full and partial lockdowns.

To write an in-depth study review on the topic of "Supply Chain Risk Assessment and Mitigation under the Global Pandemic COVID-19"; This work starts by introducing the concept and evolution of SC management, then provides a brief background before moving on to the risk of COVID-19 lockdowns on SCs. Such an introduction helps to build up the main body of the work and to figure out the main contribution that would be added from the current work to this field. Various resources are used, including books and papers to collect the required information.

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The primary research objective of this study is to investigate the strategies and mechanisms adopted by industrial corporations, specifically focusing on JHHC (i.e., International fabric Company), to ensure resilience in their supply chains during the COVID-19 pandemic. Given the unprecedented disruptions caused by the pandemic, understanding these resilience strategies becomes crucial. The research delves deep into the corporation's approach towards risk management, its relationship dynamics with partners, and how it navigated stringent governmental regulations during lockdowns. Our case study on JHHC, a company that not only weathered the storm but also increased its revenue during the crisis, offers valuable insights. This research is of paramount importance because it provides a template and insights for businesses globally on how to prepare and respond to unforeseen, large-scale disruptions. By studying successful resilience strategies, companies can be better equipped for future challenges, ensuring continuity and sustainability.

2. Literature Review

A correlation between COVID-19 and the risks of supply chain (SC) management is established through a comprehensive literature review. In this section, emphasis is primarily placed on supply chain risk management in the context of COVID-19, and it is divided into six subsections.

2.1. Supply chain management concept and evolution

Supply Chain Management (SCM) is of critical importance, as enterprises are challenged to satisfy their customers at a reasonable cost. In the past, manufacturing companies drove SCs completely. They managed the product manufacturing paces. Nowadays, customers are the actual drivers, and manufacturers work to understand and implement customer needs.

After World War II, most factories focused on mass production to reduce the cost per unit, although the product was less flexible. After that, bottleneck processes were buffered to sustain a balanced flow, leading to a significant reduction in work-in-process stock (Farmer, 1997). In the 1970s, manufacturing resource planning was launched, and manufacturers noticed the effect of work-in-process on production cost, product quality, product development, and product lead time. The world's tough industrial rivalry in the 1980s obliged international enterprises to offer good, reliable, and cheaper products. Manufacturers applied lean manufacturing to reduce cycle time and increase proficiency. The adoption of SCM proceeded into the early 1990s as enterprises expanded to best practices in managing corporate assets to join strategic key suppliers. However, only the implementation of modern information and communication technologies has led to a remarkable integration of SCM, which should be rooted in the exchange of information, risks, and benefits. The increasing degree of SC automation and digitization has been a dominant aspect of physical distribution and SCM evolution.

Based on the recent development of the SCM literature, there has been much debate about the definition of SCM. Early definitions of SCM were limited to material flow, and over the years, definitions have been expanded to include financial flow and information flow. Later, the external and internal networks are considered in the definitions. It has been observed that the definitions continued to evolve until they included value-adding activities, enhancing efficiency, and satisfying customers.

Ganeshan and Harrison (1995) have defined SCM as a network of logistics locations and distribution alternatives that implement purchasing items, parts, and materials and converting them into products for end or intermediate customers. Lee & Corey (1995) expressed that SCM consists of consolidated activities that are carried out among a network of facilities. It started with purchasing materials, converting them in a series of processes to final products, and delivering them to customers through a specific network.

Stewart (1995) included all the previously mentioned elements in his definition, saying that the SC involves informational and logistical components that are confined by the market's aggregate demands. Chen & Paulraj (2004) pointed out that SCM identifies inter-organizational strategic issues, defines and explains an organization's relationship with its suppliers, and discusses purchasing and supply.

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2.2. Effect of COVID-19 on the supply chain

Supply chain disruptions were massive in 2020, with many manufacturers being forced to close their operations temporarily. Even the worldwide air transportation network is highly impacted, as Zhou et al. (2021) and Amankwah-Amoah (2020) reported. There have been many shifts in demand as some countries have implemented lockdowns. In general, the situation was complex, and it was difficult to predict the future spread of the disease and the future of possible drugs and vaccines to treat it. Moreover, there were still many manufacturing and distribution challenges as the SC's globalization can be seriously impacted.

(SCRM) has been known since 2011. However, it has been brought into focus more than ever due to the spread of the Coronavirus. In addition, the pandemic has changed enterprises' attitudes toward risk. As a result, enterprises are working to become more resilient.

The influence of the COVID-19 lockdown was unique for every enterprise. Some enterprises have struggled and even declared bankruptcy. Other enterprises were not affected due to the type of business and good management. Nevertheless, even some enterprises increased their profits. Amazon, for example, expanded its revenue by about 70% in the first nine months of 2020 (Amazon, 2021), while airlines incurred billions of dollars in losses (Abate et al., 2020). The most successful response to the pandemic is to transform its production lines to suit the requirements required in the pandemic. For example, Bauer, a hockey equipment enterprise, has turned the manufacture of hockey masks into medical shields (Pelc, 2020). Brooks Brothers has transformed its products from ties, shirts, and suits to medical masks and gowns (Bryson and Vanchan, 2020). Several auto enterprises have begun producing medical kits, improved respirators, and ventilators (Attaran, 2020). For example, in 2020, Mercedes planned to make 10,000 continuous positive airway pressure (CPAP) ventilators (Buheji et al., 2020). Furthermore, many alcohol enterprises have started making hand sanitizers, such as petrochemical giant INEOS (Singh et al., 2020). Ant Financial implemented a promising idea to add free ads for Coronavirus to their service offerings, and the result was to increase their income by 30% (Lucivero et al., 2020).

There has been a long list of bankruptcies due to the spread of COVID-19. The list's enterprises fail to deal with long periods of shutdown and changes in demand (Banerjee et al., 2020). For example, the enterprise that owns 'Cirque du Soleil' in Canada, which is world-famous in the entertainment field, has filed for bankruptcy. The closure of their facility for more than three months has exacerbated their debt. Furthermore, their debt problem was exacerbated by its suspension of about a dozen art shows worldwide (Spraakman, 2020). The German restaurant chain Fabiano went bankrupt in the restaurant sector (Carletti et al., 2020), while the British restaurant chain "Restaurant Group" closed 125 restaurants, and 3000 jobs were lost (Belger, 2020). The energy sector suffered as well. It faced a significant drop in demand, especially in the United Kingdom, where oil services such as the Houston-based giant Schlumberger planned to cut 21 000 jobs.

Enterprises need to recognize the critical factors in achieving resilience and absorb and overcome any coming disruptions. With more globalization, it has to specify and mitigate SC disruption risks and take appropriate steps in dealing with disasters to reduce losses. SCs are exposed to risks because most enterprises rely on offshore enterprises. Therefore, any disaster or unpleasant event, even if it is not in the same area, plays a role in causing SC disruptions.

This paper explores the characteristics of the SC that make it resilient, the strategies enterprises can adapt to, responses to different types of risks, and the steps to take in the case of an SC disruption. SCs have evolved into networks, and any node disruption will affect the SC entity, so more focus should be on SCRM.

The research on the relationship between COVID-19 and the SC is enormous. For example, Choi (2021) discussed the impact of COVID-19 on the global SC in general. Chowdhury et al. (2021) provide a systematic review of the effect of COVID-19 distribution on SCs. In addition, many authors studied the impact of the COVID-19 lockdown on supply chains, such as the following examples. Lin et al. (2021) conducted a study on more than 1400 industrial companies to measure the degree of impact of COVID-19 on them. The results showed that companies with diversity in their sources of supply are affected less and have achieved greater profits than similar companies with limited sources of supply. Mitręga and Choi (2021) conducted qualitative interviews with representatives of small Polish companies, in addition to checking their social media posts. Their study aimed to assess the relationships between companies during the COVID-19 pandemic. The results refer to a positive effect if the contracts signed between the partners can be modified. In addition, the results refer to a negative effect if there are debts with the pivotal companies. Gupta and Perera (2021) discussed sudden increases in demand and how to deal with them, taking the example of the rise in home delivery orders during the COVID-19 pandemic. They provided solution models at the end.

Other authors studied the effect of the COVID-19 lockdown on SCs on certain products/services, such as the following example. Cheramin et al. (2021) have been working on modeling the unique impact of the COVID-19 pandemic on the Neodymium-iron-boron magnet supply. They formulated a two-stage stochastic programming model constrained by opportunities to maximize profit while ensuring network resilience against interruption risks. Manupati and Schoenherr (2021) focused on the problem of plasma supply during the COVID-19 pandemic to patients. Given the importance of plasma for patients who need it, the supply must be guaranteed. Therefore, they presented a model for a plasma SC that takes into account the special variables and the associated randomness. Burgos and Ivanov (2021) focused on the situation of retail food SCs during the COVID-19 pandemic in Germany. So they designed a discrete-event simulation model to examine the processes and their dynamics in SCs. It showed very high flexibility in selling and supplying retail foodstuffs in times of turmoil, including lock and unlock down. They also noted that sharp increases in demand had the most significant effect while transportation disruptions had a relatively low impact. Finally, Yazdekhasti et al. (2021) discussed the effect of the COVID-19 pandemic on poultry SCs in Mississippi, USA.

2.3. Supply chain risk management and evolution

'Risk analysis and control' is now required to reduce the effect of economic uncertainty and complexity. The risks were fundamentally recognized and well-detailed, but different concepts and approaches to risk management have been developed. In addition, the impact of previous SC disruptions has led to increased interest in risk analysis and management.

According to Lavastre et al. (2012), below are some of the components that increase the complexity of SCRM: globalization of the market, low product life cycles, manifold interconnected international networks of suppliers, and markets uncertain demand and supply, cost pressures, tremendous outsourcing. Nowadays, global and rapid transformations have forced enterprises to apply risk management to control unsafe conditions in their SCs.

Due to the growth of recent SC's complexity, developments or the impact of any event became harder to predict. Moreover, many disasters happened in the past years, such as Hurricane Katrina, the global financial crisis, floods in Thailand, the Japanese earthquake, the 2011 tsunami, and others. These events showed a shortage of preparation of SC in the direction of generally uncertain events.

SCRM has been investigated from several angles. March and Shapira (1987) were among the first authors who established a definition of SCRM. They defined (SCR) as the variance in the SC's supply, outcomes, and values. Jüttner, Peck, and Christopher (2003) have given plenty of conceptual work. They describe SCRs as the impact of a gap between demand and supply. Peck (2006) also describes SCR as any event that disrupts information, materials, or product flow from suppliers to the end-users. Finally, Heckmann et al. (2015) redefined SCR as the possible loss of the SC in the matter of efficiency and effectiveness target values provoked by developing the uncertainty of the characteristics of the SC whose changes caused triggering events.

The expressions supply risk and supply chain risk are comparable. However, supply risk is practically focused on the short term, including supplies, delivery, orders, and operations management. On the other hand in (Ho et al., 2015), SCR is more strategic and relates to managing and regulating the flows between SC partners and the consequences of supply risk.

SCRM has become a big concern for enterprises. According to a survey conducted by Snell (2010) 90% of enterprises felt in danger of SCR issues. However, 60% of the enterprises noted insufficient knowledge about thesis issues (Snell, 2010). Li and Barnes (2008) developed proactive SCRM methods for developing SCM systems tracing new markets. Kull and Closs (2008) investigated the risk failure in the SC due to second-degree suppliers.

2.4. Supply chain risk management strategies

Over the past ten years, natural disasters, financial crises, disease outbreaks, and other unpleasant events have frequently disrupted SC activities. SC disruptions significantly affect the long and short-term performance of the entire SC. For example, enterprises that experienced SC disruptions show a 33-40% decline in stock return compared to industry standards on average.

As governments controlled the COVID-19 pandemic, manufacturers have struggled to manage the pandemic's influence on the SCs. The impact of the COVID-19 shutdown on SCs can be easily mitigated if enterprises have a robust mitigation plan and do not depend on a single source of supply (Majid, 2020). Thus, the success of the SC crisis depends on management's reaction to changes in business and consumer psychology. Therefore, it is necessary to identify long- and short-term changes in consumer psychology and analyze the consumer's signals and their demand change during the lockdowns (Majid, 2020). Once an enterprise has identified immediate SCRs, manufacturers must plan for a long-term resilient SC. Using SC management's digitization enhances supply risk control's objectivity and adaptability (Alicke and Barriball, 2020).

Majid (2020) said that the fragility of the SC is making enterprises struggle to absorb the fallout. Fragility can be the result of one or more of the following weak aspects: 1) Combined centers of production; 2) Deficiency of SC transparency; 3) Manual SCM; 4) limited inventory levels; and 5) Rigid SCs. Moreover, he said it is essential to make the SC anti-fragile. Then, decision-makers must focus on determining the potential disruption and prevent it.

The SC's resilience in the face of any distribution becomes the biggest problem facing the enterprise. However, making it anti-fragile can become his greatest strength (Brun, 2020). Thus, it is essential to make the SC support its operations during disruption and quickly recover back to regular operations. Tang (2006) pointed out two important SC characteristics for operational continuity and ensuring profitability, resiliency, and efficiency. Resiliency means that the strategy will enable the SC to support its work during disruption and recover quickly after a disruption, while efficiency means that the strategy can allow the SC to control operational risks. Govindan et al.

(2020) discussed the risk mitigation of the healthcare SC during lockdown periods, such as the COVID-19 lockdown. They used a fuzzy inference system to manage this critical demand. Choi (2020) and Choi (2021) discussed the possibility of transferring service operations from their normal location to their homes during the COVID-19 lockdown. He used certain technologies in logistics.

Ji and Zhu (2008) mentioned four types of strategies that support supply management. These strategy types are discussed in the rest of this subsection.

The first type is supply management strategies. Although the strategy of having one supplier is suitable for controlling quality and cost, the strategy of multi-suppliers from a theory and practice perspective is the most popular approach to reduce disruption risks. It transfers orders between selected suppliers to assure the operational continuity of the SC and business efficiency (Sheffi, 2001).

The second type is demand management strategies. Under uncertain demand conditions, many enterprises use different strategies for demand management. Therefore, the demand can be adjusted to match the limited supply. The strategies include a quick-to-respond pricing strategy and a demand delay strategy (Chod & Rudi, 2005). This strategy improves SC efficiency by mitigating risks of uncertain demands. Moreover, the order delay strategy involves delaying shipments or services as necessary. However, the enterprise makes the price of services or products depend on the delivery time.

The third type is product management strategies. If the customer demands are diverse and customized, the enterprise can increase the variety of products to meet customer needs. However, the cost rises with the variety of products due to the increased complexity. However, the inventory cost and the demand uncertainty may increase significantly. Therefore, some cost-effective product diversification strategies are being developed to reduce the uncertain demand risk, such as interchangeable and postponement strategies (Lee, 1996). Product management strategies generally improve SC resilience by improving manufacturing flexibility.

Flexibility is an essential element in the interchangeability strategy. It refers to a feasible choice depending on the situation. When the SC fails due to interruption, the impact can be minimized by using interchangeable production systems and components. For example, Intel can redistribute its capacity to different plants worldwide. They announced that the SARS outbreak in 2003 did not interrupt their production, even with the closing of their production plants in Shanghai. They transferred production capacity quickly among these plants. The production process in the postponement strategy could be classified into general production and customization production processes. In the postponement strategy, the allocation points must be relocated back as far as feasible to offer the allowance for adjusting production. The postponement strategy is the right choice if the demand fluctuates (increases or decreases abruptly and dramatically), and it can enhance SC resilience. Philip's semiconductor, for example, experienced a plant conflagration in 2000. As a result of this conflagration, they were experiencing a severe supply disruption of some essential elements for a new product. However, postponed the introduction of this product, and they can steadily meet customers' demands and win the highest market share in cell phone technology.

The fourth type is information management strategies. Information is essential for decision-making in every plan. In an SC, a group of enterprises decided to share information. Every member must share their information with the group. This may include a financial plan, inventory level, sale information, demand information, and other uses for all information. This strategy improves SC visibility. As a result, they develop a more accurate forecast plan for each enterprise related to SC, reducing the uncertainty, and enabling the SC to quick to respond to the market. Once the disruption influences the enterprise, other enterprises will get useful information as quickly as possible. The IT industry needs to create a resilient information system in these strategies, for instance, backing up the information system data during a specified period. Once an information system failure occurs, it can be resolved quickly.

Although the strategies mean to protect the profit of the SC by mitigating SC risks, they can increase the operating cost of the SC. For example, SC needs to invest additional costs to involve additional suppliers, carry out fundamental options strategies, or create a resilient information system. Therefore, considering whether specific strategies are adopted to counteract the risk of SC disruption and the amount of cost to be invested, decision-makers must analyze the incremental profit and cost to improve the strategy's effectiveness.

2.5. A Conceptual model for supply chain risk management

Most studies divide the risk management process into four general steps (tasks) (Hallikas et al., 2004; Harland et al., 2003; Zsidisin, 2003). The tasks are 1) Classification of risks; 2) Identification of risks; 3) Calculation of risks; and 4) Implementation of risk resilience. Sometimes monitoring of risks is added as a fifth step. In addition, Kleindorfer and Saad (2005) introduced a three-task model, SAM. SAM, refers to the first letter of the consequent three tasks: 1) Specifying weaknesses and sources of risk and; 2) Assessment of risks; and 3) Mitigation of risks. In practice, the three tasks must be implemented continuously and simultaneously as a basis for managing SC-disrupting risks. Lavastre et al. (2012) introduced a model for SCRM. The model is a set of three elements, as follows: 1) the level of risk that the decision makers are willing to take action (Attitude toward risk); 2) tools used to analyze and eliminate risks; and 3) Techniques used to decrease risk in the SC.

According to Harland, Brenchley & Walker (2003), attitude toward risk depends on the enterprise, the definition of a minimum risk level to take an action, the amount of benefit of risk mitigation, and the enterprise's philosophy about risk. Some enterprises are risk-averse, while others are risk-taking. In addition, the nature of the work affects the attitude to risk, and it may also change after experiencing heavy losses.

Jüttner et al. (2003) and Miller (1992) dedicated five strategies to deal with risk: imitation, avoidance, control, cooperation, and flexibility. For example, enterprises can avoid risk by canceling certain products, geographical markets, suppliers, or customers. However, risks are easy to predict in all cases, so people focus on enterprises' strategies to prevent future losses. The activities that lead to the reduction of SCRs are cooperation and unification of efforts to improve visibility, exchange information regarding risks, and the necessary plans to be taken to guarantee the continuity of the SC. Moreover, resilience strategies such as postponement strategies and multi-resources will reduce risk.

The tools used to deal with the various stages of SCRM are identification and analysis of risks, assessment of risks, decision-making, implementation of risk management procedures, and risk control. There is a relation between total quality management (TQM) and SCRM in terms of the tools used. Tari and Sabater (2004) classified seven tools from TQM that can be used in SCRM: scatter diagrams, histograms, Pareto charts, run charts and graphs, flow charts, Shewhart control charts, and cause and effect diagrams. Furthermore, other tools related to quality engineering are used for the same purpose, such as internal audits and Failure Mode and Effects Analysis (FMEA), Failure Mode Effects, and Criticality Analysis (FMECA). FMECA is a process of evaluating and classifying risks according to their severity and identifying their effects to deal with the most important ones. Logically, FMECA is an extension of FMEA.

2.6. Techniques to minimize risk

Kleindorfer and Saad (2005) divided the risks into two categories: 1) risks related to the coordination of demand and supply, and 2) Risks of disruption caused by events such as natural disasters, war, political conflicts, and labor strikes. Furthermore, they formulated ten principles for managing the risk of SC disruption, focusing mainly on internal organizational policies and the interrelationship between the numerous components of the SC. The principles can be summarized as follows: 1) It must precede the integration of the internal SC and the improvement of any interfaces between enterprises; 2) diversification of facilities, goods, purchasing options, modes of operation, and processes; 3) Finding weaknesses in the supply network; 4) Risk evaluation and planning for an emergency should go before risk minimizing; 5) Managing the trade-offs between disruptive SC robustness and overall SC efficiency in day-to-day operations; 6) estimating redundancies; 7) Collaboration and coordination among SC partners; 8) Incorporating vulnerability measurement into the management of ongoing operations; 9) Implementation of resource flexibility, agility, and flexible design; and 10) implementation of TQM concepts and Six sigma methodology to reduce risk.

Braunscheidel and Suresh (2009) defined business routing and learning to reduce risk as solutions for developing integration, flexibility, and agility. In addition, much research claims that internal safety stocks considerably mitigate procurement risks. Safety stock allows enterprises to react to the fluctuations in supply flow and other problems that may happen to supply. However, safety stock increases the cost of storage, obsolescence risk, and wastage of capital risk. In addition, external safety

stock, if applicable, can be used as an alternative to internal safety stock. It can be wholly or partially with Vendor Managed Inventory and Jointly Managed Inventory.

The supplier must be authorized to supply the products to the customer and it requires knowledge exchange between the industrial partners. In addition, sourcing with many suppliers is vital to reduce SCR. Creating an emergency scenario is an excellent help. One of the best contributions to creating emergency scenarios was taken up by Knemeyer & Eroglu (2009). Their idea is to create a set of steps that enterprises can use to prepare for terrible disruption in their SCs. They recommend developing a strategic plan process including the following steps: 1) Identifying key places and risks in the SC; 2) Estimating possibilities and losses for each place; 3) Evaluating alternative solutions for each place; and 4) selecting the best solutions for each place.

Furthermore, hiring a professional SCR manager can be a way to manage risk in an enterprise. This manager should be tasked with developing and planning business continuity (Zsidisin et al., 2005). A manager's tasks include creating awareness, avoiding interruptions in supply, addressing potential risks, and promoting knowledge management. To prepare responses to catastrophic incidents, Alpaslan and Mitroff (2003) suggest the creation of a crisis center where specialized managers work exclusively on SCRM. Braunscheidel and Suresh (2009) focus on collaboration and information sharing to reduce risk. They have shown that integration SC (i.e., management information system-based SC) is the best indicator of SC resilience. Thus, Enterprises can enhance their response to market uncertainty in customer requirements and expected and unexpected interruptions (Liang and Huang, 2006).

3. Methodology

For further understanding of the effect of the COVID-19 pandemic on industrial Holding corporations, we chose to elaborate using a case study. The case study examines a corporation in Jordan and analyzes its response to COVID-19 disruption in 2020. The corporation showed the handling of resilience in its SC, operations, and market.

Since our research aims to explore resilience strategies, we conducted multiple interviews with the corporation enterprise managers to determine which strategies most helped survive the pandemic. Our questions focused on the dynamics of their SC and how it was affected. We also highlight how they bypassed harsh government regulations since the lockdown and their arrangements against the spread of COVID-19. Finally, we asked about their relationships with their partners and how they were affected this year.

SC resilience mainly relates to the attitude towards risk and examining this in practice. So, the uses of the Failure Mode Impact Analysis (FMEA) table help to detail the risks, and also help in the formulation of actions to respond to the risks. Due to limited historical data, the scores used in the table are subjective and based on interviews with managers/directors. Risks are visualized using a risk matrix to enable us to focus on the most impactful risks.

As a result of implementing resilience strategies, the corporation faced the pandemic resolutely without exposing themselves to the impact of the disruptions. They even increased their income by manufacturing essential products for the pandemic, such as face masks and shields. As a result, their net revenue increased from $5.1 million in 2019 to $6.5 million in 2020.

The methodology starts by collecting the required information from the corporation, and then analyzing this information to focus on the corporation's structure, activities, and the corporation's responses during the pandemic. This information helps to highlight the corporation's resilience and ability to handle the pandemic effects and merge the work with challenges that are added by the adaptation of new changes. The implemented case study starts by collecting information about the corporation factories, production type, income, the required materials suppliers, and production flow. All these details are required to address the difficulties that are caused by the COVID-19 lockdown and it has a direct impact on the production quality standards, also affecting maintaining strong relationships with the customers.

After that, based on the SC analysis of the corporation which is classified as a business-to-business enterprise, and the multiple lockdowns and closers in Jordan during COVID-19; The methodology defined the SC resilience contents According to

(Badri Ahmadi et al., 2016). And then, the Failure Mode and Effect Analysis (FMEA), is applied as a detection risk methodology to identify the title of the main risks and the impact method on the enterprise. Finally, the General Model for Building An FMEA Table is designed with a given risk identifier to calculate the risk priority number (RPN) using the selected parameters including intensity, occurrence, and the detectability of risks. Then conducted some studies on these potential risks and their impact on an enterprise's SC. As discussed in the following subsections, the risk assessment was performed in three areas: environmental, operational, and demand.

4. Case Study

Many enterprises have struggled with the COVID-19 lockdown and have tried to deal with an entirely uncertain situation. But, on the other hand, many others have shown their resilience and ability to adapt to new changes.

4.1. The corporation background

This corporation is an enterprise that manufactures and exports ready-to-wear sportswear. Many famous trademarks and stores use their products and services, such as Walmart, G-III, Costco, New Balance, Hanes, VF Corporation, Calvin Klein, IZOD, and Tommy Hilfiger.

The selected Corporation has exceptional development capabilities in converting designs into mass production. The corporation includes four main factories with approximately 4200 employees. The total annual capacity as of September 2020 is about 12.0 million pieces. This enterprise increased its net income from $5.1 million in 2019 to $6.5 million in 2020 despite all the challenges faced this year.

The corporation has many wholly-owned subsidiaries with factories in different regions in Jordan, Germany. Their factories have full-service production capabilities. First, they receive their designs from the previously mentioned partners, and then the process starts from the warehouse, where more than 500 rolls of fabric are unloaded every day. Then the rolls are checked based on the 4.0 system and sent to the cutting department. About 30 000 pieces of fabric are cut every day and sent to the embroidery departments to complete production. The production flow goes through various stages aimed at flawless packaging before it reaches its product and is exported to its destination. They produce more than 8 million pieces annually; however, their priority is maintaining the corporation's subsidiaries's high-quality products to maintain a strong relationship with their customers.

4.2. Supply Chain Analysis

The selected Corporation is an outsourced manufacturing enterprise. In other words, it is a corporation that other brand owners use to manufacture their products. It is classified as a business-to-business enterprise. The clients of this enterprise are retailers, and they deal with a variant demand. They work in a shorter time cycle. So cycle time is critical, and any delay may cause huge losses. Losses can take the form of financial loss, customer confidence, or enterprise reputation. The cycle time from order to delivery is about three months (95 days), and any delay is critical. The facility does not have any long-term supply contracts or arrangements with suppliers. Most of their final suppliers of raw materials, such as fabric, zippers, and stickers, are selected by customers. They buy these materials on a purchase order basis, which gives them a very dynamic SC.

4.3. COVID-19 pandemic

On March 17, 2020, Jordan announced the closure of most activities to counter the spread of COVID-19, except for essential activities, such as hospitalization and food distribution. Therefore, industrial facilities have suspended their operations in Jordan. Then, based on the approval of the Jordanian government on April 1, 2020, the operations of industrial facilities resumed in the Jordanian industrial zones for expatriate workers only, as of April 4, 2020. First, however, the resumption of work took place under strict health precautions. Then it resumed workshops outside the industrial zones on April 26, 2020. Finally, local workers and employees were able to work in the industrial facilities on June 1, 2020.

There was also a loss of productivity during the shutdown period, which negatively impacted full-year profitability. However, given the significant uncertainties surrounding the COVID-19 pandemic, they cannot reasonably estimate the extent of business disruption and the associated financial situation by the end of 2020.

In general, the COVID-19 pandemic can be rated as least likely to occur, yet it has had a significant impact. Institute of Supply Management stated that suppliers were operating at an average of half their capacity, causing their lead times to extend. The result was based on a survey of 600 US enterprises. The negative impact of the pandemic on revenue ranged from 5.6% to 15%. Under this pandemic, some enterprises have been completely closed, and others have managed to reopen. The adverse impact of the pandemic underscores the importance of a dynamic SC with shorter lead times. It also highlights the importance of full-span SC planning.

4.4. Supply chain resilience

With globalization and the change in how enterprises operate, they are becoming more dependent on overseas manufacturers. SCs struggle to be more resilient, so they will not be severely affected when disruptions occur. Enterprises can learn lessons from COVID-19 to become stronger. They can fix weaknesses and adopt new strategies. SC resilience is the ability to absorb disruption, emerge stronger, recover quickly, and adapt to changes. Resilience is the ability to respond to disturbances, whether they are expected or not. According to (Badri Ahmadi et al., 2016), there are three stages of resilience, as follows: 1) Anticipation, which is the ability to anticipate risks and prepare for them; 2) Resistance which tries to reduce the impact of the disturbance once it occurs before it expands and causes more damage; 3) Recovery and response, which is the ability to return the enterprise to a pre-disruption state (steady-state) using available resources while keeping damage as low as possible. Table 1 lists resilience strategies.

5. Risk Assessment

An essential aspect of SC resilience is anticipation and resistance to risks. Therefore, enterprises must have their risk detection methodologies and have a backup plan to use in the event of a risk. Failure Mode and Effect Analysis (FMEA) is one of the most common tools used in risk assessment. Risks that can interrupt the SC can be analyzed using FMEA. SCR often comes from five sources; environmental, operational, supplier-related, customer-related, and logistical risks (Ho et al., 2015; Manuj & Mentzer, 2008; Sodhi & Tang, 2012), as shown in Figure 1.

FMEA and other similar tools can be summarized in four steps, risk identification, analysis, evaluation, and mitigation. See Figure 2. Identifying risks refers to the title of the main risks and the impact method on the enterprise. Risk evaluation refers to assessing risks using a risk priority number based on three classifications: occurrence, severity, and detectability. Risk assessment refers to evaluating the overall impact of risks on an enterprise and listing the risks from highest to lowest. Finally, risk mitigation refers to reducing the likelihood of a risk occurring and minimizing its effects.

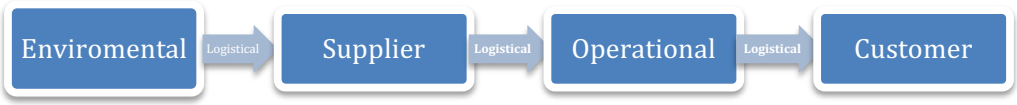

Figure 1. SCRs.

Table 1. Resilience Strategies.

Strategy	Definition
Excess Inventory	Excess inventory to cover any late shipments or in case of increased demand.
Collaborations and Visibility	More than one enterprise works jointly to carry out SC operations. It can provide significant advantages and advantages to participating enterprises.
Capacity Flexibility	The ability to control production levels.
SC Flexibility	Uses a multi-source strategy; This can be achieved through diversification. It is implemented by awarding business to additional suppliers.
Internal Optimization	It is the ability to use and make the most of existing resources, managing and sustainably maintaining available assistance
Adjusting the environment	It is one of the strategic decisions to start a business in a welcoming environment where there are not many strict regulations

Figure 2. Risk Assessment Process.

5.1. General model for building a FMEA

In this paper, the FMAE is designed, as shown in Table 2. It begins by giving a risk identifier (ID), which is filled in column A1. In this paper, the series R1, R2, etc. are used to identify risk. Next, the risk domain, such as environment, regulatory, supplier, demand, and logistics, is identified and filled in column A3. The impact of the occurrence of risks on the SC is filled in column A4. The next step is to calculate the risk priority number (RPN) resulting from the multiplication of three parameters, their intensity, occurrence, and the detectability of risks. Each parameter is a rating scale that takes an integer from 1 for the lowest possible to 10 for the highest possible. The severity rating indicates how much the event will affect the process as a whole. The order of occurrence indicates how often such an event occurs. The detectability rating indicates how detectable an event is. These parameters (ranks) take columns A5, A6, and A7 while RPN takes column A8. Estimating an RPN requires judgment from a team of experts that analyze historical data and assess each potential risk according to specific metrics. The metrics used in this research are listed in Table 3.

After the FMEA is completed, an action plan is required to either reduce the risk, classify the occurrence, or enhance the detectability of the risk with the highest RPN. A new order must be created after the action plan has been executed, and a new RPN must be calculated, as shown in Table 4.

Table 2. FMEA General Model.

Risk ID	Risk Domain	Risk Identity	Effect	Severity Ranking	Occurrence Ranking	Detectability Ranking	Risk Priority Number
A1	A2	A3	A4	A5	A6	A7	A8

Table 3. Ranking for Severity, occurrence, and detectability.

Severity Ranking		Occurrence Ranking		Detectability Ranking	
Rating	Degree of severity	Likelihood of occurrence	Probability	Ability to Detect	Detectability %
1	Unnoticed effects	Remote Likelihood of Failure	1 in 1000000	Certain Detectability	95-100
2	Relatively low effects	Low Likelihood of Failure	1 in 300000	Almost Certain	90-94
3	Low effects	Infrequent Failure	1 in 25000	High Detectability	80-89
4	Noticeable effects	Occasional Failure	1 in 2000	Relatively High Detectability	70-79
5	Relatively moderate effects	Relatively Moderate Failure Rate	1 in 500	Moderate Detectability	60-69
6	Moderate effects	Moderate Failure Rate	1 in 100	Relatively Moderate	50-59
7	Relatively high effects	Relatively High Failure Rate	1 in 20	Occasional Detectability	35-49
8	High effects	High Failure Rate	1 in 8	Infrequent Detectability	20-34
9	Significant effects	Almost Certain Failure Rate	1 in 3	Low Detectability	0-19
10	Critical effects	Certain Failure Rate	1 in 1	No Detectability	0

Table 4. FMEA after performing the action plan.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN

5.2. Supply chain risk assessment for the selected corporation

Key risk points in SCs were examined through interviews with the management of the Corporation and several of its employees. We then conducted some studies on these potential risks and their impact on an enterprise's SC. As discussed in the following subsections, the risk assessment was performed in three areas: environmental, operational, and demand.

Environmental risk assessment includes risks based on the work environment, such as accidents, weather, earthquakes, politics, and terrorism. This type is usually difficult to predict, difficult to control and has a severe impact. Table 5 below, identified the main environmental risks and their impacts on the enterprise.

Table 5. Environmental Risk Identification and Analysis.

Risk ID	Risk Domain	Risk Identity	more details	Effect	S	O	D	RPN
R1	Environmental Risks	Accidents	fires or machine accidents	e.g., Gas leakage and explosions, objects falling, and heavy machinery malfunction. Any of these accidents can harm workers and/or disrupt the work.	8	4	7	224
R2	Environmental Risks	Politics	Complete cut-off	e.g., trade relations between the United States and China are becoming increasingly tense. If they worsen, it will prevent trade between them.	10	1	9	90
R3	Environmental Risks	Politics	Demand	Wars lead to a lack of control over suppliers, which affects price and demand.	6	2	4	48
R4	Environmental Risks	Weather	snow, heavy rains, storms, or floods	Bad weather is a seasonal obstacle in global supply chains, leading to higher supply costs and higher insurance rates.	4	2	4	32
R5	Environmental Risks	Earthquakes		Buildings can collapse, demolish, crack, become inoperable, or unusable. Therefore, enterprises incur direct economic losses related to the business. Businesses can temporarily lose their ability to generate income due to business interruption.	7	1	8	56
R6	Environmental Risks	Terrorism		Terrorism increases uncertainty, which increases the cost of goods in circulation, increases the cost of doing business by increasing insurance premiums and security costs, and reduces the competitiveness of goods, and slow-moving resources, raw materials, and goods due to increased inspection operations.	8	2	8	128
R7	Environmental Risks	Currency Fluctuations	Shortage in finances	Currency fluctuations increase the cost of imports, which can lead to a widening trade deficit, currency weakening, and funding shortfalls.	5	2	3	30
R8	Environmental Risks	Closures due to COVID-19	ranges between 5-14 days	With consumer markets entering a state of lockdown, the demand for clothing products has fallen. Meanwhile, clothing supply chains have collapsed due to the supply shock.	8	8	4	256

Table 6. Environmental Risk Mitigation.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN
R1	8	4	7	224	incorporate a safety and wellness plan, provide protection equipment, Inspect and maintain all enterprise machines, and monitor safety measures.	7	3	7	147
R2	10	1	9	90	-				
R3	6	2	4	48	-				
R4	4	2	4	32	-				
R5	7	1	8	56	-				
R6	8	2	8	128	-				
R7	5	2	3	30	-				
R8	8	5	4	256	Having a backup inventory will help mitigate the effects of disruptions. And getting access from the government to work normally under closures.	6	6	4	144

An action plan is implemented on two risks with a higher RPN. As a result, new ranks of severity, incidence, and total (RPN) were initiated, as shown in Table 6.

There are many risks within an enterprise, yet they can be controlled in one way or another. Hence, tracking those risks and performing regular maintenance is necessary to keep their business going. For example, under COVID-19, the human factor (work) is at risk and may cause work to be temporarily interrupted, which may cause delivery delays. Table 7 shows the FMEA's analysis of operational risks.

Table 7. The Operational Risk Identification and Analysis.

Risk ID	Risk Domain	Risk Identity	more details	Effect	S	O	D	RPN
R9	Operational	Labor	Labor Injuries	Any injury can cause a decline in productivity rate.	3	3	4	36
R10	Operational	Labor	Labor strikes	Stop the entire production, massive delays in the delivery time	9	1	7	63
R11	Operational	Labor	Few COVID-19 cases among workers (<2%)	According to government instructions 2020, workstations must be sterilized, which will lead to work disruption. A sick worker must take 14 days to return to work	6	8	3	144
R12	Operational	Labor	More COVID-19 cases (>2%)	The entire facility will be closed for 14 days	8	7	3	168
R13	Operational	Labor	Random Failures in IT Systems	Inability to track production rates and communicate with other parties	5	2	3	30
R14	Operational	IT-System Failures	Quality detector fails	Reducing the quality of the products produced, which may lead to their reproduction	6	1	4	24
R15	Operational	IT-System Failures	Cyber Attacks	Unauthorized parties may take financial information from the computer system	8	2	5	80
R16	Operational	IT-System Failures	Machine Failures	Damage to the products being worked on or could result in worker injury	6	6	3	108
R17	Operational	Labor	poor employee utilization	Inadequate management arrangements and human use can increase costs and may result in unavailability or inaccuracy of delivery information	7	3	2	42

Table 8. Operational Risk Mitigation.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN
R9	3	3	4	36					
R10	9	1	7	63					
R11	6	8	3	144	Keep workers isolated as much as possible and perform regular testing to increase detectability.	4	6	3	42
R12	8	7	3	168	Separate workers from each department, especially in breaks, and get safe stock ahead of time.	6	5	3	90
R13	5	2	3	30					
R14	6	1	4	24					
R15	8	2	5	80					
R16	6	6	3	108					
R17	7	3	2	42					

An action plan is implemented on two top RPN risks to assess operational risks. As a result, the new ranks of severity, frequency, and total (RPN) were initiated, as shown in Table 8. Details of the action plan appear in the same table. Demand under the COVID-19 situation is very volatile and uncertain. Therefore, it was necessary to increase forecasting efforts that do not rely heavily on historical data and have subjectivity.

The summary of the potential risks and their assessments for this category are shown below in Table 9.

In addition, Table 10 indicates the order of risk mitigation for the four risks, which have the four highest RPN numbers. Supplier management can be the key to an enterprise's success. Good quality and good lead time can play a big role in providing

Table 9. Demand Risk identification and analysis.

Risk ID	Risk Domain	Risk Identity	more details	effect	S	O	D	RPN
R18	Network-Related	Demand	Volatility in demand due to the COVID-19.	Increasing demand for face masks will force the enterprise to produce more of them.	8	8	2	128
R19	Network-Related	Demand	Fluctuation in demand	Demand continues to fall due to lockdowns in different countries, affecting customers' attitudes towards buying, and leading to additional inventory.	7	7	3	147
R20	Network-Related	Demand	Excess Demand	Increased demand due to reopening can put the enterprise in a position where it cannot meet customers' needs.	6	7	3	126
R21	Network-Related	Demand	Losing significant clients in the absence of long-term deals with any of them.	Losing up to 70% of its revenue.	7	3	6	126
R22	Network-Related	Demand	Not meeting customer demand on time	The period of garmenthe t industry cycles is short. Therefore, if they fail to meet the deadlines, they may have to use other shipment methods that cost more, or the customer refuses to purchase, causing significant losses and a bad reputation.	7	4	4	112
R23	Network-Related	Demand	Bullwhip effect	Sometimes, a slight change in demand can cause manufacturers to increase their production at the beginning of the supply chain. However, overproduction is based on false assumptions that increased demand will continue, and as a result, they will be hoarding excess products and may be sold at a loss.	8	6	6	288

good services and products. Also, over-reliance and dependence on suppliers can negatively affect enterprises because they are not immune to failures and disruptions.

The results in Table 11 summarize the FMAE analysis of supplier risk assessment, while Table 12 summarizes the FMAE after implementing action plans to mitigate all of their risks, except for the lowest RPN risk (i.e., R24).

Usually, all exported goods are shipped by sea transportation due to their stability and minimum chance of accidents or obstacles. However, the COVID-19 precautionary shutdown prevented some shipments from moving as scheduled. the analysis in Table 13 refers to Logistics Risk Identification while Analysis (FMEA) and in Table 14 refers to Logistics Risk Mitigation Analysis (FMEA). FMEA is performed on the data. They are illustrated in the risk matrix for a more visual view of the risks, as shown in Figure 3. Thus, there is no need to worry about the dangers of the green areas, while those in the yellow area are alarming. Red is the highest risk.

The results in Table 15, consist of all risks combined with their risk priority numbers. They are illustrated in the risk matrix for a more visual view of the risks.

Table 10. Demand mitigation.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN
R18	8	8	2	128	Work on having flexible production lines that allow changing the products produced in a short time.	6	6	3	72
R19	7	7	3	147	Production of products required for the crisis, such as face masks	6	6	3	108
R20	6	7	3	126	Have backup inventory.	5	5	3	75
R21	7	3	6	126					
R22	7	4	4	112					
R23	8	6	6	286	Have backup inventory and improve the forecasting system.	7	5	5	175

Table 11. Supplier Risk identification and analysis.

Risk ID	Risk Domain	Risk Identity	more details	Effect	S	O	D	RPN
R24	Network-Related	Supply	key suppliers' financial failure	delays in deliveries which may result in low production rates	7	4	4	112
R25	Network-Related	Supply	discontinuity in the supply of essential goods	low production rates.	7	5	4	140
R26	Network-Related	Supply	Poor supplier performance	it could result in losing key customers and use air freight for faster delivery of delayed orders.	6	6	5	180
R27	Network-Related	Supply	First-tier inability to deliver because of internal closure	delays are in production.	7	5	5	175
R28	Network-Related	Supply	supply or service interruption	delays are in production.	7	5	5	175
R29	Network-Related	Supply	prices up	This may result in losing customers.	7	5	6	210

Table 12. Supplier Risks Mitigation.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN
R24	7	4	4	112					
R25	7	5	4	140	Enhance suppliers (Dealing with more efficient and committed suppliers.)	6	4	4	96
R26	6	6	5	180	Enhance suppliers (Dealing with more efficient and committed suppliers.)	5	5	5	125
R27	7	5	5	175	Dealing with multiple suppliers.	6	4	4	96
R28	7	5	5	175	Having a detailed agreement with the supplier to offer the best service	6	4	5	120
R29	7	5	6	210	Search for other options with lower prices and good quality.	6	4	5	144

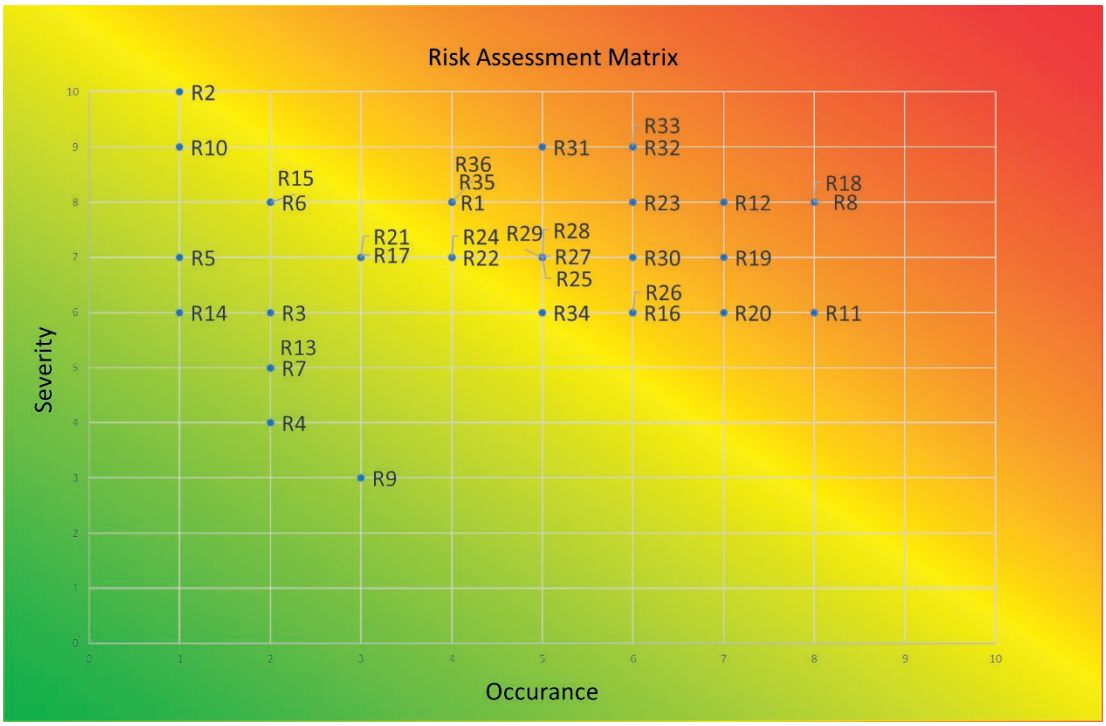

Figure 3. Risks Matrix.

Table 13. Logistical Risk identification and analysis.

Risk ID	Risk Domain	Risk Identity	More Details	Effect	S	O	D	RPN
R30	Network-related	Logistical	Unable to deliver due to the spread of COVID-19 cases among third-party employees	This may affect the delivery time of shipments, and it depends on the third party's policies and ability to fulfill its obligations.	7	6	4	168
R31	Network-related	Logistical	Unable to deliver due to complete shutdown	Shipments will be delayed for the closing period.	9	5	7	315
R32	Network-related	Logistical	Inability to deliver due to accidents on ships	Shipments will be delayed for a period dependent on the ability of the third party to recover from the accident and its severity.	9	6	3	162
R33	Network-related	Logistical	Lack of Inventory	Loss of sales and customers affects the reputation of the enterprise.	9	6	4	216
R34	Network-related	Logistical	Credit risk	Penalty for switching to another service provider.	6	5	3	90
R35	Network-related	Logistical	Lack of security procedures	Loss of assets, reduced profits, civil or criminal lawsuits, or even enterprise closures.	8	4	6	192
R36	Network-related	Logistical	poor communication	Failure to provide correct delivery information on time or lack of communication about delivery issues.	8	4	3	96

Table 14. Logistical Risks Mitigation.

Risk ID	S	O	D	RPN	Action plan	New S	New O	New D	New RPN
R30	7	6	4	168	Hire temporary service providers	6	5	4	120
R31	9	5	7	315	Hire additional service providers to meet the customer needs in a short time after the lockdown period.	7	4	7	196
R32	9	6	3	162	Separate deliveries to minimize losses in the case of an accident.	8	5	3	120
R33	9	6	4	216	Have backup inventory and improve the forecasting system.	7	5	3	105
R34	6	5	3	90					
R35	8	4	6	192	Improve inventory management and forecasting system	7	3	6	126
R36	8	4	3	96	have strong relations with tiers and distributors, share information, and collaborate	6	3	3	54

Table 15. FMEA.

Risk ID	Risk Domain	Risk Identity	More details	S	O	D	RPN
R1	Environmental Risks	Accidents	fires or machine accidents	8	4	7	224
R2	Environmental Risks	Politics	Complete cut-off	10	1	9	90
R3	Environmental Risks	Politics	Demand	6	2	4	48
R4	Environmental Risks	Weather	snow, heavy rains, storms, or floods	4	2	4	32
R5	Environmental Risks	Earthquakes		7	1	8	56
R6	Environmental Risks	Terrorism		8	2	8	128
R7	Environmental Risks	Currency Fluctuations	Shortage in finances	5	2	3	30
R8	Environmental Risks	Closures due to COVID-19	ranges between 5-14 days	8	8	4	256
R9	Operational	Labor	Labor Injuries	3	3	4	36
R10	Operational	Labor	Labor strikes	9	1	7	63
R11	Operational	Labor	Few COVID-19 cases among workers	6	8	3	144
R12	Operational	Labor	More COVID-19 cases,	8	7	3	168
R13	Operational	Labor	Random Failures in IT Systems	5	2	3	30
R14	Operational	IT-System Failures	Quality detector fails	6	1	4	24
R15	Operational	IT-System Failures	Cyber Attacks	8	2	5	80
R16	Operational	IT-System Failures	Machine Failures	6	6	3	108
R17	Operational	Labor	poor employee utilization	7	3	2	42
R18	Network-Related	Demand	Fluctuation in demand	8	8	2	128
R19	Network-Related	Demand	Fluctuation in demand	7	7	3	147
R20	Network-Related	Demand	Fluctuation in demand	6	7	3	126
R21	Network-Related	Demand	Losing Key customers if there are no long-term deals with any of them	7	3	6	126
R22	Network-Related	Demand	failing to meet customer demand in time	7	4	4	112
R23	Network-Related	Demand	Bullwhip effect	8	6	6	288
R24	Network-Related	Supply	key suppliers' financial failure	7	4	4	112
R25	Network-Related	Supply	discontinuity in the supply of essential goods	7	5	4	140
R26	Network-Related	Supply	Poor supplier performance	6	6	5	180
R27	Network-Related	Supply	First-tier inability to deliver because of internal closures	7	5	5	175
R28	Network-Related	Supply	supply or service interruption	7	5	5	175
R29	Network-Related	Supply	prices up	7	5	6	210
R30	Network-Related	Logistical	inability to deliver because of COVID-19 cases among the 3rd party employees	7	6	4	168
R31	Network-Related	Logistical	inability to deliver because of total lockdown	9	5	7	315
R32	Network-Related	Logistical	inability to deliver because of accidents on the ships	9	6	3	162
R33	Network-Related	Logistical	lack of inventory	9	6	4	216
R34	Network-Related	Logistical	dependence risk	6	5	3	90
R35	Network-Related	Logistical	Lack of security procedures	8	4	6	192
R36	Network-Related	Logistical	poor communication	8	4	3	96

Thus, there is no need to worry about the dangers of the green areas, while those in the yellow areas are alarming. Red is the highest risk.

6. Conclusion

The research paper examines the extensive disruptions in the SC in 2020 due to the COVID-19 pandemic. Focusing on the imperative of adapting to sustainability challenges in an era where many enterprises are reliant on third-party services, the study delves into risk assessment and mitigation strategies during the lockdown. It leverages the Failure Mode Effect Analysis to identify associated risks and suggests measures to enhance supply chain resilience. As a part of the study, the paper also presents a detailed case study of JHHC, an enterprise that not only navigated the pandemic's disruptions but also increased its revenue. Their ability to swiftly adapt to unforeseen challenges, both governmental

and operational, underscored the significance of a well-strategized SC resilience framework. The study particularly highlighted the utility of the FMEA as an effective tool for risk assessment and mitigation. Despite the vast array of potential disruptions, from environmental to logistical, the corporation not only weathered the storm but also managed to enhance their revenue. Their success story in 2020, marked by an increase in net income and pivot to manufacturing essential products, is a testament to the advantages of proactive risk management, sound operational agility, and a forward-thinking approach. In light of such unprecedented global challenges, other enterprises can glean insights from this case study to bolster their SC resilience and future-proof their operations. SC resilience can be achieved by identifying and preparing for risks. FMEA is used to investigate the originals in detail. SCR is any risk that may stop or delay the flow of goods. SCR comes from five domains: environmental, operational, supplier, demand, and logistical. Each domain is examined under the pandemic because COVID-19 plays a significant role in determining the continuity of operations. However, demand and Closures due to COVID-19 risks gain the risk priority, while weather related risk has the lowest risk priority. We also noted the importance of strategic planning because environmental factors cause a lot of risks.

The study illuminates the paramount importance of a resilient supply chain in facing unprecedented challenges like the COVID-19 pandemic. The research finds that despite the vast disruptions, some enterprises, with efficient risk management and resilience strategies, were able to turn potential losses into revenue. Using JHHC as a case in point, the study underscores the necessity of short lead times, dynamic SC, and full-span SC planning. Furthermore, the research showcases the application of Failure Mode Effect Analysis in identifying and mitigating risks in the supply chain, which could be invaluable for future crisis management.

From a theoretical standpoint, this research enriches the existing literature on supply chain management, particularly in the context of unprecedented global disruptions. It offers a systematic approach to risk assessment and mitigation using the Failure Mode Effect Analysis. For managers and decision-makers, the findings emphasize the importance of anticipating and preparing for risks, enhancing resistance to disruptions, and ensuring a swift recovery. The success story of JHHC serves as a practical blueprint for enterprises, highlighting the benefits of a resilient supply chain, proactive risk management, and adaptability. The detailed risk assessment and mitigation strategies provided can guide businesses in fortifying their supply chains against potential future crises. The study provided significant insights into supply chain risk assessment and mitigation strategies during unprecedented disruptions such as the COVID-19 pandemic. However, the case study's focus on a single enterprise, JHHC, might not offer a comprehensive view of the entire industry. Relying predominantly on interviews and historical data, the study may be limited in its applicability to other industries or regions with different supply chain dynamics. The use of Failure Mode Effect Analysis (FMEA) as the primary tool for risk assessment, while effective, might not capture all possible risks, especially those outside of the studied categories. Additionally, the subjective nature of ranking risks based on expert judgments can introduce biases, which might affect the generalizability of the results.

Given the evolving nature of global disruptions, there is an evident need for continuous research in the domain of supply chain resilience. Future research could delve into comparing multiple enterprises across different industries to offer a broader perspective on risk assessment and mitigation strategies. Analyzing the supply chain dynamics of various regions, especially those hardest hit by the pandemic, can provide diverse insights. Embracing a multi-modal risk assessment approach, by incorporating tools other than FMEA, can offer a more holistic view of potential risks. Furthermore, as businesses adapt and innovate post-COVID, new case studies showcasing successful adaptation strategies will be invaluable. Integrating technological advancements like artificial intelligence and machine learning in predictive risk modeling might also be a promising avenue for forthcoming works in this domain.

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