Enhancing Supply Chain Resilience: An Empirical Analysis of Industrial Management Practices and Risk Mitigation Strategies

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***Abstract*—. The global supply chain faces complexity and vulnerability due to geopolitical stress, epidemic and market instability. The study explores the role of industrial management practices and explicit risk mitigation approaches towards supply chain resilience in sourcing, manufacturing, and demand-side risks. With global supply chains increasingly vulnerable to disruptions, it has become imperative to build resilience through strategic interventions. Using Structural Equation Modelling (SEM), the research analyses risk mitigation approaches such as hedging, postponement, risk-sharing, control mechanisms, and strategic sourcing as moderator variables between supply chain risks and resilience. It emerges from the findings that supply chain resilience is not just a default reaction to external pressures but is highly enhanced when the parties involved engage in a proactive approach to risk management. Industrial management practices of inventory control and supplier relationship management coupled with the application of advanced technologies such as AI, IoT, and block chain mediate resilience in firms and improve resilience in organizational quick response and agility. The results reveal that actually implementing targeted risk mitigation mechanisms reduces the intensity of disruptions and firms' capability to adapt to, recover from, and continue with operations. The study remains insightful for practitioners to embed resilience into their firms, while it also sheds light on strategic levers which are adaptable to various risk scenarios. Findings provide a basis for drawing up customized, evidence-based resilience strategies for different industrial settings**

Keywords- Supply Chain Resilience, Industrial Management, Risk Mitigation, Structural Equation Modelling, Supply Chain Management

1. INTRODUCTION

New business environments and the globalization of supply processes have made supply chain networks more complicated than a set of connected links between multiple geographically located points. This increases a variety of risks, including the operational or supply risk, the external market or the political risk, among others. Recent occurrences such as the COVID-19 pandemic have made organizations realize the risks of supply chains, and this has made industries of all fields to reconsider their supply chain management strategies. Today's companies had begun to understand that supply chain risk management is not only a source of competitive advantage, but also a fundamental requirement for business survival in economies characterized by volatility and disruption. Crisis resilience supply chain means the capability of a structure and its suppliers or their configurations in responding, reconstructing and continuing functions in disruption and beyond. While the conventional risk management paradigm is centered on predicting and avoiding disruptions, resilience targets at the creation of the ability to maintain operations despite of shocks [1], [2], [3].

This means that in addition to operational flexibility, it needs to have a well-coordinated and centrally driven plan with visibility and proper working collaboration throughout all the links in the supply chain. This is the ability of a supply chain to hold on to its parameters of efficiency, costs and service quality even during disruption and in turn enable firms to sustain competitiveness. Contemporary industrial management processes are considerably different and are tending towards more flexible, analytical, and integrated ones, which promote SCR. The incorporation of technologies like AI, block chain, and IoT also helps organizations to track the supply chain disruption and its impact in real-time as well as mitigate them at the earliest. Moreover, in industrial management, there is a keener focus on the organization's relations with the supplier, logistics and making sure that the manufacturing systems are flexible to expand or contract according to the prevailing circumstances. Such practices as inventory control, strategic sourcing, and among others serve as the basis of the modern supply chain resilience strategies with the mentioned innovations [4], [5], [6].

However, adaptability in supply chain is rather unique. Various sectors, areas, and organizational structures need the development of unique strategies for risk and organizational vulnerability management. For

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instance, industries, which rely on just in-time manufacturing as the automotive or electronics industries, require a more prominent supply diversity, as well as lead-time authority for coping with disruptions. Meanwhile, organizations that belong to sectors such as manufacturing of drugs or food companies that require stable supply chains would focus on minimizing risks by having measures concerning quality assurance and meeting the standards and having backup systems. Therefore, knowing the unique factors that characterize specific industrial settings affects the improvement of SCR performance. It is very important to note that risk management strategies form a very core component of SCR. Risk management on the other hand is the act of taking measures that would reduce the chances of the disruption or the extent of disruption. Such strategies include sourcing diversification, inventory management, postponement and hedging and others [7], [8], [9]. Continual risk management is implemented by considering possible threats and contingency plans that enable a firm to act fast and proficiently in case of interferences. Therefore, those organizations that properly incorporate risk management strategies in their supply chain management effectively deal with disruption consequences and enhance organizational resiliency. The importance of SCR has emerged now in view of the contemporary global issues going around. The Standard COVID-19 pandemic that went across the world affected the supply chains in a very great way because it exposed the organization to the vulnerability of supply chain networks that depend much on several key suppliers or specific geographic locations. There are multitude of examples where supply chains of healthcare products, automobiles and consumer goods were severely impacted due to lack of availability of raw materials, components and finished products which resulted in heavy losses in terms of revenue as well as customers' confidence. The study found out that those companies which had implemented SCR were in a better place to deal with these disruptions by either changing the production location, sourcing other suppliers or even making their operations more responsive to these changes [10], [11], [12].

Beside massive threats, regional threats, for example, in the form of natural disasters, cyber threats, or political instabilities pose threats to supply chains as well. For instance, lasting impact of Japan's 2011 earthquake and tsunami was to disrupt the global automotive and electronics industries by denying accessible parts produced in the country. In the same way, a container ship getting stuck mid-2021 at the entry of Suez Canal forced a realization that trade channels are hazards. In such cases, firms that had developed supply chain with better buffers, flexibility, and responsiveness were in a better position of handling these disruptions. They are the features, which make today's supply chains much riskier as the number of regulations governing the international trade continuously grows and the emphasis on sustainable and ethical supply chain practices become stronger. There is an ongoing pressure from the consumers and the regulators that seek to reveal the company's impact on the environment, employment practices, and supply chain. Consequently, supply chains that do not respond to such concerns are exposed to operations and reputation risks [13], [14], [15]. It is therefore an advantage of a firm to embrace sustainability and Ethical consideration in resilience strategies so as to manage these challenges and secure consumer trust while avoiding hefty fines due to regulatory issues. Further, SCR plays an important role for competing successfully on the world stage. A shifting operating environment makes the speed of recovery from disruptions a key determinant of market share in today's business environments. This research shows that firms that can quickly respond to supply chain shocks through shifts in resource allocation, production tightness or logistics of flow, are better placed to protect customer satisfaction and consequential loss. On the other hand, companies that have not developed resilience could take longer time to recover, end up incurring higher costs than their counterparts with resilience and definitely may suffer a major blow to their reputation. The study endeavors to examine the involvement of industrial management practices & risk management procedures in improving SCR. This study aims at establishing understanding about how firms can strengthen their supply chain management that would enable them to cope with the various types of disruption risk through examining the relationship between the risk, resilience and the techniques that can be adopted [16], [17], [18]. The key contributions of this research include:

- The study has discovered the key internal and external threats that create disruption of supply chain in global operations. These are business risks that affect operations such as supplier, disruption in production, external risks which are natural catastrophes and political instability. It is in identification and categorizing of these risks that the study was able to reveal when the matter of resilience is most pertinent.
- This research seeks to analyze the industrial management practices used in developing SCR. Such practices include the supplier relationship management, the logistics management, inventory management and the use of technologies like artificial intelligence and the internet of things. The research also seek to find out how these practices can help the firms to prepare for disruptions, adapt to them or even recover from them.
- The body of the research shall therefore explore the usefulness of other methods of managing and reducing risks which include hedging, postponement, diversification among others in boosting the SCR. This will also consider the reality of the study by exploring the real-life situation and case studies to assess how firms have managed to adopt these strategies to avoid any intermission towards enhanced performance.
- They are also a critical element in today's supply chains to track and monitor, analyze, and facilitate

communication in real-time.

The remainder of this paper is structured as follows: The literature review in section 2, comprises issues related to SCR, risk mitigations strategies, and industrial management practices. The research's theoretical foundation and hypotheses are presented in section three based on the dynamic capability's view. Section 4 describes the methodology that was used in the study, data collection and analysis methods. Finally, in section 5 conclusions are given and prospectus of the further research is outlined.

2. Related Works

In recent decades, globalization and the swift evolution of information technology have intensified competition among organizations. To attract new customers, companies are increasingly focusing on expanding their market presence at the regional level [19]. In response, researchers have explored various approaches to bolster supply chain resilience, such as fostering stronger collaboration among supply chain partners and enhancing corporate reputation by closely monitoring supply chain developments and disruptions. Studies have shown that information technology contributes significantly to the improvement of supply chain resilience. For example, information-sharing platforms encourage teamwork and visibility strategies. Even while IoT is becoming more and more popular, not much study has been done on its practical applications. Research is required to examine the potential that IoT offers for redesigning SC, which in turn supports supply chain flexibility and parts of product quality assessments and how it may help businesses increase their SCRs.

The importance of the performance and flexibility of the supply chain has increased considerably in response to recent disintegration, which has occurred due to pandemics and other global crises. Additionally, increasing digitisation, integration and globalisation of supply chains have increased interest in availing Artificial Intelligence (AI) and advanced data analytics to strengthen flexibility and increase overall supply chain performance [20]. The authors in their study investigate the role of uncertainty, both directly and indirectly, in AI, supply chain dynamics and supply chain Resilience (SCR) and supply chain performance (SCP). their ideological structure is in the perspective of organisational data processing capabilities. To evaluate this structure, they employed structural equation modelling using data collected from 279 firms of different sizes operated in many countries and industries. Conclusions suggest that AI has a direct short-term impact on the SCP; however, its actual value lies in taking advantage of its data processing strength for the construction of flexible supply chains, which are necessary to maintain long-term performance. The research comes out as one of some empirical tests, which provides information about how AI capabilities can run sustainable SCP.

The COVID-19 epidemic is the largest disaster for humanity that the world's industries have ever experienced [21]. Massive amounts of interruptions in the supply chain system have been attributed to physical lockdowns, social estrangement, and movement restrictions. The aim of the article in [21]is to assess solutions for decreasing risks in the supply chain structure by strengthening its resilience and to identify crucial elements impacting the worldwide supply chain. In order to investigate the elements that influenced the supply chain systems with the commencement of COVID-19, the research authors combined an integrated decision-making method utilizing the AHP and the DEMATEL. While DEMATEL determined the links between the elements and categorized them according to cause-and-effect groups, the AHP technique allowed the components to be ranked systematically according to their relative significance. According to research outcomes, most essential component in lowering network of supply chains vulnerability was cost optimization, while handling human resources had the least impact.

Throughout the COVID-19 pandemic, a company's capacity to handle hazards and rebound in its supply chains has shown to be extremely useful [22]. Companies that were able to quickly respond, make decisions, and rearrange their supply of resources throughout the pandemic—for which they were unprepared—benefited from these traits. The researchers examined how the COVID-19 pandemic has affected organizations' flexible capabilities and how these abilities have affected supply chain resilience using the dynamic capability view as a conceptual framework. Having these skills is essential to surviving the epidemic. Based on the outcomes of the poll, the developers discovered that COVID-19's effects on a company's primary supply chain affect that company's capacity to take advantage of opportunities and counteract risks. Moreover, we discovered that supply chain resilience is significantly impacted by reconfiguration capabilities. As a result, businesses were forced to reallocate resources in order to better meet demand due to the effects of COVID-19 on the supply chain downstream. While downstream disturbances made use of reconfiguration capacity, upstream disturbances forced businesses to respond to possibilities and hazards in the supply environment.

The effects of supply chain agility, resiliency, collaboration, and internal cooperation on long-term benefits were investigated in [23]. The research's respondents were employed by Indonesian industrial enterprises. An online survey with a five-point Likert scale was utilized to gather data and get the thoughts of those who responded. The survey was sent to the pre-selected group of production companies through emails and the social networking platform WhatsApp, employing a hyperlink from a Google Form. Out of the 672 surveys that respondents completed, 456 of them successfully completed them and were deemed legitimate for additional study. The information was analyzed using SmartPLS software version 3.3 and partial least squares regression. The outcomes validated each of the nine

postulated theories. Supply chain collaborations, SC flexibility, and sustainability are impacted by internal cooperation by means of interdepartmental data exchange. Furthermore, SC collaborations enhance SC resiliency, flexibility, and long-term advantages by managing demand fluctuations and ensuring timely material supply. SC resilience and long-term benefits are impacted by SC agility, which controls production capacity and maintains the smooth operation of the manufacturing operation. By ensuring consistent sales volumes and prompt product delivery during pandemic situations, SC resilience enhances long-term advantages.

Previous studies have pointed to the growing relevance of SCRs due to existing global threats such as: COVID-19, globalization and technological innovations. Supply chain disruptions can be in the form of pandemics or any other disasters and this requires adaptiveness, integration and handling of risk. Technologies that have been mentioned as important for the improvement of SCRs include AI, IoT and information-sharing platforms. In particular, several works are devoted to managing potential threats by adopting approaches such as cost control, people management, and versatile reconfiguration resources. There are important factors that need to be evaluated on SCRs and these include techniques like AHP, DEMATEL among others. The study also points out that internal cooperation, flexibility, and collaborations have the most and long-lasting effect on supply chain by stabilizing during disruptions. These findings offer useful recommendations to firms on how they can strengthen supply chain management for resilience through dynamism, innovation, and teamwork.

3. THEORETICAL FRAMEWORK AND HYPOTHESES

With growing interest in SCRM all across the globe, it is important to identify foreseeable risks, which would affect the material and information flow and hence useful to decide on the possible strategies. Literature review carried out on how supply chain risks are managed across the globe has revealed that such disruptions are complex. Supply chain risks can be broadly categorized into two types: The intrapersonal and interpersonal communication are the modes of communication that are comparable to the internal and external. Business discretionary risks are internal issues with concerns to capacity and operation involving factors like suppliers and customers while operating. Risks on the other hand are external factors like natural factors, political systems and market drifts. In the context of this investigation, it is important to note that the work addresses the supply chain risk management at the operational level, which is involved in sourcing, manufacturing and delivery. This paper does not focus on factors outside the company's control including: Security concerns, macro-economic factors, policies, competition, political systems, and natural calamities. The major example of external risks is the natural disasters or terrorist acts, the probability of which is low and thus makes it rather challenging to control them. Hence, this study focuses on internal risks that are usually sourced mainly from customers and suppliers. Such internal risks are easily managed and are less risky compared to other risks since they can be easily administrated by strategic industrial management practices [10, 11, 12].

3.1 *Risks in Global Supply Chain Management*

Today, supply chain risks lurk vastly to contest the global supply chains and impede the smooth flow of goods affecting overall business performance. These risks can be broadly classified into two categories: there are internal and external factors that affect performance by organizational members. Internal risks are those risks that are inherent in the supply chain operation and are linked with factors such as supplier reliability, production capabilities, and delivery performance. On the other hand, external risks are those that are beyond one's control such as acts of God, political instabilities among others and market fluctuations. Escalations risks are internal and business risks originate from functioning areas such as procurement, production, and supply. Delays, quality problems or even working capacity problems from suppliers may actually severely disrupt production lines. Likewise, problems in the manufacturing capacity, deterioration of equipment, or absence of workers can result to manufacturing setback. Moreover, it is possible to encounter some difficulties in the delivery of goods to the customers due to such factors as transportation problems, incorrect storing of products in warehouses or fluctuations in the demand. All these risks are however manageable through proper partnerships, organization capacity and inventories control. Geopolitical factors are always located outside the organization and may include factors such as a change in leadership among ISA members and the signing of new contracts with other countries or an unfavorable weather condition or natural disasters. Political risks may restrict access to specific markets, goods or services due to trade wars or imposition of sanctions. External factors, which may be the fluctuating exchange rates or change in legislation on matters concerning supply chain, influence the cost structure. Also, disasters that occur naturally such as earthquake, floods or, pandemics can shut down entire regions and certainly no company can continue his normal business [13], [14], [15]. External risks are more difficult to control and model, yet, by creating a supply chain risk management program by diversification, risk sharing or contracting with reliable strategic suppliers, these risks can be mitigated. Mitigating these risks remains crucial in improving the ability of organizations and firms to cope and recover with the disruptions that affect their supply chains. The diagrammatic representation of Supply chain risk management process has been depicted in Fig 1.

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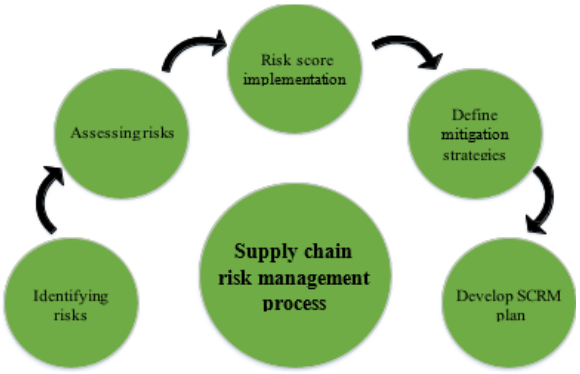

Fig 1. Risks in Global Supply Chain Management

3.2 *Supply Chain Resilience*

Supply chain resilience therefore means the capability of the supply chain system to respond to shocks, absorb the impacts of shocks and recover from shocks in a way that has minimal effect on business performance. Resilience has thus been seen as of a growing value in an organization, enabling it to confront disruptions of different natures, from catastrophes to economic downturns within the shortest time possible. The concept of supply chain resilience, therefore, is not only concerned with reacting to disruptions by developing the capability to manage disruptions effectively, mitigate risks and rebound. Flexibility is the most important attribute of supply chain management since it enables organizations to respond to unpredictable changes in demand, supply and or market forces. The last is the visibility that keeps track of all the activities of the supply chain in an organization and promptly acknowledge supply chain breakdowns. The IoT, block chain and artificial intelligence are the trends which allow supply chain visibility hence improving an organization's possibility of addressing risks [2], [21], [22]. It is also important to engage in efforts to collaborate so that shocks do not catch organizations off guard. Map of supply chain relations imports and share supplier and customer's reaction and strategies during the disruption and workers of logistics providers for retaining safety. Flexibility also builds on resiliency by enabling organizations shift production, supply or delivery in the event of an occurrence of an unpredicted event. Moreover, there is also back-up supplier, resource in double or even triple contingency of transport as well as additional stocks for more security if there are any interruptions. This, of course, results in a rising of the cost of operation but it also strengthens three key aspects with the understanding that the primary resource is at risk Redundancy. Through such ERPMES elements interconnection, the resilient supply chains instead of only aiming at continuing operations and restoring loss, can provide customer satisfaction, operation efficiency and competitive advantage after the disruptions. Risk management strategies and industrial management practices come into play to fashion out an organization's resilience to achieve the desired durability. The diagrammatic representation of Supply chain resilience has been depicted in Fig 2

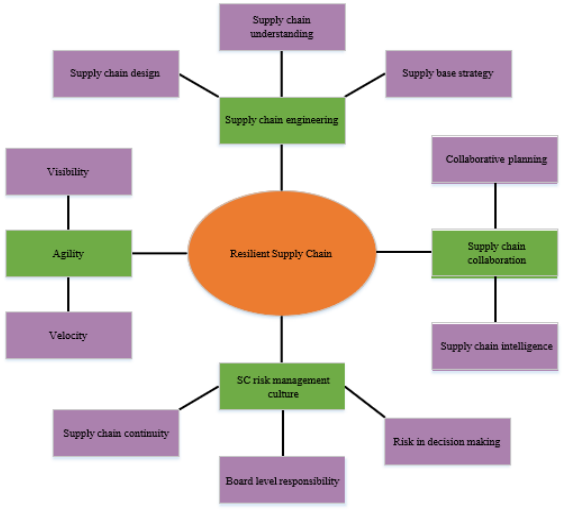

Fig 2. Supply Chain Resilience

3.3 *Mediating Role of Supply Chain Resilience Capability*

Supply chain resilience capability can be viewed as the moderator of the relationship between supply chain risks and resilience. It concerns the data that defines that certain fundamental capabilities that make a supply chain capable of absorbing, adapting and getting back on its feet when disrupted. These capabilities put together essentially define the scaffolding of a supply chain risk management which turns threats into opportunities in the management of supply chain risks. Through buffering the disruptions, resilience capability augments the existing capacity of a firm to deal with internal and external threats. The foundation of resilience capability is agility that enable organisations to shift quickly and adapt manufacturing, supply or logistics plans when facing disruption. Flexibility means that while supply chains will remain fully functional in terms of stress in capability, positioning, or demand they can easily adapt. Visibility works hand in hand with agility by giving an updated review of the supply chain undertakings [3], [4], [23]. Increased awareness enables business organizations to discover new threats, foresee disruptions and act to prevent them. Another building block of resilience capability includes the concepts of collaboration with suppliers, distributors and logistics providers. These familiarity leads to good working relations and ensure that all stakeholders act in harmony in dealing with supply chain issues. Thus, the dissemination of pertinent data and physical commodities can decrease the effects of disruptions and shorten recovery time. Duplicity of supply chain resilience capability creates another line of defence to supply chain disruption, having backup plans, backup suppliers and safety stocks to support operations in such circumstance where the main supply resources have been disrupted. Despite the fact that redundancy leads to increased costs it is useful in helping counter act

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certain risks that are beyond the normal course of business. Consequently, through bridging the relationship between risks and resilience, the supply chain resilience capability enables organizations minimize adverse effects of disruptions. It involves itself in the establishment direction and implementation of industrial management practices and the control and prevention of risks in the industrial growth of supply chain hence contributing positively to the solidity of the supply chain.

3.4 *Moderating Role of Risk Management Strategies*

Risk management strategies are found to occupy a significant moderating role in increasing levels of SCR through proper management of the disruptive impacts and contingent risks. These strategies operate as a shock absorber which dampens the impact of risks in the Supply Chain and slows down the formation of resilience capacities. When proper risk management techniques have been adopted by firms/organizations, then the impact of disruptions are brought down, costs are also reduced including claims and recovery time are also raised. One of the biggest tools of risk management is hedging which can be done through operating with different suppliers, purchasing the materials in different countries or using many ways to transport the goods. A hedge has the effect of surrounding a firm from a sole supplier, thus minimizing the chance of supply interruption in future in cases there is an element of bottleneck in the supply chain or perhaps some geopolitical instability. Fourth, postponement which also known as end-customers delay means that the final production is deferred until demand is more certain to minimize overproduction risk [7], [8], [9]. Thus, the decision-making about certain key production factors can be flexible and timely depending on the demand on the market, with no additional costs on overstock. On the other hand, speculation is handy in low risk by enabling businesses to make a huge quantity of products that are assumed in the market as they are produced, and delivered early. Although, it can be disadvantageous if the demand or supply conditions are unpredictable as it is most advisable to use it together with sound market assessment and projections. Mitigation activities like vertical integration or better supplier control increase the level of control and influence over the supply chain and therefore helps increasing the level of SCR. Finally, the strategic use of outsourcing means that there are key processes which can be directly controlled by a company, thus minimizing the risk of outside interference. Finally, risk sharing or transfer includes insurance and outsourcing where the firm is able to take the risk and transfer it to other parties. These strategies minimize the cost consequences of disruptions and help the companies to remain functional even if some event occurs. These risk management strategies are also helpful to the overall supply chain by reducing the effects of risks which exist in the environment. They make sure that firms are not only in a position to manage risks but also in a position to protect themselves and be in a position to restore-normalcy in a short span of dry spell period or other calamities that disrupt business operations. The diagrammatic representation of Moderating role of risk management strategies has been depicted in Fig 3

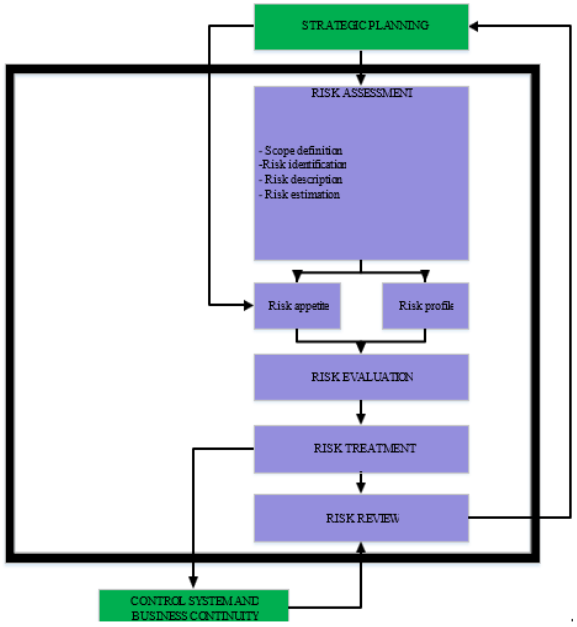

Fig 3. Moderating Role of Risk Management Strategies

3.5 *Development of Hypothesis*

H1: Among businesses with high supply chain risk, there is a noteworthy positive correlation between supply chain risk management and industrial management techniques in the following domains: (a) sourcing; (b) manufacturing; and (c) demand management.

H2: In the interactions between the total degree of SC resilience and the risks associated with sourcing, production, and delivery, SCRC serves as a moderating variable.

H3: The utilization of industrial risk mitigation strategies by firms, such as acceptance, avoidance, postponement, hedging, control, sharing and transferring of risks, intensifies the positive and significant association between supply chain resilience capability and sourcing risk.

H4: Production risk is positively correlated with a company's capacity for supply chain resilience; however, when a company uses risk management strategies, including risk acceptance, avoidance, postponement, speculation, hedging, control, sharing, and/or transfer, the correlation is not as strong

H5: Strategies for sharing and/or transferring risks, hedging, control, delay, approval, avoidance, and speculations all mitigate delivery risk and supply chain resilience.

4. RESULTS AND DISCUSSION

4.1 *Structural Equation Modeling Analysis*

SEM is a statistically sound method for analyzing patterns of observed and latent data which are interrelated in a multivariate manner. Situating SEM in the context of supply chain resilience is also beneficial because the methodology is designed to support the evaluation of complex relations between risks and industry- level management practices firms deploy to manage these risks. Unlike simple regression analysis, SEM can capture multiple relationships at once making it possible to uncover complex interactions of factors as far as building resilience in the supply chain is concerned. This method is especially useful when working with such variables as supply chain risks or resilience that are not quantifiable but can be reasoned from the corresponding proxies. The rationale for adopting SEM in this study is as follows: To determine the extent and direction of association between supply chain risks, industrial management practices, risk management strategies on the one hand, and supply chain resilience on the other. In particular, SEM may assist in identifying how sourcing, manufacturing, and demand risks impact a firm's resilience, in particular. Further, SEM enables assessing a mediation effect, when IM practices moderate the risks and resilience and moderation effects, where risk management implementation enhances or diminishes these relations. In this way, SEM can help to study not only the direct effects, but also the indirect effects of the factors under investigation, so as to gain a clear understanding of how the variety of factors may work in concert in order to improve supply chain resilience. SEM is justified to be used in this research given that the relationships that are under investigation in this study are multivariate in nature. The research explores various facets of supply chain risk and the interactions between these risks and supply chain resilience could be moderated and mediated by the set contemporary management practices and supply chain risk mitigation techniques respectively. The great advantage of SEM is that it allows for the testing of these relationships detecting not only direct effects, but also indirect effects. Further, it has been found that SEM is efficient when it comes to working with research hypotheses that involve one or more latent variables like resilience which are not directly measurable but are expressed through a number of other variables. The technique also makes it possible to determine the kind of effects that various risk management measures have on the strength of the associated relationships, thus, offering rich insight on the dynamics in supply chain management.

4.2 *SEM Measurement Model Specification*

In this study, the measurement model in the structural equation modelling (SEM) approach was designed to validate the relationship between latent constructions, such as supply chain risk, industrial management practices, risk mitigation strategies, supply chain flexibility (SCR), and flexibility capabilities (SCRC). SEM technology is particularly favourable for this research, The measurements that was carried out for the model are:

- Construction reliability: using overall reliability (CR) values with a threshold of 0.70 for acceptable reliability.
- Convergence validity: Using the average variance (AVE) with a minimum range of 0.50, and checking the factor loading for each indicator (preferably> 0.50).
- Discriminated legitimacy: Ensured using the Fornle-Larkar criteria, where the square root of AVE for each construction exceeded its correlations with other constructions.

The model includes latent variables:

- Sourcing Risk (SR): Supply disruption, material quality, seller is measured through indicators related to reliability and cost issues.
- Production Risk (PR): Operating breakdown, process complexity, product quality and cost related items.
- Distribution Risk (DR): Demand was captured through ups and downs, inventory issues and logistics dependence.
- Supply chain flexibility (SCR): represented the ability of a firm to recover and recover from disintegration.
- Supply chain flexibility capacity (SCRC): defined through accountability, adaptability and visibility.

All measurement indicators were tested using the confirmation factor analysis (CFA), and the construction with insufficient loading (<0.40) was either modified or dropped to increase the model fit. The results of this verification are presented in Table 1, confirming that the construction of the use is both reliable and valid for subsequent SEM analysis.

4.3 *Model Specification*

In this study, the correlations between supply chain risks, industrial management practices and resilience capability are tested by the method of SEM. This model uses both the independent, dependent as well as mediator and moderating variables to describe how various risks affect SC resilience and how SC management practices and risk mitigation solutions may interact in the process. The independent variables in the model are the key sources of supply chain risk: Here, there are three main risks namely sourcing risk, manufacturing risk and demand management risk. All of these risks are indicative of various forms of vulnerability of the supply chain on capability to deliver for a smooth operation of the firm. Sourcing risk relates to some of the difficulties that may occur during the procurement process of raw materials or components from the suppliers such as delay or quality or reliability. Manufacturing risk relates to internal risks affecting the production processes of the manufacturing firm for instance, the breakdown of production tools, a shortage of employees or a hitch in the production process. . Demand management risk has to do with unpredictability of customer demand in the market

and a firm being unable to match up its manufacturing to suit the market requirement as captured through order sizes. These risks become the forces that may have the capability of interrupting the supply chain operation and overall supply chain resilience as long as they are not well managed. The dependent variable is the firm's supply chain resilience capability which measures degree of capability of the supply chain to resume operation when they encounter risks. This construct reflects on the supply chain ability to be averse to change, sensitive to shifts and versatile to new occurrences. The resilience capability is a hypothesized construct, and thus cannot be actually observed, but it can be inferred out of the delivery reliability, availability, and flexibility to supply and demand changes. This variable is the dependent variable which the model seeks to predict because increasing resilience is what firms exposed to supply chain risk seek to achieve. It means that the industrial management practices act as a mediator variable in the model developed here. It is a way that firms use to control risk factors associated with the operation of supply chain. Organizational activities can encompass workflow mapping, implementing measures in conformance to ISO standards, stocks minimization, or application of execution procedures.

4.4 *Measurement Model Validation Process*

To ensure the strength and validity of the SEM measurement model, a comprehensive verification process was performed using the established statistical benchmark. First, construction reliability was assessed through Cronbach's Alpha and Composite reliability (CR), both measure internal stability. In this study, all constructions gained more CR values than the recommended range of 0.70, indicating that indicators firmly measure their respective latent variables. Next, convergence validity was evaluated to determine whether the items that are related, in fact, are related. This was done by calculating the average variance (AVE) and by checking the factor loading of individual items. AVE above 0.50 shows that more than half of the variance in the indicators is explained by latent construction. In addition, the factor loading for each indicator exceeded 0.50, which supports the strength of the item-to-construction relationship. A loading below the acceptable limit was reviewed for theoretical relevance before maintaining or removing any item review. To assess discriminatory validity, the Fornell-Larcker criterion was applied. This includes comparison of the square root of each construction AVE with its correlations with other constructions. A construction satisfies discriminatory validity if the square root of its AVE is more than this inter-construction correlation, which confirms that the construction shares more variance with its own indicators than others. This step was necessary to ensure that latent constructions measured different concepts and it was not more overlapping. Collectively, reliability, convergence validity, and discriminatory validity analysis confirmed that the measurement model was both statistically and theoretically, after which the structural model was provided a reliable basis for the evaluation.

The moderation analysis appears to indicate that the relationship between supply chain risks and the capability of resilience is indirect and conditioned by industrial management practices adopted. That is, better management is useful in managing risks and subsequently improving resilience within the firms that embrace it. This is an important aspect of the model as it reveals that facing risks does not guarantee resilience, there is a need for proper management to close that gap. The moderating variables in the model are the several risk management tactics that firms use to eliminate supply chain risks. Such risk management strategies are Acceptance, Hedging, Control, Postponement, Sharing/ Transferring, and Avoidance, Speculation. Acceptance is a policy by which the business accepts certain type of risks to happen and aims at reducing their effects rather than preventing them from happening in the first place. Avoidance pertains efforts used to reduce risk sources for instance supplier diversification or relocating production from high-risk areas. Put-off decision means that the individuals in the organization decide to defer certain decisions or actions until the level of uncertainty of the organization is reduced. The definition of speculation is to act in anticipation and/ or expectation of a certain occurrence with the intention of benefitting from it, for instance, buying the raw materials earlier in preparation for increased production. Managing means the insuring against the risk by making offset positions or the seeking of other sources. Control refers to measures put into place that can minimize the occurrence of risks such as having better quality controls or more stringent supplier agreements. Sharing or Transferring refers to distribution of risk with other entities for instance insurance firms or even suppliers. These strategies also act as the mediator of the relationships between the independent variables and the dependent variable. This indicates that the risk management strategies that are in place can amplify or diminish the effect that sourcing, manufacturing and demand management risks have on resilience. For instance, a high sourcing risk firm may demonstrate more organizational resilience if the firm engages in risk management tools such as hedging or sourcing from multiple suppliers. The SEM framework makes it possible to model how these various supply chain risks impact resilience and how that influence is conditional on the management frameworks for supply chain risk, as well as the actual risk mitigating approaches taken by firms.

Table 1 shows the Confirmatory Factor Analysis (CFA) results for five constructs -Sourcing Risk (SR), Production Risk (PR), Delivery Risk (DR), Supply Chain Resilience (SCR), and Supply Chain Resilience Capability (SCRC). All constructs are checked by multiple statements (items), along with their factor loadings, Composite Reliability (CR), and Average

Variance Extracted (AVE). For Sourcing Risk, item loadings reveal contributions ranging from 0.526 (SR7) to 0.653 (SR5) (e.g., risk of higher quality of the materials, or complexity of the product of materials):CR of 0.701 and AVE of 0.466. Production Risk shows loadings of from 0.429 (PR1) to 0.607 (PR2), considering the process and disruptions in operations as indicators: CR of 0.767 and AVE of 0.422. Delivery Risk, includes eight items with loadings varying from 0.398 (DR1, DR7) to 0.574 (DR4), covering fluctuations in demand, interruptions in inventory, and reliability of transportation: CR of 0.799 and AVE of 0.430. The Supply Chain Resilience construct includes three indicators with loadings ranging from 0.509 to 0.642, including risk to supplier, risk to customer, and risk to operation: CR of 0.666 and AVE of 0.439. Measures of the Supply Chain Resilience Capability include ten items with loading ranging between 0.478 and 0.536, including capability for rapid response, adaptability, trust, visibility, and ability to manage change due to disruptions: CR of 0.811 and AVE of 0.406

Table 2 displays correlation projections between five constructions: Source Risk (SR), Production Risk (PR), Distribution Risk (DR), Supply Series Flexibility (SCR), and Supply Series Flexibility Coming (SCRC), as well as their respective means and standard deviations. The diagonal values represent the average variance (AVE) for each construction: 0.466 with SR, PR 0.422, DR 0.430, and SCR at 0.439, and SCRC at 0.406. Correlation coefficients give moderate indications of strong positive relationships between constructions, with the highest correlation between SR and PR (R = 0.627), after PR and DR (R = 0.592), and all 0.53, all 0.53, and coherent associations between SCRC and other constructions. The instruments for constructions range from 3.12 (SCR) to 3.22 (DR), which suggest a relatively high level of agreement between respondents. Standard deviations range from 0.397 (SCRC) to 0.552 (SCR), indicating some variation in reactions but overall moderate stability in constructions. These correlations suggest interdependence between different types of supply chain risks and the need the need to reduce them.

Table 3 presents three structural equation models M1, M2, and M3 that test the mediating effect of SCRC in the association between supply chain risks; SR, PR, and DR and SCR. In model M1, the ability of SCR is compared to the capacity of SR. The path coefficient for the direct link from SR to SCR especially in figure 1 is 0.193 with t-value of 2.812, thus, revealed significant differences in the mean scores for each of the groups, p = 0.003. However, the path coefficient between SR and SCRC is stronger which shows that there is a moderate and positive relationship between them with the path coefficient of 0.664 and a t-value of 8.119, significant level of p = 0. 000. It is ascertained that SCRC has a positive impact towards SCR effecting a coefficient of 0. In the current study, the mean estimated value was 0.522, proving that SCRC moderately and positively mediates the association between SR and SCR. The two sets of values for indirect impact and for the total impact again support the mediating role of SCRC in this relationship. Thus, the model M2 focuses particularly on the relation between the PR and SCR. The direct path from PR to SCR is also prominent emerging with path coefficient of 0.190 and t-value of 2.533 respectively. Like M1, there is a direct connection between PR and SCRC, which is positive and fairly robust of 0.683 while SCRC has considerable value on SCR of 0.514. The indirect influence of the PR variable on the SCR via the SCRC is 0.381 and thereby making the overall impact been 0.671. In Model M3 the impact of DR on SCR has been taken into consideration. Significantly, the path coefficient between the first path, DR and SCR is slightly lower with a value of 0.166 and t-value 1. These results underscore H2, showing that Supply Chain Resilience Capability mediates the connection between risks in sourcing, production, and delivery and overall supply chain resilience. Further, these findings corroborate with the propositions stated in Hypothesis 3, Hypothesis 4, and Hypothesis 5 suggesting that in order to more effectively build up the risk coping capacities it is crucial for firms to proactively implement risk management strategies in relation to sourcing management, production management, and supply delivery management.

Table 1 shows the Confirmatory Factor Analysis (CFA)

STRUCTURE	CODE	STATEMENT	FACTOR LOADING	CR	AVE
Sourcing Risk (SR)	SR1	Risk of Supply Disruption	0.545	0.701	0.466
	SR2	Risk of Sourcing Flexibility	0.530		
	SR3	Risk of Material Quality	0.606		
	SR4	Material Pricing and Procurement Costs	0.578		
	SR5	Complexity of Product Materials	0.653		
	SR6	Vendor Relationships	0.535		
	SR7	Vendor Selection	0.526		
Production Risk (PR)	PR1	Operational Disruptions	0.429	0.767	0.422
	PR2	Process Architecture	0.607		
	PR3	Manufacturing Disruption	0.544		
	PR4	Ownership risk	0.585		
	PR5	Product quality	0.523		
	PR6	Production Cost	0.524		
Delivery Risk (DR)	DR1	Demand Fluctuation	0.398	0.799	0.430
	DR2	Market Forecast Risk	0.507		
	DR3	Introduction of New Products	0.532		
	DR4	Product Range	0.574		
	DR5	Inventory Interruption	0.538		
	DR6	Transportation Dependability	0.524		
	DR7	Service Excellence	0.398		
	DR8	Transportation and Inventory Expenses	0.507		
SC Resilience (SCR)	SCR1	Supplier-Related Risks	0.509	0.666	0.439
	SCR2	Risks related to customers	0.642		
	SCR3	Operational Risks	0.541		
SC Resilience Capability (SCRC)	SCRC1	Capability for Rapid Response	0.505	0.811	0.406
	SCRC2	Adaptability to Change	0.479		
	SCRC3	Resilience to Supply Chain Disruptions	0.531		
	SCRC4	Capacity to Sustain High-Risk Awareness	0.527		
	SCRC5	Capacity to Uphold Trust with Partners	0.536		
	SCRC6	Enhancing Supply Chain Visibility	0.509		
	SCRC7	Capacity to Manage Changes Resulting from Supply Chain Disruptions	0.483		
	SCRC8	Capacity to Implement Adaptive Capabilities	0.525		
	SCRC9	Flexible Supply Chain Structure	0.478		
	SCRC10	Ability to Manage Changes Induced by Supply Chain Disruptions	0.505		

Table 2. Correlation estimates

	SR	PR	DR	SCR	SCRC
SR	0.466				
PR	0.627	0.422			
DR	0.507	0.592	0.430		
SCR	0.545	0.422	0.404	0.439	
SCRC	0.537	0.537	0.534	0.531	0.406
Mean	3.15	3.15	3.22	3.12	3.17
SD	0.482	0.481	0.434	0.552	0.397

Table 3. Mediation Relationships

Models	Path coefficient	t value	Significance	Indirect impact	Total impact
1.SR-SCRC-SCR (M1)					
SR-SCR	0.193	2.812	0.003	0.375	0.668
SR-SCRC	0.664	8.119	0.000		0.664
SCRC-SCR	0.522	5.240	0.000		0.522
2.PR-SCRC-SCR (M2)					
PR-SCR	0.190	2.533	0.007	0.381	0.671
PR-SCRC	0.683	8.251	0.000		0.683
SCRC-SCR	0.514	5.217	0.000		0.514
3.DR-SCRC-SCR (M3)					
DR-SCR	0.166	1.700	0.062	0.436	0.622
DR-SCRC	0.664	7.229	0.000		0.664
SCRC-SCR	0.602	5.561	0.000		0.602

5 . Conclusion and Future Works

This investigation offers important information on how firms may improve the supply chain vulnerability to the key risks that affect sourcing, manufacturing, and demand management through effective industrial management and risk management strategies. Overall, the evidence supports the proposition that supply chain resilience is not a function of the risks that firms have to endure but the actions that these firms take to deal with those risks. The study also shows that IM practices act as essential antecedents that firm can use to enhance resilience, this shows that vulnerabilities can be turned to be advantages. Also on the same note, the research highlights the need for risk management strategies including acceptance, avoidance, delay and hedging in order to reduce the effects of risks on resilience capability. The strategies help the firms to maintain functionality and reduced loss after the disruptions have occurred. As has been shown in the study using SEM, there exists a possibility that firms can attain improved supply chain risk management when they incorporate proper management practices and mitigation methods when confronting high risk in the networks. It goes further in protecting companies' supply chains from the effects of disruptions and enabling fast rebound and continuation of operations in an unstable climate. Therefore, it is possible to assert that increasing the organizational supply chain responsiveness enhances control activities and investigates the sources of risks and uncertainty in supply chains. Further development of this research can generalize this study in different sectors and countries to provide in-depth analysis of how the variety of risks and mitigation approaches work in different supply chain environments.

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