



**SELINUS UNIVERSITY**  
**BUSINESS SCHOOL**

**THE IMPACT OF ANTI-FRAGILE SUPPLY CHAIN  
MANAGEMENT ON THE OPERATIONAL PERFORMANCE  
OF THE RUBBER MANUFACTURING SECTOR IN  
SRI LANKA**

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## **Abstract**

The research has aimed to analyse the impact of antifragile supply chain management to measure the operational performance of the rubber manufacturing sector in Sri Lanka. The research has scope on identifying how the rubber industry in Sri Lanka is updating with the improving supply chain based on the speed and accuracy. It is measured with the manufacturing processes and determination on how international and domestic markets have demands of the local rubber products and raw materials. Additionally, it is introduced with the research issues that Sri Lanka is facing regarding their natural rubber output. They have identified the slow manufacturing process and decreased international competitiveness and increased market rivalry in recent years. The operational performance has been measured with reverse logistic, lack of literacy about antifragile supply, lack of preparedness in their SCM.

The second chapter different literature has been discussed which has helped to understand the importance of anti-fragility within the supply chain. It has been further depicted from the literature that supply chain often faces significant complex behaviour while operating in competitive market. The application of the relevant theoretical frameworks such as RBV theory, Stakeholder theory and theory of constraints also led to examining and demonstrating the operative concepts of Sri Lanka based rubber manufacturing industry. Thus, the firms need to embrace sustainable practices through which they can ensure positive contribution to the environment. However, the rubber manufacturing can adhere to suitable strategies such as life cycle assessment, sustainable transportation to leverage their operational efficiency.

The study adhered to the positivism research philosophy, descriptive design, and deductive approach. It has adhered to both the primary and secondary data collection methods. While the primary data is gathered through survey and the secondary data is extracted through the aligning to the peer reviewed sources. The research has undertaken both qualitative and quantitative data analysis approaches. In case of quantitative data analysis, the research has considered graphs and charts to represent the data in a numeric way whereas the qualitative data analysis ensures to undertake thematic analysis approach where sufficient articles were collected to proceed with thematic analysis.

From the data analysis, it has been depicted that the antifragile supply chain has become the most significant topic and is being undertaken by the business to handle disruptions in the most effective way. This has also helped to enhance the resilience of the supply chain. Business resilience is significant to recover the uncertainties with antifragile supply chains as measuring the business deliveries. It is noted from the survey or the primary data that factors such as the lack of the sufficient resources affect the antifragile supply chain management on operational performance. It is witnessed that the majority of the people agree to the fact that an antifragile supply chain system has the ability to foresee and prepare for the uncertain risks.

Fragile supply chain management process on the operational performance development process in Sri Lanka's rubber manufacturing industry was the subject of a critical discussion in the research study's fifth chapter.

In fact, the term "antifragile supply chain" refers to a system that is shock and volatility proof, implying a stronger and more resilient supply chain procedure within the rubber business. However, on the base of the chapter a thorough discussion has been presented. Moreover, the discussion has been segregated into two parts which are quantitative analysis and qualitative analysis. Discussion based on quantitative analysis focused on the primary analysis where primary data has been presented. Then, discussion based on qualitative analysis considered where thematic analysis has been presented.

The conclusion and recommendations section had focused and explored the well-defined topic based elements that were found to be useful and methodical for examining and understanding the application of antifragile frameworks in rubber manufacturing units of Sri Lanka. The relevant objectives were linked and recommendations were provided. Finally, few suggestions have been listed which the study can follow in the upcoming time.

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# Chapter 1: Introduction

## 1.1 Introduction

According to Jayalath et al. (2017), the rubber industry is emerging in different countries by key players such as Turkey, Brazil, India, and others. These listed countries are expected to record the strongest market gains with acceleration in industrialisation efforts and economic growth. Sri Lanka's growth in manufacturing industry is emerging from current few years. Their rubber growth and natural rubber products are leading industrialisation in the country. Nearly 152,100 metric tons of natural rubber is manufactured per year with 0.68% of global rubber production (Vidanagama&Lokupitiya, 2018). In the rubber industry, energy sources play crucial role in determining the rubber products manufacturing and laboratory uses in purchased grid electricity. According to Sadeghi, Akbarpour and Abbasianjahromi (2022), supply chain management (SCM) is a main approach to deal with chaotic situations. It is management of materials, tools, logistics and information between parties. It could have anti-fragile effects on resisting the operational efficiency. Anti-fragile SCM can grow on the disruptions on unique sets of capabilities and maintaining the exhibiting characteristics of anti-fragile.

It is helpful in increasing efficiency and improving the supply chain based on speed and accuracy. By monitoring the performance and waste management process, it is important to focus on engaging how disruptions can require the unique sets of capabilities (Nikookar, Stevenson & Varsei, 2024). It is important to determine how concepts of antifragility can have resilience on SC domain and the current research contributes to identify the capabilities to enable the growth by following the disruptions. Additionally, it is important to engage with capabilities could have mindfulness and plasticity to feature the method in increasing operational efficiency and quality in industry standards. As the current research is based on bringing the supply chain resilience and better operational efficiency in the rubber manufacturing industry, it is emphasised on how the anti-fragile SCM can be applied as it is contributing towards enabling growth and supply chain disruption. Moreover, it is helpful in engaging the cost reduction, increased efficiency and better decision-making while implementing the cost-saving measures. Additionally, it shows how the country-specific measures are undertaken to develop and utilise the core resources as firm's supply chains are measured. Quality management and anti-fragile SCM are the main variables to research on the industry.

The chapter has purposes to identify background research on achieving the higher firm performance with new technologies, which are interconnected in rubber industry. Therefore, Sri Lanka's rubber manufacturing industry and its growth are interpreted to assess the research in-depth. It stimulates implementation of synergies with research aim, objectives, and questions. Research rationale, scope, contribution, and significance are also discussed to make the research as base. It is important to explore the areas on Anti-Fragile Supply Chain Management, Operational Performance, Rubber Manufacturing Sector in Sri Lanka and other.

## 1.2 Research background

The essence of SCM is considered as integration and coordination of the process on upstream and downstream of supply chain. It is important to establish the national boundaries on domestic and international business management. "Whole-of-the-supply-chain approach" is applied in the rubber manufacturing industry with different personal agendas. It describes how customer relationship, supplier partnership, postponement and strategic supplier partnership are the main roles while measuring the SCM practices. Internal supply chain processes can be engaged with internal supply chain and activities. Operational Performance is emerged with certain supplier competence and its management on overall financial and firm performance of the rubber manufacturing industry in Sri Lanka (Jayalath et al., 2017).

### 1.2.1 Overview of the industry

Sri Lanka is pioneer of the Asian rubber manufacturers from 1876. In western Sri Lanka, Botanical Gardens in Gampaha first introduced rubber seeding and the manufacturing is re-traded in post 1950s. After several economic policies and investment promotions in 1970s, the manufacturing growth as viable and noticed worldwide (Srilankabusiness.com, 2023). During the last decades, Sri Lanka has operated into global markets with their value-added rubber products by processing natural raw rubbers, which includes:

<b>Extrusion rubber products</b>	rubber bands, beadings
<b>Latex rubber products</b>	medical, industrial, and household gloves.
<b>Industrial rubber products</b>	hoses, industrial components, auto parts, tyres, tubes, automotive tyres.
<b>General rubber products</b>	floor mats, sports goods, carpets, footwear, hot water bottles and others.

**Table 1.1: Rubber products**

(Source: Srilankabusiness.com, 2023)

In addition, it is identified that Sri Lanka has become cradle of rubber industry by leading destination of global sourcing and rubber-based products. The country is serving the first seeds of rubbers in the last 150 years age. Currently, the industry is having export revenue of \$930.23 million in 2023 (Refer to figure 1.1). It describes how the revenue is increased with rubber production and manufacturing items.

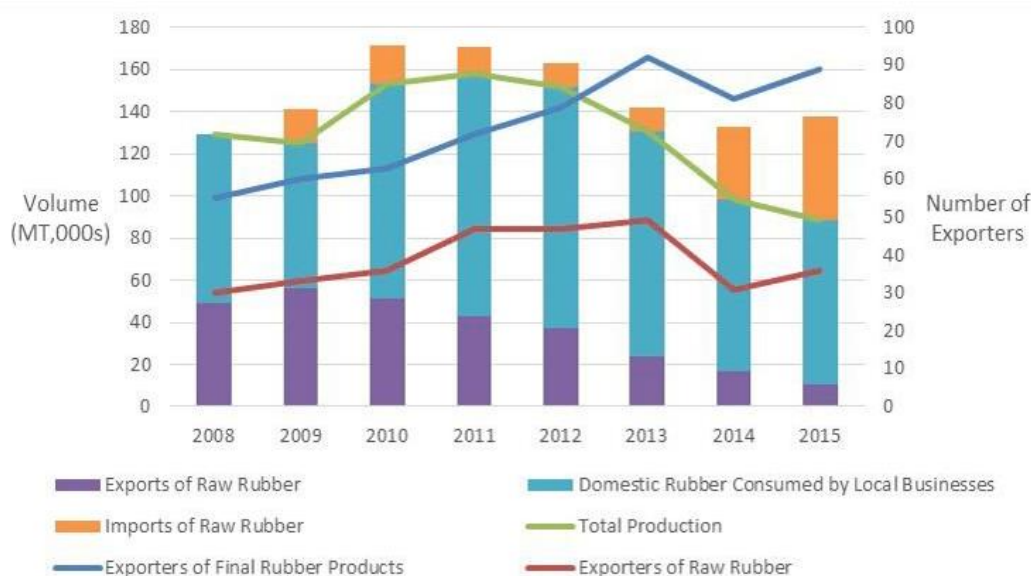
**INDUSTRY FACTS**



**Figure 1.1: Industry facts of Sri Lankan rubber industry**

(Source: EDB Sri Lanka, 2024)

In addition, the country is having high raw materials with rubber development and subtracting the exports from production volumes. There are local consumptions as per Sri Lanka’s import volume. Referring to figure 1.2, it is clear that the industry is experiencing the exports and raw material management as per the demands. It has less demands of export of raw rubbers, whether it has more demands of domestic rubber by local businesses (Daly, Bamber & Gereffi, 2017). Thus, it has some clear views on how the industry is having export demands and consistency on both domestic market and international capture.

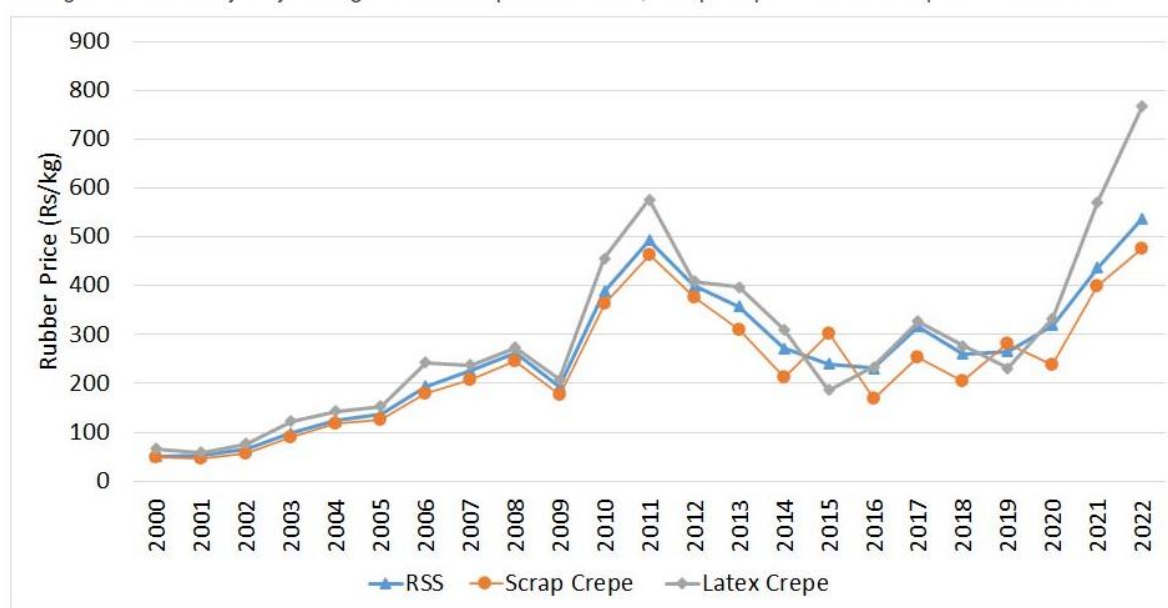


**Figure 1.2: Production and Export Profile of Sri Lanka Rubber Industry**

(Source: Daly, Bamber & Gereffi, 2017)

Referring to figure 1.3, it can be said that the demands of scrap, latex and RSS have different considerations over market value adoption and trends over recent times. It has different considerations over yearly averages. In 2022, the demands of latex crepe were highest as identified (Statistics, 2024). Moreover, technical efficiency is observed as identifying the policy measurements and examination over agricultural involvements with higher output. It has different sets on farmer's conditions, rubber plant quality and policy measures. It is important to ensure how the structure reveals the notable differences on smallholding sector particularly. It is expected to exhibit different efficiency and productivity patterns (Gunathilaka & Gunawardana, 2018). It is estimated how environmental protection and deep ecology play another crucial role in resolving the resource management on financial performance in the international market conditions.

Changes observed in yearly averages of auction prices for RSS, Scrap Crepe and Latex Crepe from 2000 to 2022



**Figure 1.3: Auction prices from 2000 to 2022**

(Source: Statistics, 2024)

### 1.2.2 Background of research areas

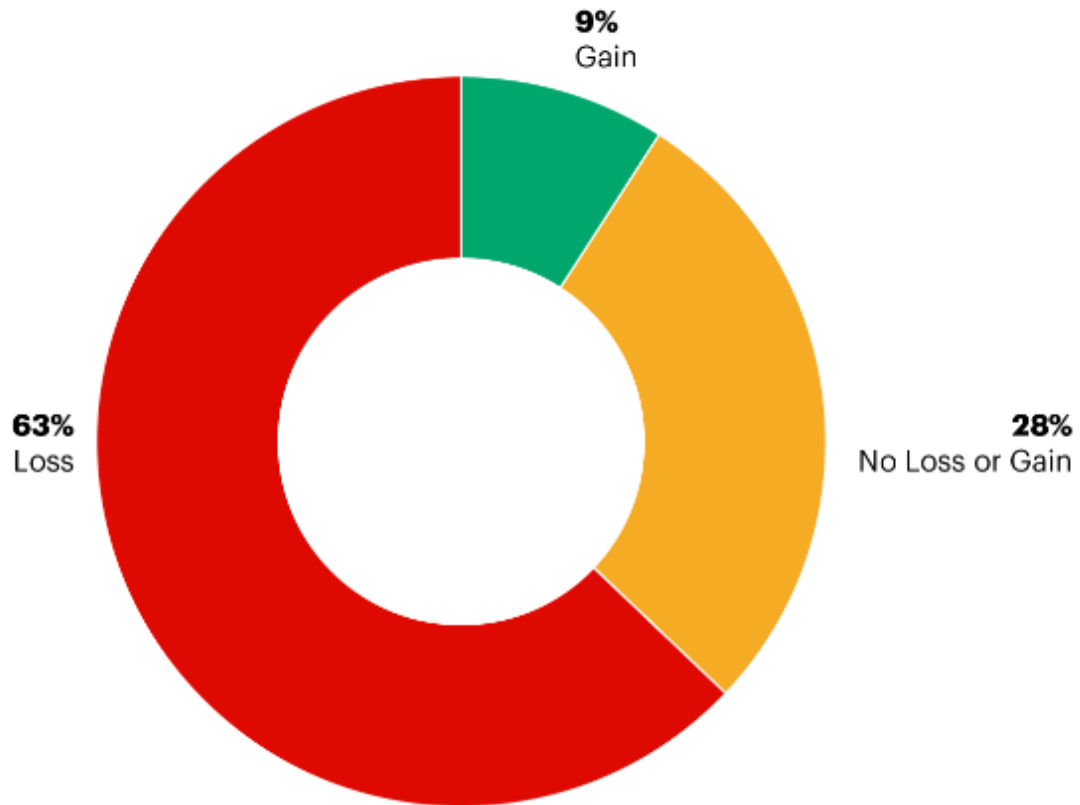
According to Nikoogar, Varsei and Wieland (2021), volatility, stressors, errors, and randomness is ruling the supply chain resilience. Today's world is characterised in gaining disorders from non-financial and financial management. Unlike the robust resilience, it is important to focus on building the unpredictable risk rate and disruption for managing the disruptions triggers. Antifragility is conceptualised based on risks robust and resilient supply

chain development against the disturbances. Antifragile supply chain captures the research development as the industry development depends on supply chain development. Referring to antifragile supply chain activities, it is important to use social responsibilities as extracting the raw rubber manufacturing and production by capturing the rubber production and sustainability as attempting the rubber manufacturing. Operationalization and anti-fragility focused on supply chain development and higher performance development (Größler, 2020). Anti-fragile SC is the key for logistics development. It is applicable in achieving the learning and adapting the change rather than avoiding. It is considered as managing best outcomes by quick adoptions to supply chain demands. The visibility is seen as in packing and loading the supply chain resilient and antifragile means of data management. It is assumed that by 2026, 55% of the manufacturers will redesign the supply chains with AI to get sustainability and efficiency (Lingaro Group, 2023).

Moreover, there are several factors to influence the initiatives despite the initial costs that can offer the significant offers and efficiency over time. Technologies and initiatives are reconsidered to show how it can value the improving revenues and technology development with strategic applications. Disruptions in the global supply chain can affect the manufacturing with cutting costs and reducing waste (Lingaro Group, 2023). Smart manufacturing is trend by involving in automated and connected machines and systems by following the main goals by investing in digital technologies with manufacturing abilities. With resilience, antifragility is also important to develop strong and efficient supply chain. It is equally important to enable the dynamic decision-making as it can accurately develop the stress testing and constant experiments with end-to-end planning in operations. It is important to assess how antifragility works in overseeing and adjusting the decision-making at logistics development. It holds the opportunities when it comes to antifragility. According to Lund, DC and Manyika (2020), shocks in supply chain depends on value chains. Vulnerabilities can be given with international decisions and quality management.

Additionally, these choices are retrieved on quick performance and product delivery within time and costs. It is important to keep constant SC systems and stress management. It is important to get right balance on how the capabilities are characterised with supply chain certainties. It is important to quantify how the organisation can develop the dynamic decision-making capabilities over the decisions taken in industry-specific standards (Robert J. Bowman, 2023). It is important to surpass how the industry examples can be drawn in product and processing manufacturing can be considered by associating with effective supply chain. It is important to convert in plantation manufacturing and rubber manufacturing with

associated energy boosts with partial life cycle assessments. In the rubber industry, it is considered by covering the product manufacturing, pre-processing, transportation, and plantation management.



**Figure 1.4: Impact of uncertainty exposure on revenue**

(Source: Payne, 2023)

Referring to figure 1.4, it is identified that supply chain activities are estimated with exposed uncertainties. Anti-fragile technologies are introduced with uncertainty as identified in loss of value and to deli with uncertainties in the logistics and supply chain activities. The fragile and antifragile exposures are introduced with coping with uncertainty spectrum. In the rubber manufacturing industry, it is identified that uncertainties can be minimised to cope better in thriving the environments (Payne, 2023). Therefore, it is important to engage with how supply chain efficiency and productivity can be improved based on developing the different exposures and revenue development in the industry. The industry is facing the challenges against the exposures in supply chain resilience.

## 1.3 Research rationale

### 1.3.1 Problem statement

Sri Lanka's natural rubber output has faced serious threat in different areas. It is identified that it may drop to 60 million within 2023 (Economy Next, 2023). Additionally, it is identified that rubber-manufacturing industry in Sri Lanka has encountered decrease in international competitiveness, reduced output, and increased market rivalry. The country is having high market competitiveness and world establishment being natural rubber producers (Dunuwila et al.,2017). It is important to establish how long-term expansion is noticed in worldwide marketplace. Additionally, it is identified that Sri Lanka is facing the critical threats while it has affected the industry with less productivity and decreased demands in international country. It is noticed that 15% is dropped from earlier year (Economy Next, 2023).

Year	Production Mt.('000)	Productivity Kg/ha/year	Rubber Extent
1980	133.20	705	222,402
1985	137.50	890	204,298
1990	113.10	773	199,048
1994	105.30	870	160,909
1995	105.70	872	161,600
2000	87.60	683	157,030
2005	104.40	1143	116,050
2010	153.00	1935	125,650
2013	130.40	1644	134,350
2014	98.60	1257	135,710
2015	88.60	1062	136,420
2016	79.10	908	136,140
2017	83.10	809	136,625

**Figure 1.5: Yearly Rubber production**

(Source: The Sunday Times Sri Lanka, 2018)

Additionally, there is global outbreak of rubber products as it is forecasted with less requirements and due to decreased income. It is noticed that from figure 1.1, after 2010, the rubber manufacturing is decreased. However, scarcity of agrochemicals resulted in severe



propagation of rubber plantation, and it has affected hectares of plantations (The Sunday Times Sri Lanka, 2018). It is identified to decreased operational performance in the current years. It is important to establish how the country is suffering from the issues, manage the rubber manufacturing, and fulfil global demands. Thus, it is significant to handle the issues and establish effective SCM across the industry standards and global markets (Robert J. Bowman, 2023). Thus, it is important to ensure how capabilities and antifragility is ensured to characterise how supply chain management can be invested on stress testing and better positions on structuring and centralising the control over the decision-making.

### **1.3.2 Why is it an issue?**

According to the view of Peiris, Kavirathna and Wijayanayake (2022), SCM seems to focus on managing the flow of goods and services along with considering all the processes that are related to converting raw material to finished goods. The Rubber Product Manufacturing Industry has become one of the leading industries that contribute to Sri Lanka's economy. However, there are several barriers that have been investigated which affect the countries productiveness towards exporting the products. It has been seen that lack of top management commitment, inadequate adaptation of reverse logistics, lack of literacy about antifragile supply chain management, lack of preparedness and others has been the major barrier to adopt an efficient supply chain.

On the other hand, it has been further stated by Dunuwila et al., (2023), it has been further depicted that the rubber industry in Sri Lanka seems to lack to promote social responsibility as well as sustainability by evaluating the company's product as well as social and economic aspects across the supply chain. Also, other factors contribute to the issue being faced by the Sri Lankan rubber industry. It also includes lack of sufficient knowledge, insufficient information flow, along with hindering technological adaptation towards the antifragile supply chain by the rubber industry.

Similarly, these factors have contributed towards the declining Sri Lankan rubber industry, which has further affected the business competitiveness also it, has been affected by the rising international market pressure. This requires the business to undertake sustainable practices, which further helps to straighten the industry's ability towards adapting and thriving towards developing a better strategic approach to overcome the issues. As per the report, it can be further ensured that the Sri Lankan rubber sector often lacks sufficient infrastructure as well as services (Rubber industry to bounce back, 2023). Many of the

companies have remained obsolete and thus require upgrading in its process management and supply chain. It would also require sufficient laws and policies that can help the industry flourish in the competitive market by adapting to a sustainable supply chain.

### **1.3.3 Interest areas to do the research.**

It can be depicted that in Sri Lanka the smallholders account for about 63% of the area that has been planted in rubber trees. Further it explains that there is government involvement within the rubber industry mostly in the plantation sector. It is also depicted that the economies of the natural rubber producing countries often advance the opportunity costs of production increases. Therefore, the problems being faced by the rubber manufacturers are like effective knowledge regarding supply chain activities, effective knowledge and others as depicted above (gartner.com, 2024). Additionally, it has been further seen that relevant competition for land as well as capital often makes it relatively expensive in terms of producing raw rubber. Therefore, it becomes most interesting to conduct research on the effectiveness of the antifragile supply chain to understand the ways it can help the business to enhance desired business production.

The research area has been significant to understand the ways managing the supply chain ensures an effective business process. Additionally, it is also depicted that antifragile supply chain management will help the industry to cope with uncertainty. Hence, it is necessary to move towards a more antifragile mindset to overcome any issue being faced by the system (gartner.com, 2024). It has been further ensured that supply chains are often exposed to uncertainty and therefore it is necessary to develop effective strategies that can enable the business to develop advanced ways to overcome the challenges.

### **1.3.4 Research contribution**

According to the view of Shafiei (2023), a globalised economy, supply chains seem to have become complex in nature. Supply chain disruptions have also increased significantly, which has affected the business operation. It has been further depicted that the supply chain disruption has affected the business profitability as well as sustainability of the supply chain thereby affecting the business growth. The research has contributed towards considering the resilience of the supply chain by developing an antifragile supply chain by the Rubber Industry in Sri Lanka. The research has been significant to develop a better understanding of the ways the selected industry can be impacted with the help of advanced supply chains.

On the other hand, it can be further noted that the research has been effective in terms of demand forecasting, inventory management and managing supplier relationships. The research has been developed to determine the uncertainty. Antifragile supply chain would help to embrace uncertainty along with the objective of learnings that would help the business to proceed to improve the business later. Thus, the research will help the rubber industry to take effective decision that can improve the supply chain management.

#### **1.4 Research aim**

According to the view of Sadeghi, Akbarpour and Abbasianjahromi(2022), supply chain management is the most significant approach in the manufacturing industry that enables it to deal with most chaotic situations.

Therefore, the research aims to understand the need to adopt antifragile SCM framework that can improve operational efficiency and resistance to fluctuating market pressures, thus potentially rejuvenating Sri Lanka's position within the international rubber sector.

#### **1.5 Research objectives**

The research objectives that have been develop for the research are:

- To understand the application of antifragile supply chain management

It is important to understand the concept of antifragile supply chain management which will enable to develop better research to perform an effective management system in the supply chain.

- To determine the factors affecting antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka

It is also important to know the factors that seem to affect antifragile supply chain performance that includes environmental uncertainty, top management support and others. Thus, the factors have been depicted from the research accordingly.

- To determine the challenges of managing antifragile supply chain management to enhance operational performance of rubber manufacturing sector in Sri Lanka

The third objective has enabled to determine the challenges being faced by the supply chain management of the rubber manufacturing sector to enhance operational efficiencies. It includes freight prices, communication and many more.

- To recommend strategies that can improve antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka

In order to overcome challenges, it is further necessary to provide certain recommendations that would be beneficial for the business to enhance operation by managing its antifragile supply chain.

## **1.6 Research questions**

The research questions for the specific study are:

- What is antifragile supply chain management?
- What are the factors affecting antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka?
- What are the challenges of managing antifragile supply chain management to enhance operational performance of rubber manufacturing sector in Sri Lanka?
- What are the recommend strategies that can improve antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka?

The research question has helped to centre the research and has enabled to understand the purpose without providing any additional explanation. The research has also considered the four above questions which has helped to develop to address the research aim. It has been depicted from the research that companies still suffer from an anti-fragile supply chain thus would require sufficient knowledge about the way it can be mitigated to ensure the business achieve the desired operational efficiency.

## **1.7 Purpose and scope of the research**

According to the view of Nikoogar, Varsei and Wieland (2021), disorder referring to volatility, randomness as well as errors seems to rule today's business world. Antifragility is referred to as practitioners who include executives. Therefore, research has been undertaken

to understand the impact of antifragile supply chain management on operational performance. The concept of antifragility is mainly concerned with growth. It would allow the business to grow through volatility as well as shocks. Therefore, to undertake research on the context of antifragile supply chains is referred to as a diverse gain to understand the financial as well as non-financial aspects that can impact the business operation performance.

As stated by Lotfi et al., (2023), there seems to be a strategic shift towards building an antifragile supply chain which includes the need to move from building resilience to becoming antifragile. Antifragile supply chain has become essential to move from outsourcing production by developing a strategic partnership. This would require sufficient research to understand the impact of antifragile supply chain on the business performance. Therefore, the research also provides sufficient scope to determine the future changes that would be implemented within the supply chain so that it can improve the business performance accordingly. Additionally, antifragility would also help to understand the ways supply chains perform in uncertain times or support the business growth agenda. The business often fails to take specific decisions based on the supply chain management. However, it has been depicted that the study has been effective to provide specific ability to develop understanding about the exposure to uncertainty.

According to the view of Priyadarshini et al., (2022), it can be depicted that most of the business are now moving from robustness and resilience and thus shifting towards an antifragile supply chain which enables the business to see disorder as an opportunity for the company. The research has been thereby undertaken to understand the ways the rubber industry can undertake an antifragile supply chain. A different development strategy for future collaboration to improve the supply chain has been established effectively.

The research has not only provided development to identify the factors affecting the antifragile supply chain whereas the ways it improves business decision making with an aim to improve operations of the business has been further evident from the research. The study will further be helpful for the companies in Sri Lanka irrespective of industry type to take significant decisions to adopt or to move towards antifragile supply chain. The company will be ensured to develop technologies that can support antifragility within the supply chain that would help the company to overcome negative consequences while the business faces ant disruptions.

According to the view of Nikoogar, Varsei and Wieland (2021), managing disruption is the most significant aspect for the business to improve performance and ensure business competitiveness. Hence, the research sheds light on the various impactful discussions through literature and data analysis which has enabled to understand the need for transformation in the supply chain.

## **1.8 Significance of the study**

It is the development of the antifragile abilities that guarantee the growth ability and aims to eliminate the mistakes. However, in the maximising globalised arena, it is both the interdependence as well as the interconnectedness that act as essential components within the provisions of products and services. Moreover, it is the impact of the COVID-19 pandemic which is considered to have showcased more the fragility of the different supply chains globally (Pandit, 2022). Furthermore, it depicted the vulnerability of the utilised and applied just in time supply chain approaches. Such issues exposed the need to adapt and embrace the antifragile supply chain management effectively.

It is the acquiring of the thorough knowledge and concepts regarding the antifragile supply chain management in the rubber manufacturing sector through the research and its contribution that can enable the business professionals, policy makers to initiate ways and approaches through which it can be used by them in Sri Lanka. On the other hand, it is noted that the urgency to lower the greenhouse gases along with the war in Ukraine has led to the witnessing of the fragility within the global supply chains (hbr.org, 2022). However, managing the various disruptions act as an empowering asset in the organisations.

It is through the antifragility within the supply chains that leads to the attaining of the best results while at the same time learning to change. However, the potentiality to grow through the multiple disruptions will need the supply chain's unique abilities. It is noted that the emerging notions of the anti-fragility within the supply chains emphasis on the smooth operations offering scope for investigating ways the company can facilitate following the uncertain disruptions. Moreover, antifragility can be shaped with the help of the supply chain mindfulness, transformative learning, plasticity as well as enhanced collaboration within the supply chain operations.

However, the comprehension of the results or the various facets of the new concept or the antifragile supply chain can make the manufacturing businesses in Sri Lanka realise the significance of its implementation. The engagement of several components related to the antifragile supply chain in the research can offer the business professionals and the policy makers' quality insights to develop strategic decision making. As per the view of Priyadarshini et al., (2022), there lies importance of the proactive top management which acts as a driving power to shape the antifragile supply chain. The significance of the research also lies in the fact that it can enable the business professionals belonging to the rubber manufacturing industry to cultivate more operational effectiveness.

Such actions and steps undertaken regarding the usage and incorporation of the antifragile supply chain within the regular business functions can also improve the overall organisational performance. The elaboration and depiction of the challenges of incorporating the antifragility within the rubber manufacturing supply chains can ensure growth and development of the sector. However, this research is of higher significance also because it can facilitate economic development through better organisational performance. Through the acquiring of better knowledge and understanding of the notion, the sector can also attain competitive benefits.

## **1.9 Dissertation structure**

It becomes crucial to ensure flow of ideas in an appropriate manner and it is the structure of the work that enables the reader to navigate the notions. The dissertation structure enables individuals to flow in a systematic manner, proceeding with the accurate steps, without which the research work might get hampered and disorganised. However, dissertation structure is premised on some of the basic sections which include the following:

### ***Introduction:***

The introduction chapter tends to lay the foundation and depicts the background of the research topic shaped by the researcher. This chapter showcases the research rationale or the issue behind the topic which triggers the execution of the research. However, this chapter exhibits the aim, objectives and the questions farmed by the study. It also shows the purpose of the work and the significance it carries.



**Figure 1.6: Dissertation structure**

(Source: Self-created)

***Literature review:***

The literature review chapter showcases the multiple opinions of the professionals, scholars or authors about the topic or the effects of Anti-Fragile supply chain management on the operational performance of the rubber manufacturing sector in Sri Lanka. This chapter has also mentioned varied theories or models and analysed them effectively. It has presented the gap, which is found in the existing literature, which the study has the goal to address.

***Methodology:***

The methodology chapter becomes crucial as it offers a roadmap and guides the study to be executed in an objective and systematic manner. This chapter has mentioned the approach, design and philosophy undertaken by the study. It also elaborates on the method adhered to by the study in case of acquiring data and depicts the technique opted for to analyse the extracted data. It has exhibited a range of information initiating from the sampling technique, time horizon and others. However, this chapter also presents the limitations encountered while conducting the study and the different ethics maintained to leverage the quality of the work.



***Results:***

The results chapter has showcased the varied data and interpretation of the acquired sources. This chapter has fulfilled the aim to meet and address the several research objectives and questions shaped. It has represented the mixed method research approaches and has also analysed the survey data through the graphical presentations and the secondary data through thematic data analysis.

***Discussion:***

The discussion chapter has mentioned the findings acquired from both the results sector and the literature review section. The discussion chapter becomes the final part in which the researcher tends to examine and interpret the multiple findings gathered through the dissertation process.

***Conclusion and recommendations:***

The chapter on conclusion depicts the ways the multiple findings link with the framed questions and objectives. It also includes the entire findings gathered and has also presented the suggestions. This chapter has offered several recommendations on ways the rubber manufacturers can adhere to the antifragile supply chain management approach, which can guarantee development and smooth functioning of the sector.

**1.10 Summary**

The first chapter has been effective to provide sufficient understanding about the ways the research will be conducted. Starting from developing research aims and objectives to understanding the research problems has been significantly portrayed in this specific research. From the research background it has been identified that it is necessary to develop supply chain strategy which can help the business to ensure becoming cost effective and accountable. Therefore, the research has been developed which ensures the need to adapt antifragile SCM framework to improve operational efficiency. It becomes important for the business to understand the ways SCM can improve business operation and reduce cost of the business accordingly.

On the other hand, the research rationale has been further depicted which shows that there is a decrease in the competitiveness of the rubber manufacturer in the international market due to the inefficient management of the supply chain. Thus, it can be stated that the initial chapter has provided a concrete understanding about the issue that has been identified and the need to conduct the research for the future benefits. The research significance and the research scope further allow knowing the importance to understand SCM and the ways it can impact the business performances. Additionally, the dissertation structure has been developed which could guide the readers thoroughly.

## **Chapter 2: Literature review**

### **2.1 Introduction**

The chapter on literature review showcases a range of views and perspectives of the professionals and authors regarding the notion and the merging concept of the antifragile supply chain management. This chapter has mentioned the literature gap found from the exciting literature. It has helped to attain a better comprehension of the prevailing research work and the varied debates pertinent to the specific topic. It has mentioned the concept of the antifragile supply chain management along with multiple facets of it. Through this chapter, the study has gathered enhanced understanding of the portions that require additional research. Literature review refers to a survey of sources for specific research topics. It shows the understanding of allowing the overview of current knowledge, identification of relevant theories, methods, and gaps in the existing research.

It is important to determine how the previously published works on a specific topic can be referred to as a section on identifying the scholarly work including book, article, journal, reports, and others, which are published by the authors. It is a critical evaluation of how the researchers can write different opinions on the topic. The existing research identifies the consideration of antifragile supply chain management to better comprehend accomplishing the reset objectives. The current research identifies different areas on antifragile supply chain, operational performance, manufacturing industry, Sri Lankan rubber manufacturing industry and others. Different opinions on the research areas with arguments and contradiction are highlighted for managing the operational delivery and deployment to answer the research questions. The chapter highlights the concepts, theory, and different considerations on additional research within the context of existing literature.

### **2.2 Concepts**

#### **2.2.1 Antifragile supply chain management**

As per the notion of Nikookar, Varsei and Wieland (2021), the antifragile systems focus on the disorders and acquire different learnings from them when compared to avoiding them. However, antifragility appears to be a modern concept which concentrates much on growth. It depicts that an approach can effectively be strengthened with the help of exposure

to a range of volatility. Moreover, the antifragile supply chain appears to be the one that can initiate gains from several disruptions both in terms of financial and non-financial aspects. As stated by Shafiei (2023), supply chains in the present arena engage to be having been posing severe complicatedness and interconnectedness. The several disruptions pose severe effects on the profitability as well as sustainability of the supply chain operations. However, such instances urge for resilience within the supply chains through which it will be able to assume, prepare and react to the multiple uncertainties.

As per the view of Shafiei (2023), “antifragile supply chain network” becomes a modern approach to supply chain management which concentrates on establishing networks in supply chains that are able to emerge as empowering rather than only withstanding the uncertainties or the disruptions. On the other hand, Nikookar, Varsei and Wieland (2021) mentioned that antifragility within the supply chains traverses much beyond resilience and aims to survive the uncertainties or the shocks. It is noted that the notion of the antifragile supply chain has been attaining more attention within actual operations after the emergence of the pandemic. However, antifragility appears to be a critical feature of the supply chains amid the social ecological systems' depiction of resilience.

As mentioned by Shoushtari and Ghafourian (2023), antifragility becomes the concept in which the designers of the “supply chain network design” enhances the ability to adjust the kinds of disruptions such as fluctuations, distinct stressors, and others. However, the new concept is considered to have appeared as a transformative notion depicting a shift from the used traditional approaches more towards resilience. On the other hand, Größler (2020) highlighted that the antifragility acts as an alternative system featured to robustness. Moreover, this concept leverages the significance of the firms to accept unpredictability when compared to removing them. Furthermore, the concept is a scope for acquiring better knowledge, evolving, and embracing capability improvement.

As per the view of Shoushtari and Ghafourian (2023) the notion of antifragility within the supply chains aims to utilise the shocks and traverses towards improvement. On the other hand, Größler (2020) opined that the antifragility traverses much beyond the robustness as well since it implies the potential to recover from the disruptions with the goal of attaining greater performance levels. It is with the antifragile abilities that are regarded to have been offering a roadmap to navigate the disruptions and such abilities involve decision procedures within the supply chains to the planning and others. However, the antifragile approach can

help the supply chains to become empowered as strains are being incorporated to it besides self-correcting it.

According to Lotfi et al. (2023), “antifragile and sustainable supply chain network” is a form of design as a new concept on the capability of facilities to cope up with different disruptions such as fluctuation, shock, volatility, stresses, and others. It is added based on the mode companies while improving the performance and using this disruption. Resilient and sustainable supply chain for the concept of a robust or positional program and viability with the scenario uncertainty. It is utilised with applied viability to cope with scenario uncertainty and demand fluctuation. Additionally, agility concepts and antifragility have the importance to determine how the volatility of the circular economy is considered as a form of minimising the cost function and risk averse approach (Lotfi et al., 2023). The robustness in risk as a circular economy can be suggested as a form for objective functions while minimising the cost with development to hybrid uncertainty. The functions are measured to solve the risk management and resilient supply chain. It ensures resilient strategies to define the optimisation on uncertainty and risks.

On the other hand, Sadeghi, Akbarpour and Abbasianjahromi (2022) opined that supply chain strategies enable the performance indicators based on sustainable evaluation and key performance development. It can be designed on how the lean and agile SCM can be bonded in line with sustainable strategy. Antifragility is a term to minimise the risk and accurate information system. The approach in dynamic and complex SCM can be managed in new management practices at operational level during the project life cycle and construction. However, the strategies are applied differently in environmental conditions and industries to manage the capabilities in different ways to lead the lean-agile strategies (Lotfi et al., 2023). The approach is to create the values stream by eliminating the wastes in non-value-added activities and processes through continuous improvement and responses to the quick change. However, it has limitations to include the longer delivery time, wasted resources, resource mix, complaints issue, financial losses and risk, uncertainties, and others. Lack of redesigning can be enabled through the continuous flow model. It is easy to streamline the product and control over inventory which can be done cyclically for avoiding supply bottleneck (Kumar, 2024). Businesses are prone to the supply chain disruptions to benefit the local raw material suppliers and local businesses in peak demand times. It can affect improper management, insufficient training, short sighted view, and development to the back orders for order fulfilment. Additionally, antifragile SCM can cause delays in delivery, long product cycles

and poor customer experience. Managing the logistics and business development depends on how the entire supply chain can be operated to agile strategy and lean management.

Martinetti, Moerman and van Dongen (2017) added that reliability and uncertainty are described as emphasising on a deterministic view of the supply chain. It ensures to embrace the disorders to control the antifragile thinking and improve the operational efficiency. Accepting the accurate predictions are managed with uncertainty, errors, disorders, and chaos. This order in the manufacturing industry introduces how the reliability of the antifragility concept can have the flexibility to increase the range of strategic options. There are potential benefits for well-known and documented antifragility SC activities (Sadeghi, Akbarpour & Abbasianjahromi, 2022). Therefore, the concept of antifragility is used as a phenomenon to increase the strength and resilience in any system. It determines how the uncertainty redundancy is seen than a defensive strategy in the supply chain.

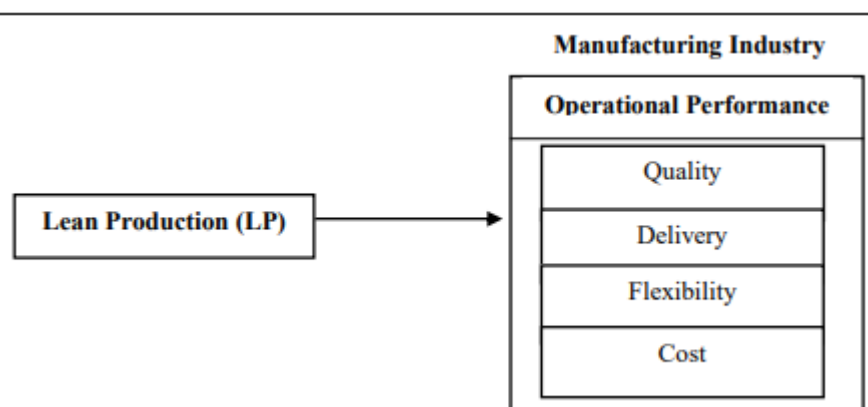
### **2.2.2 Concept of operational performance**

As per the view of Battesini, ten Caten and de Jesus Pacheco (2021), operational performance is the primary concern of the industrial firms. It addresses and examines the element antecedent for design and optimisation of competitive supply chain. The concept and assumptions are proposed in manufacturing systems. It is well recognised that there is a significant relationship between interrelated and complex decisions, which can be implemented by understanding the operational management practices. The systemic interrelations are overlooked in terms of facilitating the industrial practice and local improvement over the global solutions. It is well recognised, as there is a significant relationship between optimisation and manufacturing design. Additionally, there is relevant technology and context to all scope of research that can be converted with resources into service and products as per the desire of the customers. Defining the eligibility in operation and process describe how the production and supply planning can have the factors at operational levels (Rasi, Rakiman & Ahmad, 2015).

Additionally, manufacturing, and operational decisions include strategic decisions, operational decisions, control decisions and others to indicate the key performance factors. The management and theoretical implications are multi-dimensional, when it comes to the numerals measurement to estimate the performance and enable the strategic targets (Battesini, ten Caten & de Jesus Pacheco, 2021). Operational performance measures in cost, time, and duration to produce different study development, which is constituted with key performance factors and performance measurement. Furthermore, there are some factors including operation of flexibility and benefit on performance delivery. Operational performance needs

improvement to the supply chain, as it can be consistent to support the relationship with performance. There is inconsistency in management support and structural model technically, which can contribute to operational inefficiency. In particular, the global economic performance can be introduced into the account of internal process and external operation in the entire supply chain. Particularly, the customer focus can be explained to better understand the market opportunity and firm planning. Customers' demands are well defined to focus on value added activities and development of supply management in the firm's activities (Truong et al., 2017). Firm's activities and suppliers are involved to process the control and improvement as per preventive equipment maintenance and company management. There is evidence to consider SCM practices as reliable for operational management and how the customers are engaged for better delivery and performance efficiency.

On the other hand, Rasi, Rakiman and Ahmad (2015) critiqued that lean production has identified the benefits of operational efficiency. It is important to increase financial flow, work capital and increasing inventory turnover to fulfil the demand from customers. Lean production originated to flourish how the customer management and production approaches can have predictive better quality and reduced lead time. It has a flexibility on competition priorities, as a critical operation dimension in fulfilling the external and internal customers satisfaction. It takes the production facilities in measuring corporation performance over flexibility, quality, delivery, and cost (Refer to figure 1.1). Lean production has effectiveness on flexibility while affecting the personal performance and delivery in the manufacturing process. It is with the customers on delivery and quality to create the production facilities instead of manufacturing development with quality management (Truong et al., 2017). The customers on quality and delivery are focused by eliminating the possibility of waste and the delay.



**Figure 2.1: Lean Production on Operational Performance**

(Source: Rasi, Rakiman & Ahmad, 2015)

Lee (2019) opined that operation performance depends on different variables and indexes. It identifies the components of financial performance, supply chain, firm product, financial variables, productivity index and others. Efficiency and availability can meet the performance in operations and production in terms of financial management. The strategic approaches are underlined in different contextual management and industry development. For example, in the *airline industry*, the operational efficiency is measured with labour efficiency, fuel efficiency, passenger yield, load factor and others (Lee, 2019). It determines how the investment can be calculated for companies' financial efficiency for the airline companies. Another example can be drawn that *healthcare operational performance* depends on different factors which are different from the previous one. Healthcare operational. Actors include technologies, adoption of healthcare facilities, cyber physical system, big data, communication, infrastructure, wireless health benefit, connections of patient data and internet determinants for disease management (Ilangakoon et al., 2022). There are different factors to measure the operation and efficiency based on the risk factors and industry development.

Rompho (2018) reviewed the accounting system and business processes to accommodate uncertainty and plan for the potential growth. The large corporations and start-up have different operational plan to deliver and the better effectiveness on firms' performance. It determines different tools to be applied in the management system and development to improve the business process with system development. Emphasising on product differentiation strategy is slightly to use the non-financial management to the customers. Different scenarios are determined for form management and system development which is used mainly by start-ups. Referring to figure 2.2, it is identified that e-commerce has different performance measures while mobile app and SaaS are considered different considerations to perceive the delivered benefit. It perceives customer cost and lifetime value based on study management to generate the solutions among the stages (Rompho, 2018).



<i>E-commerce</i>	<i>SaaS</i>	<i>Mobile app</i>
Conversion rate	Attention	Downloads
Purchases per year	Enrollment	Launch rate
Average shopping cart size	Stickiness	Percentage of active users/players
Abandonment	Conversion	Percentage of users who pay
Cost of customer acquisition	Upselling	Cost of customer acquisition
Revenue per customer	Cost of customer acquisition	Customer lifetime value
Top keywords driving traffic to the site	Revenue per customer	Ratings click through
Top search items	Virality	Virality
Effectiveness of recommendation engines		Time to first purchase
Virality		Monthly average revenue per user
Mailing list effectiveness		Churn
<i>Media site</i>	<i>User-generated content</i>	<i>Two-sided marketplaces</i>
Ad inventory	No of engaged visitors	Buyers and sellers growth
Ad rates	Content creation	Inventory growth
Content/advertising balance	Engagement funnel changes	Search effectiveness
Audience and churn	Value of creation content	Conversion funnels
Mailing list effectiveness	Notification effectiveness	Rating and signs of fraud
	Content sharing and virality	Pricing metrics

**Figure 2.2: Performance measures by type of startup**

(Source: Rompho, 2018)

Marimin, Wibisono and Darmawan (2017) added that supply chain and operation all performance are measured as a long chain to formulate the measurement model. In the *rubber manufacturing industry*, it is set to integrate the company's strategic elements and business unit. Supply chain performance includes latex quality, prospective product selection, SCM performance and others as identifying the product priority and customer demands. Thus, it is important to determine how different considerations on operational efficiency and performance can be delivered with quality management and production as per market growth and workers satisfaction. The strategic objectives and performance indicators are measured for a better delivery of managerial implications and operational efficiency.

### **2.3 Significance of the antifragile supply chain management**

Supply chain management becomes crucial since it offers mechanisms for getting the goods to the customers. As per the view of Zitzmann (2014), to establish competitive benefits within the uncertain times triggers the notion of the antifragile supply chains. On the other hand, Priyadarshini et al., (2022) mentioned that the resilience depicts bouncing back of the supply chains and such instances pose the requirement of the hour to shape an antifragile supply chain. It becomes significant to note that antifragility is still considered to be a new notion which is still left to be effectively explored. However, the firms are required to traverse towards the resilient, antifragile as well as robust supply chains. Moreover, the companies must shape dynamic abilities to meet multiple uncertainties within the supply

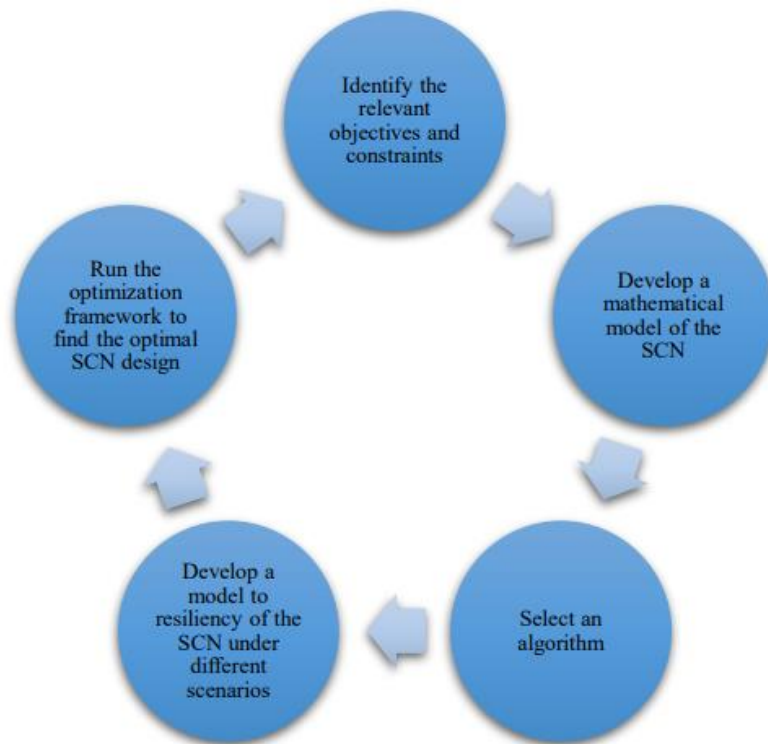
chains in a systematic fashion to neglect the negative results on the organisation's overall performance.

As per the perspective of Zitzmann (2014), if the system or the firm adheres to the antifragile approach they will not lose profit, however, will be able to profit from the impact. On the other hand, Priyadarshini et al., (2022) mentioned that while the resilient supply chain has their goal to absorb the different uncertainties of the shocks, the antifragile supply chain witnesses the uncertainties as a scope is much better. However, besides reacting to the various uncertainties, the antifragile supply chains tend to thrive them effectively. Moreover, the significance of such an approach also lies in the fact that the antifragile supply chain attains benefits from the disorders and appears to be empowered by being thrown out to randomness.

On the other hand, Hadizadeh et al., (2023) opined that the antifragility tends to have become one of the notions which is closely associated with the supply chain sustainability. However, the antifragility in the supply chains of the firms renders the scope to present issues into scopes and initiate progress in the present times. On the other hand, Munoz, Todres and Rook (2021) mentioned that considering the business companies, within the period of uncertain times, present contributions tend to have depicted attention to the value of enhancing the antifragile methodology which can complement the multiple scenario planning. Moreover, the antifragile systems are recognised with features such as unexpectedness, balancing freedom and constraints, adequate supervision, and others.

As per the opinion of Hadizadeh et al., (2023), antifragility exhibits the obtaining of strengths amid the various pressure factors. Similarly, Munoz, Todres and Rook (2021) stated that antifragility aims to gather more knowledge, flexibility and support new things or actions amid the uncertain times. However, the antifragility permits the companies to acquire benefits of multiple unknown instances or the events to place themselves in enhanced position when compared to the prior times. Antifragile supply chain is managed to determine how the resilience is required as per the economic management and factor analysis. It contributes to demand forecasting, inventory management, supplier relationship management, information sharing, risk management and others. It concerns strong supplies during the disruptions of research delivery and likelihood of descriptions to occur in SC activities. It recognises antifragility in the supply chain as a growth for improvement and organisational performance (Shafiei, 2023). Referring to figure 2.3, the optimisation steps are identified from constant

identification to running the optimisation. It improves how the different considerations and benefits are extracted to determine the quality management and supply chain delivery within the time.



**Figure 2.3: Optimization steps**

(Source: Shafiei, 2023)

Moreover, anti-fragility is significant in terms of profitability and business recognition to underline the strategic development and identification in the industry standards. It determines the disruption mitigation and risk management to bring the susceptible supply chain. The government in post measures refers to replication of critical supply chain activities as it can lead to a robust relationship. Additionally, it improves the injustice standards and development for a better opportunity categorisation and strong relationships with backup suppliers. Antifragile SCM aligns with production schedule, boost overall efficiency, and reduce delay risk. Comprehensive supplier communication system can deliver with substantial cost savings and punctual payment to adhere to contractual terms to foster the long-term commitment. Promoting diversity inclusion can provide access to developmental training opportunities for goods and services. The robust supplier relationship is measured to craft the antifragile and resilience supply chain by collaborative planning, communication, goal alignment and ethical treatment of suppliers.

## 2.4 Theories

The different relevant theories can be studied and examined for demonstrating and evaluating the designing and functioning of the anti-fragile supply chains-based operations that are found to exist within the Sri Lanka Rubber Manufacturing Industry entities. The three specific theories of RBV theory, Stakeholder theory and the Theory of Constraints chart make sure that the well-defined and standardized knowledge can be shared among the different business professionals and customers so that the overall Rubber manufacturing industry strategies could be developed effectively. The three different categories of theories that are adopted and discussed for explaining the topical elements are as follows-

### 2.4.1 Resource-based view (RBV)

The RBV or Resource Based View theory proves to be significant and effective as it refers to the possession of the valuable and irreplaceable resources that provide the necessary support to the organizations to acquire competitiveness advantage. Sri Lanka Rubber Manufacturing Sector companies also make sure that they can plan and design the resources aligned to their anti-fragile supply chain framework and functioning so that the competitive advantage could be achieved (Holmes, 2023). Today's market is driven by customers, they are the king. In this case, satisfying the customers will boost sales and there will be growth in the business which will ultimately make the shareholders happy with good returns. The different categories of supply chain standards that could be related to anti-fragile aspects were demonstrated so that the competitive advantage could be acquired by the rubber manufacturing entities working in Sri Lanka. The disruptions in supply chain result from a lack of raw materials, transport hitches or political instabilities, with significant impacts on the industry. Moreover, such interruptions may also drive-up production costs, cause delivery delays and eventually result in customer dissatisfaction.

In the recent years, the Sri Lankan Rubber Manufacturing Sector companies have recognised the supply chain management (SCM) as a critical element playing crucial role in strategic management (SM). According to Vitorino Filho & Moori (2020), strengthening the supply chain network and management is considered to a measure of increasing the competitiveness of the Sri Lankan Rubber manufacturing companies in the global market. Within the purview of the Resource-based view (RBV) theory, the Sri Lankan Rubber manufacturing businesses are assisted in developing agility as well as adaptability, and the RBV aligns the SCM with other operations (Dobroszek, 2024). With the application of the RBV, such companies have ensured efficient allocation and independence of heterogeneous

resources; their effective use as well as imitability which stands out in creating separate operational capabilities for increasing the business performance (Vitorino Filho & Moori, 2020). The RBV also aids the rubber manufacturing business of Sri Lanka by enhancing SCM which offers a new level of strategic management analysis; by creating interaction amidst different areas that broadens the ability of these businesses in achieve their goals (Vitorino Filho & Moori, 2020). With introduction of RBV in the rubber manufacturing businesses of Sri Lanka, the supply chain strategies have provided better agility towards the operational efficiency while working with integrated information systems.

To enhance performance and continue surviving within an increasingly competitive market, the Sri Lankan rubber manufacturing businesses have directed their efforts towards establishment of relationships in collaboration with partners both, upstream and downstream, thereby providing advantages throughout the supply chain (Peiris, Kavirathna, & Wijayanayake, 2022). Within this given scenario, the application of RBV utilizes the resources, which consists of all the tangible as well as intangible assets; human as well as non-human; for adding value to all the products of the rubber companies (Gamini, & Rajapaksa, 2020). In contrast to the above, this theory also highlights the relevance of collaboration and integration within inter and intra-organization activities on the SCM for increasing BP (Vitorino Filho & Moori, 2020). For this end, the rubber manufacturing companies of Sri Lanka seek on operating together via integration with the suppliers for ensuring the product quality, and along with the clients for following the emerging changes in demand.

As per Peiris, Kavirathna, & Wijayanayake (2022), the ambits of the RBV theory also could be understood in relation to the integrated strategic vision of Sri Lankan rubber manufacturing businesses, that the fragile SCM of these businesses are likely to fail if the businesses engaged within the supply chain puts its focus only on own results instead of focusing on returning its efforts for integration of activities and goals with potential partner organizations. Thus, with the application of RBV, the main goal of such businesses should be Supply Chain, for reaching the individual partners and increasing business performance. According to Gamini & Rajapaksa (2020), Presently the RBV theory has received widespread recognition within the operational management studies and SCM in the strategic management of the Rubber Manufacturing companies of Sri Lanka. This is also because RBV leads to increased efforts in improving the SC operations to ensure sustainability while

providing competitive advantage (Gamini & Rajapaksa, 2020). The RBV is thus adopted in the rubber manufacturing companies of Sri Lanka as it is considered as one of the best conceptual theories in the supply chain performance.

#### **2.4.2 Stakeholder theory (ST)**

As per the elucidation by Kivits et al, (2021), the Stakeholder theory (ST) and its features also help in applying the influence of the various stakeholders so that the wide range of operational practices and services could be shaped up and implemented. As per the elucidation by Kivits et al, (2021), the stakeholder theory refers to the influence and impact that is exercised among multiple stakeholders leading to the perfect achievement of the desirable targets. The ethical standards are stressed upon, and the basic evaluation of the market position could be done for understanding the details of the Rubber manufacturing sector entities. Supply chain management contributes to value creation for the customers by improving the performance of the firm (Freeman, 2023). Stakeholders have a strong influence in helping a firm to gain and sustain in the market with a competitive advantage so that they can capture much of their value in the market. Stakeholders are groups that are within or outside any organization that have a stake or interest in the performance or affect the decision-making process within the organization. Stakeholder theory strikes a balance between the interests of the customers, employees, suppliers, government, and most importantly the firm (Kivits et al, 2021). This theory supports that the firm should create value for all the stakeholders not just shareholders. This theory has become the key concept for implementing business ethics.

Stakeholder theory has re-invented the practice of value creation and trade. Before, it was stated that business is all about profit maximization for the shareholders, but this theory is outdated and does not work in today's world of value creation. Stakeholder theory sees business as a unit to focus on value creation with a purpose to maximize the value of all the stakeholders and not just the shareholders (Freeman & Sisodia, 2020). This theory requires that the company should not be limited to short-term profits but must have a vision of long-term sustainability in the business (Barney & Harrison, 2020). While abiding with this theory many companies take the concept of corporate social responsibility seriously. This also helps the company to make sufficient provisions to cater to the needs of various people who relate to the entity.

According to Qazi, Apolloni, & Shaikh (2022), the stakeholder theory within the ambit of supply chain management for any business affects the supplier relationship (SR) as well as the customer relationship (CR) largely creating a significant and positive impact on

relation between the supply chain resilience and the organizational performance. As per Wittke (2023), the stakeholder theory also highlights the critical relationship between organizational performance and the customers' relationship where the mediating role of supply chain resilience has been found to be positive and significant. Similarly, the application of the stakeholder theory with the purview of the rubber manufacturing businesses of Sri Lanka can also be held to be of utmost importance.

The application of the stakeholder theory within the supply chain management of the Rubber Manufacturing companies of Sri Lanka has gained a huge amount of attention and significance over the last few decades. According to Herath & Endagamage (2022), the Sri Lankan companies identify the stakeholder's theory as a significant approach for enhancing the strategic management, by creating room for accommodating the interests and relationships of multiple stakeholders, unlike other theories that focus upon single area of interest or solely on shareholders. In addition to this when it comes to the process of decision making, as well as focusing on value creation for different stakeholder groups, the stakeholder theory plays a very crucial role. As per Edirisinghe, Hossain & Alam (2024), the decision points quite fairly consist of the key considerations in the development of the strategies for supply chain management, and this is predominantly relative to the fulfilment of orders of customers. The rubber manufacturing companies of Sri Lanka identify the stakeholders' groups as those that are capable of affecting or easily get affected by an organization's achievement of different objectives. Stakeholder theory has found wide applicability within the supply chain and strategic management context of these businesses for explaining the issues associated with the supply chain (Qazi, Apolloni & Shaikh, 2022). This is critical and makes perfect sense, as supply chain is the central link in value creation for the Sri Lankan rubber manufacturing businesses and is capable of determining the fragility of the same.

According to Wittke (2023), with the application of the stakeholder's theory, the rubber manufacturing companies of Sri Lanka has identified three main SCM strategies which includes the innovators, the marketers, and the caretakers. All three strategies lay down their focus upon fulfilment of the customers' orders, whereas the means differs. Here the innovators put emphasis on rapid introduction of new product and designs; marketers focus on offering broad product lines; and the caretakers focus upon offering low price (Wittke, 2023). Evidently, the cost, speed, variety, and quality matters prove to be of relevance for the

rubber companies' Supply Chain Management strategies. The variables also depend fairly upon decisions made regarding outsourcing and in-sourcing, single or multiple sourcing, strategies of suppliers; and contracting (Herath, & Endagamage, 2022). Thus, it can be deduced that the rubber manufacturing businesses of Sri Lanka is efficient in identifying the significance of different stakeholders, as it is critical to understand the relation existing between the SCM and the stakeholder theory.

#### **2.4.3 Theory of constraints chart**

Theory of constraints chart and its features also could be demonstrated and evaluated for understanding the role of anti-fragile supply chains that would influence the functioning of the Rubber Manufacturing Sector companies of Sri Lanka. The theory of constraints indicates to the most effective and methodical practice or concept that creates obstacles within the supply chain operations and leads to devising the ways that are effective for resolving the constraint being raised. As per the opinion of Hadizadeh et al., (2023), the anti-fragility features and designs could be explained by the theory of constraints so that the well-defined issues could be examined, and the perfect form of knowledge could be incorporated for addressing and solving the issues that have been raised within the supply chain operations and services. The theory of constraints chart also would be able to process and decode the different complexities that arise while the rubber manufacturing units within Sri Lanka operate within the regions with clarity. The overall methods and precisions could be adapted perfectly. One of the main difficulties is volatility in global rubber prices. Market price fluctuations can greatly affect local manufacturers' profitability. As per the logic-based illustration by Gunarathne et al., (2023), changes in demand-supply dynamics, geopolitical tensions, and economic situations in major countries that consume dry rubber are some of the factors behind price instability. The industry's financial stability heavily relies on managing these irregularities and having sound pricing strategies. This can be done by application of theory of constraints to get the desired outcomes.

### **2.5 Overview of Rubber Manufacturing Industry of Sri Lanka**

The Rubber Manufacturing Industry of Sri Lanka has been very popular across the entire country of Sri Lanka as well as in the world market. Sri Lanka has been one of the largest global producers of Natural Rubber and the different Rubber companies of Sri Lanka had helped to strategies and produce unique designs of Rubber products and services with success and adaptability. The Sri Lanka Rubber Manufacturing Industry has faced numerous



issues in the near past such as the financial strain that the island country and its regions had faced after the pandemic was over. According to the discussion and analytical examination by Cho et al., (2022), the deforestation related issue and risk also existed for the Rubber industry companies that had operated in Sri Lanka and that had affected the export of Rubber from Sri Lanka to USA. The different regions of Sri Lanka have various rubber manufacturing units that could be productive and profitable for meeting the different relevant needs of the consumers and stakeholders. Sri Lanka has started the manufacturing process of natural rubber in 1876 by the planting of more than 1900 rubber saplings at Gampaha Botanical Gardens. Sri Lanka is also considered as an exporter and importer of natural rubber products across the world.

### **Production Process and Products:**

Several stages of manufacturing rubber products are gone through by the rubber industry of Sri Lanka, and these starts with planting trees. The trees are then tapped for rubber latex, which is subsequently processed into different forms such as RSS (ribbed smoked sheets), and latex crepe among others. These materials in turn find their use in making a variety of other rubber products including:

- ☐ Extrusion rubber-like bands and beadings
- ☐ Medical gloves made from latex, household gloves, and industrial gloves.
- ☐ Industrial items such as hoses, automotive parts, tires, and tubes.
- ☐ Sports goods like floor mats, shoes, hot water bottles plus carpets among others.

Gamage & UdaniUdya (2023) opined and evaluated that Sri Lanka's overall economic landscape depends heavily on its rubber mostly manufacturing which has a significant impact on its economy. This sector has also played an important role in providing job opportunities, especially in rural communities with most people living around rubber plantations. This brings in forex and enhances the balance of payment position. According to Gamage & UdaniUdya (2023), it is also good for the country as it helps diversify its exports by reducing reliance on traditional sectors such as tea, garments, and textiles because they are involved in the sale of latex gloves, automobile components as well as industrial hoses. The Rubber Industry of Sri Lanka has been empowered by different steps taken by the government to see it develop and grow. These are in terms of:

- ☐ Financial Support: To ease smallholder farmers' financial burden for replanting, the government offers subsidies and incentives.

- ☐ **Research & Development:** According to Gamage & UdaniUdya (2023), the Rubber Research Institute of Sri Lanka (RRISL) is at the forefront of producing techniques development and quality improvement through constant research and development activities.
- ☐ **Export Promotion:** In its bid to improve rubber exports from Sri Lanka, the government is engaged in trade agreement negotiations and the establishment of partnerships that will promote favourable export conditions.

**Technological Advancements:** In recent years, technology in the Sri Lankan rubber industry has taken considerable strides. Increased productivity rates through automation, less labour-intensive techniques and improved product qualities are some of the reasons for this (Suryanarayanan & Azevedo 2023). This occurs because supply chain management automation facilitates simple workflows that enhance transparency, traceability, and communication among stakeholders. Furthermore, lean manufacturing practices such as Six Sigma principles adoption helped optimize resource utilization while minimizing waste generation.

**Major challenges faced by the rubber industry.**

- ☐ **Global Competition:** Sri Lanka is faced with competition from other rubber producing countries such as Thailand, Indonesia, and Malaysia. These nations are most times favoured by low-cost manufacturing, better infrastructure, and economies of scale hence it is difficult for companies in Sri Lanka to compete on price or volume. The products must be well differentiated based on quality, sustainability, and innovation for them to remain competitive globally (Suryanarayanan & Azevedo 2023).
- ☐ **Sustainability:** Rubber Growing and Processing There are major environmental problems that come with rubber growing and processing. The industry can only survive by observing environmental laws, encouraging ecological methods of farming, and encouraging waste disposal systems.
- ☐ **Technological Progress:** Moreover, coping with fast-changing technological developments is another potential barrier. Automation as well as digitalizing production processes and integrating smart technology can help in making better quality deliveries that are more efficient and cost-effective. The disruptive features of supply chain operations of the Rubber Manufacturing units in Sri Lanka proves to be affecting the application of the anti-fragile supply chain practices and services.

### **Future Prospects-**

The future marketing prospects that are designed to be used within the Rubber Manufacturing units of Sri Lanka can enhance their sustainability with the support of anti-fragile supply chains that raises the complex ethics and other risks related to the operations and services. The wide range of risks that exist within the Rubber Manufacturing unit of Sri Lanka are useful and affect the overall progress of the companies. The digital tools could be used, and the use of social media and AI based technological services could enhance the profitability of the Rubber organizations that operate with success and accuracy. The relevant marketing standards could be enhanced by the application of the KPIs. Also, Sri Lanka could innovate and collaborate with foreign partners to acquire and implement the expertise in tactical skills for strengthening the Rubber plantations and address the problems that exist in the different regions. The suggestions of the professional experts would guide the Rubber market entities to shine.

Investment in Human Capital: As per the illustration by Zaw (2023), investing in workforce development programs, training initiatives, and fostering a culture of innovation and sustainability within the industry can create an enabled staff force capable of engaging in continuous improvement processes thus adapting well to various challenges.

## **2.6 Supply chain management practices in manufacturing**

The SCM or Supply Chain Management practices include optimisation and coordination of different activities associated with the production and distribution of products by the manufacturing organisations (Aslam, Saleem, Khan & Kim, 2021). These firms in Sri Lanka can benefit by focusing on the unique issues, opportunities, as well as situations in their country. Hence, the key supply chain and logistics-related work practices include the following.

### ***Inventory Management***

Manufacturing firms use various techniques such as Material Requirements Planning (MRP), Just-In-Time (JIT), as well as Economic Order Quantity (EOQ) to optimise their inventory levels and minimise overall wastage (Helo & Hao, 2022). This is a critical process for organisations to minimise their resource needs to prevent cost overruns.

Considering the different challenges that Sri Lankan manufacturers face because of limited warehouse space, restrictions in exporting or importing goods, as well as fluctuations in the currency exchange rates, inventory management plays a crucial role in ensuring the management of products and their net costs by the firm.

### ***Supplier Management***

Manufacturing firms are required to ensure the development of strong relationships with their key stakeholders, including the suppliers (Attaran, 2020). This influences their overall capabilities by providing the firms with the ability to choose the right suppliers, negotiate contracts, monitor performance, as well as collaborate to ensure improvements in their overall business practices and processes.

### ***IT Integration***

The usage of SCM and ERP software with advanced analytics aids businesses in gaining better visibility and coordination, which ensures the development of their decision-making in the long run (Wieland, 2021). This ensures the growth of streamlining business processes, adapting to market changes, as well as upscaling the businesses in the long run. With the benefit of quality and reliable data in real-time, businesses are now able to efficiently monitor their processes and growth to make better decisions to ensure their sustenance in the market.

### ***Planning and Scheduling Processes***

Factors such as volatility in demand because of seasonal aspects, market trends, as well as economic situations require the firms in Sri Lanka to invest in planning and forecasting processes. This leads to the development of better production planning and resource and inventory management with effective resource allocation.

The aspects of planning and scheduling events would lead to the optimisation of the projects, which would aid in enhancing efficiency and minimising the cost requirements of the firm (Attaran, 2020). Hence, with the usage of agile, lean methodologies, the firms in the Sri Lankan manufacturing industry would streamline their processes to ensure their sustenance in the market in the long run.

With the usage of historical data, trends, as well as forecasting techniques, the firms would be able to ensure the adjustment of their production schedules in an optimum manner (Shoushtari & Ghafourian, 2023). In addition to the aspects, by accurate demand forecasting, the Sri Lankan firms would further ensure the maximisation of their efficacy and plan and execute their operations.

### ***Total Quality Management***

TQM or Total Quality Management is another important aspect that the firms in the present scenario focus on (Cai & Choi, 2020). This aids them in ensuring the development of their brand reputation, as well as in ensuring consumer satisfaction. With the usage of tools such as Statistical Process Control and ISO standards, businesses are now able to monitor and optimise their efficacy and quality in their manufacturing processes.

### ***Risk Management***

The firms in the manufacturing industry of Sri Lanka are further required to ensure the assessment of their possible risks. By means of identifying, communicating and mitigating business risks such as supply chain disruptions, quality issues, as well as other concerns such as geopolitical issues are required to ensure that the operations are continuous.

The risks such as political issues and natural disasters could be fatal to the supply chain and overall operations of the firm (Aslam, Saleem, Khan & Kim, 2021). As a result, there is a need to ensure proper risk assessment and management techniques.

Manufacturing businesses often use various risk management strategies including the diversification of suppliers, contingency planning, as well as supply chain mapping to address the potential threats to the business.

### ***Logistics and Transportation Management***

Apart from the aspects, the manufacturing businesses in the Sri Lankan market are focusing on efficiently moving the goods from suppliers to manufacturers and to the customers. This has saved the firms in minimising their lead times and overall costs (Cai & Choi, 2020). Hence, by choosing the right transportation modes, optimising routes, as well as coordinating the logistics activities, the firms in the manufacturing industries can prevent cash overruns and ensure the resource utility in an optimised fashion.

Being an island country, the aspects of an efficient port system, multiple transportation options, as well as other mix of factors are crucial to optimise the lead times and transportation costs for these goods.

### ***Sustainability and Environmental Considerations***

Manufacturing companies are also significantly concerned about the sustainability trends in the present market situation due to a range of factors such as the rise in public awareness and to meet the regulatory requirements (Attaran, 2020). This involves the reduction of waste and emissions, optimising energy usage, as well as using more eco-friendly materials in the manufacturing processes.

Hence, the firms are required to comply with the regulatory guidelines as the Sri Lankan commitment to environmental consideration and sustainable development requires an extensive focus on these aspects. Furthermore, the aspects of corporate social responsibility (CSR) are also crucial to ensure long-term competitiveness in the market.

### ***Continuous Improvement and Workplace Development***

Additionally, the significance of continuous development of the workplace environment is also a major focus for manufacturing firms as they seek to foster collaboration and communication within the firm (Rahimian Asl & Maleki, 2023). This aids them in ensuring efficiency in decision-making making, innovation, as well as the development of an agile supply chain system.

The supply chain management practices are being used by firms to enhance their product quality and operational efficiency to meet consumer demands by minimising costs and ensuring their sustenance in the highly competitive marketplace (Cai & Choi, 2020). Nevertheless, the government has a major role in creating and managing policies and support to foster antifragile supply chain management practices within the rubber manufacturing sector of Sri Lanka. This could be in the forms of incentives, the creation of regulatory frameworks to promote collaboration among the stakeholders, as well as support in R&D to ensure the development of relevant resilient technologies for the businesses in the country.

Hence, by the means of identifying the potential threats to the implementation of such a resilient system in the supply chain management practices is quite crucial in order to ensure

the development of the operational performance of the rubber manufacturing businesses in Sri Lanka. Furthermore, more research in this regard would also ensure the development of organisational expertise in planning for resilience against uncertain and unfavourable business situations.

## **2.7 Resilient and anti-fragile business ecosystems**

While resilience and antifragility refer to completely different aspects, their focus remains on ensuring the sustenance of business firms in adverse market conditions. Resilience refers to the ability of a business organisation to withstand the stress and threats because of disruptions in the market (Chatzinikolaou & Vlahos, 2021). Hence, they are required to be more persistent to mitigate the influence of disruption and ensure to attain the desirable results to recover from the issues. However, the antifragile systems are stronger organisations that seek opportunity from a disruptive situation and focus on gaining a competitive advantage in the market. Hence, various literary sources are used to shed light upon these two concepts in detail below. Many companies still operate with their backdated strategies and management techniques, which impacts their productivity and sustenance in the market. Uncertain and unpredictable situations such as COVID 19 have shown the importance of resilience and antifragility of organisations. Alongside the other issues such as socio-political and geographical considerations also play a crucial role in planning and managing sustainability (Chatzinikolaou & Vlahos, 2021).

The business ecosystems with the ability to withstand disruptions, alongside ensuring to thrive and develop in negative circumstances are known as resilient and antifragile business ecosystems (Chatzinikolaou & Vlahos, 2021). These include the following key aspects. By being able to recover from shocks, disruptions, as well as stress, businesses become resilient. In such an ecosystem, the issues of economic downturns, supply chain issues or natural disasters do not hamper the productivity and functioning of the businesses. Such firms have the following key characteristics. Collaboration persists among the stakeholders of the firms in the manufacturing industry, which aids in ensuring the flow of resources in an efficient supply chain management system in a smooth manner despite issues such as market volatility (Herdianti, 2022). Additionally, for agile and adaptable businesses, adaptability is a highlighted aspect considering the changing market situations. Moreover, such firms are also quite diverse and are able to be more resilient in the market (Timashev,

2020). Furthermore, such businesses are also quite innovative with a healthy workplace environment, which fosters the exploration of new opportunities, technologies, as well as business models to drive resilience and growth in the long run.

In Sri Lanka, the development of ports and alternative energy sources could aid the manufacturing businesses in the country to be more resilient. In addition, the promotion of agile management practices and focus on SMEs would lead to the development of the strength of the national economy (Bliekendaal, 2022). Moreover, with the help of R&D and public-private partnerships to develop infrastructure and innovation, as well as address the socio-economic challenges in the country. On the other hand, the antifragile business ecosystems go one step ahead to find opportunities in such disruptive environments (Chatzinikolaou & Vlados, 2021). They seek to benefit from these volatile and uncertain situations to promote innovation and growth, and hence, gain a competitive advantage in the market. Mostly their approaches include the following.

With the help of a redundant system and diversification, the firms ensure more stability during disruptive situations as they serve as a buffer during such crises. It also ensures the flow of resources and capital smoothly (Chatzinikolaou & Vlados, 2021). In addition, positive feedback loops and network effects further enhance the aspects of collaboration and knowledge management in the organisational workspace. Moreover, the inclusion of adaptability and experimentation ensures innovation and continuous development, owing to the development of their overall decision-making abilities. Furthermore, a decentralised approach also ensures the provision of faster responses to changing market situations and opportunities in the market.

It has become a growing need considering the turbulence and uncertainties in the market, which often challenges the sustainability of firms in the market. There are collaborative efforts between the business's ecosystems would lead to the development of resilience towards uncertainties in the market, owing to the development of better opportunities for the future. This also ensures the sustainability of those adaptive firms in the highly competitive market.

The government of Sri Lanka can also empower the local communities and foster entrepreneurship outside the major urban centres. By the means of prioritising resilience and antifragility in businesses, the Sri Lankan manufacturing sector could foresee enhanced



competitiveness in the market with scopes for attracting new investors and gaining sustainable growth in the market in the long run. The firms would become more resilient and stronger to withstand such issues and ensure their growth and development in the long run (Blienkendaal, 2022). Hence, there exists a need to ensure effective collaboration among the government, businesses, academics, as well as society in ensuring the development of the market for ensuring the growth and sustenance of firms in it.

## **2.8 Antifragile SCM application in the manufacturing industry**

There are numerous benefits of ensuring the successful implementation of an anti-fragile supply chain management system to ensure the development of supply chains quite resilient to the changing market situations (Shoushtari and Ghafourian, 2023). In addition, the aspects of changing market demands, consumer preferences, as well as uncalculated risks can also be mitigated with the assistance of the latest IT gadgets that support real-time data to enhance the overall decision-making process. In addition, these aid in the proper adjustment of production volumes, and product quality, as well as strategies to meet the changes in the market.

However, there are various issues such as the infrastructure, such as transportation networks, ports, as well as IT is not as advanced as many countries. In addition, the other key aspects such as resource constraints and dependencies on imports are another major concern for the firms in the Sri Lankan manufacturing business. This includes the issue of the lack of awareness and education, where the firms often lack awareness regarding the best practices for their supply chain management. Furthermore, the lack of access to technology, education, as well as training is also a major constraint that leads to inefficiencies within the firms.

Apart from the factors stated above, other concerns such as geopolitical factors including political unrest and trade disputes, or cultural aspects could considerably threaten the supply chain stability (Rahimian Asl & Maleki, 2023). Hence, addressing these challenges, government support, industry collaboration, investments in technological infrastructure, as well as education and training initiatives would lead to the development of resilience, competence, as well as sustenance in the market in the long run.

However, there are benefits such as the development of a sense of embracing volatility, uncertainty, complexity, as well as ambiguity (VUCA), which aids the firms in

making their supply chains more adaptive and resilient to uncertain events including, but not limited to natural disasters and geopolitical and economic uncertainties (Shafiei, 2023). Hence, the firms also benefit from enhanced risk management practices and ensure collaborative approaches to leverage resources and address vulnerabilities to enhance the supply chain resilience in the long run. This aids them in responding quickly to consumer needs, delivering products efficiently, saving costs and navigating disruptions, which ensures the firms capture the market more effectively, win and sustain consumers, as well as outperform the competitors with an efficient market share. This aids the firms in building their competence in the market, owing to their sustainability in the long run.

These processes would aid in ensuring the satisfaction of the key stakeholders of the firm, including their key consumer segments. In addition, through the minimisation of disruptions and ensuring the development of the consumer experience, loyalty and retention of the customers can be ensured (Rahimian Asl & Maleki, 2023). Hence, the firms in the manufacturing sector of Sri Lanka can ensure the application of anti-fragile principles in the supply chain management system (SCM) to create systems to benefit from the uncertainties in the market.

The organisations can ensure the implementation of the analytics in an advanced fashion with the usage of technology such as the Internet of Things (IoT) sensors, as well as predictive maintenance technologies, which aid the manufacturers in monitoring their supply chain performances to identify and mitigate the potential issues before their occurrence (Rahimian Asl & Maleki, 2023). This is benefited with the aid of real-time data and predictive analysis, which aids in addressing issues such as inventory shortages, quality defects, as well as operational efficiency of the businesses.

Apart from the businesses can also ensure the diversification of their supply chain by not relying on a single source to seek raw materials, technology, or infrastructure, which would reduce the risks of streamlining operations in unfavourable business situations. Moreover, this would also assist them in being more competitive in the market with a flow of resources and capital efficiently. In addition, with the help of a flexible manufacturing process, the firms would ensure to adjust their product volumes, quality, as well as configurations to ensure their efficiency in the disruptive market environments (Größler, 2020). Moreover, with agile manufacturing techniques, they can ensure to rapidly meet the

changing demands in the market. Furthermore, the benefits of redundancies could also ensure the maintenance of operational efficacy during unfavourable market conditions.

The manufacturing firms can also ensure engagement with the risk management practices in a collaborative manner where communication plays a key role. This ensures the development of a sense of trust, transparency, as well as resilience with the key stakeholders of the firms such as the suppliers and consumers of the firms. The stakeholders are required to share information regarding potential threats, develop contingency plans, as well as coordinate a response aid at the time of such vulnerabilities (Rahimian Asl & Maleki, 2023). These approaches to risk management further ensure the development of collective intelligence and resources to mitigate risks and situations in a more efficient manner.

Furthermore, it has further been assessed from the studies that the development of individualistic skills, capabilities, as well as mindsets would ensure the development of sustainability during dynamic and uncertain business environments (Rahimian Asl & Maleki, 2023). This includes the investment into employee training, cross-functional collaboration, as well as initiatives for innovation to promote agility and creativity, and hence, promote an innovative work culture.

Hence, by the means of implementing antifragile principles in the supply chain management of the businesses in the manufacturing sector of Sri Lanka, the development of a more resilient, adaptive, as well as competitive supply chain could be ensured. With the assistance of regular stress tests and analytics, the manufacturers could ensure the assessment of their supply chains to evaluate their potential threats and assess their readiness for such situations. This would ensure the development of mitigation strategies during negative circumstances such as supplier failures, fluctuations in demand, as well as transportation delays to gain supply chain resilience in the market (Größler, 2020). This would ensure the development of a stronger operational system and risk management mechanism to overcome the challenges faced by the firms in such adverse market conditions.

## **2.9 Sustainable supply chain management strategies**

It becomes significant to note that the rubber industry in Sri Lanka aims to improve sustainable development principles which are drawn from the magnificent landscape all around (samsonint.com, 2024). However, the rubber industry of Sri Lanka acknowledges the

requirement for responsibility and the use of the sustainable resource usage to develop energy utilization, lower the wastes, reduce the pollution in case of air, water as well land contamination. Such instances urge the industry to adhere to measures through which they can attain sustainability and leverage the performance and thereby the profit margins. On the other hand, Sadeghi, Akbarpour and Abbasianjahromi (2022) opined that the sustainable supply chain strategy becomes one of the strategies that involves economic, environmental as well as social leadership. However, natural rubber is being utilized in numerous essential goods and since rubber acts as a renewable resource, there appears a need to produce it and process it in a sustainable manner because of the increasing global demands (Preferred by Nature, 2024).

As per the view of Sadeghi, Akbarpour and Abbasianjahromi (2022), the firms to initiate responsiveness to the distinct environmental conditions can traverse towards more sustainable, agile supply chain management systems. Most importantly, besides concentration on the stability and resilience, the organisations can also opt for another strategy, which is antifragile. On the other hand, it is found that the expansion of the different rubber plantations renders negative environmental effects including deforestation, pollution, unsustainable pricing, gender inequality as well as displacement of the varied local communities (Preferred by Nature, 2024). However, to lower the environmental risks, the rubber producers are required to function together to guarantee that rubber production is executed by maintaining sustainable measures. Moreover, it is with the assistance of sustainable supply chain management that the rubber manufacturing sectors can lower the negative environmental contributions and develop the continuity of their supply chains.

As per the opinion of Nikookar, Varsei and Wieland (2021), the antifragility lens can help the firms to rebalance trade-offs denoting the new manners of shaping global supply chains within which the different environmental sustainability will facilitate antifragility. On the other hand, the investment of the firms in their environmental as well as social sustainability in all aspects of the supply chain can enable the organisations antifragile during the times of environmental disorder or the climate crisis. On the other hand, Lotfi et al., (2023) opined that the antifragile, sustainable along with the agile network design exhibits to be a new kind of design within the supply chain network design sphere. However, firms can make use of a hybrid approach that involves the antifragility, sustainability to utilise disruptions to develop the environmental effects and to react to the consumers in the supply chains. However, sustainable supply chain management practices enable the firms to shift to the suppliers who are closer to the business to lower the carbon footprint. Shoushtari and

Ghafourian (2023) mentioned that productive supply chain design along with risk measure implements antifragile, sustainable principles to establish a system which is adaptable, eco-friendly, and socially responsible to all the shifts in the business environment. Thus, the rubber manufacturing firms can undertake sustainable supply chain strategies such as sustainable transportation, life cycle assessment that can help them to enhance operational efficiency.

As stated by Lotfi et al., (2023), a hybrid approach traversing beyond antifragility, agility as well as sustainability has the potential to harness disruptions within the business to leverage the environmental outcomes while adhering to the requirements of the consumers within the supply chains. However, the following of the sustainable supply chain can help the firms to achieve long term value creation. It is with the reduction in the carbon footprint and enhancing of the operation efficiency that can enable the firms to lower their costs. On the other hand, Jahromi and Akbarpour (2022) mentioned that the social, operational, economic, and other resilience within the critical conditions appears to be in line along with sustainability. It is because the philosophy revolving around sustainable development implies establishing sustainability within unstable instances. Moreover, adhering to the sustainable supply chain management can help the business to leverage their reputation and become more appealing to the audiences. Furthermore, the sustainability within the supply chain apart from becoming appealing to the staff also becomes impressive for the customers.

On the other hand, Dubey, Bag and Ali (2014) stated that the manufacturing sector becomes one of the sectors that is connected with the attentive utilisation of the different resources, and it is with the enhancement of time that the level of material usage has been leveraging that paves the way towards a diverse effect on the atmosphere. However, it is noted that the manufacturing sector through several of their stages such as procurement, disposal and others negatively contribute to the environment. It is found that the actual incorporation of the socially responsive supply chains faces a dearth of a holistic approach. On the other hand, Jayalath et al., (2017) highlighted that the dearth of strategic connection and reduced quality goods with greater costs make Sri Lanka's performance of the rubber sector much lower when compared to the global market. The firms can undertake several strategies such as eliminating waste generated, maintaining compliance to guarantee that the supply chain addresses the environmental regulations and rules for the purpose of sourcing, emissions, and others (Lotfi et al., 2023).

As per the view of Dubey, Bag and Ali (2014), the green practices might help to lower the environmental effect of manufacturing along with the disposal of the different end of life goods and enhance the social positioning. However, the sustainable supply chain management practices directly assist in leveraging the export of sales. On the other hand, Jayalath et al., (2017) opined that in the shifting arena, the competitive benefit advances from the establishment of the supplier abilities to establish consumer value and attain cost differentiation leading in profitability and greater market share. However, the competitive benefit of an organisation can be addressed by developing the operational performance. Moreover, dimensions such as quality, responsiveness, price, and others engage within the operational performance (Florescu et al., 2019). Most significantly, it is noted that the supply chain management and the operational performance tends to be engaged in empowering connections.

As per the view of Florescu et al., (2019), the sustainable supply chain management strategies tend to have important influence on all the supply chain functions. It is also found that the manufacturers in the supply chain can make use of several other strategies which involve ethical sourcing, sustainable packaging, and others. However, sustainability becomes essential to develop the productivity of the firm and to optimise the costs. On the other hand, Bratt, Sroufe and Broman (2021) mentioned that sustainable supply chain management can be illustrated as integrating systems thinking, “strategy”, practices within supply chain management such as ecological, social as well as financial performance.

Moreover, a critical strategy for incorporating the sustainable supply chain management is to initiate operations with the first-tier suppliers who are recognised as significant collaborators to attain the mission and to execute so from the created association amid the people. As per the perspective of Bratt, Sroufe and Broman (2021), the organisations also make use of the “FSSD based tools'(Frame work of strategic sustainable development) ' which are also known as the strategic life cycle assessment within workshops. Such tools can assist the firm as it offers a strategic look of the opportunities regarding the social as well as the ecological sustainability all throughout the life cycle of the goods.

## **2.10 Ways to cope with uncertainty in supply chain.**

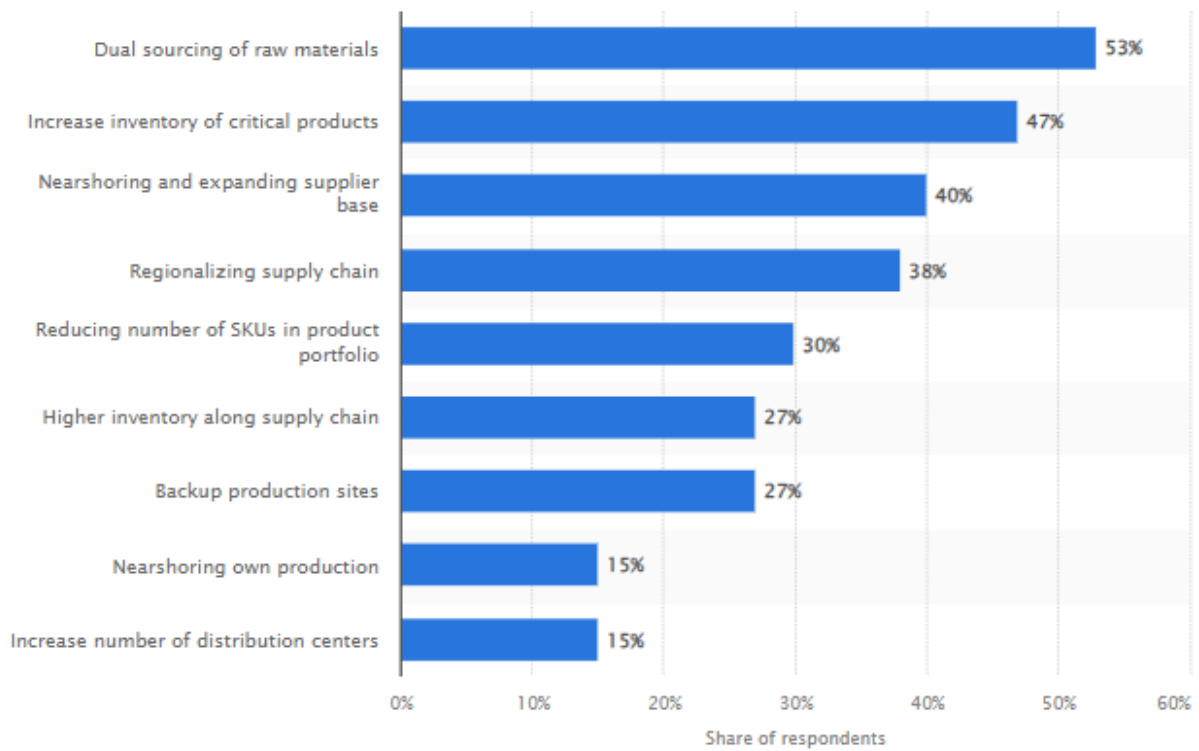
According to the view of Sreedevi and Saranga (2017), supply chain flexibility is referred to as the key solution to the rising uncertainty as well as competitiveness in the market. There are also empirical studies that have stated that supply chain flexibility is

uncertain and competitiveness within the market has helped to contribute to enhancing business performance. On the contrary, the author has further stated that the studies which seem to investigate the role of supply chain flexibility to mitigate the supply chain risk has been sparse. Relevant studies will be required to understand the type of flexibility that is essential to mitigate the supply chain risk. For instance, in the year 2013 a survey undertaken where it is evident that 27% of the respondents have stated that flexibility to be the major supply chain value driver to ensure consumer value proposition (Sreedevi & Saranga, 2017). Therefore, it is imperative to determine as well as identify the context that ensures different flexibilities that can reduce supply chain risk through different conjectures by considering appropriate empirical investigations.

On the other hand Flynn, Koufteros and Lu (2016), supply chain integration (SCI) is referred to as the scope as well as the strength in terms of linkage of supply chain processes throughout the business. SCI is facilitated by different aspects of information operations along with relational integration. Therefore, it can be used as the most effective behavioural response to a certain type of uncertainty. This is because it helps to facilitate lateral relations which further helps in collaboration, coordinating and controlling relevant information and material movements throughout the supply chain (Flynn, Koufteros & Lu, 2016). This allows the supply chain to improve capabilities to operate in any uncertain condition or changing market demand. It would further allow the supply chain to develop supply chain trust, shared meaning which ultimately improves the supply chain culture. By referring to figure 2.4, it can be further depicted that almost 53% of the business executives have revealed that dual sourcing of relevant raw materials is one of the planned actions that enables to enhance resilience within the supply chain and the production process (Placek, 2022).

## **Planned actions to enhance supply chain resilience worldwide as of 2020**

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**Figure 2.4: Ways to enhance resilience within the supply chain**

(Source: Placek, 2022)

According to the view of Govindan, Fattahi and Keyvanshokoo (2017), supply chain network design (SCND) is the potential planning problems in supply chain management. It has also become important for the business to design decision that needs to be viable to function in complex as well as uncertain business environment. SCND, which is also known as strategic, supply chain planning which is further referred to be the planning process within the supply chain management that enables the business to determine infrastructure also the physical structure of supply chain (Govindan, Fattahi & Keyvanshokoo, 2017).

The business needs to undertake larger sufficient investments that are essential for the strategic decision making. Therefore, an effective decision will help the supply chain to ensure long term benefits and enhance business performances. On the contrary Gunasekaran, Subramanian and Rahman (2015), stated that manufacturing as well as services have been sourcing from different countries so that they can acquire relevant competitive advantage to the business through effective supply chain management practices. Therefore, to manage uncertainties and complexities in global sourcing it is thereby important for the business to maintain transparency within the supply chain management that would help to maintain an end-to-end visibility, order processing and to determine inventory status. There are also



certain ways to improve supply chain resilience by providing sufficient training to the professionals, cross fertilise learning from suppliers, collaboration with other buyers, developing networks to reach out to the lower tier suppliers and many more (Gunasekaran, Subramanian & Rahman, 2015).

The business can further use an enterprise information system that would enable the business to collect real time data which would further be helpful in data collection and data analysis process. On the contrary Gunessee and Subramanian (2020) Individual coping mechanism is further referred to as individual decision maker who probably deals with or intends to manage ambiguous situations. Coping is further termed to be a mechanism that is often triggered once a problem or challenge is encountered. It has been further stated by the author that organisations develop coping strategies to navigate supply chains under ambiguity. By considering “managing supply chain uncertainty and supply chain resilience”, it can be identified that the two main strategies that can be outlined are mitigation and preparedness. It is often considered that “ambiguity mitigation” strategies would allow the supply chain to minimise fuzziness that often deals with ambiguous disruption.

As stated by Tordecilla et al., (2021), the risk and vulnerability can be closely related to resilience therefore it becomes important for the business to manage the supply chain effectively that can lead towards achieving the desired goal. It has been stated that the literature optimization or sometimes pure simulation method often does not have the power to provide sufficient answers to the decision makers. On the contrary, the use of stochastic programming is more appropriate to deal with problems as well as uncertainty within the supply chain.

As stated by Um and Han (2021), globalisation has enhanced international competition, which has further enabled to reshape the trade environment. Therefore, the global supply chain is associated with relevant internal risk, which includes quality defects, higher inventory level and delays. Therefore, under an uncertain supply chain it becomes essential for the business to adopt strategies. Through the above discussion, it can be further noted that there are several ways to reduce supply chain uncertainty and complexities. Hence it can be therefore stated that it is important for the business to align the supply chain strategy with the demand characteristics thereby it will help to improve visibility through technology and data analysis (Ramezani and Camarinha-Matos, 2019). Additionally, it can be further stated that by establishing long-term relationships and collaborating with relevant alliances would enable to reduce uncertainty and risk in the supply chain.

## **2.11 Effectiveness of antifragile supply chain management to improve business performance.**

Since antifragility directs towards the property of systems that enhances their abilities to survive because of the volatility, mistakes, and others, it traverses much beyond the robustness as well as resilience. As per the view of Martinetti, Moerman and van Dongen (2017), while fragile desires tranquillity, it is the antifragile that tends to grow from multiple disorders and engage to be more empowering when stressed. On the other hand, Munoz, Todres and Rook (2021) highlighted that shaping antifragile as well as resilient organisational ecosystems can help to cope up with several unexpected events. However, it is the antifragility that permits the betterment of the performance due to the firm's exposure and learnings from the stressors and the volatility. Moreover, the systems that engage the antifragility could attain from the disorder with the help of the configuration of the multiple abilities as well as resources.

As stated by Martinetti, Moerman and van Dongen (2017), the notion of antifragility provides a modern approach to deal with and manage indeterminism. On the other hand, it is found that the problem that the firms encounter while adhering to the notion of antifragility within reliability is the shifting of the existing mind-set in case of determinism while experiencing uncertainty. In contrast, Munoz, Todres and Rook (2021) opined that for firms the challenge persists in the recognition and the delivering of the different fundamental artefacts to fulfil the work to attain antifragile results. However, it is with the assistance of the antifragile supply chain management that the manufacturing firms can effectively gain profitability and produce a broader range of greater quality goods and services within limited processing time. It is found that enabling and facilitating digital procedures becomes the essential task for establishing an antifragile supply chain management.

As per the view of Ramezani and Camarinha-Matos (2019), the unexpected events are gradually enhancing with increasing effects that denote severe issues for the sustainability of the firm. Such practices can help the manufacturing firms within their decision-making procedures and thus will lead to the spotting and predicting of different disruptions that can be experienced by the business. It will further enable the firm to initiate accurate decisions and actions and develop informed choices to handle and surpass the volatility. However, this will develop the potential to collaborate with distinct suppliers of the business and thus enabling the firm to rapidly acquire ways to conveniently manage the disruption.

As per the perspective of Ramezani and Camarinha-Matos (2019), the adherence to the mobile technology along with the block chain connected technologies that encourage the incorporating of fairness and dutifulness within collaboration becomes beneficial to shape antifragile and resilient systems. However, the early detection of the issues with the help of the modern technologies will enable the companies to stay prepared ahead of the uncertain times. Thus, it can be stated that the antifragile supply chain management practice can assist the firm to stay ahead of the times and acquire growth abilities.

As stated by Shafiei (2023), it has been ensured that due to the globalised economy supply has become increasingly complex as well as interconnected. Therefore, it has also enhanced the severity and disruptions within the supply chain such as political instability and economic downturn. Additionally, it has been further stated that resilience within the supply chain has become unimportant to anticipate, prepare along with responding to disruptions. Therefore, it further ensures to deliver products and services to the customers. Hence, by undertaking an antifragile supply chain the business induces resilience as it is based on identifying as well as assessing risk, developing and mitigation strategy and implementing mitigation strategy has enabled the business to ensure uninterrupted services to the business. On the contrary, Zitzmann (2014) in the current era competition seems to take place within the supply chain and not between single companies therefore it makes it important for the business to create a network. It further helps to enhance efficiency which otherwise leads to operational uncertainty. It is further ensured through the antifragile supply chain that it helps the business maintain resilience and emphasise on the growth and development of the business. By undertaking an antifragile supply chain allows the business to grow under socio ecological circumstances.

As per the view of Größler (2020), robustness seems to be the most important characteristic of a dynamic system to perform satisfactorily over a certain range of parameters. Therefore, antifragility is sometimes referred to as the system that intends to gain volatility and disorder which enhances performance under uncertain situations. The antifragility supply chain further encompasses the ability to recover after shock which enables the organisation to achieve a higher performance level. On the other hand, it has been further identified through literature that planning plays the most pivotal role while creating an antifragile supply chain. This enables the supply chain to survive under stress and improve itself thereby making it stronger which ultimately leads to achieving the desired business outcome.

As stated by Hadizadeh et al., (2023), antifragility often helps the supply chain to foresee as well as prepare to overcome potential risk. It also provides supply chain managers with relevant planning thereby it helps to identify risk or any vulnerable situation that can be riskier for the business. For instance, antifragility helps to diversify suppliers, increase inventory for any critical components along with establishing any alternative logistic routes (Linkedin.com, 2024). As stated by Priyadarshini et al., (2022), advanced technology along with data analytics also plays a major role in the antifragile supply chain. It allows the business to better forecast and ensure real time monitoring. Therefore, these capabilities allow the business to respond quickly towards any uncertainties that can arise through disruptions. It can be understood from the literature that antifragility helps the business to effectively plan that minimises the occurrence of uncertainties and therefore reduces the chances of supply chain disruptions (Bag et al., 2023). However, it is also important to induce significant technologies to enhance the effectiveness of the antifragile supply chain.

As per the view of Chenaru et al., (2022), an antifragile system fosters learning through the usage of both the flexible as well as resilient practices and strategies. However, to practise and become antifragile it becomes essential for the firms to stay prepared to experience uncertainty. It is found that some of the antifragile systems have attained expansion and provided several implementation solutions. On the other hand, Corvello et al., (2023) mentioned that the supply chain connectivity and the several resources enabling information exchange paves the way towards the supply chain visibility ability that leverages resilience and robustness. However, it is planning that will act as a significant role in establishing an antifragile supply chain and it is the antifragility that needs the potential to witness and get prepared for the varied risks.

As per the view of Chenaru et al., (2022), Europe's industry elaborate as customer driven, antifragile manufacturing, omnipresent. However, the major benefit of the antifragile system is the fact that it can adapt to various uncertain times or events. Moreover, it is through careful planning that the firms can recognize multiple vulnerabilities in their supply chains and initiator strategies to resolve the varied risks that they pose to be disruptive.

## **2.12 Digital technologies in promoting antifragility in supply chain.**

As stated by Corvello et al., (2023), the utilisation of the various digital technologies is assumed to play a significant role in shaping the antifragility. As per the view of Jørgen Hole (2016), cloud-computing platforms make use of the virtualisation of modern

technologies that promote the establishment and maintenance of the antifragility when compared to the distinct traditional data centres. However, digital technologies can adapt new contexts and assist the business to survive uncertainties and thereby effectively manage the supply chains. Moreover, digital technologies engage a crucial role within the chances or scope of success even more after the advent of the COVID-19 pandemic. Furthermore, it is noted that the firms have been adhering to new technologies since it enhances the resilience of the organisations at the time of the disruptive and uncertain times. Such notions frame the idea or the fact that the digital technologies enable the supply chains to shape antifragility.

As opined by Alexander et al., (2022) resilience at the time of pandemic has been facilitated by the existence of the global digital interactions or the communications. However, the disruption within the supply chains has been regular phenomena and the emergence of the pandemic lead to negative impacts on the supply chains. On the other hand, it is noted that with the utilisation of digital technology the firms can achieve the potential to improve the resilience within their supply chain systems. Bag et al., (2023) mentioned that the application and the usage of the digital technology in sourcing, distribution and other aspects act as a crucial mediator within shaping a productive antifragile supply chain management system. However, it is the data driven modern technologies that can initiate substantial shifts in the way the supply chain functions.

As per the view of González et al., (2017), the blockchain technology is being used for monitoring digital usage, within the supply chains, smart contracts, and others. It is however, considered as a shift in organising the procedures with more productiveness. However, digital technologies including the Internet of Things, Big data and others are affecting the development of the firms and the supply chain operations. Moreover, there are several other modern technologies such as artificial intelligence, radio frequency identification and others that can help the firms to predict situations and act accordingly. According to the view of Ramezani Camarinha-Matos (2019), in the current era it has been identified that industry as well as services is going through profound transformation. Digital transformation or industry and others such as Economy has enabled the business to overcome any challenges being faced by the business supply chain. It can be further assumed that antifragility within the supply chain has helped the business to develop collaborative approaches and achieve supply chain resilience. Additionally, it can be further depicted that to overcome any supply chain disruption the business seems to undertake supply chain antifragility by developing the business potentialities and capabilities to overcome the supply chain disruptions. On the contrary quantum computing seems to have greater potential that

seems to have great potential to change supply chain, value chain which helps the business to forecast demand and operate accordingly. This influences the business to enhance business performance level. On the other hand, it has been further noticed that dynamic supply chain concept, home assisting techniques would allow supply chain to work significantly and effectively to improve business performance.

According to the view of Lund, DC and Manyika (2020), the business seems to face a wider range of hazards in terms of natural disaster along with vulnerabilities in geopolitical uncertainties. Therefore, by inducing an antifragility supply chain the business can explore shocks, the vulnerabilities, and the expected financial losses. The adoption of digital technologies in global manufacturing has been significant in terms of enhancing the business resilience. Additionally, the supply chain management is now considerate about lessening the importance of low labour costs along with ensuring more automated plants that can be resilient to overcome any natural disasters. As stated by Al-Banna et al., (2023), supply chain resilience has become the most significant aspect for the business. The business is now considering adopting a wider range of technologies such as technologies which has been inserted to reach the desired Supply Chain resilience state. This ensures that with the use of modern technologies the businesses are most concerned about improving the supply chain process to avoid any disruption in the business (Lund, DC & Manyika, 2020). Antifragility supply chain enables augmented data intelligence, warehouse automation, robotics, and mothers to improve the resilience that can help in achieving desired business success. Hence, it can be ensured that the business must undertake effective measures to induce relevant technologies to enhance supply chain resilience.

As per the view of Corvello et al., (2023), the different digital technologies navigate the resilience at the supply chain stage as they lead to the maximised flexibility to establish redundancy and to form collaborative connection and to develop the knowledge acquisition. On the other hand, digitalisation within technology tends to be the journey and it encourages multiple business models, manufacturing industries and others for their growth and designs the business and the advantages consumers. However, it is the industry that makes use of the modern technologies that can be incorporated globally, produce wealth and offer growth to countries.

As per the opinion of Lund, DC and Manyika (2020), the technology has been challenging prior assumptions that resilience can be attained at the cost of productivity. On the other hand, Arenkov, Tsenzharik and Vetrova (2019) opined that big data technology permits larger quantities of both structured and unstructured data. However, the modern and

digital technologies impact and accelerate the incorporation of the non-digital innovations including the new manufacturing materials, extraction, energy storage and others. It is with the help of the new technologies that the manufacturing firms can ensure that their supply chain has adequate visibility, better collaboration, and developed data insights.

As stated by Arenkov, Tsenzharik and Vetrova (2019), the supply chains are being gifted into ecosystems which are navigated by a central platform which is processing varied data. However, the digital technologies within the supply chain enables the manufacturing firms to better forecast and initiate rapid processing. On the other hand, Núñez-Merino et al., (2020) opined that the digitalisation has been implied to the usage of the distinct technology for productive economic value establishment procedure. Moreover, the use and the application of the new technologies also could leverage flexibility as well as transparency which can enable them to operate in a better manner.

On the other hand, the COVID-19 depicted the issues regarding addressing of the consumer's demand about the supplying of goods services as well as manufacturing. Such critical times made the manufacturers and forms rethink strategies, digitalisation, and others. As per the view of Núñez-Merino et al., (2020), the supply chains have been experiencing various issues including uncertainty, complications, vulnerability, and others. However, the technologies incorporated within the supply chains can enable the firms to leverage inventory visibility and effectively manage the risks or uncertainties through predictions.

### **2.13 Sustainability approach in improving rubber supply chain.**

While discussing the sustainability in supply chain, it can be stated that global production and harvest depend on how manufacturers can focus on elasticity and consumer reach. According to Inkonkoy (2021), rubber supply chain is tapped over 70% of annual global production. Natural rubber production can have different environment and social impacts for managing the sustainable natural rubbers. Therefore, it is crucial for promoting the sustainability in supply chain. It is crucial to promote the natural supply chain for maintaining the healthy and fostering practices across the environmental concerns. However, it is to promote and address the social and environmental issues by highlighting the impacts on rubber supply chains. It is important to focus on business activities in rubber pricing and increase volatility in supply chain. To apply deforestation-free supply chains, traceability is significant factor to sustainable sourcing commitments (Inkonkoy, 2021). Without knowing origins, it is being produced with compliance and processing factories for independent trees.

60% of companies have clear public commitments to implement successfully. Thus, it is clear to determine how the areas on global supply chain can be managed to increase demands on natural livelihood of producers and human rights violations (Susanto et al., 2021).

Additionally, it is important to assess how supply chain activities are assessed to domestic supply chain requirements, as there are most effective supply chain activities through utilisation (Chienwattanasook et al., 2022). Big data is useful in engaging how the human activities are replaced and minimised. SC sustainability requires how sustainability can be developed based on examining the rubber industry. It is effective to utilise order management in the rubber manufacturing industry. It is important to facilitate the SC sustainability as it has positive role in determining the cortical development in order management and data development. Order Management and SCS have significant role to measure the benefits as decreasing the labour work. Hence, data storage is managed to identify how the industries can have significant role in warehousing and data transformation. Data transformation is important to set how various countries have different data warehousing and data management. Data transformation technology has different role in organising the relationships with rubber making companies. On the contrary, Tanielian (2018) opined that knowledge and skills are often deficit in agriculture commitments. Labour is ubiquitous in Asia whereas the knowledge and skills have deficit view in agricultural communities. transitions in sustainability framing can generate how labours with such consistency can be undertaken based on skills and knowledge. Thus, it is important to portray how the rubber manufacturing can have significant considerations in sustainable development in different supply networks. Thus, it is important to determine circular supply chain adaption in rubber industries.

As per the view of Sitepu, McKay and Holt (2016), there is significant challenge to assess how different of options are measured and quantified as identifying the needs of composite indicators for different dimensions of sustainability. For example, it is evident that Natural rubber contributed 5.94% of Indonesian GDP (Sitepu, McKay & Holt, 2016). It has increased the household and rubber plantations in Indonesia, which are significant to manager how sustainability and technology adaptation can play significant role in the natural rubber industry. Dubey, Bag and Ali (2014) defines global SCM as integrating the environmental management. It is important to determine how upstream and downstream linkages can be identified to decrease the firm business management and product delivery. There are



contributing factors to moderate the main aspects on advancing resources and materials and organisational involvement on product recycling and regulations. For example, *Indian rubber industry* set for water proofing rubber manufacturing in Kolkata. There are rubber industries that shot up with pollution treatment systems (Dubey, Bag & Ali, 2014). The industry is undertaking the insights over deep insights on rubber goods manufacturing industry. GSCM and SC sustainability have been undertaken to identify how findings can be identified because of identifying the research on rubber manufacturing and research contribution.

Susanto et al. (2021) reviewed that supply chain models have guided how the quantity-based discounts can be gave different environmental factors for rubber supply in different forms. It is additional to determine how latex, plantation and others are utilised to centralise the SCM in determining the plantations over multi-objective developments. It is significant to occupy with engaging how the industry is coping with significant sustainability challenges. Costing and quality are measured in determining how different countries take different standards to optimise how the companies can focus on company development. Supply chain activities are interpreted to develop how quantity-optimised measurements are determined to centralise the rubber manufacturing and delivery (Chienwattanasook et al., 2022). Supply chain references are applied to get attributes on determining the strategic implementation for manufacturing development. SCM for natural rubber products can have different criteria, as it is significant to relegate with operational efficiency. It is important to ensure how the supply chain activities can be applied to accomplish the SCM. Thus, it is important to ensure how plantations have significant coordination on SCM development and activities.

## **2.14 Literature gap**

While discussing the existing literature on supply chain activities on rubber manufacturing and operational efficiency, the existing literature is focused on supply chain efficiencies, activity and models used in rubber manufacturing. The existing literature is mostly focused on different supply chain activities, concept of antifragile and others SC concepts, frameworks, models in different countries and different industries. However, the current literature has lacking areas on how antifragile supply chain can have impact on operational efficiency in manufacturing industry. It is identified that current research papers

are mostly focused on determining the how antifragile SC activities are applied in determining how organisational performance can be followed in adopting the SC activities to operational performance. The current research has scope to discuss how the antifragile SC activities can have impact on operational efficiency in the rubber manufacturing industry with case emphasis on Sri Lanka.

## **2.15 Summary**

It can be summarised that the antifragile systems concentrate on the disorders and attain various learnings despite neglecting the uncertainties. However, antifragility poses a new concept that focuses on the growth factor and empowers the firms, and the supply chain functions through the assistance of exposure to a variety of volatility. On the other hand, it becomes essential to maximise financial flow, enhance the inventory turnover to meet the demands of the audiences. However, the operational performance relies on multiple variables as well as indexes and it recognises the elements of supply chain, goods, and others. The overview of the Sri Lanka based rubber manufacturing units could be evaluated with success and clarity. Therefore, it requires business to develop effective strategies to ensure forecasting and develop better planning to improve business performance. It is found that the Sri Lanka manufacturing firms tend to acknowledge the significance of concentrating on the sustainability.

The antifragility within the supply chains offers opportunity to specific problems and indicates at attaining of beneficial amid several pressure elements. However, antifragility within the supply chain enables the firms to have growth for development and enhanced performance. Moreover, antifragility is important to manage disruptions and recognise the industry standards. It can also be summarised that the Sri Lanka manufacturing sector also acknowledges the need for the sustainable measures.

## **Chapter 3: Research methodology**

### **3.1 Introduction**

It is with the help of the methodology that the research can be equipped with both reliability and validity of the data gathered. The methodology ensures that the data extraction methods for the purpose of the study are appropriate and consistent. The chapter on methodology forms an integral part of the work and guarantees that the study can effectively address the objectives and the questions framed. It is with the assistance of methodology that the research can attain lawfulness and acquire scientifically sound conclusions. However, the research methodology becomes the manner of illustrating the way an individual intends to execute their research.

This chapter has presented the research philosophy, approach and design that has been followed. This chapter has mentioned the methods used to gather data and information to meet the research aim. However, it also highlights the distinct techniques that are being adhered to examine the extracted data and information. This chapter has exhibited the different ethics that are being followed by the study to leverage the quality of the work. It has further discussed the validity and reliability maintained by the study and ways it contributes to the work and mentioned the limitations faced.

### **3.2 Research philosophy**

As per the view of Al-Ababneh (2020), the research philosophy connects to the feature and the development of quality knowledge. However, it is a well-defined philosophy that tends to guarantee coherence within the research procedure and assist justify varied research choices. On the other hand, it is noted that the research philosophy acts as a significant component since it is beneficial for determining the research design that can be productively applied. The philosophy helps to unveil the predictions made by the people regarding the research work paving the way towards the several choices. There are several kinds of research philosophy that can be utilized within the work including interpretivism, positivism and realism research philosophy.

As per the opinion of Al-Ababneh (2020) interpretivism stands in contradiction to positivism to better comprehend and illustrate the social reality. However, interpretivism intends to focus on the culturally and historically premised interpretations and emphasis on subjective methods. On the other hand, Junjie and Yingxin (2022) stated that interpretivism

engages its roots in phenomenology that believe the fact that values, neutral facts do not prevail. However, positivism research philosophy relies on facts which are being derived with the help of varied observations. It is with the help of the positivism philosophy that the researcher can execute their work in an objective manner.

According to the view of Alharahsheh and Pius (2020) positivism is measured on a philosophical stance which is operating with the different observable reality paving the way towards the production of generalizations. However, positivism emphasizes more on pure data without being impacted by the interpretation of the bias of mortal beings. In contrast, the methods applied in positivism to comprehend the world might not be transferable to the social arena and can be considered as one of its limitations. On the other hand, realism research philosophy is premised on the prediction of the scientific approach. Moreover, it adheres to the fact that the truth is one of the crucial goals of science. Most significantly, the study has adopted the positivism research philosophy since it tends to rely on facts and data for meeting the objectives.

The study has followed the *positivism philosophy* since it delivers appropriate knowledge of the world and thereby revealing the accurate effect of the antifragile supply chain management on the operational management in case of rubber manufacturing in Sri Lanka. It has also been selected as it is premised on direct experience leading to gathering of more accurate data and information which are updated. As per the view of Al-Ababneh (2020), the positivism philosophy depicts scientific discovery, and it is the scientific knowledge which is certain. Since this philosophy is objective, the objects within the globe from this philosophical stance engage meaning prior to and much independently of being aware of them.

However, positivism is selected also because the depiction of facts can empower the work. The facts are regarded to be central and significant elements of the method. The study has rejected the inclusion of the interpretivism philosophy since the study did not intend to merely engage in interpretation of the scholars regarding the ways anti fragile supply chain management contribute to operational performance in Sri Lanka in case of the rubber manufacturing. It has been avoided as this philosophy might involve biases and connect to the subjective nature. On the other hand, the study has avoided the inclusion of the realism research philosophy since it tends to neglect the cruciality of the imaginations that are essential for the mortal life. However, it also places no importance to intuitions and depends on assumptions which might pave the way for attaining inaccurate outcomes for the study.

### 3.3 Research approach

Research approach is referred to as the plan and procedure to conduct research accordingly. It enables to consider broad assumptions in terms of developing a detailed method for data collection, analysis, and interpretation. It offers several decisions that enable better research and presentation. According to the view of Proudfoot (2023), research approaches are thus referred to as the general plan and procedures in terms of conducting research. There are mainly two types of research design such as deductive and inductive research. The research undertaken deductive research approach. This is mainly because deductive research approaches start with theory, hypothesis or sometimes generalisation. Thus, it helps to test them with the help of observations and data collection methods.

According to the view of Casula, Rangarajan and Shields (2021), deductive approach is a top down approach where the research intends to start with a general idea and thus enables it to test it through a specific observation. Additionally in case of deductive research approach it is important to note that deductive approach further enables to collect data from a set of research participants who have sufficient knowledge about the research topic. The present research is based on a mixed method approach where the primary as well as secondary research has been undertaken. Therefore, the deductive research approach is the most effective one for this purpose.

On the contrary inductive approach has been avoided in this specific research because in case of inductive research the study begins with specific premises and thus it intends to develop a general conclusion. Additionally, it has been further identified that the inductive approach does not involve developing any hypothesis and therefore it starts with research questions and objectives which need to be achieved through the research. In the case of an inductive research approach, it is mainly considered for qualitative data. However, the present study based on quantitative approach may not be relevant by undertaking this specific approach.

According to the view of Pacheco-Romero et al., (2021), it can be noted that undertaking deductive research approaches helps to explain concepts as well as variables that are related to one another and therefore helps to identify the cause-and-effect relationship. It further enables the possibility to measure data and concepts in a quantitative manner. Lastly, it would further help to apply the research findings to a broader context to a certain extent. Considering the differences between the deductive and inductive approach it can be stated that deductive approach enables one to investigate an existing theory and enables one to

determine whether the theory can be applied for future research. It is further supported with evidence. By undertaking the deductive research approach, it is evident that the study has been able to draw effective conclusion on the research topic along with relying quantitative analysis. Hence, it is effective in terms of “impact of Anti-Fragile Supply Chain Management on the Operational Performance of the Rubber Manufacturing Sector in Sri Lanka”. Thus, it can be ensured that the deductive approach is the most effective choice for the research.

### **3.4 Research design**

The major purpose of research design in the study is that it permits people to proceed in the accurate direction. However, it is a well-planned design that guarantees that the methods undertaken by the study aligns with the aim farmed by the study. The design of the work becomes crucial as it might impact the validity of the outcomes. As per the view of Pandey and Pandey (2021) the research design leads to the yielding of maximal data and information. The research design offers gathering of varied relevant evidence within accurate time and expenditure. Moreover, it is also regarded to be the framework for the study as it tends to guide in extracting and examining the collected data and information.

There are three kinds of research design such as explanatory, exploratory, and descriptive research designs. However, the explanatory research design assists the study to comprehend the specific issue, for instance the reasons that have been leading the rubber manufacturing in Sri Lanka to face severe threats in a much more detailed manner by offering varied data and information regarding the challenge. Moreover, the explanatory design enables the study to assume the cause that prevails behind a phenomenon and also to assume the future occurrences effectively. On the other hand, Nayak and Singh (2021) mentioned that the exploratory research design intends to engage in unexamined topics and issues or the new arenas of enquiry. It also tends to offer qualitative data and interpretation of which can cultivate biasedness.

The descriptive research design utilizes both the qualitative and quantitative data and information to generate appropriate assumptions regarding a specific issue. As per the view of Nayak and Singh (2021), descriptive direct towards the making of the observations and thorough documentation of events of interest. It is with the help of the descriptive design that the study can illustrate the data and information extracted to meet the questions. For the current research study, *descriptive research design* has been applied to focus on how the operation can be maintained with business development and appropriate to support the

research purpose. Descriptive research has been chosen because it is helpful to understand characteristics of the phenomenal and understand the research nature. It is applied to identify the patterns of characteristics on how the research can establish the design and coordination to explain the decided description. While discussing the research findings from mixed types of research, it is important to determine how the problems can be analysed through the findings (Pandey & Pandey, 2021). Discussing the antifragile supply chain operations as well as the performance development is to conceptualise the research in a descriptive way. This method has treated the style based on aggregated data groups.

On the contrary explanatory research design is applied while the interrelationship between the variables is interpreted through the correlation analysis. This design has been discarded because it is applicable to identify the research in a descriptive way rather than the correlation analysis between the variables and cause and effect analysis. Additionally, exploratory research design determines how the research is based on identifying and investigating the literature that have not been studied previously in depth. It is important to determine how the research exploratory can be quantitative as well as qualitative in nature. The current research discarded exploratory design as it is not fitted for the mix method. The current research applies for the mixed method which fits descriptive design rather than the exploratory or explanatory design.

### **3.5 Data collection method**

According to Cyr (2016), data collection method is considered as a plan to gather and measure the information and variables related to the research context. Data Collection is the foremost important factor that can establish the research system in a systematic fashion to answer the stated research question, evaluate outcomes and accomplish the objectives. Data Collection depends on how the research demands conducting the processes to complement the research objectives. It aims to identify the enquiry on the research participants as well as the existing data. Additionally, the data of coherence and alignment depends on how different types of data can be gathered based on their limitations and weaknesses. Data collection methods are used to generate how the analytical approach can be applied for the researcher which can be described in several techniques such as survey, interview, Focus Group, observation, textual or content analysis and others (refer to Figure 3.1) (Paradis et al., 2016). Generally, there are “two types of data collection methods including primary and secondary”. “Primary data collection method” includes the raw data directly from the participant. While

secondary data collection refers to the existing research publications and papers which are already published in any platform regarding the research topic area. It establishes how the research nature establishes the data collection while it argues over the research methods and topic area. Primary data includes the methodological alignment to the research objective as views from the participants are gathered (Cyr, 2016). On the other hand, secondary data argues with the existing research papers and the views from the researchers and authors with different perceptions and arguments.



**Figure 3.1: Methods of data collection**

(Source: Mazhar et al., 2021)

For the current research papers, *“both primary and secondary data collection methods”* have been chosen. To proceed with primary data, survey technique has been applied to collect the data. Additionally, to proceed with secondary data different journals, papers, newspapers, reports, articles, books, and others have been chosen as a qualitative form of data collection. Recording to table 3.1, it can be stated that the quantity and qualitative data have been chosen to proceed with the analysis. Quantitative data through survey was helpful as proceeding with how particular geographic areas are suffering with supply chain disruption. As the research is focused on a particular geographic region, data from the participants working in supply chain activities were important to select while proceeding with the data analysis. Additionally, the antifragile supply chain is a huge and vast research area, which needs existing research publications equally to interpret how the specific sector can outperform on this.



<b>Data collection method</b>	
Primary data	Quantitative through Survey
Secondary data	Qualitative through thematic analysis

**Table 3.1: Data collection method**

(Source: Created by author)

### **3.5.1 Primary data collection technique**

Mazhar et al. (2021) opined that primary data includes the fresh and original data which are collected for the first time. It is undertaken as an experiment in case of descriptive research and development as a direct communication with the respondent. It includes observation, interview, questionnaire, scheduled and other methods. The current study has identified survey techniques as a design to get information from the people. Surveys with close-ended questionnaires are important to the other two models and ethical codes of conduct and the population development not to affect the respondent's data. The present study includes the mixed methods research to access the antifragile supply chain management of the Sri Lankan rubber manufacturing industry. To proceed with quantitative survey, SCM practices along with operation performance parameters have been ensured to conduct the research process. It implements the practices across the rubber manufacturing industry. The operational efficiency is the main motto while selecting the population for the sampling.

#### ***Sampling strategy and sample size***

Sampling strategy for the survey places crucial rules to find appropriate supports and research development to make while informing decisions on strategic intervention. Here, ***purposive sampling technique*** has been applied to select the research participants for the survey. According to Obilor (2023), purposive sampling process comprises different stages including the target population, chosen the unit of analysis, object on statistical inferences, choosing the sampling frame and using well defined technique. It is important to focus on deviation and unbiased estimation of population parameters. For the current research, the population was the appropriate stakeholders across the rubber manufacturing industry in Sri Lanka. The process of purposive sampling must have the clear criteria and rationale for the inclusion. The criteria to choose the sample size are:

Exclusion criteria	Inclusion criteria
<ul style="list-style-type: none"> <li>• Less than 1 year of experiences in rubber manufacturing industry</li> <li>• Does not know English.</li> <li>• Outside Sri Lankan industry</li> </ul>	<ul style="list-style-type: none"> <li>• Current workers or past workers in the Sri Lankan rubber manufacturing industry</li> <li>• Has experiences and knowledge on supply chain and antifragile concept?</li> <li>• Other industry rather than rubber manufacturing</li> </ul>

**Table 3.2: Exclusion and inclusion criteria for survey**

(Source: Created by author)

Based on the above criteria, *80 participants* across the rubber manufacturing industry in Sri Lanka have been chosen by applying the purposes sampling technique. The participants have been contacted over the social media platforms. They have been involved in the application in supply chain activities and the operation department. Google Form with 15 close-ended questionnaires have been asked to each participant and recorded for the data analysis. Google Form was sent to each participant through email and their responses have been recorded for further analysis. After signing the information sheet and ethical form, the survey was intended to start. The survey results through Google form have been collected for quantitative analysis. The close-ended questionnaires have been made based on how the researcher has an attitude on the participation and developed based on the research objectives and research questions. Identifying the variables such as operation and efficiency and supply chain management have been considered to form the close ended questionnaires with multiple choice questions. It is significant here to determine how the participant can put their own perception regarding the research area.

### **3.5.2 Secondary data collection technique**

Secondary data collection method refers to identifying the databases from which the data is collected and detected based on the data set. It is important to identify the news articles, reports, literature reviews and other data documents to carry out the research. It is retrieving the available data from sources rather than the target audience (Lobe, Morgan & Hoffman, 2020). Secondary data is retrieved while analysing the magazines, books, newspapers, journals, and others in various resources. It includes both published and unpublished data from various sources. For the current research, different databases such as Science direct, Wiley, Springer, MDPI and others have been selected to gather the

information. Different elements such as impact of SCM and operation efficiency are identified as the research papers including the government document, business report, and research paper have been collected. At first, keyword search techniques were applied to search for the sources. Different keywords such as “antifragile supply chain management, factors affecting antifragile SCM, operational efficiency, management supports on operational performance, rubber manufacturing sector in Sri Lanka, antifragile SCM in rubber manufacturing sector, challenges to manage SDM to enhance operation performance, strategies of antifragile SCM” and others have been used to search for the articles. At first, 50 sources have been collected to proceed with data collection. After applying exclusion and inclusion criteria, 30 sources have been identified to proceed with the analysis (Refer to table 3.3).

Exclusion criteria	Inclusion criteria
<ul style="list-style-type: none"> <li>• Papers older than 2014</li> <li>• Unavailability of PDFs and online access</li> <li>• Written in other languages rather than English</li> </ul>	<ul style="list-style-type: none"> <li>• Matched the keywords.</li> <li>• Abstracts containing reliable findings.</li> <li>• Reliable publishing site and journal</li> <li>• Sufficient information on the research topic areas</li> </ul>

**Table 3.3: Exclusion and inclusion criteria for secondary sources**

(Source: Created by author)

The exclusion criteria shaped by the study involves the avoiding of the sources that are issued prior to the year 2014. The study shall also neglect the sources or materials that are not accessible in pdf format and are not available online. However, the study has also avoided the sources that are being penned in languages other than English. Moreover, the study has advocated the inclusion of the sources that connect with the distinct keywords developed. It shall also include the sites and the journals that are authentic and reliable and engage adequate data and information on the specific topic.

It is after the designing of the inclusion and exclusion criteria that the study has conducted screening of the sources gathered to address the objectives of the study. However, it is with the help of the initial screening of the sources that the study has been able to remove the sources that engage insufficient information and fail to depict the information desired. The screening has enabled the study to eliminate the sources or the materials prior to the

initiation of the analysing of the data and information. It is after conducting screening of 100 articles at first that the study has selected 20 articles for conducting thematic data analysis.

### 3.6 Data analysis technique

Data analysis techniques permit the study to acquire better understanding of and recognise the several patterns, connections within the gathered data and information. However, it is by investigating the patterns, trends the study can effectively leverage the understanding of the impact of the antifragile supply chain management on operational performance. As opined by Pandey and Pandey (2021) the dearth of acquaintance with the research technique can lead to the attaining of the research outcome. Moreover, this study has adhered to *mixed data analysis techniques*. It has examined the gathered data from the survey in a quantifiable manner. On the other hand, it has investigated the secondary data gathered with the help of qualitative data analysis techniques.

The data and information extracted with the help of the survey has been investigated with the help of the graphical presentation and through the pie charts and others. Such actions have offered empirical evidence to support the varied claims made by the study. The adhering to the quantitative data analysis technique enabled the study to initiate a rapid, scientific outcome. The graphical presentation facilitated the better understanding of the content, leading to improved and convenient analysis of the data extracted.

According to the view of Mezmir (2020), qualitative data analysis is referred to as the classification and interpretation of linguistic material that enables one to make a statement. The secondary data collected is analysed using text and thus *thematic analysis* has been undertaken. To develop themes different scholarly articles were used. Qualitative data analysis has also helped to discover and describe issues in terms of practices. By considering these relevant themes were developed. Similarly, to develop the theme certain steps were undertaken such as in first step data familiarising with the data, generating initial code, developing themes, reviewing them, and creating a report accordingly. According to the view of Lester, Cho and Lochmiller (2020), qualitative data analysis is often undertaken to develop a deep understanding of the specific phenomenon. The outcome for qualitative research helps to identify a detailed description for a given problem. Therefore, with the help of the thematic analysis approach it has been effective to understand the impact of anti-fragile supply chain management on the operational performance of rubber manufacturing in Sri Lanka.

Therefore, with the help of quantitative and qualitative methods the research has effectively achieved the desired aim.

### **3.7 Ethical consideration**

Suri (2020) stated that research ethics helps to govern the standard to conduct scientific research. It is necessary to adhere to ethical principles that enable to protect dignity, rights as well as welfare of the research. Both qualitative and quantitative research ensures to gather information that is effective for the research, and this must be done considering research ethics. The current research has maintained ethical standards that have helped to accomplish the research on time and with quality. Initially the research proceeded with the university rules and regulation so that there is no impact on the ethical standards. As the research is based on both qualitative and quantitative data collection procedure, it is necessary to maintain research ethics accordingly.

For quantitative data, the research has ensured to take consent from the participants before any data is being collected from them. On the other hand, the participants were aware about the research aim and that it does not include any kind of risk while participating in the research. The research has also ensured that the data collected from participants were fully protected from any third party use along with protecting the participant's personal information. It has also been ensured to imply data protection act to protect the participants information. Ethical standards were also maintained while developing the questionnaires. This includes that the research did not use any personal information of the participants and has avoided asking any questions that may hurt the participant's sentiment. The personal details were completely anonymous which has helped to gain trust among the research participants. Thus, the research has also ensured that data confidentiality is maintained throughout.

According to Nii Laryeafio and Ogbewe (2023) ethical consideration while conducting qualitative research is important. In case of qualitative research there is no need of collecting information from the participants that can be sensitive or confidential. It is important to maintain ethical consideration in terms of collecting secondary data as well. This is because it is necessary to ensure that the secondary data collected is authentic and does not provide any misinterpretation of data. The information that has been collected from the secondary sources are well cited and referenced accordingly. This has enabled to maintain

data authenticity and has helped in the process of delivering results that are authentic and contain most relevant information.

According to the view of Montreuil et al., (2021), it is further important to maintain and to be aware about strict research principles that would help to ensure that the data collected is authentic and has maintained research ethics.

In the case of conducting research, ethics plays a major role as it ensures to protect human subjects through the appropriate ethical principles. With an effective research ethics, process decision making becomes appropriate. This has allowed understanding what is right and what is wrong for the research. Therefore, it can be stated that by following all relevant measures and ethical consideration the research has been effective in terms of reaching the specific objective.

### **3.8 Research validity and reliability**

According to the view of Sürücü and Maslakçı (2020), reliability and validity is a concept that is significantly used to evaluate the quality of the research. While conducting the research it is important to ensure research reliability and research credibility for the research. In case the data collected for the research and method is not valid, it may lead to developing an inappropriate or misleading conclusion. In addition, it is ensured that if the data and method is no significant or reliable then it would be difficult to replicate or to generalise the results that have been identified. Thus, it is important for the current study to ensure that the research is accurate, trustworthy and provides meaningful information. The research that provides meaningful information to the readers enables to ensure that the research is highly effective.

According to the view of Quintão, Andrade and Almeida (2020) often research is criticised in terms of its reliability and validity. It is necessary for the research to maintain trustworthiness in terms of research validity and research reliability; it is also considered to be a fundamental element to acquire the findings in the most significant manner. However, research validity and research reliability are closely related to each other and thus they seem to express the most different properties in terms of measuring instruments. Often it is denoted that a measuring instrument can be reliable without being valid whereas if the measuring instrument is valid, it is necessary that the instrument is reliable as well.

To maintain the present research validity, it is important to undertake different types of validity measurements (Sürücü & Maslakçı, 2020). Construct validity has been undertaken

which has ensured understanding of the expression and has enabled it to serve the purpose of the scale. This enabled them to maintain quantitative statistical studies.

On the other hand, it is unimportant to maintain reliability of the research to ensure that the research has been undertaken under healthy circumstances. There are different measures which are often undertaken to ensure research reliability. However, the present study has opted for a test-retest reliability approach. It has helped to understand consistency of the results obtained when the measuring instrument is applied among the sample group at different times (Sürücü and Maslakçı,2020). However, there are also certain threats that can occur while undertaking the research such as sample bias. In case the research avoids undertaking an effective sample population it would impact the research findings due to inappropriate results.

### **3.9 Research limitation**

Conducting research often comes with certain limitations that affect the research in terms of accomplishing the research on time. Therefore, the current research also had certain methodological limitations such as the research being undertaken considering both primary as well as secondary methods. Primary information required ample time and cost to collect data from the selected population. It required sufficient time in terms of connecting with the participants, getting their consent, accessing them and others. This has undertaken a sufficient portion of them, which has also extended the data of research completion. It was necessary to collect information based on the participant's convenience and thus it has been the major limitation. On the other hand, with time it also incurred a minimum cost such as internet charges, stationeries, and others. Additionally, in order to gather secondary information, it also required a certain subscription from the library and other resources, which has also incurred time and cost as well. This has also limited the research. In case the research was focused on only one method it would be of greater advantage as it required on collection of specific information which can be primary or secondary.

### **3.10 Summary**

The chapter has significantly depicted the research methods that have been used in the present study. The research has undertaken positivism research philosophy along with deductive approach as it supports quantitative and qualitative research. To conduct research in a systematic manner it is essential to decide the type of data that is to be used to achieve

the most effective information. In the methodological section the research has proceeded the ways the research has collected sufficient information. It is evident from this that the research has undertaken a mixed measure approach where 100 participants were selected for the purpose of collecting primary research along with 20 articles which has been effective in terms of acquiring secondary data.

The research also has opted for quantitative and qualitative approach to analyse the data. In case of quantitative approach, the research has used graphical representation, charts, and tables to represent the data collected on a numeric basis.



## Chapter 4: Results

### 4.1 Introduction

Data analysis is an important part of the research as it enables to understand whether the research has achieved the desired goal. The chapter has mainly focused on analysing the data that has been collected through primary and secondary data. In the case of the primary data collection method the data has been collected from 80 participants where Google scholar has undertaken to collect information from the participants. Additionally, the research has undertaken the use of graphs and charts to develop better understanding about the ways the participants think that the research has been helpful. Additionally, from the secondary data collection method it has been helpful in terms of understanding the ways antifragile supply chain helps the business. In order to collect secondary data relevant articles were collected almost 20 articles were collected by using Google Scholar as the search engine. With the help of the articles relevant themes were developed and therefore it has helped in developing significant writeups. The chapter has also focused on understanding the ways an antifragile supply chain can be impactful for the business and the ways rubber manufacturing companies in Sri Lanka are using it to enhance business performance.

### 4.2 Quantitative data analysis

*Survey analysis.*

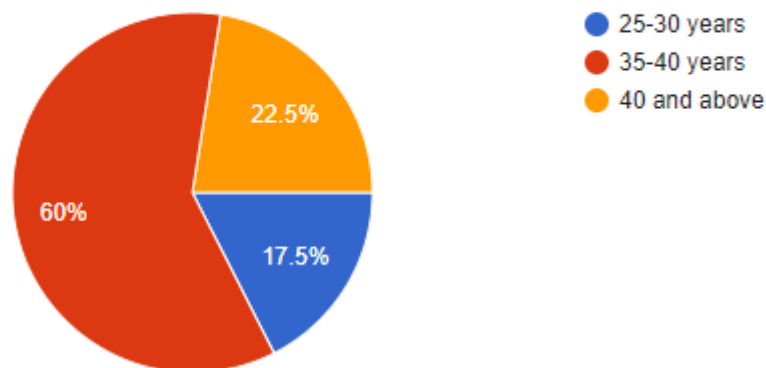
**Q1. Age?**

Options	Responses	Percentage	Total responses
25-30 years	14	17.5%	80
35-40 years	48	60%	80
40 and above	18	22.5%	80

**Table 4.1: Respondents age**

## Q1. Age?

80 responses



**Figure 4.1: Respondents age**

### *Analysis*

The first question of the survey was about knowing the respondents age. It can be depicted from the survey responses that most of the employees belong to mid age group. It can be considered from the responses that have been acquired that the Sri Lankan manufacturing industry consists of employees who are having sufficient knowledge and experience. Additionally, with determining the respondents age it can be clearly ensured that the employees who are working in the rubber manufacturing company in Sri Lanka have worked before and have gained sufficient knowledge from the past experiences. This has significantly helped to draw better conclusions from the survey responses.

Additionally, it can be considered that the rubber manufacturing industry in Sri Lanka appoints a minimum number of employees who belong to the age group of 25-30 years. It can be ensured that the rubber manufacturing industry in Sri Lanka intends to appoint employees who are having sufficient knowledge about supply chain and the ways it can improve the business performance. On the other hand, it can be further highlighted from the data that the manufacturing industry in Sri Lanka has also appointed employees who belong to the age group of 40 and above. Therefore, it can be stated from the analysis that the Sri Lankan manufacturers intend to enhance the performance of its supply chain by undertaking knowledge and experienced employees who can add value to the business thereby providing the rubber manufacturers with greater advantages.

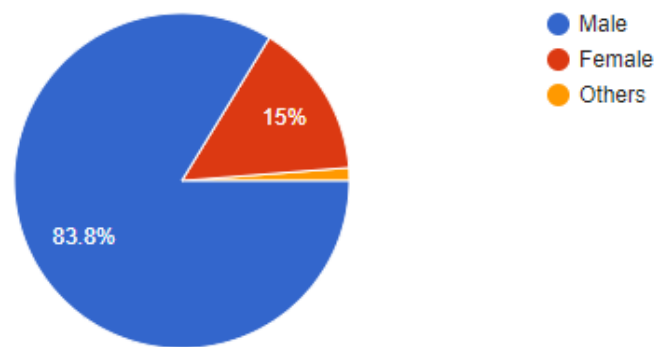
## Q2. Gender

Options	Responses	Percentage	Total responses
Male	67	83.8%	80
Female	12	15%	80
Others	1	1.2%	80

**Table 4.2: Respondents gender**

### Q2. Gender

80 responses



**Figure 4.2: Respondents gender**

### *Analysis*

While conducting the research it is important to determine the gender of the respondents. Hence the second question was about the respondents' gender who are the employees of the Sri Lankan rubber manufacturing companies. From figure 4.2 it is clearly depicted that the rubber manufacturing industry in Sri Lanka is having a majority of male employees. It can be noted that more than half of the employees are male and are working with the rubber manufacturing business in Sri Lanka. However, the participation of female and other gender classes also ensures that the companies are intended to follow gender diversity. Attaining gender equality within the workplace is necessary as it alone improves the country's economic performance. However, it can be further stated that involvement of women in the business can help the rubber manufacturer to bring in more innovative ideas and thoughts into the business.

Additionally, it is further noted that only a few female employees seem to be working with the rubber manufacturer. It can be further concluded from the research that it is

necessary for the business to indulge a more diversified employee base in order to enhance the performance by inducing innovative thoughts and ideas within the business process.

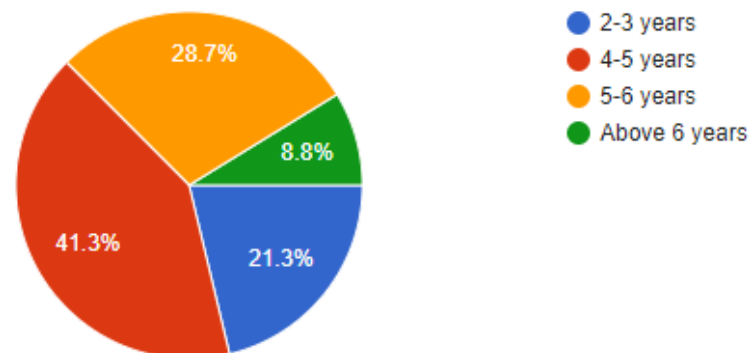
**Q3. For how long have you been working in the rubber manufacturing industry?**

Options	Responses	Percentage	Total responses
2-3 years	17	21.3%	80
4-5 years	33	41.3%	80
5-6 years	23	28.7%	80
Above 6 years	7	8.8%	80

**Table 4.3: Respondents working tenure**

**Q3. For how long have you been working in the rubber manufacturing industry?**

80 responses



**Figure 4.3: Respondents working tenure**

**Analysis**

The fourth question of the survey was to identify the number of work experience that the employees have in order to determine the experience that the employees have gained while working within the rubber manufacturing industry in Sri Lanka. It can be depicted from the survey that the majority of the respondents have been working with the organisation for almost 4-5 years. This can be concluded that the respondents are well informed and have gained sufficient knowledge about the ways an antifragile supply chain can help the business to gain competitive advantages. Additionally, with the employee skill and knowledge would help the rubber manufacturers to develop better strategies that can be effective in terms of managing the supply chain.

It can be further depicted from figure 4.2 that almost 21.3% of employees seem to be working with the industry for almost 2-3 years' thus it can be stated that the industry is thereby focusing to acquire sufficient innovation through diversifying the employees and ensuring the work structure that can benefit the business. Including freshers and experienced employees in the rubber manufacturing industry has been effective to manage the business process more effectively and efficiently. Additionally it is also noted that only 8.38% of employees have a work experience of above 6 years. Therefore, it can be concluded that the rubber manufacturing industry seems to appoint employees and also ensures to retain them accordingly which will help the business to progress and helps to achieve the desired supply chain goal.

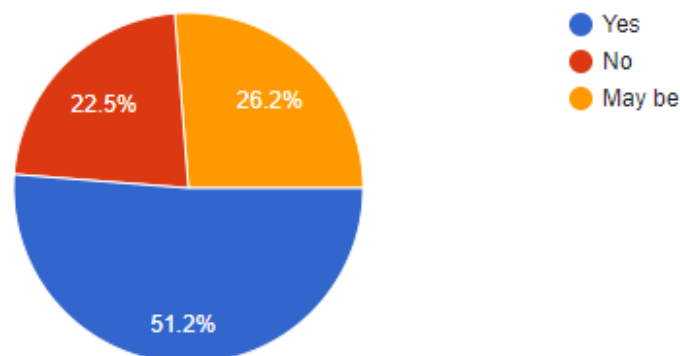
**Q4. Antifragile SC being a new concept do you have any idea about antifragile supply chain management?**

Options	Responses	Percentage	Total responses
Yes	41	51.2%	80
No	18	22.5%	80
May be	21	26.2%	80

**Table 4.4: Respondents idea about antifragile supply chain management**

**Q4. Antifragile SC being a new concept do you have any idea about antifragile supply chain management?**

80 responses



**Figure 4.4: Respondents idea about antifragile supply chain management**

### *Analysis*

The fourth question that was asked to the respondents was about whether the respondents have any idea about the antifragile supply chain. It is evident from the research that the majority of the participants have great ideas about the antifragile supply chain management. Antifragile supply chain management enables the development of a resilient supply chain that would help to overcome any future issues. Nikookar, Varsei and Wieland (2021), stated that volatility, stressor as well as errors are the major factors that are rolling around the supply chain. Therefore, it can be depicted that an effective use of supply chain management helps to develop unpredictable risks and enables to manage disruptions. It can be further noted from the responses that the employees of the rubber manufacturing industry in Sri Lanka are well aware about the use of an antifragile supply chain, which intends to benefit the business performance and ensures to achieve the desired research outcome.

However, considering the survey responses it is further assumed that the employees have a great knowledge about the ways anti fragile supply chain can enhance resilience and focus on growth opportunities of the business. In addition to that it is also noted that the employees of the rubber manufacturing industry also have developed a better understanding about anti fragile capabilities that can help the business to grow in social-ecological resilience.

Additionally, from the survey responses it can be further depicted from the survey that only 22.5% of the employees were unaware about the antifragile supply chain management. It can be considered that this can belong to the newly appointed employees with less experience or is having lack of knowledge in the supply chain field. Additionally, it can be further ensured that it is necessary to provide sufficient training to the employees so that they can acquire relevant knowledge in terms of achieving the desired objectives of the research. While conducting the research it is also depicted that 26.2% of employees responded that they are having knowledge which is not sufficient for them. It also requires further enhancement so as they can perform well in terms of managing the desired supply chain. Hence, through this research question it can be depicted that there is a need to improve understanding among the employees regarding the antifragile supply chain. Additionally, it can be further stated from the response that an effective program must be developed by the rubber industry in Sri Lanka that can better be helpful for the employees to acquire understanding and knowledge in order to improve performance of the business.

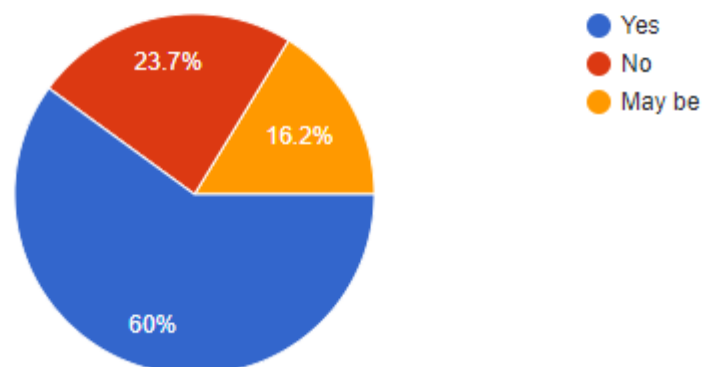
**Q5. Do you believe that the rubber manufacturing industry is considering anti fragile SCM?**

Options	Responses	Percentage	Total responses
Yes	48	60%	80
No	19	23.7%	80
May be	13	16.2%	80

**Table 4.5: Rubber manufacturing industry is considering anti fragile SCM**

**Q5. Do you believe that the rubber manufacturing industry is considering anti fragile SCM?**

80 responses



**Figure 4.5: Rubber manufacturing industry is considering anti fragile SCM**

**Analysis**

It can be depicted from the survey responses that rubber manufacturing industry in Sri Lanka are considerate about using anti fragile supply chain management to improve the business performance. Considering the literature it can be stated that an anti-fragile supply chain has become the most significant modern approach that enables the management of supply chain. It further helps the business to develop a better network that helps them to emerge as empowering other than withstanding any uncertainties (Shafiei, 2023). Therefore, it can be ensured through the survey that the Rubber manufacturers are more considerate about using the anti-fragile supply chain management. This helped the manufacturers to survive the uncertainties and shocks. The survey has helped to understand that with the help

of an anti-fragile supply chain the business can acquire significant advantages such as acquiring resilience in the supply chain. However, it is a critical feature in the supply chain which would require social ecological system depiction of resilience.

From the survey responses it can be further depicted that majority of the respondents have responded positively which is they have effectively stated that the Rubber manufacturers in Sri Lanka is undertaking the transformation towards implementing the anti-fragile supply chain. Additionally, this has helped to ensure that the majority of the employees are aware about the business practices and the idea of an anti-fragile supply chain. According to the view of Größler (2020) anti fragile supply chain has enabled the firm to accept unpredictability and thus learn from the disruption about the future changes that are to be made. The employees who are having greater knowledge about the usability of an anti-fragile supply chain can be beneficial for the company to develop better strategies that can protect the business from any severe consequences. It enables the firm to enhance the performance by focusing on the quality and delivering the products to the desired customer time and with its efficiencies.

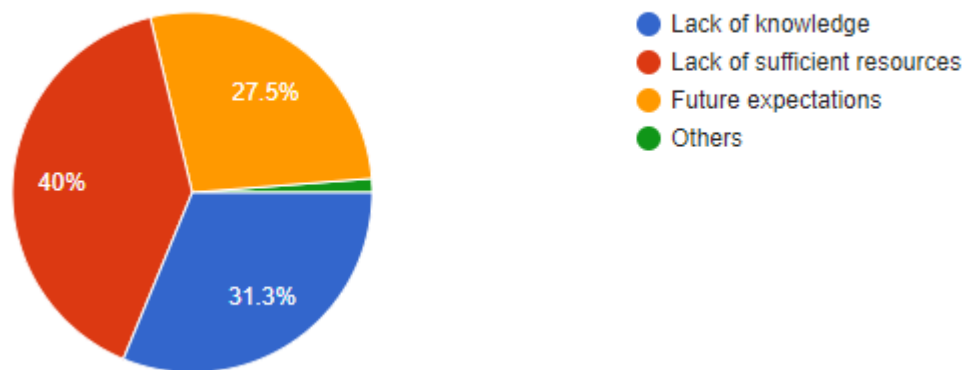
However from the survey responses it is also identified that there are still employees who does not have any idea about the business operation whether the companies are using anti fragile supply chain or others. It is therefore important for the business to focus on the areas of concern that would enable the business that

**Q6.What are the factors that seem to be affecting antifragile SC management on operational performance?**

<b>Options</b>	<b>Responses</b>	<b>Percentage</b>	<b>Total responses</b>
Lack of knowledge	25	31.3%	80
Lack of sufficient resources	32	40%	80
Future expectations	22	27.5%	80
Others	1	1.2%	80

**Table 4.6: Factors that seem to be affecting antifragile SC management**





**Figure 4.6: Factors that seem to be affecting antifragile SC management**

### *Analysis*

It is from the above table and the figure that it becomes clear that the participants were asked regarding the distinct factors that affect the antifragile supply chain management on their operational performance. However, the results show that the majority of the participants or the 40% of the respondents state that it is the dearth of the sufficient resources that affect the antifragile supply chain management in the operational performance within the rubber manufacturing sector in Sri Lanka. However, it becomes significant to note that antifragility boosts the culture of continuous development and agility. It is the dearth of appropriate resources that might pave the way for the manufacturer to not have adequate resources to establish an antifragile supply chain management system.

As per the perspective of Del Rosario Pérez-Salazar et al., (2017)) a competitive benefit relies on the durable, unique as well as imitable resources within the supply chains. The antifragile supply chain management approach boosts the potentiality to shift the utilisation of the prevailing resources and at the same time supports the availability of the new resources.

On the other hand, it is noted that almost 31.3% of the respondents or the rubber manufacturers in Sri Lanka opined that it is due to the dearth of knowledge that affects the antifragile supply chain management. As per the view of del Rosario Pérez-Salazar et al., (2017) it is the knowledge management that is considered to be enhancing mechanisms for the improvement of the supply chains. However, the businesses need to be equipped with supply chain mindfulness and adopt the transformative learning which acts as a continuous procedure fuelled by what the companies understand from the disruptive circumstances and amalgamating such knowledge with the prior experiences. It is not without the rubber

manufacturers within Sri Lanka acknowledging the importance of the antifragility within the supply chain that they can acquire enhanced knowledge of its benefits and also of the manner in which the antifragility approach tends to contribute to the operational performance of the businesses.

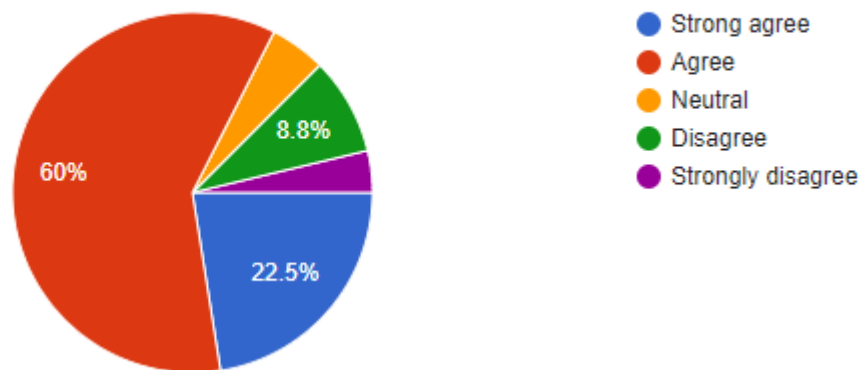
The rubber manufacturing firms in Sri Lanka can render quality and valuable training to the employees regarding the advantages offered by the antifragile supply chain management approach. However, it is also with the help of the knowledge on effective collaboration and whom to collaborate and connect with that the manufacturers can initiate an effectively antifragile approach to their supply chains. Besides they also need to gather sufficient knowledge on the ways the different modern technologies can lead to productive working of the antifragile approaches. On the other hand, approximately, 22 respondents stated that it is the future expectations that tend to affect the antifragile supply chain management of the firms.

**Q7. How far do you agree that the antifragile supply chain is able to foresee and prepare for potential risk?**

Options	Responses	Percentage	Total responses
Strong agree	18	22.5%	80
Agree	48	60%	80
Neutral	4	5%	80
Disagree	7	8.8%	80
Strongly disagree	3	3.7%	80

**Table 4.7: Whether antifragile supply chain can foresee**

80 responses



**Figure 4.7: Whether antifragile supply chain can foresee**

#### *Analysis*

The above figure depicts the extent to which the respondents feel that the antifragile supply chain has the ability to foresee as well as prepare for the uncertainties. It is noted that almost 60% of the manufacturers believe in the fact that the antifragile supply chain has the potential to foresee the varied uncertainties and undertake steps in order to prepare and combat the risks. This clears the fact that the manufacturers within the rubber firms in Sri Lanka are all well aware of the contribution of the antifragile supply chain management approach within the businesses. However, it is with the detailed knowledge of the notion of the antifragile system that the rubber manufacturer can incorporate effectively the new approach to develop their operational performances.

On the other hand, it is found that almost 22.5% of the respondents strongly agree to the fact that the antifragile supply chain has the capability to witness and prepare for the uncertain events within the supply chains. While almost 8.8% of the people disagree with the mentioned fact, 22.5% of them strongly disagree with the question. As per the view of Nikookar, Varsei and Wieland (2021) the antifragility within the supply chain denotes the potential to gather from the varied disorders when compared to the neglect of those instead. It is noted that the conventional risk management systems as well as alternatives fail to act as adequate measures to combat against the uncertainties and deal with the varied disruptions that are increasingly being experienced by the supply chains.

As mentioned by Nikookar, Varsei and Wieland (2021) there prevails another system or the approach to combat against the disruptions which is resilience. However, it is with the help of the antifragile supply chains that the rubber manufacturers in Sri Lanka can traverse much beyond the resilience to witness the varied uncertainties of disruptions as a scope to

become more strengthened. However, while the participants agree to the fact that the antifragile systems can prepare for the uncertainties, they are also of the belief that the antifragile supply chains permit the business to transform the challenges faced into scopes and survive within the randomness. The antifragile supply chains are depicted to be dynamic and at the same time flexible or fluid despite being static.

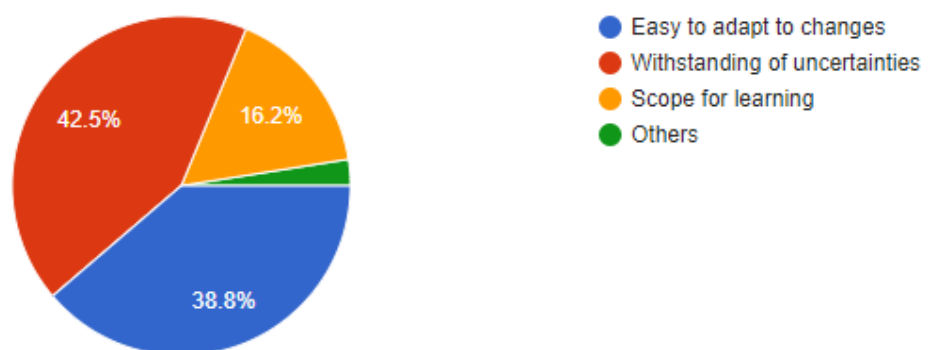
It is noted that the antifragility with the ability to foresee the upcoming instances are able to develop the unpredictable disorders which is one of the features of the modern business environment. It is within the antifragile supply chain management that the people embrace the disorders faced and amalgamate leading to the social attainment for the entire chain.

**Q8. What do you think are the benefits of antifragile supply chain management?**

Options	Responses	Percentage	Total responses
Easy to adapt to changes	31	38.8%	80
Withstanding of uncertainties	34	42.5%	80
Scope for learning	13	16.2%	80
Others	2	2.5%	80

**Table 4.8: Benefits of antifragile supply chain management**

80 responses



**Figure 4.8: Benefits of antifragile supply chain management**

### *Analysis*

It is noted from the above figure that when asked regarding the advantages rendered by the antifragile supply chain management almost 42.5% of the respondents state that it is the withstanding of the varied uncertainties that makes the antifragile supply chain approach suitable. However, approximately 38.8% of the people opined that it is the convenient adapting to the changes that engages distinctions within the antifragile supply chain management. While 16.2% of the manufacturers of the rubber firms in Sri Lanka depict that antifragile supply chain management benefits the firms with the help of the scope for learning, 2.5% of them exhibit some other reasons that act as the advantages of the antifragility within the supply chains.

As per the view of Martinetti, Moerman and van Dongen (2017) the notion of antifragility provides modern insights in order to prepare as well as combat the uncertain future through the accepting of the disorders. However, it is noted that the systems that pose to be convex acquire benefits from the uncertainty. On the other hand, it is observed that the firms experience issues in adhering to antifragility within their supply chains in terms of adhering to the notion of antifragility within reliability which is shifting existing mindset while facing the uncertainty (Martinetti, Moerman & van Dongen, 2017). However, it is the antifragile system that tends to enhance from the disorders of the uncertainties and becomes empowered while it is stressed.

The antifragile approach implies the attaining of the suitable and the most appropriate result while learning and shifting to the changes within the business environment. Since the antifragile concept tends to embrace the uncertain circumstances and desires to learn from the uncertainties as it prepares to combat the situation, it engages in a higher ability to adapt itself with the varied situations. Such abilities permit the rubber manufacturing firms in Sri Lanka to embrace any uncertainties or disruptions within their supply chains and learn the best examples or the instances faced. Such abilities will enable them to stay prepared for the next uncertain situation.

It is with the help of modern technologies that the businesses or the rubber manufacturer can acquire better understanding and predict effectively the way in which they can stay prepared ahead of the uncertainties. Such experiences can be applied while facing another disruption within the supply chains. Antifragile supply chain management facilitates the scope for continuous learning and rather than making the disruptions out of the way, it tends to embrace and learn from the uncertain situations to build better strategies and options to combat the events. However, the antifragile supply chain management approach

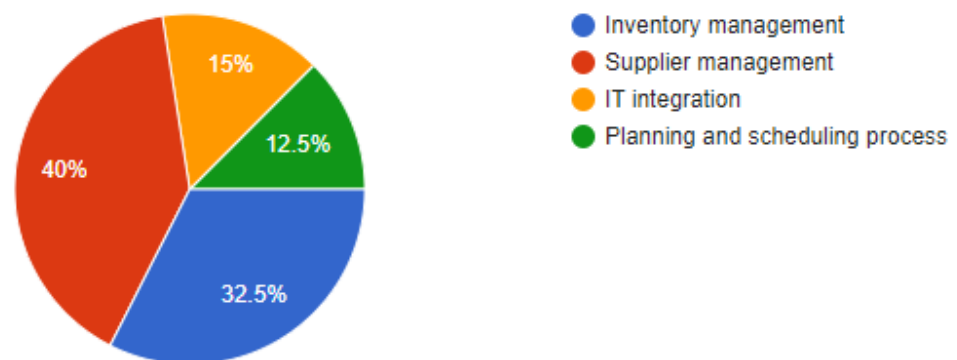
fosters the attaining of the best or the suitable results while learning as well as adhering to the distinct changes.

Antifragile supply chains have the characteristics of embracing the disruptions with the goal of learning new things. As per the view of Priyadarshini et al., (2022) while resilience depicts the bouncing back it fails to identify the need to have continuous learnings from the disruption faced within the supply chains. However, it is noted that some of the abilities for shaping the antifragility within the supply chains are transformative learning, collaboration and others. To gain antifragility, the business has to learn from their different failures. Therefore, it is also prior to the incorporating and applying of the antifragile supply chains that the businesses need to be equipped with the transforming learning abilities that can further help with the process.

**Q9. What are the areas that rubber manufacturers in Sri Lanka uses antifragile supply chain?**

**Q9. What are the areas that rubber manufacturers in Sri Lanka uses antifragile supply chain?**

80 responses



**Figure 4.9: Areas that rubber manufacturers in Sri Lanka uses Antifragile supply chain.**

<b>Options</b>	<b>Responses</b>	<b>Percentage</b>	<b>Total responses</b>
Inventory Management	26	32.5%	80
Supplier Management	32	40%	80
IT Integration	12	15%	80
Planning and scheduling process	10	12.5%	80

**Table 4.9: The areas where rubber manufacturers in Sri Lanka use an antifragile supply chain.**

***Analysis:***

The above table represents the areas where rubber manufacturers in Sri Lanka utilise antifragile supply chain practices. Those areas include Inventory management, Supplier Management, IT integration, and Planning and Scheduling Processes. Antifragility; using the responses in reference to each area, in-depth insights about the strategies employed by rubber manufacturers to enhance the supply chain resilience and adaptability can be developed.

Based on the responses, it can be stated that Inventory management plays an important role in ensuring supply chain resilience in the respective industry of Sri Lanka. The percentage of using an antifragile supply chain in inventory management, it can be stated that by effectively managing the inventory levels, the rubber manufacturers of the country can buffer against the disruption of supply and demand fluctuation, Antifragile inventory management includes the aspect of managing the flexibility in inventory levels, which employ the dynamic demand forecasting strategy to respond the change in market demand rate and supply chain disruption while minimising the excess inventory costs, and stockouts (Gunasekaran, Subramanian, & Rahman, 2015).

As per the graphical representation, it can be stated that supplier management is another important area where the antifragile supply chain management process is used by

rubber manufacturers. As per the rubber manufacturers of Sri Lanka, developing a strong relationship with the suppliers can help them diversify the supplier base, which minimises the suppliers' bargaining power, and mitigates the impact of supplier disruption on the manufacturing process. Antifragile supplier management includes the identification of possible risks related to supplier disruption and the high bargaining power of the suppliers within the industry. Antifragile supply chain management is used for supplier management to develop a contingency plan and foster a culture of trust and transparency between the manufacturers and suppliers (Munoz & Zhou, 2023). More specifically, by taking the tabular format into consideration, it can be stated that the use of an antifragile supply chain management approach can help the manufacturers to develop a resilient supplier network which can minimise the risk of supply chain disruption and enhance the ability to be adaptive to market conditions.

Integration of information technology also plays an important role in enabling agile, and responsive supply chain development in the rubber manufacturing industry of Sri Lanka. According to the graph, in 15% of the cases in antifragile supply chain management systems, information technology has been used for improving decision-making, optimising resource allocation, and carrying out real-time tracking, and monitoring of the supply chain in the respective industry (Gupta et al. 2019).

Lastly, in planning, and scheduling processes, the antifragile supply chain management system has been used to ensure the efficiency, and resilience of the process. Effective planning and scheduling processes are essential to ensure the resilience and effectiveness of the supply chain process. Antifragile planning and scheduling practices include the agile planning methodology, which employs scenario-based planning techniques and implements the risk management framework in the operational and supply chain management processes (Lotfi et al. 2023). This in turn enables the manufacturers to quickly adopt new methods of logistics, and supply chain as per the changing demand rate in the market, requirements of production, and as the basis of supply chain disruption.

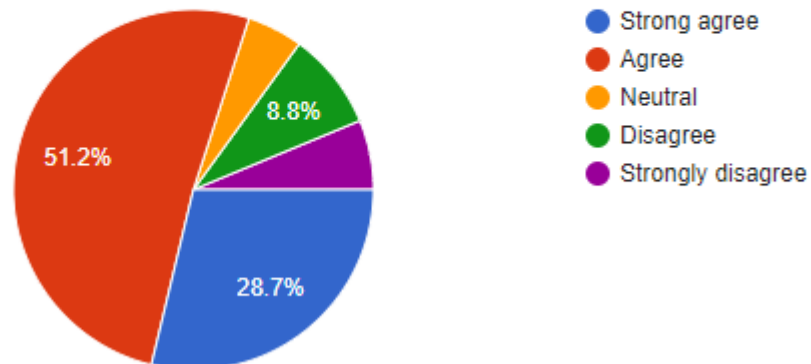
Therefore, by focusing on these key areas, the rubber manufacturers of Sri Lanka can build an adaptable and flexible supply chain capability to withstand the disruption, and volatility in the market environment.



**Q10. How far do you agree that supply chain management intends to improve organisational performance?**

**Q10. How far do you agree that supply chain management intends to improve organisational performance?**

80 responses



**Figure: 4.10 Supply Chain Management intends to improve organisational performance**

Options	Responses	Percentage	Total responses
Strongly agree	23	28.7%	80
Agree	41	51.2%	80
Neutral			80
Disagree	7	8.8%	80
Strongly Disagree			80

**Table: 4.10 Supply Chain Management intends to improve organisational performance**

**Analysis:**

The above table and graph represent the responses regarding the perspective of using supply chain management of SCM to improve organisational performance. As per the result, most of the

respondents strongly agreed with the fact that SCM or supply chain management has the potential to improve organisational performance to a considerable extent. Approximately, 51.2 per cent of the respondents and 28.7 per cent of respondents have agreed with the fact that effective use of supply chain management can increase the efficiency, effectiveness, and competitiveness of the logistics, and supply chain within an organisation. According to Saragih et al., (2020), effective SCM practice including optimisation of inventory management, streamlining of logistic processes, and strong relationships with suppliers can directly contribute to improved operational processes, cost reduction, and customer satisfaction. Therefore, integration of SCM in the operational process can ultimately enhance and improve the organisational performance to a considerable extent.

According to the responses, it can be realised that the respondents are aware of the interlink between SCM and organisational performance efficacy and success. The respondents agreed with the fact that by leveraging the technologies, streamlining the business operational process by optimally utilising the resources and collaborating with customers, and suppliers closely, supply chain management can create value mitigate potential risks, and increase growth opportunities throughout the business ecosystem (Asamoah et al., 2021). Therefore, an organisation which has the capability to manage the supply chain can better position the business and acquire the competitive advantages of the business from the market.

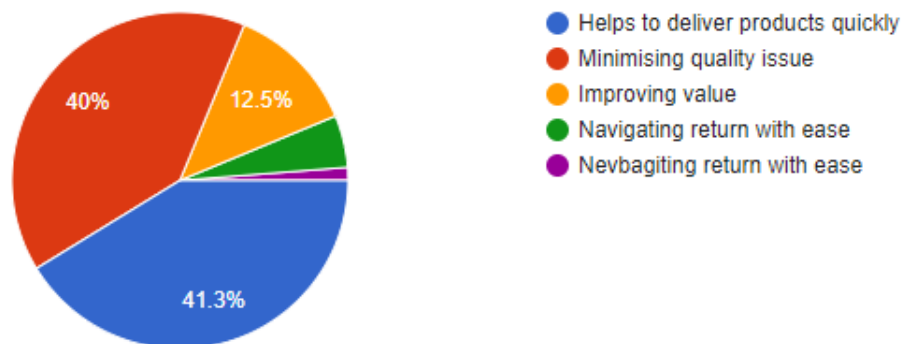
According to Saragih et al. (2020), supply chain management practices or SCMP can be defined as approaches applied to managing, integrating, and coordinating the supply, demand, and relationship to satisfy the customers and promote effective management of the supply chain. Asamoah et al. (2021) has mentioned that supply chain management practice can be considered as a tangible tool whose function is to ensure effective collaboration between the focal firm its suppliers, and customers. According to the responses, it can be stated that strategic supplier partnership, customer relationship, information sharing, and quality of information sharing are important components of the Supply chain management process. Therefore, in business perception, supply chain management can allow an organisation to deliver its products, and services quickly by ensuring the availability of the product, reduction of quality-related issues, and navigating the returns with ease. These approaches of SCM can ultimately improve the value both within the organisation and for the customers.

However, 8.8% of the respondents disagreed with the fact that supply chain management can improve organisational performance. In this context, it can be stated that SCM alone cannot ensure organisational success, as it is the critical enablers that significantly can influence the business outcome while implementing, and aligning it with the strategic objectives of business, effectively.

**Q11. How does an effective supply chain management help rubber manufacturing industry in Sri Lanka?**

**Q11. How does an effective supply chain management helps rubber manufacturing industry in Sri Lanka?**

80 responses



**Figure 4.11: Effective Supply Chain Management helps Rubber Manufacturing Industry in Sri Lanka**

Options	Responses	Percentage	Total responses
Helps to deliver products quickly		41.3%	80
Minimising the quality issue		40%	80
Improving value		12.5%	80
Navigating return with ease			80
Navigating return with ease			80

**Table 4.11: Effective Supply Chain Management helps Rubber Manufacturing Industry in Sri Lanka**

**Analysis:**

This graph represents the way supply chain management is helping the rubber manufacturing industry of Sri Lanka. Considering the responses, it can be evident that in the respective country, and in industry, the effective use of SCM or supply chain management

process has helped in several ways, including minimising quality issues, improving the product values, navigating the return of products quickly, and ensuring availability of the products in warehouses. According to Jamaludin, (2021), SCM or supply chain management systems can ensure the timely delivery of products, which is considered to be important for the growth and business profitability of any industry. In the case of the rubber manufacturing industry, the manufacturers, and entrepreneurs can use the SCM for optimising the production scheduling, so that they can ensure the completion of product manufacturing and delivery of product to the clients on time (Parente et al. 2020). This capability is particularly important to not only meet the deadline, but also to meet the needs, and requirements of the customers, which in turn can lead to the development of a strong customer base for the rubber manufacturing industry in the country.

According to the responses, the majority of the respondents' state that effective implementation of SCM can remove the product quality issue to a considerable extent. According to Shivankar & Deivanathan(2021), an optimised SCM looks at the lifecycle of every part of the product in a holistic manufacturing process. Ivaşenco, (2023) has mentioned that supply chain management is comprised of many different processes and participants, and any error at any point of the chain provides a cascading effect on the rest. Therefore, the early stage of the product lifecycle is the focus area of SCM. By eliminating the below-par materials, SCM can ensure the reduction of cost defects down the line and ensure the quality of the products being delivered by manufacturers to the clients.

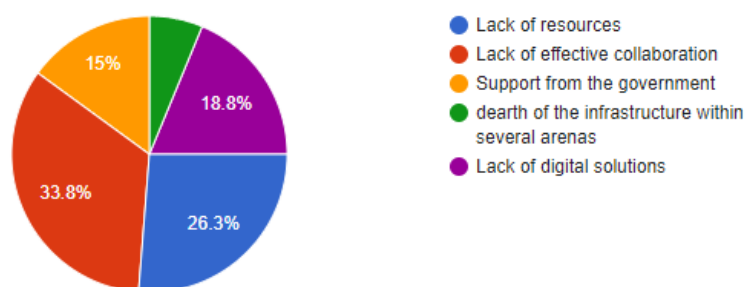
Additionally, as per the responses, SCM effectively contributes to improving the value proposition of the rubber manufacturers in Sri Lanka. By optimising resource utilisation, streamlining the manufacturing process, and developing a strong collaboration with the supply chain network, the manufacturers can reduce operational costs and increase operational effectiveness. This in turn allows the manufacturers to offer a competitive price of the product while managing the profit margin and delivering greater value to the customers. Lastly, SCM eases the navigation of product returns, which is an important customer service facility in any manufacturing industry. Considering the responses collected from the rubber manufacturing industry of Sri Lanka, the majority of the manufacturers believe that SCM can enable them to efficiently handle the exchange and return, by minimising the operational disruption and preserving the relationship with customers. Here, the reverse logistic process is usually used by the manufacturers by leveraging the real-time visibility tool in inventory and order status. This SCM system can ultimately provide an opportunity for the rubber manufacturers to expedite the return prices, and policies, resolve

the issues and mitigate the negative impact on customer satisfaction and brand reputation related to the product return policies within the organisation.

**Q12. What do you think are the issues faced in terms of managing the antifragile supply chain management to enhance the operational performance of the rubber manufacturing sector?**

**Q12. What do you think are the issues faced in terms of managing the antifragile supply chain management to enhance the operational performance of the rubber manufacturing sector?**

80 responses



**Figure 4.12: Issue faced in terms of managing the antifragile supply chain management to enhance the operation performance of the rubber manufacturing sector.**

Options	Responses	Percentage	Total responses
Lack of resources		26.3%	80
Lack of effective collaboration		33.8%	80
Support from the government		15%	80
Death of the infrastructure within several arenas			80
Lack of digital solution		18.8%	80

**Table 4.12: Issue faced in terms of managing the antifragile supply chain management to enhance the operation performance of the rubber manufacturing sector**

**Analysis:**

The table highlights several challenges faced in managing the antifragile supply chain within the rubber manufacturing industry of Sri Lanka. Considering the responses, the majority of the respondents agreed that lack of effective collaboration is one of the major

issues faced by rubber manufacturers in terms of managing the antifragile supply chain management to increase the operational performance of the sector (Mahmud et al. 2021). From the response, it can be assumed that ineffective collaboration between the suppliers, customers, distributors, manufacturers, and other stakeholders leads to inefficiency in operational processes, communication breakdowns, and delays in responding to the disruption or change in market demand on time.

On the other hand, many responses showcase that lack of resources puts significant challenges while implementing antifragile supply chain practices in the rubber manufacturing sector. Limited financial resources, human resources, and lack of technical capabilities impede challenges in the supply chain management process, specifically when it comes to developing resilience, and adaptability within the supply chain network (Kumar, Liu, & Shan, 2020).

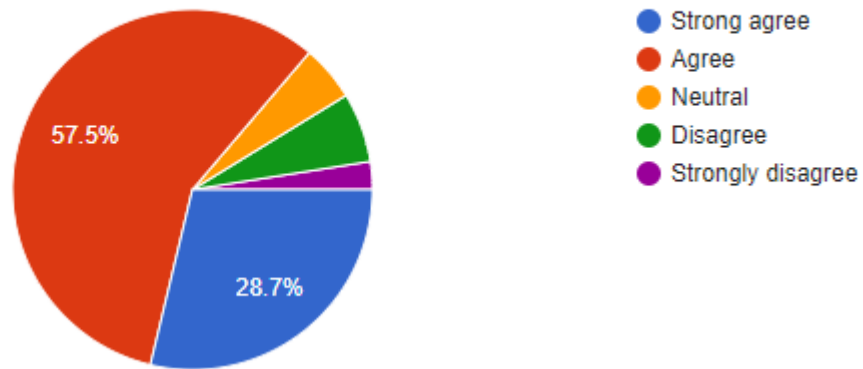
Apart from these two limitations, lack of governmental support, lack of digital solutions, and limited infrastructure have been considered as another limitation in the rubber manufacturing sector arising while managing the antifragile supply chain management for enhancing operational performance.

**Q13. How far do you agree that the issue faced hampers the effective management of the antifragile supply chain management?**

<b>Options</b>	<b>Responses</b>	<b>Percentage</b>	<b>Total responses</b>
Strongly agree	23	28.7%	80
Agree	46	57.5%	80
Neutral	4	5%	80
Disagree	5	6.3%	80
Strongly disagree	2	2.5%	80

**Table 4.13: whether issues faced hampers the effective management of the antifragile supply chain management**

80 responses



**Figure 4.13: whether issues faced hampers the effective management of the antifragile supply chain management**

#### *Analysis*

It becomes significant to note from the above figure that the people were asked regarding whether the problems experienced in terms of managing the antifragile supply chain to develop the operational performance within the rubber manufacturing sector hamper the management of the antifragile supply chain. It is observed from the participants that almost 57.5% agree to the fact that the problems faced hamper the management of the antifragile supply chain within the rubber manufacturing in Sri Lanka. On the other hand, approximately 28.7% strongly agree that the challenges disrupt the productive management of the antifragile within the supply chains in the rubber manufacturing.

Therefore, it can be stated that it is not without proper collaboration among the government, distinct stakeholders and others that the rubber manufacturers in Sri Lanka can effectively manage the antifragile system within their supply chains. However, it is with the help of the operating in an amalgamated manner that the manufacturer can anticipate in an effective way the varied disruptions. As per the view of Nikookar, Stevenson and Varsei (2024), one of the critical abilities for shaping antifragility within the supply chains depicts supply chain collaboration. By operating together, the rubber manufacturers in Sri Lanka can better share the risks and at the same time coordinate the further measures, thereby leveraging the antifragility within the supply chains. Moreover, collaboration within the supply chains can enable manufacturers to function together towards leveraged transparency and promote greater practices.

Therefore, it can be stated that the rubber manufacturer in Sri Lanka needs to concentrate on facilitating productive collaboration through which they can properly manage the antifragile supply chain management. As per the opinion of Nikookar, Stevenson and

Varsei (2024) supply chain collaboration leads to the use of the capabilities and helping supply chains to become empowered from the disruptions. On the other hand, it is also due to the dearth of resources that the manufacturers feel hampered in terms of the effective management of the antifragile supply chain management. However, it is by being equipped with better resource capability that the supply chains can predict the uncertainties and engage in detailed insights of the ways to cope up with the uncertain events. The resources can enable them to boost transparency and enhance visibility within the supply chains.

The distinct resources can enable them to be equipped with better options to traverse through and overcome the disruptions. Therefore, it becomes significant to mention that the rubber manufacturers in Sri Lanka need to ensure that they have adequate resources that can help them to combat the uncertain times and stay prepared. Besides these, it is also noted that the dearth of digital solutions hampers the effective handling of the antifragile within the supply chains. As per the opinion of Priyadarshini et al., (2022) the allocation of resources in terms of digitalisation act as one of the essential elements that drives the performance within the supply chains with the help of antifragile approach. It is in the present times that digitalisation and the new technologies have been shifting the way the business tends to function.

**Q14. What are the strategies you feel can develop antifragile supply chain management on operational performance?**

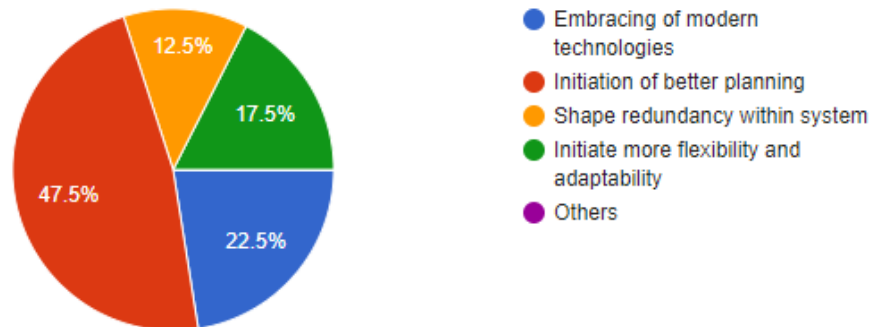
Options	Responses	Percentage	Total responses
Embracing of modern technologies	18	22.5%	80
Initiation of better planning	38	47.5%	80
Shape redundancy within system	10	12.5%	80
Initiate more flexibility and adaptability	14	17.5%	80
Others	Nil	Nil	80

**Table 4.14: Strategies to develop antifragile supply chain management to improve performance management**



#### Q14. What are the strategies you feel can develop antifragile supply chain management on operational performance?

80 responses



**Figure 4.14: Strategies to develop antifragile supply chain management to improve performance management**

#### *Analysis*

It was further asked to the respondents about the strategies that they feel are important to develop in order to acquire an anti-fragile supply chain management. It can be noted from the research that the majority of the respondents stated that in order to develop an anti-fragile supply chain to improve operational performance it is necessary to have better planning. Planning can significantly include creating a supply chain operation which can significantly adapt for changes. This can be also effective in terms of understanding to switch to suppliers along with altering production schedules and modify product design accordingly. Therefore it can be assumed that almost 47.5% of respondents stated that by developing effective planning initiation will be impactful for the business to induce an antifragile supply chain.

Not only would it be required to develop effective planning whereas the rubber manufacturing company requires to undertake effective technologies that can help the business to enhance the supply chain management. It is necessary for the companies to focus on artificial intelligence, machine learning as well as to undertake supply chain security. This would likely help the company to work efficiently across the supply chain. Referring to the survey respondents it is also depicted that 22.5% of the respondents intended to respond that undertaking an innovative technology is important for the purpose of achieving a desired supply chain. According to the view of Truong et al., (2017) it is also noted that firms' activities as well as suppliers are intended to get involved in the process which intends to be maintained in order to effectively manage the business operation. Through effective technological advancement and innovation the company can provide better delivery to the ultimate customers.

Similarly through the survey responses it is further identified that the rubber manufacturer needs to be more flexible and ensure adaptability of the business. Referring to the figure above it can be noted that the rubber industry must be open to consider change that occurs within the supply chain. Developing adaptability and flexibility within the supply chain will help the company to enhance its inventory optimisation, helps the rubber manufacturing company to develop better scenario planning and others.

However, it can be noted that 12.5% of the individuals have responded that it is necessary for the rubber manufacturers to shape the redundancy within the business. Therefore, to develop an antifragile supply chain management the rubber manufacturers can hold onto extra inventory, maintain low capacity utilisation and others.

Therefore, it can be stated that in order to develop an anti-fragile supply chain it is essential for the rubber manufacturers to develop better strategies to ensure successful supply chain management.

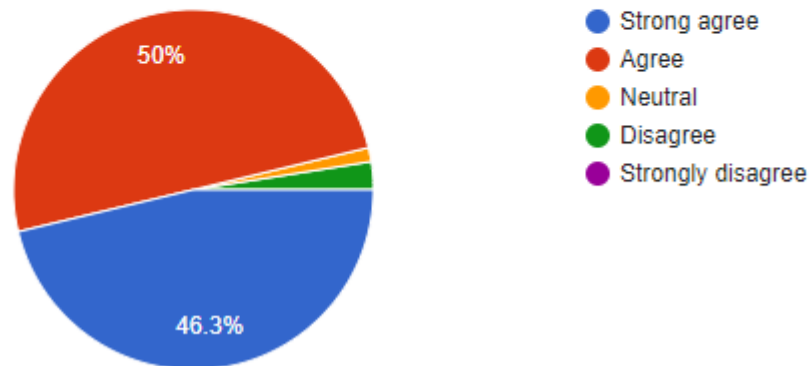
**Q15. How far do you think that these strategies can help to enhance the operational performances?**

<b>Options</b>	<b>Responses</b>	<b>Percentage</b>	<b>Total responses</b>
<b>Strong agree</b>	37	46.3%	80
<b>Agree</b>	40	50%	80
<b>Neutral</b>	1	1.2%	80
<b>Disagree</b>	2	2.5%	80
<b>Strongly disagree</b>	Nil	Nil	80

**Table 4.15: Strategies can help to enhance the operational performances**

**Q15. How far do you think that these strategies can help to enhance the operational performances?**

80 responses



**Figure 4.15: Strategies can help to enhance the operational performances**

***Analysis***

In order to overcome business challenges it is important to develop effective strategies which can be beneficial for the business to operate effectively and efficiently. The last survey question was developed in order to understand the ways strategies as stated above would be effective for rubber manufacturers in Sri Lanka to improve operational performances. Considering the survey report it can be depicted that the majority of the respondents agreed positively to the question. It represented 50% of the respondents. This can be clearly stated that with the help of effective strategy development and planning it can be beneficial for the business to overcome the challenges that the business faces. Additionally 46.3% of the respondents have strongly agreed that with effective strategies the rubber manufacturers can easily implement the anti-fragile supply chain management. The strategies will be beneficial for the industry or evolve and adapt their capabilities which are mostly based on the improved knowledge. According to the view of Priyadarshini et al., (2022) anti fragile supply chain is considered to be the new concept which would require the industries effectiveness to adapt to the changes. The capabilities of the business to meet the uncertainties and thereby improving the business performances.

It has been identified through the survey that the employees however believe that the company would not lose any profitability whereas undertaking an anti-fragile supply chain will help the business to learn to acquire profit from the impact. Hence, by leveraging on

technology effective planning and others will help the business to witness any uncertainties as the scope that can enable the company to succeed.

Through the survey responses it is possible to determine that although anti fragile supply chain is a new concept it has ensured that the employees are aware about the ways antifragile can benefit the business and helps to improve business performance along with minimising the negative effect from the business. Additionally it can be identified that along with the benefits are known to the employees it is still essential that the company must provide sufficient training to improve knowledge among the employees.

### 4.3 Qualitative data analysis

#### 4.3.1 Summary table

Articles	Findings	Keywords	Themes
Khodaparast et al., (2023)	Antifragile ensures to achieve the most significant outcome by understanding and adapting to the changes. Antifragile supply chain is further ensured to be a living supply chain, which ensures to gain from disorder. An antifragile supply chain is thereby dynamic and fluid and not static thus it evolves to improve with any unpredictable disorder.	Antifragile supply chain, supply chain management	<b>Application of antifragile supply chain management</b>
Fauji, Pratikto, & Handayati (2022)	Antifragile, sustainable as well as agile supply chain networks has become a new concept to manage supply chains effectively. Anti-fragile supply chain is often implemented to cope with certain disruption which includes stress, fluctuation, volatility and others.	Supply chain network, risk, robustness	

Bangui, Buhnova & Rossi (2022)	Ant fragility is further referred to as the evolutionary understanding in terms of resilience and therefore become a predominant concept. It helps the business to enable a significant infrastructure to gain from any disorder that would help to foster the adaptability in terms of real and unexpected environmental changes.	Critical infrastructure system, ant fragility and security	
Nikookar, Stevenson & Varsei (2024)	The article has significantly focused on the ways a supply chain can be improved in order to handle any disruptions. The emerging concept of supply chain fragility has been brought into focus, which helps the firm to grow considering the disruptions.	Supply chain resilience, disruption, fragility	
Jodlbauer et al., (2023)	The article has stated that in the past decades the supply chain has evolved as per the changing customers' expectations. Antifragility, which is further known to emerge stronger from disruption, has become most effective to overcome and learn from disruption in the supply chain. It has been applied by the business in order to operate services effectively.	Supply chain management, uncertainty, ecosystem	

Priyadarshani, Singh, Mishra & Bag, 2022	This study highlights the key implementation of additive manufacturing technologies to foster the development of an antifragile supply chain, which would aid in the organisational efficiency in managing its product quality in the market.	Antifragile supply chain, Resilience, Additive manufacturing, TISM-MICMAC, Covid-19, Pandemic	<b>The factors affecting antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka</b>
Shivajee, Singh & Rastogi, 2023	This article suggests the directions for future research works on the aspects of procurement function in order to enhance the resilience of the organisational supply chain.	Procurement system, Supply chain, Resilience, Disruptions, COVID-19	
Lotfi, Mehrjardi, MohajerAnsari, Zolfaqari & Afshar, 2023	This article proposes a viable SCND (VSCND) by considering blockchain technology and cryptocurrency as viability tools for an antifragile, sustainable, as well as agile supply chain network by focusing on the risk, robustness, resilience, as well as environmental concerns.	Antifragility, Sustainability, Agility, Supply Chain Network Design, Risk, Robustness	
Hadizadeh, Khodaparast, Ghasemi & Fakhrzad, 2023	This study is focused on the designing of an antifragile supply chain in the uncertain situations using the TOPSIS method to identify and evaluate the stressful factors.	supply chain anti-fragility, textile industry, antifragility theory, fuzzy BWM, TOPSIS	

Nikookar, Stevenson & Varsei, 2024	This article highlights the development of collaborative relationships to enhance the organisational supply chain performance with robustness.	Antifragility, Antifragile supply chain, Supply chain disruption, Resilient supply chain, Purchasing, Robust supply chain, Supply chain management, COVID-19	
Nikookar, Varsei & Wieland, 2021	The article has identified disorders including the error, variability and certainty, randomness, incomplete knowledge in the business world. These are the challenges identified as a negative approach towards supply chain management. It characterises the ubiquity of disorders in supply management.	Challenges, supply chain management, disorders, business	<b>The challenges of managing antifragile supply chain management to enhance operational performance of rubber</b>
Größler 2020	The article identifies how antifragility can have consequences in supply chains. Antifragility can be operationalized in managerial settings and existence for supply chain performance and behaviour. It introduces the factors over managing the supply chain operations.	Challenges, consequences of antifragile supply chain, supply chain management,	<b>sector in Sri Lanka</b>

Chourasia et al., (2022)	The article depicts the fact that several of the modern industries have been facing several issues such as allocation of resources, collaboration, freedom to initiate effective research and others. While the evolution emphasis on the antifragile manufacturing and services, it needs to emphasise on the flexibility, collaboration, and others.	antifragile manufacturing , flexibility	
Tiwari and Bhatt (2023)	The article showcases that antifragility acts as a new notion which tends to have engaged in essential improvements through the years. However, it becomes important to align to a disorder that engages as central to the antifragility within supply chains which can attain benefits from disorders.	Antifragility, supply chain, disorders	
Ivaşenco (2023)	It is observed that there prevail several issues and restrictions in terms of shaping effective antifragile businesses. Some of the challenges in order to facilitate antifragile businesses include the dearth of infrastructure, less access to financial resources and others, which hampers the implementation and managing of the antifragile businesses.	Antifragile, business strategies	



Zitzmann, 2014	The article has identified resilient and agile supply chains which are suggested to handle the uncertainty in the networks. The strategies for antifragile supply chain is important to demand volatility and delivers are comparative advantage within the supply chain. It is important to create the demand as the customers are focused to handle the uncertainties.	Strategies, antifragile supply chain management, operational performance, supply chain improvement,	<b>Strategies to improve antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka</b>
Payne, 2023	The paper has portrayed how antifragile supply chain management is applied to develop and modify the supply chain efficiency and volatility as ensuring the advantages in the supply chain activities. It is important to ensure resilience to cope up with the uncertainties.	antifragile supply chain, strategies	
Patrucco and Kähkönen (2021)	The sectors such as the pharmaceuticals and others need to be equipped with structured strategies in case of the supply chain risk management. The firms need to incorporate the barbell approach, establishing redundancy to establish more agile approaches.	Pharmaceuticals, redundancy, agile approach	

Ahmed et al., (2024)	The supply chain strategies act as an essential role to attaining more and responsible procedures of manufacturing. There also prevails a significant role of collaborative strategies so as to leverage the supply chain operations. Industry leaders need to shape strategies that meet and enhance the drivers of growth.	supply chain strategies, collaborative strategies	
Derbyshire and Wright (2014)	It is noted from the article that with the antifragile the notion of the hormesis is connected to that of redundancy. The advantage of the redundancy is to maintain the stock for the purpose of supplies. However, the final step or the measure of the process investigates the robustness of the firm's strategy which is against the cultivated scenarios.	Antifragile, redundancy	

**Table 4.16: Summary table**

(Source: Self-created)

### 4.3.2 Thematic data analysis

#### *Theme 1: Application of antifragile supply chain management*

According to the view of Khodaparast et al., (2023), opportunities in manufacturing or logistics often come with certain challenges due to the change in market expectations and the rising technological advancements. This requires the leaders to be more resilient towards the changes. The new concept of antifragile supply chain has been use in order to enhance the resilience in logistics. It is further depicted that an antifragile supply chain is the key to success for the business in the future. Antifragility ensures achieving the best result by learning along with adapting to change (Khodaparast et al., 2023). It further enables the business to use uncertainties for growth other than avoiding it. In the recent era it is ensured that logistics has become more antifragile as well as resilient which has helped to gain sufficient visibility in the supply chain. The sources have been effective in terms of providing

sufficient information about the ways the antifragile supply chain is used to achieve the desired outcome.

On the other hand Fauji, Pratikto and Handayati (2022), states that it is unimportant to develop an antifragile model in procurement as well as supply chain management. Antifragility being applied in the supply chain will bring positivity to volatility. Antifragility supply chain ensures to be the most relevant system which thrives amid uncertainty. On the contrary, implementing an antifragility supply chain would also require an effective strategic approach. Additionally, the author has also stated in the article that it is necessary to develop future research in order to contextualise the ways different industries can develop knowledge about developing a brittle supply chain. In simpler words recently, the existence of a resilient and robust supply chain is lying between fragile chain to antifragile. It is important to notice the way a company moves from fragile to resilient to antifragile and the ways it perceives supply chain redundancy. For insurance a fragile supply chain would view redundancy to be a cost which needs to be reduced for example inventory, suppliers, or capacity.

On the other hand, a resilient supply chain is going to view redundancy as an insurance premium. This further ensured to bear insurance against any damage. On the contrary antifragile supply chain will help to view redundancy to be the most significant investment opportunities. This will likely provide the company with a positive return at the time of uncertainty. However Bangui, Buhnova and Rossi (2022) stated that modern society often depends on critical infrastructure in terms of safety, security and wellbeing. The society has become vulnerable to disruptions therefore requires the most effective infrastructure that can assess disturbance or any disruptions to operate effectively. Thus, the application of an antifragile supply chain helps to develop a system that does not tolerate adverse events whereas it allows to strengthen the process to overcome any possible threats in the future.

According to the view of Jodlbauer et al., (2023), it is further determined that supply chain managers are seeking to balance risk mitigation along with recovery capabilities along with analysing the impact of disruptions on SC. Anti-fragility which is emerging stronger from disruption ensures business success. This is because it enables the companies to reduce capacity whenever demand is low and increase it whenever the demand is higher. It is further ensured that the antifragility supply chain seems to benefit from the disorder. Disorder, disruption, risk and uncertainty are inevitable in the SCM. Therefore, the business needs to ensure that SC flexibility is maintained to overcome any challenges encountered by the supply chain. Therefore, the businesses are more concerned to promote antifragility in terms of becoming stronger from disruption. On the other hand, the study by Nikookar,

Stevenson and Varsei (2024), have stated that sufficient investigation has been undertaken which entails the ways a business can handle disruptions by developing a supply chain robustness as well as resilience. The disruptions that emphasise on positivity ensures to be the catalyst for the business growth. Growth is further conceptualised by considering supply chain resilience. Antifragile is the most emerging concept that enables a business to focus on growth. Additionally, it is also noted that by implementing it into the supply chain it can effectively strengthen and grow through exposure to volatility and shocks. By implementing an antifragile supply chain enables the company to gain profit in terms of financial as well as non-fragility.

According to the view of Fauji, Pratikto and Handayati (2022) supply chain is a complex process which requires sufficient understanding to deal with complexities that can better help the business to overcome any uncertainties in the supply chain. A change in the approach is essential as it ensures to recognise SC complexities other than developing a linear process that aims to robustness that can lead to fragility in terms of identifying the fragility in terms of any unforeseen events. By applying an antifragile supply chain, it would help the company to automatically self-correct whereas it enables it to grow even stronger whenever stressor, stains as well as shocks are applied. On the other hand, Bangui, Buhnova and Rossi, (2022), stated that sustainable research was being undertaken in the last two decades to develop better understanding about the ways companies are handling disruptions by developing an effective supply chain robustness as well as resilience. Therefore, the antifragile supply chain has become to be the most effective and diverse gain. The disruptive events seem to be triggered by volatility as well as shocks. Antifragility is thereby gaining the most traction in practice to be the most significant element post pandemic. Therefore, the application of an antifragile supply chain has enabled the companies to enhance capabilities and growth after disruptions.

It is essential for the supply chain to survive a disruption before any events seem to leverage it as an opportunity for growth. Therefore, the concept of antifragility supply enables to develop relevant theories of SC robustness along with ensuring robustness and resilience. As stated by Khodaparast et al., (2023), Additionally it has been further stated in the article that SC is the basic element of any manufacturing industry and therefore it must be protected to overcome any failure in the business. The importance of managing SC has been enhanced because of the rising population growth. Thus, with antifragility the manufacturing business can adapt to antifragility that bring in sustainability within the supply chain. Antifragility therefore ensures to provide opportunities to turn any uncertain situation into

advantage that would help the business progress in a random world. It can be ensured that it is important to investigate the effect of applying the theory of antifragility in SC. This would further ensure the business to improve productivity. The risk acceptance as well as the learning criteria is the most important aspect of the business. On the other hand Fauji, Pratikto and Handayati (2022) it has been identified through the research that the manufacturing industries need to improve or to build a significant network in the antifragile supply chain. This can be further ensured to be the most effective way to strengthen the source resilience for the business. A strong networking will help the business to grow and acquire competitive advantages for the business.

As per the view of Bangui, Buhnova and Rossi, (2022) the antifragility property aims to acquire better learning and at the same time acting upon the resilient strategies. However, the antifragile denotes that potential to grow and succeed despite the issues that may stem within the supply chains. Moreover, the robust is not harmed and assisted by any kind of disorders while advantage is gained by the antifragile systems. It is noted that the antifragile within the supply chains prefer randomness along with the severe uncertainty and is featured by the ability to deal with unknown circumstances. Furthermore, the antifragile systems manage the scalability of varied services and develop the storage of data and information.

On the other hand, Fauji, Pratikto and Handayati (2022) mentioned that the antifragile is being widely researched about and ways it can establish models within the supply chain. However, it is observed that the antifragility approach acts as an approach that tends to survive and continue its presence amid uncertainties. Furthermore, the antifragile system needs an effective strategy which can rapidly and appropriately adapt as well as learn. The benefits of the antifragile are witnessed in several aspects as the entrepreneurs are also advised to shape networks within the antifragile supply chains. However, it is with the help of the support that the businesses can effectively shape the antifragile management and acquire the enhanced potential to mitigate their different risks. Furthermore, the academicians along with the business actors in this arena can keep developing and shaping the notion of the antifragile management actions and practices. Such notions of the scholars depict the significance and the essentiality in terms of its application within the supply chains.

As per the view of Khodaparast et al., (2023) the supply chain acts as the most severe components within the manufacturing arena and therefore, the smooth working of this chain becomes crucial for the development of the business as well. Besides rendering several benefits such as assuming the uncertainties and enduring them effectively, the antifragile supply chain also helps the businesses to attain sustainability. However, because of the

strategic business benefits, sustainability tends to have achieved higher significance within the supply chain systems and therefore several industries experience the risks within their supply chain instability and disruption cultivated by several sources. The significance to adhere to the sustainable supply chains have maximised over the past years because of growing population, restrictions in terms of sources, activities revolving around the consumption along with the enhanced levels of pollution. It is in such circumstances that the antifragile approach acts as one of the notions which is closely associated with the supply chain sustainability.

As per the view of Bangui, Buhnova and Rossi (2022) resilience within the supply chain is referred to as the potential to fulfil demands of the audience after and prior to or any post disruption resolving efforts. On the other hand, Khodaparast et al., (2023) mentioned that the supply chains amid varied instances tend to develop and unpredictability becomes one of the characteristics of the modern business arena. However, antifragility within the supply chain can permit the manufacturers to attain the scope to shift from the challenges faced to the enhanced scopes as well as progress within the shifting and evolving business environment.

***Theme 2: The factors affecting antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka.***

Priyadarshini, Singh, Mishra & Bag (2022) describes the need for ensuring sustainability in the supply chain management with the help of a skilled workforce trained for technological adoption. Hence, this study highlights the implementation of Rubber manufacturing technologies to ensure the development of an antifragile supply chain. Hence, with a focus towards the development of strategies to foster innovation within the firm would ensure the provision of resources for digitalisation. This would aid in the organisational efficiency in managing its product quality in the market in a more sustainable manner.

Shivajee, Singh & Rastogi (2023) identified a strong relationship between resilience and procurement in the supply chain management. With the help of collaboration and cooperation between the suppliers and the firm, resilience could be ensured within the firms. Hence, with the help of technology such as AI, big data and robotics, the disruptions could be mitigated. Therefore, this article suggests the directions for future research works on the aspects of procurement function to enhance the resilience of the organisational supply chain.

The study conducted by Lotfi, Mehrjardi, MohajerAnsari, Zolfaqari & Afshar (2023) proposes a viable SCND (VSCND) by considering blockchain technology and

cryptocurrency as viability tools for an antifragile, sustainable, as well as agile supply chain network by focusing on the risk, robustness, resilience, as well as environmental concerns. This study focuses on the importance of cost reduction in ensuring its effective implementation within the firm.

Hadizadeh, Khodaparast, Ghasemi & Fakhrzad (2023) further focused on the designing of an antifragile supply chain in the uncertain situations by investing into research and development, with local sourcing and production to ensure the development of brand presence in the market. This would also require the firm to form partnerships and enhance the organisational connection with the key customers to ensure their loyalty towards the firm. With the help of new technologies, new products with high-quality materials, as well as sustainable and ethical business processes could be produced, which would ensure the development of the organisational efficiency. Apart from the, businesses are also required to focus on the training and development of employees and ensure the aspects of accountability and transparency throughout the supply chain to gain value for the organisational stakeholders. This would aid the firms in ensuring their sustainability in the long run.

It can further be inferred from the study of Nikookar, Stevenson & Varsei (2024) that the development of collaborative relationships is crucial to ensuring the efficacy of the organisational supply chain performance with robustness. This study suggests that the supply chains are quite fragile systems, which would require the firms to treat disorders as an opportunity rather than avoiding them. Hence, the study suggests that robustness and resilience is not enough to sustain in the highly volatile market. The study details its focus towards understanding the key aspects of antifragility, describing disorder, as well as suggests some ways to develop an antifragile supply chain.

According to the above studies, it can be stated that the development of an antifragile supply chain management system in the rubber manufacturing sector in Sri Lanka can be ensured by a range of factors that impact operational performance, which have been highlighted below.

The studies also describe that the ability of the supply chain to adapt to changing circumstances and recover from disruptions is required for them to be antifragile (Nikookar, Stevenson & Varsei, 2024). This implies that by accessing flexible production processes, agile manufacturing systems, and adaptable logistics capabilities that can quickly adjust to changes in demand or supply conditions, the firms could ensure their competence and sustenance in the market in the long run.

Apart from the studies show that effective communication and information sharing among supply chain partners aids in enhancing the organisational visibility and enable quicker response to disruptions. Technologies such as AI, Blockchain, big data and real-time data analytics can aid in enhancing the information sharing and enhance the responsiveness of the supply chain (Lotfi, Mehrjardi, MohajerAnsari, Zolfaqari & Afshar, 2023). This would not only aid in enhancing the supply chain management of the firm but would also ensure the development of the trust and communication amongst the key stakeholders of the firm, owing to the development of their motivation and satisfaction in the long run.

It can be observed from the above studies that by relying on a single source for raw materials or components makes the supply chain vulnerable to disruptions (Hadizadeh, Khodaparast, Ghasemi & Fakhrzad, 2023). As a result, the companies are required to have a diversified range of sourcing strategies, which could include the involvement of multiple suppliers and supply sources with the business. This can considerably enhance the organisational resilience by the means of minimising the bargaining power of its suppliers.

As highlighted in the study of Hadizadeh, Khodaparast, Ghasemi & Fakhrzad (2023), the enhanced visibility and traceability throughout the supply chain can help the firms in identifying potential risks, opportunities, as well as areas for improvement, which would enhance the organisational decision making. Moreover, with the usage of technologies, the firms can enhance their visibility and enable better risk management, which would ensure the satisfaction of their key stakeholders such as suppliers, customers, as well as the employees of the firms.

Apart from the aforementioned, the firms are required to ensure their compliance with relevant regulations and standards, such as safety, environmental, and labour regulations in order to ensure the efficacy of their business. The firms could further ensure their operational continuity and avoid disruptions because of legal or regulatory issues. This would prevent the risk of unrequired charges because of incompliance with the regulations and hence, would prevent cost overruns for the firm.

With the help of proactive risk management practices, such as risk assessment and contingency planning, the firms could identify the possibilities of disruptions and mitigate their impact on the supply chain. They might, as well, find opportunities within disruptions to ensure their development in the long run, as per the views of Nikookar, Stevenson & Varsei (2024). Thus, this could involve the implementation of strategies such as inventory planning, alternative suppliers, as well as the usage of technology in identifying market trends. This



would aid the firm in identifying the changes in the market and respond to different situations appropriately.

The study conducted by Shivajee, Singh & Rastogi (2023) suggests that having strong partnerships and collaboration among the key suppliers, manufacturers, distributors, as well as customers can enhance the resilience of the entire supply chain system for the company. This would include various collaborative efforts including joint risk mitigation initiatives, information sharing, as well as the provision of coordinated response plans. This would aid the firms in enhancing the strength of their overall resilience of the supply chain while also establishing trust and consistency in communication with the key suppliers of the organisations.

There is a need for the firms to ensure the resilience of its supply chain as it is heavily dependent on the robustness of the supplier network (Lotfi, Mehrjardi, MohajerAnsari, Zolfaqari & Afshar, 2023). These include factors such as supplier diversification, geographic distribution of suppliers, as well as the supplier relationship management practices, which could aid the firm in responding to disruptions positively.

As suggested by Priyadarshini, Singh, Mishra & Bag (2022), the firms are required to ensure the adoption of latest technological interventions in their business processes, while also ensuring to train and develop their workforce to efficiently use these systems. This would not only aid in the development of the organisational productivity and efficiency but would also ensure its resilience in the market. By the means of embracing advanced technologies such as Internet of Things (IoT), blockchain, artificial intelligence (AI), and predictive analytics, the firms can ensure to gain predictive measures with the assistance of real-time monitoring, along with proactive risk management. This would aid the firms in enhancing their overall efficiency, as well as the resilience and antifragility of their supply chain in the long run.

Lotfi, Mehrjardi, MohajerAnsari, Zolfaqari & Afshar (2023) further ensured to focus on the development of a culture of continuous improvement and learning within the firms and across their supply chain, which could aid them in assessing innovation, resilience, and adaptability within the business culture. This could further be enhanced with a focus towards encouraging feedback, conducting analyses of potential threats and opportunities of the firm, and hence, implementing the required solutions as per the communication with the stakeholders. This would assist the firms in strengthen their antifragility of the supply chain and remain sustainable in the market in the long run.

The aspects are crucial for ensuring the implementation of antifragility within the supply chain network of the business organisations. Nikookar, Stevenson & Varsei (2024) further affirmed the need for future research works in this field to provide a better method to implement efficacy and antifragility within the organisational context of different industries. However, the studies considered a range of identified threats, opportunities, as well as solutions to the problems for different industries. Nevertheless, with the addressing of these key factors by the firms, the antifragility of the supply chain could be ensured along with the other key benefits to the firms such as the development of their operational performance despite the risks of uncertainties and disruptions in the market.

Hence, by considering the above factors affecting the antifragility of the supply chain management for the businesses, the firms can ensure to assess opportunities during supply chain disruptions and ensure their sustenance and competence in the market in the long run. The firms are also required to ensure the development of their relationships with the key stakeholders and encourage R&D and innovation in the firms.

***Theme 3: The challenges of managing antifragile supply chain management to enhance operational performance of rubber manufacturing sector in Sri Lanka***

According to Nikookar, Varsei and Wieland (2021), in today's business world, it is characterized by different disorders such as randomness, volatility, error, stresses, uncertainty, incomplete knowledge, variability and others. It is important to identify how an antifragile supply chain is an approach to avoid disorders and randomness. Antifragile SC is a new approach with the recent reflection on the supply chain management and operations, which are served to achieve the growth in different manufacturing industries. While dealing with the SC activities, organisations are identifying how the challenges can be mitigated based on the situations. For example, COVID-19 pandemic has weakened the supply chain, and it has interrupted the supply chain across different industries. Additionally, it optimized how the profit margins are also increased for firm's tendency to employ the strategies and supply chain risk. Business leaders are expecting the supply chain disruption, which is caused by the global events including the political unrest, COVID- 19, weather related emergencies. Meanwhile eCommerce is becoming popular as the customers can have the option of streamlined and efficient order fulfilment to ensure high quality products for delivering to the locals (Größler, 2020). Businesses are unable to adopt experience in abundant carts that can satisfy the individual needs.

Modern supply chains are interconnected and global to the disruptions in the past. Businesses need to address the customer satisfaction and challenges to create effective and

efficient operations. Most businesses depend on the supply chain to produce good delivery orders and customer management that the companies rely on international suppliers for raw materials and third-party logistics for the last mile delivery (NetSuite.com, 2024). Additionally, the challenges observed for the business supply chain can be managed in definite circumstances. The businesses have suffered due to different complex logistics services, business delivery operation and management delay. In this consideration, supply chain challenges can be identified as increased material scarcity, lack of supply chain visibility, restructuring increased freight prices, communication, complex demand forecasting, port congestion, environment and social impact, customer behaviour, data sharing, supply relationship, fragmentation, digital transformation, clearing warehouses and others (NetSuite.com, 2024). Companies identify how it can help to overcome an efficient supply chain. Determining the business efficiency for the manufacturing is important in engaging the customer as well as the individual satisfaction. Additionally, antifragile operations have different consequences in supply chain activities. It is important to demonstrate the concept to focus on advantages which are highly dynamic to develop the formal structural modelling conducting the simulation. Größler (2020) added that system dynamics is indigenously explaining the structural behaviour, which can recover from the shocks. It identifies how the structural explanations can be achieved to possess the robustness system, which can be antifragile. It employs how managerial satisfaction can be induced the way the processes can be designed and invested into scaling up for higher performance.

Moreover, the antifragile supply chain activities share the potential cost reduction based on the external shock and conditions to lower the inventory cost and robustness in supply chain. Logistics costs including the transportation, electricity, energy, labour and fuel are going up with constant market disruption (Lingaro Group, 2024). It is important for delivering how the supply chain activities are managed while delivering efficient logistics and performance management in the manufacturing firms. Referring to Sri Lanka's rubber manufacturing industry, they have faced the push to lower prices which are lower for the rubber farmers to compete. Regarding dry zones, rainfall, evaporation, temperature and relative humidity, their climate has affected the rubber manufacturing supply chain, which is challenging for the sector. Despite the challenges, they have a lack of insufficient infrastructure and services which are global market challenges to expand in different markets (Rubber industry to bounce back. Daily FT, 2023). Additionally, the international markets are suffering from the desirable solution which can be done to the disorders, and it is helpful to build robustness into the supply chain. Moreover, the manufacturing industry is working to

determine how the supply chain challenges can be developed to enhance operations and market management (Nikookar, Varsei & Wieland, 2021).

As per the view of Chourasia et al., (2022), the shifting attitude of the customers and their varying requirements have cultivated several issues for the manufacturing firms about the accurate services offered to them as per their needs and others. However, it is noted that the industrial revolution can be effectively obtained by conducting systematic work and through the collaborative work of the government along with the manufacturers to ensure the welfare of the community. It is the industry that experiences issues including the digital shift, the problem in case of adapting to the new as well as modern technologies, accurate allocation of the needed resources, collaboration, and others. Moreover, the industry also faces issues in terms of freedom to conduct research for the purpose of development, costs to develop and incorporate the technologies and other systems.

As per the opinion of Chourasia et al., (2022) the government, different agencies as well as reactions from the industry is witnessed to be limited to promote industry and for the purpose of the improvement. Therefore, it can be stated that the manufacturing forms in Sri Lanka might have been facing issues such as the adoption of new approaches because of the dearth of cost factors. However, the implementation and application of the antifragile supply chain management needs resources along with varied strategies. Moreover, it is also due to the lack of the productive resources that the manufacturing firms can experience issues with the handling of the antifragile supply chains.

It is also not without productive collaboration among several partners that the manufacturing businesses can effectively shape their antifragile supply chains. Therefore, it is also because of the loose and inadequate collaboration that hampers the adhering to and proper management of the antifragile supply chains. As per the view of Ivaşenco (2023), the shaping of the antifragile business model engages its unique limitations and it is the dearth of the infrastructure within several arenas that creates problems for the companies moving forward to embrace the antifragility within their business. However, the incorporating of the digital solutions to leverage the agility of the business might be restricted due to the insufficient internet connectivity. Therefore, it can be opined that such infrastructural limitations might hamper the rubber manufacturing in Sri Lanka to adapt to new and emerging concepts such as the antifragile supply chain management.

It is noted that such infrastructural limitations also restrict the businesses to initiate more innovation within their business and thereby limits the potential of the businesses to enhance their performances (Ivaşenco, 2023). On the other hand, Tiwari and Bhatt (2023)

mentioned that the notion of antifragility acts as an emerging idea and traversed through several improvements over the years. However, the traditional approaches in case of the software architecture emphasis on reducing the failure points and guaranteeing the stability. Moreover, while such ideas are valuable, they avoid the dynamic characteristics of the distinct real-world systems and also tend to fail to witness the unforeseen challenges. It is observed that while the antifragility approach renders several benefits, it also tends to pose varied issues for the rubber manufacturing firms in Sri Lanka. There prevail several challenges connected with the incorporating of the antifragility approach within the business including the maximised complications, resource equipment and others (Tiwari & Bhatt, 2023). Therefore, it can be stated that the rubber manufacturing firms in Sri Lanka besides facing the lack of resources, experiences the complications in terms of the approach involved in the antifragility.

As per the perspective of Ivaşenco (2023), the access to quality financial resources become another challenge in case of adapting to the antifragility within the businesses. However, capital becomes significant in case of ensuring and promoting business agility since it tends to provide the business with the varied resources that are crucial for adapting to the multiple antifragile strategies along with the creativity involved within the supply chains of the rubber manufacturing businesses. Several of the rubber manufacturing firms tend to struggle so as to have an accurate number of financial resources so as to follow and manage the antifragility to enhance business operations.

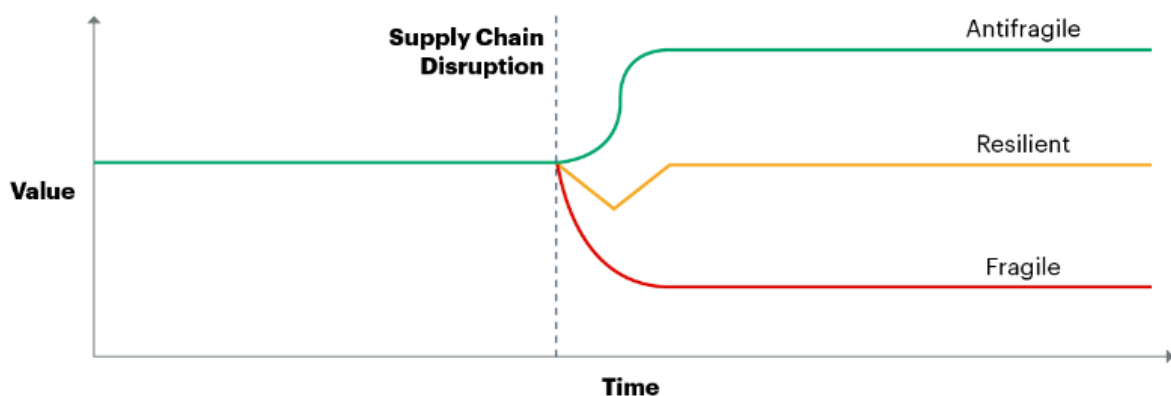
***Theme 4: Strategies to improve antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka***

According to Zitzmann (2014), today's complex marketplace is leading to the value for creating the network over time to get the complexity and inefficiency in the supply chain. To handle the challenges, supply chains should be designed and operated without failure. Here, the idea of an antifragile supply chain is important to handle the uncertainty and the differences in the supply chain management. Moreover, the antifragile SC is a concept to identify the values in the network. The agile supply chain is a customer focused to handle the uncertainty where the robustness is important to determine the flexible adoption of the SC. Additionally, the performance for supply chain can include robust optimisation, which is fit and can improve the redundancies. There are robust supply chain platforms on how the supply chain resilience can have the ability to state the dramatic impact on SC performance. Covering the risk in the supply chain is important to deliver the different angles of the resilient SC mitigation and consistency. Moreover, continuing management is important for

disaster recovery and business planning. It is important for trade of resilience capabilities as the antifragility is important here to show the strong supply chain management. Additionally, anti-fragile SCM aims to address different issues to develop the damages which are caused by uncertainty, increasing the company numbers, resilience building, and significant change in supply chain redundancy and others (Payne, 2023). It determines how most of the SC management takes place to address the issues in manufacturing units.

On the other hand, an anti-fragile and resilient supply chain can be centralised to build redundancy into the system for managing the potential new partners effectively. Additionally, anti-fragile supply chain is implemented to identify and withstand the system redundancy to utilise the strong management. It determines how the antifragile supply chain is identified towards the changes and solutions over the partners and business management (Payne, 2023). Additionally, substantial uses of antifragility are an emerging concept, which originated on growth and established theories recently inside by offering the focal examination of how the firms can grow by following the disruptions. The supply chain should survive on the disruptions, as it is leveraged for examining the firm management as a critical characteristic of supply chains. The strategies are improved by identifying the global supply management. Referring to figure 4.1, it can be said that the fragile and resilient supply chain at the time duration, which is not the same as identified to survive uncertainty. Anti-fragile supply chain is identified over value and supply chain disruption.

### Fragile vs. Resilient vs. Antifragile Supply Chain Management



**Figure 4.16: Antifragile, fragile and resilient supply chain**

(Source: Payne, 2023)

Moreover, building a resilient supply chain is important on which the operational function and management depend on the disruption management. Antifragile supply chains inspired the leaders to build resilience and help the customers to foster sustainable and

improved supply chains. It focuses on network depth, building of system engagement, sustainability in the supply chain, opportunities in uncertainty and others (Besse, 2023). The supply chain delivery depends on the resilience and strength of the operations management, which can be delivered within time and quality. It generates strong supply chain strategy so that organisation can deliver effective and developed supply chain management over the fragile operations in the manufacturing industry. Antifragile supply chains reduce vulnerability, diversify the supplier base, leverage that technology, reality and visibility convergence, sustainability, and others, which are important to increase the efficiency in the supply chain (GEP, 2016). Thus, the strategies are significant to improve the entire performance management and manufacturing units.

Uncertainty in supply chain is a framework to highlight how responsiveness and flexibility can be portrayed. It is interrelated to develop the resilient supply chain and continuity management as a part of a flexible supply chain. Antifragility is conceptualized for developing the abilities of resiliency and agility in the entire operations management (Zitzmann, 2014). Moreover, it determines the modern supplier management and development. The supply chain visibility is significant to focus on the performance management and deliverables.

As per the view of Ahmed et al., (2024) the incorporation of the sustainable practices has been identified as important for resolving the negative contribution connected with the manufacturing practices. It is noted to have been acting as dual purposes that meets varied concerns and at the same time places the firms to leverage their competitiveness within the market and ensure operational resilience. The planning becomes essential to develop the antifragile supply chains. However, the incorporating of the innovative strategies provides a pathway to attain more responsible and efficacious manufacturing procedures. The Sri Lankan rubber manufacturing firms can initiate careful planning and recognise the vulnerabilities in supply chains and accordingly develop strategies to resolve risks prior to initiating disruptions.

As per the opinion of Patrucco and Kähkönen (2021) the notion of antifragility and its significant utilisation during the crisis periods such as COVID-19 pandemic urges the importance of shaping the antifragile supply chains. Most significantly, it is observed that the sectors including the pharmaceuticals need to keep and design their supply chain management strategies in an accurate place. However, adaptability is referred to as the ability to adjust the designs of the supply chain to address different structural shifts within the markets and rectify the supply networks to depict the changes within the strategies. On the

other hand, Derbyshire and Wright (2014) opined that the antifragile approach within the supply chains exhibit as the preparation for the upcoming days and exhibit as a step by step methodology which can be adhered to in case of replacement to a casually emphasised approach of planning. It is with the assistance of the focal strategy or the investment strategy that the manufacturing firms in Sri Lanka can initiate more antifragile systems within supply chains.

As per the view of Patrucco and Kähkönen (2021), there can be several strategies including the improving of operationality, establishing redundancy, adopting a barbell approach and others. However, such strategies have the ability to lead to the establishing of more agile systems and approaches that can initiate gains from the varied disorders when compared to the damages. Moreover, it is the redundancy within the supply chains that depict to be initiation point in case of generating the supply chains more agile. On the other hand, Derbyshire and Wright (2014) mentioned that the connection of the barbell strategy is witnessed in which the strategies tend to avoid the notion of moderate risks as implemented within the “stress testing” and instead emphasise on undertaking no risks in places that engage large scale negative results. However, in antifragile redundancy is witnessed as a kind of investment when compared to the defensive strategy.

Planning is also regarded to be significant in establishing the antifragile supply chains and the antifragility needs the potential to foresee as well as prepare for the probable risks. The rubber manufacturing firms in Sri Lanka can effectively diversify their suppliers, enhance the inventory for the crucial elements and at the same time create the alternative logistics routes. As per the opinion of Derbyshire and Wright (2014) scenario planning is considered to be one of the most increasingly adopted approaches within the sectors. However, it is also accepted that several firms incorporating the scenario planning utilise an approach which is premised on the intuitive logistics. On the contrary, it is found that the limited potential to deal with uncertain events is being recognised as the insufficiency within the popularly incorporated methods or approaches of the scenario planning.

As per the perspective of Taquechel and Lewis (2017) the antifragile systems tend to survive and acquire advantages from the perturbations. The practitioners or the people involved within the supply chains need to incorporate strategies which are premised on the sound theories, however, theories tend to evolve similar to that of the different strategies. However, it is found that the modern technologies along with the data analytics act as a pivotal role within the facilitating and planning of the antifragile supply chain. However, the new technologies offer the tools that help in better forecasting and enabling the firm to



generate real time monitoring. Moreover, these technologies also permit the rubber manufacturing firms in Sri Lanka to initiate better scenario planning. Therefore, it is with the help of these abilities that the manufacturing firms in Sri Lanka can effectively anticipate the shifts and react to the varied emerging threats more rapidly. Furthermore, they can also recognise the scopes for the development that stems from the several disruptions.

As stated by Ahmed et al., (2024) the emergence and the incorporation of the modern technologies including the AI, blockchain, IoT or Internet of things has been evolving and improving the supply chain management measures or practices. However, the connection amid the modern technologies and the “circular economy principles' ' provide a quality framework for redesigning the supply chain management particularly within the manufacturing sector. However, it is found that the new technologies have the ability to positively lead to sustainable growth. Moreover, visibility is considered to be one of the crucial steps towards the agility and the investing in the technologies can enable the manufacturers to have end- to-end visibility all throughout the supply chains.

The supply chains can also lower their risks through the shaping of the redundancies. As per the view of Patrucco and Kähkönen (2021) the establishment of the redundancy can help the firms to shape more agile approaches. The incorporating of the strategies to traverse beyond the fragility the firms need to embrace both the flexibility along with the redundancy. On the other hand, Derbyshire and Wright (2014) mentioned that the notion of redundancy as implemented within the antifragile engages additional focus on the ability of attaining and not simply defending the uncertainties. The rubber manufacturer needs to guarantee that their supply chains have adequate backup plans for the logistics, raw materials and others. They can incorporate dual sourcing, several transportation routes to establish a buffer against varied disruptions. However, the global trade solutions can assist them to optimise and recognise the alternative carriers to reduce the risks.

#### **4.4 Summary**

It can be summarised that the supply chains tend to serve as the most significant elements within the manufacturing sectors. However, the antifragility applied within the supply chains initiates positivity in terms of volatility. Moreover, the incorporation of the antifragile supply chain management within the rubber manufacturing will require the strategic approach. The business faces several issues in terms of effectively using and applying antifragile within the supply chain including the lack of collaboration, resources,

infrastructure, costs, and others. Moreover, the businesses can adhere to several strategies through which they can better use and implement the modern approach within supply chains such as the development of operationality, catering redundancy and others.

It can also be summarised that most of the participants or the respondents from the rubber manufacturing firm in Sri Lanka tend to engage adequate knowledge on the concept of antifragility in supply chains. There are varied elements that navigate the antifragile management such as the dearth of adequate knowledge, resources, and others. Majority of the people agree with the fact that the antifragile supply chain can witness the uncertainties and also at the same time prepare for the risks. Some of the advantages rendered by the antifragile supply chains depict to be the withstanding and controlling of the varied uncertainties followed by the convenience in terms of adapting to the transformation.

## **Chapter 5: Discussion**

### **5.1 Introduction**

The fifth chapter of the present research study focused on the critical discussion regarding the impact of anti-fragile supply chain management process on the operational performance development process in the rubber manufacturing industry in Sri Lanka. The antifragile supply chain is denoted as the system which is shocked and volatility proof for suggesting a more resilient and stronger supply chain process in the rubber industry. Thrive to face shock and maintain resistance in the target market is the only process available in the strategic growth and optimum developmental capabilities in the rubber manufacturing industries in Sri Lanka. The rubber industry of Sri Lanka is already vulnerable to the different shocks and disasters along with political instability and fluctuating global demand for the critical sourcing and anti-fragile technique implication in the supply chain process to generate optimum benefit in the target market. The present study utilises a mixed method approach and focuses on both qualitative and quantitative analytical framework to gain optimum insight into the supply chain management process in the Sri Lankan rubber industry. The adaptability and flexibility of the antifragile supply chain management process has also been discussed in this research to schedule production processes along with optimising the inventory management process within the rubber industry.

### **5.2 Discussion on quantitative Analysis**

By analysing the response of Q1, it can be stated that, majority of the people working in Sri Lankan rubber industry belong to the mid-age group 35-40 years. This discussion shows that 60% of the employees in the Srilankan rubber industry belong to this middle age group. As suggested by Nikookar *et al.*, (2024), middle-age working groups are more reliable and covenant workers who are more productive and less involved in conflict that enhance organisational productivity This survey also stated that, as the Sri Lankan rubber industry intends to appoint the mid-age workers in its supply chain management, this industry grabs highly experienced and knowledgeable staff. As compared to the young staff belonging to the age group 25-30 years, the middle-aged people are more skilled and experienced who are more productive and knowledgeable to achieve the common organisational goals. The quantitative analysis shows that Sri Lankan rubber industry has taken initiatives to choose the middle-age group as the target employees that not only assists this industry to share enough

skill knowledge in the workplace to enhance the organisational productivity but also improve the overall competitive edge of this industry in the global market.

Analysis of the response of Q2 shows that, in Sri Lankan rubber industry, nearly 83% of the employees working in the supply chain management are males. As compared to this massive percentage of males, the females working in Sri Lankan rubber industry is only accounted for 13%. From this statistical presentation, it can be stated that, that, Sri Lankan rubber industry intends to follow the gender diversity that somehow interfere with the concept of gender equality in this industry. As suggested by Lotfi *et al.*, (2024), in every manufacturing industry, gender equality is necessary to maintain a healthy economy in a nation. The quantitative response from the Q2 also suggests that Sri Lankan rubber industry present the gender bias that widens the gaps between male and female employment opportunity in rubber industry. From this analysis it can be stated that the Sri Lankan rubber industry needs to change their gender perspective to include more women in this sector that will improve overall productivity and the work process of this industry. In this context, the inclusion of more women into Sri Lankan rubber industry will improve the overall process of supply chain management by carry out proper inventory management, maintaining proper good and commodity supply and connection with suppliers.

The analysis of the response of Q4 presents the fact that, in Sri Lankan rubber industry majority of the employees have a work experience of 4-5 years. The statistical data shows that more than 41% of the employees working in the Sri Lankan rubber industry have 4 years' experience. From this statistical data analysis, it can be concluded that, more of the employees in the Sri Lankan rubber industry are well-knowledgeable and well-skilled as they gathered a long-term experience in this industry. As suggested by Corvello *et al.*, (2024), the work experience is necessary for an industry to achieve its optimum economic growth. The statistical analysis of the response of Q4 suggests that 28% of the employees in the Srilankan rubber industry contain 2-3 years' experience and only 8% of employees gain 6 years of experience. From this data analysis it can also be stated that, in this every changing market, if Sri Lankan rubber industry intended to maintain an antifragile supply chain management it needs to increase the percentage of employers having more than 6 years of experience. The more years of experience employees will have the more efficiently they will meet the organisational target. In this context, the Sri Lankan rubber industry needs to consult more training programs, skill development programs and the conference to improve the skills and knowledge of the staff to improve their productivity.

The response from the Q4 suggested that, nearly 51.2% of the employees working in the Sri Lankan rubber industry have ideas and knowledge on the antifragile supply chain management. This is a positive aspect for the Sri Lankan rubber industry, which will boost the economic growth and the organisational productivity of different rubber manufacturing companies (Maemunah, 2024). Antifragile supply chain management assists the companies to maintain a sustainable and consistent supply chain that will ensure the consistent flow of raw materials and goods to maintain sustainable productivity. Therefore, employees working in the Sri Lankan rubber industry need the proper knowledge and skills of operating the antifragile supply management process. The analysis of statistical data shows that more than half of the employees working in the Sri Lankan rubber industry have good understanding on how the antifragile supply chain management works and what are its necessary factors that are to be implemented during the work process. Moreover, the analysis also recommends the Sri Lankan rubber industry to conduct training and workshop programs for the employees who do not have ideas or knowledge on antifragile supply chain and assists this industry to maintain its supply chain sustainability.

From the survey of the Q5 it can be depicted that, majority of the employees (60%) acknowledge that the Sri Lankan rubber industry is highly supportive and considerate to the antifragile supply chain management. The evidence suggested that antifragile SCM is a necessity for an industry to overcome all the uncertainties in the operation and management of raw material and goods (Ahmed *et al.*, 2024). The survey result concludes that the Sri Lankan rubber industry is highly inclined towards making the necessary transformation in the workplace and employee management to implement the antifragile SCM. majority of the respondents believe that Sri Lankan rubber industry is willing to bring about innovative changes in its SCM process to make it antifragile in terms of combating the issues of unpredictable scarcity of the supplies. Moreover, the survey also suggested that the Sri Lankan rubber industry can achieve a sustainable connectivity with the remote suppliers thereby ensuring the consistent supply of materials. The survey helps to understand the necessity of the antifragile SCM in terms of avoiding the risk of supply chain disruption that interferes with the production and operation management. However, this survey also shows that 23% of the respondents do not think that the company wants to apply the process of antifragile SCM. This is because of the lack of proper knowledge on the antifragile SCM, the lack of information updates regarding what is going into the business structure and the lack of employee engagement. In this context, it is recommended to the Sri Lankan rubber industry

to promote the knowledge development initiative for developing the skill of antifragile SCM operation in all employees to overcome all hurdles associated with the SCM.

The response from the Q6 depicted that, while it comes to determine the factors affecting the antifragile SCM, majority of the employees (40%) consider the scarcity of the resources as the main factors that interfere with the antifragile SCM. The dearth of the necessary resources leads to the uncertainty of supplying the necessary goods and raw material that interferes with the productivity of the Sri Lankan rubber industry. The overall operation performance of the Sri Lankan rubber industry is mainly dependent on the effective resources allocation. Now, the lack of available resources leads to inconsistent supply of necessary raw material that may cease the operation of this industry. The second highest percentage of employees (31%) agreed that lack of knowledge is the major reason that affects the antifragile SCM. poor skill and knowledge of employees in the antifragile SCM process leads to disruptive SCM that affects the overall operation management of the Sri Lankan rubber industry. Future expectation is also pointed out by 27% employees as the factor that affects the antifragile SCM. in this unpredictable market, the future expectation of the supplies of goods and commodities lead the marketers of Sri Lankan rubber industry to complex and unrealistic business decision that affect their economic growth.

The analysis of the survey of Q7 showed that, while it comes to determine the effectiveness of antifragile SCM in predicting risk, the majority of the employees (60%) agrees to this fact. Based on this response it can be concluded that, the antifragile SCM assist marketers of Sri Lankan rubber industry to determine the possible risk associated with the future pertains, productivity and supply chain management. More than 22% of the employees strongly agreed to the fact that antifragile SCM is effective in preparing an industry for the future risk. The application of the antifragile SCM into the work process assists the Sri Lankan rubber industry to connect to the suppliers and dealers consistently that provide them with the necessary information regarding the future volatility in the market, thereby assisting marketers to restructure their supply chain framework.

By analysing question 8, while it comes to get the response on the benefits of antifragile SCM, majority of the employees of Sri Lankan rubber industry (43%) believe that it supports the industry to predict the uncertainties. Based on this perspective it can be stated that, the major benefit of antifragile SCM is it prepare the marketers working in Sri Lankan rubber industry to prepare for the future uncertainties and volatility and set essential goals to combat these issues.

### 5.3 Discussion on qualitative analysis

Secondary qualitative data set has been collected and analysed by using thematic analysis to gain optimum growth opportunity into the target market. The argumentative discussion has been conducted here to generate optimum ideas regarding the beneficial impact of anti-fragile supply chain management techniques in the rubber industry of Sri Lanka. A total of four themes have been generated and discussed in the research study to increase knowledge regarding the applicability of the antifragile supply chain process within the organisation.

#### ***Theme 1: Application of antifragile supply chain management***

The first discusses the applicability of the antifragile supply chain in the market for the optimum revenue generation within the organisation. The study of Nikookar *et al.* (2024) stated that the Implication of logistics and manufacturing challenges within the business process has only been solved with the resilient changing process within the company. Advancement of technology already focused on the antifragile supply chain and critical endurance achievement in the applicability increment in different industries.

The application of antifragile substance can only be incorporated in the operational and resource procurement process to generate optimum growth and strategic opportunity in the target market with direct involvement in the flexible and adoptable supply chain solution to the global business set up. Antifragile supply chain helps to provide desired supply chain solutions in the market by achieving optimum support and strategic success parameters into the target market. The study of Sadeghi *et al.* (2022) stated that the development of antifragile models not only increases profitability of the company but also increases the change management and implication process easier than the traditional supply chain process implication. Resilient and robust supply chain can be procured with the help of antifragile scheme of supply chain management which only provides beneficial opportunities in the target market. Developing profit-based supply chain procurement also generates a strategic approach which implements progressive growth and revenue generation processes within the target market.

The robustness of this supply chain approach has been utilised in different organisational resource allocation and procurement processes to generate flexible and

adaptive supply chains within the organisation. Apart from that, the antifragile supply chain mainly focused on the culture of innovation and improvement in the organisation that directly increases the implication of antifragile techniques in the industrial realm. Easier reduction, efficiency improvement and process optimization became easier due to the incorporation of sensor based advanced technology and IoT based product optimization process to generate profitable growth in the inventory management and production monitoring process in the larger supply chain within the industrial set up. As per the study of Priyadarshini *et al.* (2022) that leveraging use of data analytics and utilising the advanced technology in the supply chain process helps to identify the bottleneck condition and real time monitoring and optimization of the organisational process to gather effective benefit into the organisation. Embracing lean manufacturing principles and streamline operational elements within the entire manufacturing process can lead towards the productive growth and beneficial opportunity into the larger business setup.

Optimum supply chain capability is only possible after the incorporation of both values added, and nonvalue added features to generate productive growth into the inventory management strategy within the company. The implication of antifragile manufacturing not only focused on the efficiency and time reduction but also it is proven to be a sustainable supply chain process which reduces waste along with uncertainty and volatility of the external market. It also helps to foster positive culture and innovative opportunity in the target market which helps to accumulate operational excellence and lower chances of data-driven innovation and experimentation in the target market. The study of Gröbler, (2020), Agility and reliability of suppliers also increased strategically with the help of lean manufacturing technique implication in the antifragile marketing process within the organisation. The large-scale operational excellence is the actual parameters that are strategically impacted on the product-based development and resource procurement process in a lean and agile methodological process. Besides, the utilisation of the antifragile supply chain also increases opportunity to increase collaboration with the available suppliers to facilitate supply specific growth within the organisation.

Developing a resilient supply chain and developing productive opportunities in the supply chain process has been strategically fulfilled with the help of antifragile supply chain inclusion in the business market. Protection against external shock and operational performance upliftment are the major criteria that has been achieved through implementing antifragile supply chain structure in the organisational set up. The study of Bag *et al.* (2023)



stated that the critical safety structure implications process has also entitled the antifragile supply chain process implementation in the target market. Better learning and resilient strategy have been entitled with the productive growth and effective strategic managerial process also provide need-based structuring of resource procurement process to gather effective growth opportunity in the target market. It also helps to generate potential risk mitigation strategies within the organisation and find out sustainable management application of products in the target market that helps to achieve optimum success in the supply procurement process.

Changes in the demand and procuring product from different suppliers not only decreases the antifragile supply chain process but it also provides a strategic shift in the evolving market sector. The operational performance and excellence can only be associated with the robust as well as flexible supply chain set up into the marketplace. As per the study of Ivaşenco, (2023), automation services and automatic self-correction through continuous monitoring process has only been included within the target market based on the sustainable and strategic procurement of the antifragile product involvement into the supply chain process helps to increase resilience and growth opportunity in the larger industrial set up.

***Theme 2: The factors affecting antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka***

The second theme is associated with the operational performance of the antifragile supply chain management process within the target market. Developing an effective operational process within the larger business segment is essential. The implication of an anti-fragile supply chain management process can lead towards the productive procurement and optimum flexibility and growth has also been associated with the antifragile supply chain management process. The antifragile supply chain process is denoted for the durability and endurance to overcome disruption within the target market. As per the study of Rahimian *et al.* (2023), it is also thriving towards the mitigation of uncertain volatility, complexity, and ambiguity within the market to generate optimum market growth within the organizational sector. Different factors are essentially impacted on the antifragile supply chain process management to gain productive growth into the organization.

The operational performance of this supply chain process in the rubber manufacturing company in Sri Lanka can impact on the operational performance in the marketplace. The resilient suppliers process development is one of the impactful factors indicated towards the

quick-change adaptation and rapid disruption recovery process to generate productive opportunity into the target market. The study of Lotfi *et al.* (2023) stated that reliability with the suppliers is one of the effective factors essential for the consistent quality management in the natural rubber procurement from the suppliers. The reliability of suppliers also increases the chances of effective change management in the rubber manufacturing market. Contribution to the quality standards maintenance and recovering supply chain disruptions are the major factors associated with the antifragile supply chain adaptation process in the large-scale industrial set up.

The diversified sourcing strategy is another sustainable benefit of an antifragile supply chain where one can source single raw material from different vulnerable sources that are directly associated with the productive growth within the target market. It decreases the vulnerability of the raw material sourcing process. The study of Hadizadeh *et al.* (2023) focused on the disruption in the supply chain due to the political instability, economic crisis or any natural disaster process also mitigated with the help of sustainable sourcing process within the target market. Availability of multiple suppliers in the antifragile supply chain process decreases the dependency of the users on the single sourcing of the suppliers. Besides, flexible manufacturing processes also act as a beneficial and flexible process which has been associated with the effective resource allocation, productive mix, and accurate responses to the changing market situation.

Changing market-based adaptability is also associated with the implication of adoptive supply chain ability in the antifragile substances for the productive and strategic growth within the industrial set up. In case of the larger industrial set up, maintaining resilience and work dependency reduction is essential to gain productive opportunity into the target market. Based on the study of Größler, (2020), information visibility and transparent supply chain sourcing has been increased due to the increased application of anti-fragile supply chain which strategically increases the supply chain possibility and proactive risk management potentiality in the business operational process. Advanced technological implication in the antifragile techniques also provide IoT based services, RFID (Radio Frequency Identification) tracking ability and anticipation process to develop effective supply chain risk mitigation strategy into the target market.

The antifragile supply chain also focused on the collaborative relationship with suppliers which helps to strengthen the supply chain network along with the effective risk

responsive strategy implication within the target market. Apart from the authenticity and transparency in the research process also associated with the productive growth and profitable inventory optimization process which is also associated with the anti-fragile supply chain management capability within the organization. Developing effective balance between the inventory stock and supply of stock materials are also developed strategic decision-making skills among the marketers to generate productive strategies in the target market. The study of Including technology-based inventory management processes also provide specific growth opportunities to generate resilient structure in the supply chain that can be a sustainable version of inventory management process. just-in-time (JIT) techniques of inventory management, vendor-managed inventory (VMI) or principle implication in the supply chain process can generate optimum output which decreases the supply chain disruption process in the target market.

In the streamline operational management process, antifragile supply chain increases the opportunity to generate robust supply chain processes along with higher levels of endurance in the inventory optimization process. The study of Rahimian *et al.* (2023) also focused on the implication of an antifragile supply chain also associated with the dynamic environment and continuous learning and improvement process within the inventory process and supply chain process for optimum resource procurement also leads towards an effective market. Encouraging innovation and fostering experimentation and adaptation process also leads towards the strategic growth within the rubber manufacturing industries in Sri Lanka. By improving antifragility in the supply chain, the business organization can produce sustainable regulatory compliances for the productive growth in the larger industrial set up. The risk assessment plan in the antifragile supply chain process also focused on the optimum benefits in the advanced technological adaptation and innovation based operational solution in the market for generating streamline operational processes within the disruption recovery process.

***Theme 3: The challenges of managing antifragile supply chain management to enhance operational performance of rubber manufacturing sector in Sri Lanka***

The technological limitation has created a significant hindrance for adapting the antifragile supply chain management practices in the Sri Lankan rubber manufacturing sector. Sri Lanka has faced numerous challenges. In the age of digitalisation next generation technology and digital infrastructure plays a vital role for implementing advanced supply chain solutions. Poor internet connectivity, back dated software systems and lack of skilled

workforce can be the obstacle for dealing with the digital tool (PECB, 2022). It creates a hindrance for antifragile practices in the manufacturing process. Embracing advanced technology like IoT, artificial intelligence, and blockchain improve the visibility in the supply chain. Antifragile supply chain management must utilise these technologies to mitigate the risk and improve the inventory management. However, on the other hand the government of Sri Lanka plays a pivotal role to facilitate the transformation towards the antifragile supply chains. The government policies significantly impact the rubber manufacturing industry. Policies and regulation promote innovation, infrastructure investment, improve the research institutions and industry stakeholders' collaboration. It is essential for adapting the modern supply chain management processes. Though insufficient support and bureaucratic obstacles can slow down the adoption pace and thus it creates hindrance in the rubber manufacturing sector in Sri Lanka.

Resilient and efficient supply chain operation requires infrastructural development. The rubber manufacturing industry in Sri Lanka faces numerous challenges that are related to the transportation networks, inefficient warehouses, and irregular energy supply. These gaps need considerable investment and coordination between the stakeholder and the government. These initiatives will improve the logistics capabilities and make sure a smooth and seamless supply chain flow. Moreover, infrastructure and technological challenges and the financial obstacle may create a significant hindrance to implement the antifragile supply chain management practices (Payne, 2023). Investing for technology upgradation requires quality financial resources. Arranging the training program for the employees and taking initiatives for infrastructure development is required. A skilled workforce development is important for improving the operational performance in the rubber manufacturing industry (Edstellar, 2023). Antifragile supply chain management requires investment in the training program to improve the employees' capabilities and empower the employees so that they can adapt to the market changing dynamics. However, multiple rubber companies in Sri Lanka struggle to find adequate funding due to many factors like high interest rate, capital market and strict loan criteria. To combat these challenges and improve the operational performance in the rubber production industry, collaborative efforts are much needed from the numerous stakeholders. This might include the governmental agencies, many financial institutions and industry associations, and tech companies. Overall, it can be stated that managing the antifragile supply chain management to improve the operational performance of the rubber manufacturing sector in Sri Lanka is significant. With the help of strategic collaboration and

proactive measures can help to overcome the challenges and assist to unlock the potentiality for improving operational performance. Sri Lanka can become a leader in advanced supply chain management practices by fixing the technological limitation, improving infrastructure, and securing financial resources.

***Theme 4: Strategies to improve antifragile supply chain management on operational performance of rubber manufacturing sector in Sri Lanka***

To make supply chain more antifragile, which implies flexibility and agility in a broader sense, we need to employ a multi-level approach comprising interconnected elements directed at strengthening the ability to react in time and adapt to changes with minimal disruption in the whole supply network (Edirisinghe *et al.*, 2024).

In ***Diversification of Suppliers*** is one of the significant approaches to enhance the antifragile will be to specify supplier sources that are not only limited to only one supplier. A complete protocol being followed by a company with the sole objective of exploiting their full potential by not maximising the cost consumed and other trade-offs lies in a supply chain breakdown. Through a complex supply chain network that involves multiple suppliers and a diverse geographic spread, industries or even alternate materials, companies are able to shield themselves from any unforeseen event such as natural disasters, political upheavals and market downtrends by using this approach.

***Redundancy in Supply Chain Infrastructure*** in supply chain infrastructure needs an introduction that should include its importance in minimising the risks and keeping business operations steady. This requires setting up alternative logistics, production sites, transport routes, as well as vital material so that the business can withstand any obstacles (Dilhara, and Chandrasekara, 2024). Companies may be able to respond fast when there is disruption in supply by having different systems designed to perform the same operations. This will then minimise or prevent disruption of delivery, no matter what the circumstances are.

***Adoption of Technology*** that incorporates leading-edge technologies like the AI, blockchain, and data analytics into the supply chain system is one of the techniques to improve visibility, the agility and responsiveness in the supply chain system. By this means questions of monitoring, analytics, and taking better decisions is possible at real time which enables companies to predict problems and make greener preventions (Wimalaweera *et al.*, 2024). Moreover, the same new technologies incorporated in blockchain also help improve transparency and traceability as two main pillars of building trust and resilience in the supply chain altogether.

**Scenario Planning and Risk Assessment** that is adopting scenario planning tools ensures that we could promptly spot the risks and proactively introduce techniques to neutralise them, so the effect would be noticeable. Through the running of imaginary scenarios, firms may forecast disruptions, and estimate the extent of them on different elements of the supply chain (Samaraweera *et al.*, 2024). Thus, this approach improves the quality and promptness of the decision-making and conditions the organisations to bounce back swiftly which reinforces the level of resilience.

**Collaboration and Partnerships** closely working with the suppliers, customers, and their other stakeholders lead to building resilience in the supply chain. Forging lasting alliances makes possible information exchange, the cumulative effect of available assets and cooperative behaviour during emergencies. Organisations will be empowered to draw upon shared experiences and capitalise on them to navigate around problems more successfully and allow them to discover solutions that will insure them against failures.

**Investment in Talent and Skills** that build up a competent and skilled workforce with the suitable proficiencies is vital for the effective management of supply chains which experience high complexities. Offering education and training more interdepartmental cooperation and talent development schemes will foster a healthy culture that is agile enough to roll with the punches affirm of changing circumstances. By giving employees, the power to steer and prevent scenarios and by doing that the resilience of the whole supply chain would increase (Partheepan *et al.*, 2024).

**Continuous Improvement and Learning** is fundamental to adopt a culture which will encourage constant development, innovations, and knowledge for the organisation to be competitive in the dynamic market. Involving risk assessments and mitigation, as well as contract and vendor analysis, e-training, and reactive and proactive communication, on an ongoing basis, tremendously reduce the possibility of a disruption. In addition, regular evaluations of performance metrics, gathering feedback from the involved parties, and post-mortem analyses of disruptions help in continuously evolving supply chain strategies and processes (Rathiverni, and Perera, 2024). The businesses, when invention and experimentation are incorporated in it, are, because of this, in a much better place to locate and possibly exploit emerging threats and already foresee the danger, in general, confront them.

Enhancing the factors to cope with stress in the supply chain system can be done by integrating several aspects including long-term thinking, technological advancement, cooperation, and discipline in the process of improving. By applying the purposeful

strategies, the companies can strengthen their supply chain network, the capability of rapid change and flexibility, which will prepare them for complicated and unstable business working environments.

Approved, the feature of ensuring that green practices are integrated is also crucial in the process of setting up antifragile supply chains. Proactive sustainability not only help overcomes negative impacts but also enable operational robustness and supremacy in the marketing environment. Companies can profit with technology champions that empower trans-shipment and correspondence in real time (Andrieu *et al.*, 2024). Hence, they are equipped with enhanced responsiveness and supply chain resilience. Using such an approach will make sure that supply chains will not just be resilient, but effective in creating opportunities from disruptions that are accompanied with these disruptions.

## 5.4 Summary

The rubber industry in the nation of Sri Lanka is now witnessing rapid growth and progression, which is placing the country at the helm of global rubber products trade. Given rising need elicited by rubber products particularly in areas of automobiles, industries, and healthcare, operation excellence applies through refining supply chain systems. The systems will ensure efficiency and resilience towards operations. Antifragile supply chain management serves as a major tool that firms can employ to navigate any disruptions and uncertainties, with the capacity not only to survive but also to build resilience, especially during tough times. Through the fusion of technology, the establishment of collaborative measures, and the adoption of pre-emptive risk management models, the Sri Lankan rubber aggregation can heighten its competitiveness and sustainability in the international market. Besides this, the deployment of intelligence on the production floor with a decision-making mechanism, which is dynamic, will most certainly contribute towards the long-term success and innovation in the sector of manufacturing.

## **Chapter 6: Conclusion and recommendations**

### **6.1 Conclusion**

The overall impact of using the antifragile supply chain framework within the rubber manufacturing entities in Sri Lanka was explained and evaluated. The word antifragile and the conceptual ideas and functional implementation associated with it could be identified and explored across the research study. The well-defined objectives were framed and the discussion and evaluation of the effective implementation of antifragile framework was accomplished smoothly. According to the discussion and evaluation by Grumiller et al. (2021), the occurrence of the Covid-19 pandemic had explained the logical aspect of the fragility that exists within the supply chain operations of the rubber manufacturing units of Sri Lanka. The effectiveness of the antifragile supply chain practices and services had to be implemented under well-defined factors. The literature review was able to highlight the different areas of business where antifragile framework of supply chain operations was effective to achieve the desirable targets that are laid down. The gap in literature was required to be fulfilled and the concept-based framework was designed and developed for discussing and evaluating the wide range of dimensional trends or theme-based patterns that would specify and enable the perfect application of antifragile supply chain frameworks. The secondary themes were framed judiciously, and the thematic coding also provided support to discuss and assess the supply chain-based operations linked to rubber manufacturing units in Sri Lanka. The information gaps could be specified and the evaluation of the operational dimensions of antifragile supply chain framework could be explained.

The relevant questions pertaining to the topic of research study were also designed for conducting the quantitative analysis. The adoption and implementation of the effective strategic approach for this research study had proved to be effective and significant for achievement of the desirable targets. The well-defined and the methodical strategies related to supply chain management could be devised for effectively processing the antifragile practices. The relevance possessed by the Antifragility based supply chain can thrive under complex situations. Contrary to the concept, the antifragility designed supply chain always possessed the requirement of the desired effectively crafted strategic approach. The author in the theme-based findings also had identified and explored that constructive research work and substantial processing and planning needs to be done for examining the capacity of a brittle networking system of supply chain operations. It can be specified and simply evaluated that



recently, the most stable and robust supply chain framework lies within the fragile and anti-fragile supply chain network. According to the discussion and evaluation by Piyatissa & Siriwardhana (2022), the Sri Lankan rubber manufacturing industry should prioritize the building of a strong supply chain as it will help in handling unexpected challenges and grow stronger at the same time. There are certain points based on which the industry can continue to largely grow.

Firstly, there can be a backup option for transportation and place of storage and supply because if the industry loses one supplier or there is some natural calamity due to which the route is disrupted then they can opt for the backup. It can somehow also be stated as risk management, where the rubber industry will identify the potential problems that might occur, be it political instability, or economic issues. The next focus point is sustainability as it plays a very crucial role in today's world. As per the logic-based illustration by Chienwattanasook et al., (2022), this means that the means to producing rubber should be environment friendly and the resources should be wisely used so they can be reused or recycled in the future. This will help the company appeal to that section of the customer base that cares about such issues by reducing the environmental impact on the planet. The relevant standards of antifragile frameworks also need to be considered and evaluated for achievement of the desirable targets that are laid down by the rubber manufacturing units that operated in Sri Lanka.

The literature review highlights the role played by technology, as in, how tools like AI, Machine learning, and data analytics can help the company make better decisions and keep track of real-time happenings. In case the stocks are about to come to an end, AI can help by sending an alert beforehand to ensure the materials do not run out. There should be a continuous improvement mindset as companies are constantly evolving to stay ahead of the competition. According to the discussion and evaluation by Piyatissa & Siriwardhana (2022), the Sri Lankan rubber industry should constantly look for ways to reduce waste by optimizing the resources that are available to them and improving customer relations. Overall, by keeping a check on areas such as flexibility, sustainability, technological adoption, collaboration and so on the rubber industry can ensure that it creates a supply chain that is efficient and capable of growing in today's dynamic world. The methodological choice was suitable and appropriate for examining and understanding the wide range of benefits that are provided to the rubber manufacturing units using anti fragile frameworks. The different set of ideas and knowledge could be shared among the rubber owners of different manufacturing units in Sri Lanka so that they can achieve the desirable targets.

From the quantitative survey that was conducted, it could be identified and analysed that numerous managers had opined about the planning and use of antifragility supply chain frameworks since they would be able to identify the basic flaws that exist within rubber manufacturing thereby leading to addressing the issues and solving them with efficiency and accuracy. Overall market standards and proficiency could be maintained by the rubber manufacturing units to ensure that the overall business and marketing operations could proceed without any difficulties. The global owners and leaders of Rubber Manufacturing estates also shared their ideas about the rubber manufacturing units that operated in Sri Lanka and they had also supported the concept of applying anti fragile supply chain frameworks.

As per the logic-based illustration by Chienwattanasook et al., (2022), the Sri Lanka based rubber manufacturing units can diversify their suppliers and at the same time make a strategic move of increasing the inventories that would guide them to maintain and manage the stocks under them suitably. Also, the antifragile framework-based operations could proceed successfully by maintaining clarity with the help of smart technology networks that are found to exist in the Sri Lanka market. As per the logic-based illustration by Chienwattanasook et al., (2022), the rubber manufacturing entities also can design and apply the sustainable plans that would also aid them to develop the alternate logistics driven solutions that are effective and methodical to meet the basic needs of the consumers. The advanced technology systems enhanced by the data analytics would make sure that the well-defined and efficient ideas and knowledge can be shared efficiently for satisfying the needs of the consumers who get access to the rubber manufacturing units that operate in Sri Lanka. The flexible patterns of the supply chain can be associated with the redundancy so that the qualitative outcomes can be developed. The leadership skills and the basic observation about the rubber manufacturing entities ends to be proper by the managers and owners so that the plantation-based rubber manufacturing is done smoothly by adhering to logical antifragile trends and practices.

In this research project, the findings have also made observations that the Sri Lankan rubber sectors require keeping and designing their SCM strategies in an accurate place. It has also been observed that the anti-fragile approaches underlying within the supply chains of the rubber sector continue to exhibit poor management and preparation showcasing poor approach of planning. The researcher thus found that it is only with the acute assistance of the focal strategy or the investment strategy that the rubber manufacturing businesses of Sri Lanka can engage in initiating more anti fragile frameworks within the supply chains. The researcher also discovered that in the purview of developing the supply chain systems,

planning can also be considered as a significant contributor in the establishment of the anti-fragile supply chains and these systems require the ability and potential of foreseeing and preparing for the probable risks thereby mitigating the risks and ensuring smooth operational performance and quality management.

This research project has also highlighted the need for effectively diversifying the suppliers of the rubber manufacturing businesses of Sri Lanka, and their potential in enhancing the inventory for crucial elements and also creating alternative logistics routes at the same time. The study also shed light upon how the anti-fragile system tends to survive while acquiring advantages from the perturbations. The practitioners or any person thus involved within the supply chains require incorporating strategies which can be said to be premised upon sound theories so that these industries can engage in continuous improvement of the supply chain management.

## **6.2 Linking with Objectives**

### **Linking with Objective 1**

The specific objective could be linked to the relevant outcomes related to the use of antifragile framework within the rubber manufacturing units of Sri Lanka. According to the discussion and evaluation by Grumiller et al. (2021), the concept-based idea and evaluation of antifragile framework could prove to be significant upon being applied by the rubber manufacturing units of Sri Lanka. Nikookar, Varsei and Wieland (2021) had opined and evaluated that the networking systems that are associated with antifragile supply chain operations that focus and explore the different complexities that are specified as effective for the business operations to grow and evolve in a better way. Many respondents out of the sample size of 80 had responded that the antifragile supply chain practices and their methods was found to be sustainable and effective for the rubber manufacturing entities operating in Sri Lanka. However, antifragility appears to be a modern concept which concentrates much on growth. It depicts that an approach can effectively be strengthened with the help of exposure to a range of volatility. Moreover, the antifragile supply chain appears to be the one that can initiate gains from several disruptions both in terms of financial and non-financial aspects.

It is quite important to implement these learning from the antifragile principles into the day-to-day operations taking place in the industry. Doing so will have a positive impact on the supply chain operations as it will help in focusing of the risk management strategies.

For example, there can be a backup in case of keeping alternative routes or suppliers to reduce losses happening from random disruptions. According to the discussion and elucidation by Aoun et al., (2021), additionally, it is important to utilize technology be it IoT, AI or blockchain as it will help in quick decision making and minimize the probability of largely making mistakes. It is also crucial to build and maintain relationships with the stakeholders like suppliers, other distributors or service providers as these relationships will help in building transparency and may act as reliable sources in the future which can lead to mutual benefit. By implementing these things and aligning with these objectives the Sri Lankan rubber industry can bring an improvement in its performance and bring in more resilience.

### **Linking with Objective 2**

The well-defined and different factors exist for shaping up the development of antifragile supply chain framework and provide idea about its application patterns while processing and manufacturing rubber. It was also identified from the findings of the primary quantitative survey that antifragile supply chain management provides support to tackle and resolve any challenges that are caused by the supply chain operations. The agility of the owners of rubber manufacturing units and the advanced use of technology also proves to be effective for examining and addressing anti-fragile supply chain based operations and services in Sri Lanka rubber manufacturing units. According to the discussion and elucidation by Edirisinghe et al., (2024), the Rubber Manufacturing units that operate within the different regions of Sri Lanka do seem to discuss and analyse the complexities that arise within the market for designing training and skill development sessions that are useful and reliable for the smooth execution of the operational tasks and procedures systematically. The performance metrics could be addressed and the evaluation of the methodical concepts and traits could be evaluated perfectly for meeting the needs.

Now if the performance metrics is kept aside, it can be seen how important it is to measure the skill set possessed by the employees and further giving them extra training sessions. It is quite important as these training sessions will help the employees in knowing the skills required to deal with this antifragile industry. The sessions alone cannot be effective, so there can be an additional assessment and feedback session that will help in understanding the usefulness or effectiveness of these sessions. It will also encourage a platform for knowledge sharing and collaboration as well as a platform for healthy competition among the employees. The employees will be more open towards brainstorming to find out the best alternative that will benefit the industry and they can grow along with the

industry itself. According to the discussion and elucidation by Edirisinghe et al., (2024), the proactive managers of the Sri Lanka based rubber manufacturing units seem to be more industrious and competent to be able to address the risks posed to antifragile supply chains and try to make the overall regulation systems more sustainable in nature.

### **Linking with Objective 3**

According to the elucidation by Lotfi et al., (2023), the specific types of challenges were encountered by the managers who owned and supervisor the manufacturing units of rubber in Sri Lanka while making efforts to apply antifragile framework within the manufacturing units. The proper organizational culture and knowledge was lacking among the individuals who worked in the rubber manufacturing units of Sri Lanka based regions. The different relevant ideas also could be processed and adapted so that the methodical goals could be achieved perfectly. According to the elucidation by Lotfi et al., (2023), the Sri Lankan economic condition was a huge challenge for the different owners of rubber manufacturing units since due to scarcity of capital; they were unable to replace the old rubber saplings with the brand-new ones that would maximize their profits. According to the discussion and elucidation by Edirisinghe et al., (2024), the managers of the rubber manufacturing units in Sri Lanka also need to become more proactive to address the presence of weedicides and pesticides that had infested the rubber plantations and damaged the rubber plants.

To solve these problems, it is crucial for the managers to opt for proactive techniques and be more flexible towards their approach so that if the plan doesn't work out well, they can customize it as per the needs or the resources available to them. It is essential to improve the culture within the organization and encourage an environment where there will be continuous learning and development for all the stakeholders involved. The focus point is not just diversification of supply chain resources in the Sri Lankan market to reduce the impact that might be caused by external sources, but it is also to improve the production by switching to more sustainable resources. The competition is rising in the rubber industry as well and to be ahead of the game it is quite crucial to know what is it that will make the buyers more inclined towards this industry and they will not run away looking for options. Adopting more environment friendly resources could be one such way of being ahead in this competitive industry.

The different types of problems are encountered at the time of planning and designing the antifragile supply chain framework and its operations effectively by adhering to the sustainable market-based trends and operational features. According to the discussion and

evaluation by Chenaru et al., (2022), the different set off supply chain concepts and practices need to be devised and adapted according to the strategic dimensions and agile marketing policies. Most of the respondents who took part in the quantitative survey had responded to the question that helped to specify the effectiveness of the anti-fragile supply chain-based operations and services proving to be useful and standardized.

#### **Linking with Objective 4**

The strategic approach or tactics are adopted and implemented for addressing and resolving the challenges that are faced by the rubber manufacturing units in Sri Lanka. The technology driven digitalized insights about the supply chain strategies and their application could be processed and demonstrated with effectiveness and accuracy. The usage of technology driven tool has its own benefits like it would help in gaining deeper insights about the industry and help in streamlining the supply chain process or optimize inventory usage. The inclusion and application of advanced technological forms such as blockchain and AI will help in gathering real time information which will any day improve the decision making of the rubber manufacturing industry. It can also be said that the installation of these things in machinery will help in recognizing the restocking or production patterns and in future it will lead to an automated system which means a less errors being created, the probability of which was much more when all these things were handled by human beings.

Coordinated approach and its features could be processed and examined so that the basic supply chain framework and its operational practices and services could be processed sustainably. The configured frameworks of the supply chain-based concepts and practices need to be devised and adapted as per the well-defined and methodically designed sustainable standards ad policies. The suitable and effective sustainable policy frameworks would enable the Rubber manufacturing units to strategize and adapt to the complex surrounding features and volatility. From the opinion and evaluation by Priyadarshini et al., (2022), the well-defined sustainable strategies and trends could be shaped up for examining and understanding the wide range of issues that exist within the Rubber manufacturing units of Sri Lanka. According to the discussion and evaluation by Attaran (2020), the expenses of the supply chain-based frameworks can be reduced and managed effectively with the aid of the antifragile frameworks. The different types of digital activities that have become popular during the occurrence of the pandemic had led the Sri Lanka based rubber manufacturing units to achieve the desirable goals of enhancing operations. According to the discussion and evaluation by Piyatissa & Siriwardhana (2022), the stable and well-built supply chain based strategies and practices could be evaluated and successfully adapted according to the basic

market-based trends and policies being used. The Sri Lanka rubber manufacturing units would be able to design and incorporate the knowledgeable ideas with the aid of agile frameworks. According to the logical knowledge and expertise, the collaborative approach of rubber manufacturing units in Sri Lanka would be able to plan and operate with the desired efficiency and achieve the goals. The advanced training methods could be designed and managed by adhering to the sustainable standards and explained with efforts. The digitized tools and strategic approach could be specified and evaluated perfectly.

### **6.3 Recommendations**

The well-defined and effective recommendations that could be followed and implemented by the rubber manufacturing units of Sri Lanka were established. The recommendations are as follows-

The Sri Lankan rubber manufacturing industry is already largely growing and certain recommendations will enhance the supply chain management system more. The rubber industry has been dedicated more towards Global suppliers. It can shift its focus a little bit to the local suppliers as well, instead of being solely dependent on the Global suppliers. This will help Sri Lanka grow its economy and reduce its dependency on foreign suppliers.

It is crucial to be well-informed about the global trends happening across and the geopolitical developments as well. Keeping a check on these things along with the change in consumer needs and preferences will help the industry in customizing its supply chain strategies accordingly. To be well-informed the industry can work on developing a collaborative data-sharing platform or networks to facilitate real-time information sharing. They can also implement a supply chain management platform like some sort of cloud that will enable the stakeholders to safely share information among them. To enhance supply chain transparency and improve accountability training programs can be provided to the supply chain professionals on usage of these software and supply chain optimization and technology adoption. The stakeholders involved can also work on a risk-sharing agreement among themselves.

In the report, the usage of sustainable materials was mentioned, but at the same time sustainable packaging solutions for these materials can be promoted. Instead of using regular packaging materials, the industry can make an extra effort to invest in research and development to find more sustainable packing options that are both innovative and cheap. This will help in creating a brand image and attracting environmentally conscious customers.

Further, the Sri Lankan rubber manufacturing businesses could also work continuously towards reduction of social footprint of the subjected rubber supply chains and thereby subsequently, making use of positivity in their marketing approaches. The above findings made regarding the Sri Lanka rubber manufacturing businesses would help them compete among the “sustainability-conscious-world rubber market”, thereby making ultimate contribution towards rebuilding the hard-hit economy of Sri Lanka.

Based on the finding made in the research, it can be deduced that initiating improvement measures in the rubber manufacturing businesses of Sri Lanka for enhancing the supply chain management would include optimization of different operational aspects like logistics, sourcing, technology integration, and inventory management. The Sri Lankan rubber manufacturing businesses need to focus upon supplier collaboration and attempt to strengthen trade relationships with the rubber suppliers. This would also require encouraging transparency as well as collaboration for ensuring quality and steady supply of the raw materials. Such businesses also need to work upon improving the long-term partnerships or contracts as it could provide operational stability. Strengthening trade relations with other stakeholders would also ensure continuous quality management for the rubber industries. This is yet another recommendation for the Sri Lankan rubber manufacturing businesses as in order to strengthen the supply chain, implementation of stringent quality control measures throughout the rubber industries’ supply chain is advised. Regular quality checks and audits at all stages could also help in identifying and addressing the potential issues at an early stage, thereby making sure that only optimum quality rubber goods continue to enter manufacturing processes.

Another recommendation made for the rubber manufacturing business of Sri Lanka is to ensure strong technology integration. These businesses need to implement sufficient technological solutions such as “Enterprise Resource Planning (ERP) systems” which can lead to streamlined processes, improved communication, and enhanced visibility across the business supply chain. This would also ensure improved inventory management, production planning and enhanced demand forecasting. The businesses should also try at optimizing transportation by improving modes and routes for reducing cost structure and minimizing delivery time. This would also mean involving optimization software for routes and leveraging data analytics for finding the highly efficient transportation solutions thereby affecting the supply chains directly.

In addition to the above recommendations, the Sri Lankan businesses engaged in rubber manufacturing can make use of the research findings for enhancing operational



performance and thereby improve the supply chain management. To do so, these firms require enhancing both Quality Management Practices as well as Supply Chain Management Practices. Doing so could help such businesses in encompassing a wide range of activities throughout the rubber manufacturing organizations and would allow addressing aspects such as top management commitment, human resource management, customer focus, as well as information, communication, and analysis. These results drawn from the research reflect upon strategic significance to be adopted via cross functional approach as well as organisational wide applications through quality management and supply chain management in the rubber manufacturing sector. Thus, it is recommended by the researcher to make investment for initiating improvements in all these aspects and continue building up strategies to ensure continuous improvement in the Quality Management and supply chain practices in the rubber manufacturing organizations of Sri Lanka thereby enhancing competitiveness in the global market.

Improving Organisational Productivity along with Supply Chain Durability in Sri Lanka's The Material Production Industry:

According to the Sri Lankan rubber material production sector, supply chain management (SCM) are looking crucial and essential for increasing competition and effectiveness in operation. Based on the knowledge gained through earlier studies as well as empirical assessment, this study makes recommendations for improving SCM procedures to support resilient and long-term expansion of the industry. The recommendations, which are based on supply chain management and practical data, cover a wide range of logistics management topics, such as workforce growth, technology and flexibility implementation, risk-reducing techniques, collaboration, and investment in talent growth. According to these recommendations, companies belonging to the rubber-producing industry might enhance their communication with vendors, minimise dangers, and utilise opportunities towards long-term company growth and competitiveness.

1. **Promote Creative Relationships:** Collaborative efforts across all involved parties are necessary to increase adaptability and overall effectiveness in general. Companies should prioritise collaborating with suppliers, customers, and additional collaborators to share risks, financial matters, and effective practices. This involves creating channels of communication, organising incentives, and cooperating in creating benefit across initiatives. By fostering a collaborative atmosphere, businesses can take advantage of collective understanding and competencies to drive development and overcome volatility. Building lasting commercial connections with significant

suppliers and customers should be a company's first goal, with a focus on advantages assurance, and authenticity. Authorities marketing business entities can both support contact by providing spaces for networking, exchange of data, and more and problem-solving skills.

2. **Use Technology for Ability to adapt:** By integrating modern innovations like artificial intelligence (AI), the distributed ledger, as well as data analysis, logistics networks may become more efficient and flexible. Companies must invest funds in digital-age initiatives that enable preventative care, continual surveillance, including demand management. Businesses may use technologies to make better decisions, streamline procedures, and take steps to minimise interruptions. Businesses may transition into electronic manufacture and swiftly adapt to evolving consumer demands by implementing Industry regulations. Moreover, inventiveness in acquiring outputs, product development, and manufacturing processes may end up in lower expenses, improved productivity, and unique selling points. Furthermore, fostering creativity in companies by means of training, departmental cooperation, and advancements can support further development and ideas for market changing circumstances.
3. **Strengthen Customer Relationships:** For being a huge number of customer base is vital for maintaining a productive relationship with suppliers. Businesses should emphasise truthfulness, optimism, and continuous expansion while concentrating on beneficial relationships with big providers. This entails collaborating on security assigns and development, encouraging open communication, and carrying out regular provision evaluations. By means of the formation of long-lasting alliances based on a common set of principles, companies can efficiently handle operational risks, improve processes for purchasing, and thoroughly promote sustainable growth. Organisations should do exhaustive complicated analyses to identify potential threats and weaknesses in the infrastructure that business depends on, especially those pertaining to international relations, situations of emergency, and market fluctuations. For reduced risks as well as improving company reliability, these assessments assist companies by creating contingency plans, altering their procurement practices, and directing funds for recovery. Additionally, businesses always need to respond faster to unforeseen disruptions and capture hold of fresh opportunities by integrating adaptive arranging, flexible development, and purchasing into their logistics processes.

4. **Improve Inventory Management:** Effective product management is necessary to maintain a balance between cost of storage and disruptions. Companies are increasingly depending on software to allow solutions like Just-in-Time (JIT) frameworks with Vendor Managed Inventory (VMI), as well as to execute storage management techniques. Additionally, implementing requirement substitute techniques and implementing flexible guarding regulations would improve responsiveness to changes in the marketplace. Businesses are able to reduce overstock, increase satisfaction with clients, through promoting their revenue from optimising levels of stock through expediting renewal procedures. Businesses have to abide by globally accepted standards and requirements, including ISO 14001 including ethical trade, those have connections to labour freedoms, sustainability, and sustainable procurement. Furthermore, promoting accountability and traceability across the supply chain—from the point of procurement of raw materials through the pickup of the finished product—can increase users' and customers' perceptions of reliability. Adopting environmentally conscious production techniques, such as eliminating waste, maximising resource utilisation, and making use of renewable energy, can reduce environmental effects while also resulting in cost reductions over time and enhanced productivity.
5. **Investment in Talent Growth:** To create an adaptive and durable organisation that can accelerate performance, it has become imperative to make developmental initiatives. Programmes for instruction and growth that improve multidisciplinary cooperation, capacity to solve problems, in addition to supply network abilities must be given the greatest attention by businesses. Moreover, encouraging a society that values creativity as well as continuous growth might offer staff members with the equipment that they require to accept novel concepts and tools and adjust according to shifting circumstances. Businesses can help develop an educated staff to encourage organisational adaptability, responsiveness, and sustainability by engaging in people growth. It is recommended that businesses give precedence on educational programmes, training sessions, and information transfer activities to augment the competencies of their workforce within a range of areas, such as focusing for supply chains, control the workshop, purchase, among transportation. Furthermore, cultivating a climate that values autonomy, cooperation, as well as constant education can increase worker engagement and company adaptability in an environment of changing possibilities as well as difficulties.

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## Appendices

### Appendix 1: Questionnaires

Q1. Age?

- 25-30 years
- 35-40 years
- 40 and above

Q2. Gender

- Male
- Female
- Others

Q3. For how long have you been working in the rubber manufacturing industry?

- 2-3 years
- 4-5 years
- 5-6 years
- Above 6 years

Q4. Antifragile SC being a new concept do you have any idea about antifragile supply chain management?

- Yes
- No
- May be

Q5. Do you believe that the rubber manufacturing industry is considering anti fragile SCM?

- Yes
- No
- May be

Q6. What are the factors that seem to be affecting antifragile SC management on operational performance?

- Lack of knowledge
- Lack of sufficient resources

- **Future expectations**
- **Others**

**Q7. How far do you agree that the antifragile supply chain is able to foresee and prepare for potential risk?**

- **Strong agree**
- **Agree**
- **Neutral**
- **Disagree**
- **Strongly disagree**

**Q8. What do you think are the benefits of antifragile supply chain management?**

- **Easy to adapt to changes**
- **Withstanding of uncertainties**
- **Scope for learning**
- **Others**

**Q9. What are the areas that rubber manufactuieresrc in Sri lanks uses antifragile supply chain?**

- **Inventory management**
- **Supplier management**
- **IT integration**
- **Planning and scheduling process**

**Q10. How far do you agree that supply chain management intends to improve organisational performance?**

- **Strong agree**
- **Agree**
- **Neutral**
- **Disagree**
- **Strongly disagree**

**Q11. How does an effective supply chain management helps rubber manufacturing industry in Sri Lanka?**

- **Helps to deliver products quickly**
- **Minimising quality issue**
- **Improving value**

- **Neubagiting return with ease**

**Q12. What do you think are the issues faced in terms of managing the antifragile supply chain management to enhance the operational performance of the rubber manufacturing sector?**

- **Lack of resources**
- **Lack of effective collaboration**
- **Support from the government**
- **dearth of the infrastructure within several arenas**
- **Lack of digital solutions**

**Q13. How far do you agree that the issues faced hampers the effective management of the antifragile supply chain management?**

- **Strong agree**
- **Agree**
- **Neutral**
- **Disagree**
- **Strongly disagree**

**Q14. What are the strategies you feel can develop antifragile supply chain management on operational performance?**

- **Embracing of modern technologies**
- **Initiation of better planning**
- **Shape redundancy within system**
- **Initiate more flexibility and adaptability**
- **Others**

**Q15. How far do you think that these strategies can help to enhance the operational performances?**

- **Strong agree**
- **Agree**
- **Neutral**
- **Disagree**
- **Strongly disagree**