

Framework for Resilient Supply Chain to Tackle Disruptions

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Abstract - *Strategic decision making plays a significant role in today's world, which is full of unpredictable activities. The decision-makers of the organization must think about the different perspectives and methods of leadership development. Right policymaking by assessing the market is key to success. This paper mainly talks about the 4 important pillars of a resilient supply chain. These are the four main identified dearth of the supply chain of any organization. These deficiencies in the supply chain are classified as monitoring systems based on artificial intelligence, risk management capabilities, mapping of supply chain and vendor/supplier capabilities assessment. This paper concludes that the risk associated with the supply chain of the organization is mainly related to data management. This insufficient data transparency can suspend the operations of any organization. The supply chain of product-based organizations is not only dependent on the first-tier suppliers. Hence the inability of the decision-makers in the organization to quickly and easily access the information about their vendors makes the supply chain more susceptible to the disruption. Access to the data of the supply chain of vendors will allow companies to predict the situation quickly. Subsequently, it will help the decision-makers to react proactively to the disruption. This report recommends the framework for the resilient/sustainable supply chain of the product-based organization.*

Key Words: Framework, Resilience, Supply chain, Business Continuity Plan, Disruption

1.INTRODUCTION

The world is more susceptible to disruption than it was ever before. The crisis will arrive from anywhere- it could be the cloudburst which will flood the headquarters in cities like Mumbai, earthquakes which will destroy the manufacturing facilities in countries like Japan, or a pandemic like Ebola, covid19, which forces your staff in the affected area to work from home, or an act of cyberterrorism which brings the whole system down. In cases like this, it is crucial to have plans in place to ensure that the employees and company will keep going. It is essential for the sustainability of our operations, even if those plans do not yield 100% continuity. The process of

bringing together plans to minimize the effects of erratic incidents is at the core of the business continuity plan. Furthermore, there is a research gap in the business continuity plan and its implementation during the disruption time. A new initiative by the organization to mobilize an environment of their businesses around the possible disruption is a dubious gambit. Yet if we focus on implementing the right and strategic approaches through concrete leadership within the organization, it would increase the odds of success (John Hagel III, John Seely Brown, and Lang Davison, 2008,[1]). To fill this research gap, this paper provides you with the theoretical framework and initial results findings for the management field of supply chains working on the disruption. The structure of the proposed framework is drawn from the literature in risk management and the different models on the mapping and supply chain coordination

1.1 MOTIVATION

After completing my bachelor's degree in mechanical engineering, I started working as a quality control engineer at the Interpack Machines Pvt Ltd, Pune, India.

In 2018, Kerala, the southeast state of India, got affected by the severe floods. The businesses in this part of the state are enormously affected by the downpour. Interpack machines had the locally based supplier who procured the motors from the company based in this state. In this flood, the manufacturing facility of that company was severely damaged. Since the financial capacity of the Interpack does not allow to have the inventory of the DC motors. Interpack Machines Pvt Ltd struggled for the next eight weeks on the production line because of the inability of the procurement team to knock the same deal from other possible vendors from an unaffected part of India.

The main reason for this production loss was to lack information transparency between the supplier. The information about the multiple tiers of the supply chain in upstream would have helped the decision-maker of the procurement team to act efficiently. So, I wanted to make my unique contribution to this field so that any organization irrespective of its size would have better preparedness for the disruption.

1.2 OBJECTIVE

Most of the organizations, be it in New Zealand or in any other part of the world, it is exceedingly difficult to develop a cogent supply chain solution. The limitation is because of the research gap in the resilient supply chain. The scale of the disruption and the pace at which it develops makes the traditional supply chain more vulnerable.

In my opinion, when the disruption is in full swing, it is very difficult to limit the consequences if we don't have a reliable business continuity plan. The best way to approach such disruption is with the safeguarding framework, which will make the supply chain more resilient

Research objective: Create a concrete solution in the form of a framework that will investigate and address the challenges faced in the supply chain and will provide a high level of preparedness before, during, and after a disruption.

Research question: How can a result yielded after the research will help to solve the discontinuity in the businesses due to the disruption in the supply chain?

2. SITUATION OVERVIEW

We have observed that a large number of supply chain disruption are happened because of a natural disaster such as earthquakes, tsunami, and pandemics. The supply chain is always subjected to numerous events that can disrupt the operations. This disruption can take the form of uncertainty in the supply of raw materials, ambiguity associated with the demands, the problems associated with the warehouses, disrupted logistics, or any other catastrophic event. So, the preparedness for the disruption plays an important role in the post disruption operational efficiency.

Figure 2.1 shows the global impact of the coronavirus pandemic. Because of the pandemic, there are restrictions over the border. The insufficient manufacturing capacities of the organizations created the demand crisis. This impact is categorized based on the unavailability of intermediate products coming from China.



Fig2.1: Global Impact of Corona Virus.

The data in the table shows the most recent and significant events in 2018. The data chronologically tells you about the disruption events in 2018 by its date and location on the map. Out of five disruptions, three happened in the USA, and the remaining two occurred in the Asia- Pacific region. From the data, we can interpret that on an average, 5000 sites were affected in the disruption. The average time to recover post disruption is reported in TTR (Time to Recovery) column. We can see that minimum time to recover from the disruption is around 5 to 7 months, which is quite significant. Therefore, it shows the necessity of a high level of preparedness and business continuity plan

Event	Date	Location	Number of sites affected	Number of Parts Affected	Average Site TTR (weeks)
1 Bomb Cyclone, USA	Jan - 18	USA	9300	43166	25
2 6.4M Earthquake in Taiwan	Feb - 18	Taiwan	4800	33191	22
3 Hurricane Florence	Sep- 18	USA	2700	32167	29
4 Typhoon Mangkhut	Sep- 18	Philippines/ Taiwan/China	6500	62963	22
5 Hurricane Michael	Oct- 18	USA	2134	11743	25

Table No 2.1: The top five significant supply chain events

3. CASE STUDY- TOYOTA

Toyota Motor has a 25% share in an automotive component manufacturing company, Denso Corporation. On a quiet afternoon of the 11th March, when the east pacific coastline of Japan was hit by an earthquake followed by a huge tsunami, Toyota Motors, the automotive manufacturer, suffered enormous supply chain damage. The inability of the supplier to provide an automotive microcontroller forced Toyota to stop the production. These microcontrollers were produced by

Renesas Electronics. The Denso Corporation was a first-tier supplier of Renesas made microcontroller for Toyota. The Toyota production system has always received byline in the literature of scholarly articles. Such well researched and organized operational setup did not function over three months. So, we cannot find any better example than such an efficient and effective production system to study the resilience in the supply chain.

Effects on the Production line of Toyota

So, from 11th of March to 30th June, the articles were published in Nikkei, a stock market index for Toyota. According to these articles following is the chronology for the events that happened in Toyota.

11th March	Earthquake in Tohoku.
14th March to 26th March	Toyota shut down all domestic production plants.
15th March	Cutdown the production in the overseas plants.
28th March	Production of hybrid vehicles in plant Fukuoka and Tsutsumi resumed.
11th April	Sagamihara Plant started the production of cars.
18th April	The management decided to start all domestic plant, and because of lack of inventory, decided to keep the utilization rate at 50 %, and optimize it by the end of June. Similarly, for plants overseas, plants will run at a 40 percent utilization rate and planned to regain it by August.
22nd April	The production across all plants around the world will normalize by Nov- Dec.
11th May	The production rate as good as pre-earthquake will be achieved by July.
6th June	Single shift a day policy changed to two shifts a day for all domestic plants of Toyota.

11th June Forecasted, the sales of the company will reach around 8 million.

3.1 Whys and wherefores of disruption in Toyota supply chain.

1. The unavailability of the data on the source and location of the parts in subassemblies takes a toll on the management of the supply chain department. It was estimated that Toyota took a week to figure out and list around 500 parts in subassemblies. By the end of this herculean task, it was reported that those 500 parts were procured from two hundred different sources involved in tier two and tier three of the supply chain.
2. The highly integrated coordination mechanism and practice of decomposing big assemblies into small subassemblies and obtaining it by contract from an outside supplier did not allow the management to map the data further down in second tier in the supply chain.
3. The concern about the unmapped supply chain was not only limited to Toyota. Tier two and tier three suppliers in the supply chain also faced similar problems like Toyota. Companies went berserk while listing the missing parts in the supply chain. It was on public record that Fujikura Rubber, a manufacturer of rubbers used in tyre, brakes, clutches, etc., came into the spotlight because of the same crisis. They were suppliers of rubber parts to Toyota.
4. Toyota took three months to recover to its production rate as equal to the pre-earthquake level. Fujimoto (2011)[2] stated that there were many direct and indirect mainspring involved in disruption, pointing out three major impetus: unmapped suppliers of semiconductors, chemicals involved in tyres and brakes, microscopic parts such as fasteners, washers, o-rings, etc.
5. The highly dependent supply chain on first tier vendor Denso Corporation for microcontroller unit. It was estimated that in the year 2007, Toyota procured around half of the parts related to automobile electronics from Denso Corporation. It was attributing a dependency of 44%. It was reduced from 75% in 1992 (Tokuda, 2008, [3]). Renesas was the supplier to Denso, whose manufacturing facilities were damaged

in an earthquake. Table 3.1 shows the world-wide share of Renesas Electronics in terms of automobile MCUs.

44%	Renesas Electronics (Naka Plant: 20%)
22%	Freescale
9%	Infineon Technologies
7%	Texas Instruments
6%	Fujitsu Semiconductor
3%	ST Microelectronics
3%	Microchip Technology
2%	Toshiba
4%	Others

(Source: HIS iSuppli)

Table 3.1 The world-wide share of Renesas Electronics in terms of automobile MCUs.

- Another reason was the single sourcing of microcontroller unit used in automobiles. Renesas Electronics was in the fourth tier or fifth tier of supplier for Denso. It was quite astonishing that Denso understood the risk associated with it, but still, it chooses to keep that risk unaddressed (Tokuda, 2008,[3]). The reasons could be related to two areas; Quality and non-transferable software.
- In regard to Quality, Toyota demanded high quality of the semiconductor. This is because of the nature of the business. The automobile is expected to have a functional indemnity of around 10 to 15 years. The conditioning of the product over this life cycle significantly dependent on many external factors. The quality parameters are not similar for the same functional semiconductor used in automobile and otherwise. Hence, the quality is expected to avoid possible fatality and risk associated with the failure of semiconductors in automobiles. Table 3.2 shows the difference in the quality required for automotive semiconductors and other consumers. Renesas had the manufacturing capacity to produce the semiconductor with defect rate as low as one ppm. Hence, the manufacturing ability to produce the semiconductor at a potentially low cost created a competitive advantage for Renesas Electronics.

3.2 The inferences are drawn from the Toyota case study

To attain a high level of QCD, the coordination among all tiers of supply chain necessary. This provide a high level of ground visibility.

- Standardization of the key component will reduce the need for extreme coordination among different suppliers and enables the multisource of the key component.
- Mapping across the supply chain will provide good visibility.
- Vendor development should have been conducted to create an option for multiple sourcing. It will reduce dependency.
- A monitoring system supported by AI should be part of the supply chain security team.
- Need for resilience tactics incorporated within the supply chain.

So, to see where this learning stand, we will further discuss the case study of Biogen and how they managed to come out of disruption efficiently. This case study will further bolster the argument of having a business continuity plan as a tool for preparedness for the disruption.

4. CASE STUDY- BIOGEN

(Source: www.reilinc.com, [7])

4.1 Introduction

In the year 2017, the supply chain was rocked globally by four disastrous events in North America. It includes three major hurricanes Harvey, Irma, and Maria, on the southeast coast of the USA and an earthquake in Mexico City. The estimated infrastructural loss was around USD 2.7 billion. These back to back natural disaster rattled the operations of many industries in that region. While most of them are trying to figure out the impact and possible ways to resume the operations, Biogen, the multinational biotech company, managed to remain unscathed and able to recuperate rapidly. The Global Security Operation Centre equipped with proper supply chain intelligence and tools and played an important role in the rapid recovery of the Biogen. This operational capacity of Biogen managed to identify the weaknesses in the supply chain by cross-functional communications and provided the go-ahead for risk management activities.

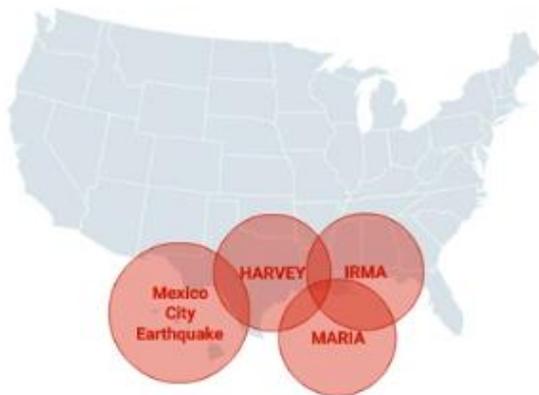


Figure 4.1 Supply chain disruption in North America, Sept 2017.

4.2 Risk Management Synergy in Biogen.

The Biogen has Global Security Operations Centre, an internal department, equipped with artificial intelligence to monitor the operations across all branches. This artificial intelligence facility was developed to monitor various manufacturing or storage facilities spread over four continents. This highly integrated inhouse system is used to monitor anything related to the safety of their people. This GSOC tool has enabled them to track the major movement of their product. It provides good insight into major political conferences and events regarding their product. It provides the data for the analyst so that they can predetermine the impact of such events moving into the future.



Fig 4.2: "Global Security Operations Centre," Biogen Corp.

Social Media and other intelligence tools are used to study the impact of possible disruption and then react proactively to safeguard their employee, products, facilities, or any other activities that Biogen possibly involved in.

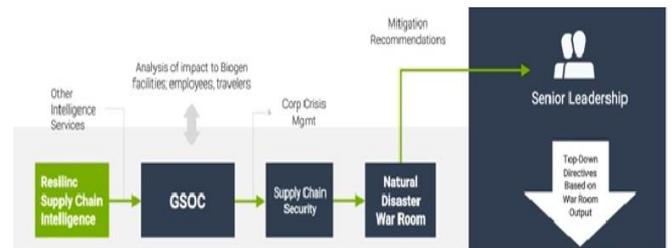


Fig 4.3 Biogen GSOC integrated with Artificial Intelligence.

So, this is a schematic diagram (figure 4.3) for the flow of information in an integrated system of GSOC. The GSOC interface is equipped with different types of supply chain intelligence in the form of social media, big data interface, and other subscriptions to the news and analysis. Every time it starts with intake from the intelligence. So much critical information is analyzed at the global security service center with the help of experts. For example, in the case of a hurricane, experts analyze it with the help of predefined questionnaires such as where it is forming where it is heading? And which regions will get affected? And what is the intensity of the impact? And what all facilities will get impacted? etc. Hence, this highly integrated GSOC gives ground-level visibility of possible impact.

In GSOC, the experts perform what-if analysis to determine the possible impact on each division of the facilities. So this information is GIS triaged to natural disaster war room for further scrutiny. The experts around the department brainstorm and produce possible mitigation recommendations for the stockholders of the company.

4.3 Role of Artificial Intelligence and Mapping

To explain it further, the below figure (figure 4.3) is an analysis of the possible impacts of Maria hurricane on Puerto Rico. With the help of data available, the crop crisis management team identified the area and people working in that region. They were contacted to ensure their safety and provide the required forecast on the possible disruption. So the supply chain security team analyzed the data available. The depth of visibility and availability of the enable to identify the manufacturing component which is supplied to the Biogen. This information was used to measure the risk index, considering if this component remains unavailable will impact the medical testing severely. It may impact 600 clinical patients by getting treatment on time. Furthermore, from the business point of view, the impedance to clinical trials will provide a competitive advantage to other companies.



Fig 4.4 Visual demonstration of AI (Hurricane Maria).

So, this visibility provides you concrete evidence so that lower management can escalate the information to the higher management. It empowered the teams to make proactive decisions by collaborating with people from different disciplines such as finance, production, quality, and logistic. And it allowed procuring necessary components if the manufacturing facilities get disturbed and ensure they have what they want for continuing the medical trials.

As a case here, most of the time, the impact on the supply chain would not be the direct impact. At times our vendors or stakeholders in business might get affected by the disaster directly or indirectly. So, it becomes very important to have clear visibility down the supply chain. Any organization usually has data about the first-tier supplier. Hence, in the time of disruption, clear information about tier two and tier three would give a good lead to the supply chain security department in the decision-making process. So, there are many pharmaceutical companies on the island, Puerto Rico. But, in the case of Biogen, they don't have manufacturing facilities. So, first perception tells us that there is no direct impact of the Hurricane on Biogen. However, because of mapping, the data available on the first tier, second tier, and third tier supplier of Biogen enables the ground-level visibility. The mapping of their supply chain attributed in identifying various specific components that are important to conduct a clinical trial. The ability to quickly identify precise information about the components, parts, and their suppliers on island, which normally an association wouldn't have, allowed to move quickly and put the mitigation in place.

There are four major takeaways that can conclude the success of Biogen in dealing with Hurricane Maria. So proactive assessment in identifies the risk and vulnerabilities, the capacity assessment of the vendors in the possible affected region, the cross-functional communication, and risk intelligence ascribed the smooth

and efficient conduct of clinical tests even after the disruption.

1.Proactive Assessment

Identification of vulnerabilities

3.Mapping to Established Streamlined Communication
Establish cross-departmental communication

2.Decision to Ensure Capacity

1. *Made Purchasing decision ensure capacity from the region at risk of possible disruption*

4.Risk Intelligence

Steadfast team for mitigating the problem.



5. DISCUSSION

The supply chain is the backbone of any product-based organization. The increase in the disruptions that occurred around the world has made the expert think and reiterate the need to develop transparency or visibility across the supply chain. From the case study of Toyota discussed above, it has been observed that companies who produce and sell the finish goods generally have a brief understanding of the production and schedules related to a shipment of their Tier1 suppliers. The manufacturing setup can succumb because of the limited knowledge further up in the supply chain. So even on the normal production day, the visibility across the supply chain of the organizations can bring efficiency. The more visibility across the supply chain will provide agility to the decision-makers. When the supply chain is hit by critical disruption, the mapping of the supply chain becomes very vital. It will provide a clear understanding of the effect of the disruption on the other parts of the supply chain. It will help the decision-makers to plan around the ecosystem and take necessary actions. Because of globalization and access to the open market, the simplest product could be integrated with a very complex supply chain in the background.

The disruptions or situations like lockdowns can cease production temporarily. The logistic support will not work efficiently in the case of an organization with a complexly integrated supply chain across the border. To advocate this, Fiat Chrysler, the automobile manufacturing setup in Serbia, announced that the production at a car factory would be stopped temporarily in the late month of January. This decision came after the lockdown in China because of the coronavirus outbreak. Even Hyundai, the car manufacturing company, decided to cut down the production because of the affected suppliers in china. The data shows that the total number of flights accounted for international air travel for trade cargo has reduced by

55% after the outbreak of coronavirus (Rebecca Liao et al. 2020,[4]).

Hereafter we will try to pinpoint some areas of supply chain coordination, which are very crucial to achieve resilience. We will critically compare both case studies and try to draw an inference from the failures and successes of both companies.

- Proactive identification and assessment of vulnerabilities.

Industries that are evolving to be robust and operate on a long supply chain, mostly because of outsourcing nature, are progressively facing challenges regarding the risk associated with demand and supply. Svensson (2000) [5] stated that "The supply chain vulnerabilities increase, and it will increase even more if companies, by outsourcing, have become dependent on each other organizations." In the case of Toyota, the management failed to assess the high risk related to single sourcing of the microcontroller MCU. However, the limitation on multi-sourcing was enforced because of quality parameters, but it can be tackled by vendor development incentives. On the other hand, Biogen managed to identify the possible risk and because of the Hurricane. So, the proactive identification and assessment of the risk become very crucial here. To be able to identify that, the need for artificial intelligence very useful. The digital platform, capable of handling big data and able to extract the necessary information out of it, is very important.

- Ensuring Inventory capacity.

The purchasing decision is solely dependent on the management after the information about the possible disruption has escalated to them. Ensuring the inventory capacity of key products from the region at risk of possible disruption is very fundamental. Biogen identified it and made decisions with regard to it. They made sure that the supply of key components used in conducting the medical test is in abundance. They assured the supply by purchasing and holding the inventory. On the other hand, Toyota, though the manufacturing facilities of domestic supplier was demolished by earthquake, the overseas production was also hampered by the lack of inventory of the microcontroller (Matsuo, H. 2015,[6]). In general, the inventory models are designed in a way that the operational cost, inventory cost, and holding cost would be optimized. Clearly, not every expert working in the field of inventory management are neutral towards the risk. Some of them showed the readiness to embrace the less operational profit for the security of the manufacturing by holding the inventory of crucial parts (Schweitzer and Cachon, 2000,[7]).

- Mapping across the Supply chain.

The need for supply chain mapping is inevitable. The mapping of the supply chain should be carried out to simplify the organization's viewpoint over the link of strategic planning and the structure of the supply chain. John T. Gardner (2003) stated that "a well-documented supply chain mapping approach can lead to an improved supply chain management procedure. In any continuous improvement environment, the need for consistent and documented processes is key for incremental improvement. While radical changes that provide quantum improvements are critical, incremental improvements will continue to be important. Mapping can be important in providing guidance in the quantum changes in the supply chain, but there should also be incremental improvements in the mapping procedure itself."

In the case of Biogen, the supply chain of the organization was mapped beyond just tier one. The identification of components and their source was possible because of the prior availability of the data. The mapping gave visibility over the supply chain. Hence, it attributed to the assured supply of a key component. Contrary, Toyota struggled for weeks just to list the missing parts, which are essential to the production of the automobile.

- Vendor Capability Assessment.

This could be the less talked area in the report but holds great importance in building the supply chain with resilience. There are various parameters such as QCD (quality, cost, and delivery), financial stability of the firm, sustainability, and potential to maintain long term relationships, logistics and other operational capabilities, which we can assess the trading potential of the vendor.

6. CONCLUSION AND RECOMMENDATION

This report concludes that the risk associated with the supply chain of the organization is mainly related to data management. This insufficient data transparency can suspend the operations of any organization. The supply chain of product-based organization is not only dependent on the first tier suppliers. Hence the inability of the decision-makers in the organization to quickly and easily access the information about their vendors makes the supply chain more susceptible to the disruption. Access to the data of the supply chain of vendors will allow companies to predict the situation quickly, and subsequently, it will help the decision-makers to react proactively to the disruption.

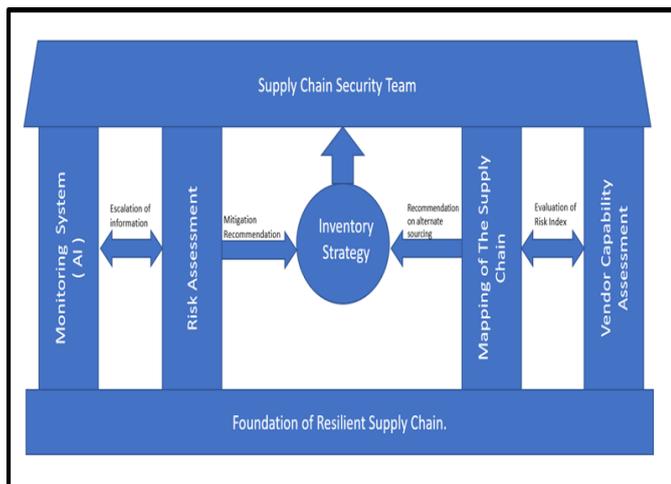


Fig 6.1 Preparedness Framework for Resilient Supply Chain.

This report recommends the framework for the resilient/sustainable supply chain of the product-based organization. The following are the points covered in the framework.

Mapping of the supply chain, establishing a platform with big data infrastructure. This platform will create the multi-enterprise network linking local or global raw material/services suppliers securely, and it will allow the decision-makers of the organization to have access and visibility of their facilities, manufacturing setup, warehouses, etc. This visibility to the parts and suppliers will reduce the effort. Encourage the system, which will allow real-time information sharing between the suppliers and the customers.

The help of artificial intelligence (AI): Companies should invest in the digital interface, which will act as an event monitor. This will allow the organizations to pinpoint the sites and all real-time information. This news extraction platform will detect any event which can possibly impact the supply chain. The platform which will restrict the unnecessary noise and will provide the important and actionable news/notifications. The comprehensive research will allow the decision-makers to react swiftly and efficiently.

Perform the assessment of the vendor/supplier capabilities. The quantitative and qualitative evaluation of the supplier should be done using a matrix that considers key factors. These factors would hold weightage in the assessment. Factors will be around the business capabilities of the vendor in terms quality of the product, location of the facilities, inventory cushioning, logistic capabilities.

Develop risk management capability of the organization. This would be mainly divided into three factors, visualize

the supply chain, measure the risk objectively by prioritizing the vulnerabilities, and finally protect the supply chain by collaborating with employees to mitigate the risk

Furthermore, to incorporate the above recommendations into the structure of the supply chain, the fully dedicated team should be developed to ensure the global security of the supply chain. The team will ensure the high level of swift coordination to develop the mitigation recommendation on the future possible risk. After analysing the big data by the monitoring systems, the escalation of the information should be carried for the mitigation recommendation. The risk management strategy integrated with the data available with vendor assessment index, the proper inventory strategy can be decided. This strategy could be long term or short term depending upon the risk assessment of the disruption

The proper inventory strategy supported with the monitoring system and mapping of the supply chain will give clear visibility on the risk index of the vendor. Similarly, the data available through the mapping of the supply chain of the same product keeping multisourcing in mind, will enable decision-makers to procure the key elements from the vendor with the least risk index. So, this highly integrated structure of the supply chain will prepare the organization for the disruption. Moreover, it will ensure the quick recovery and efficient operation of the supply chain.

ACKNOWLEDGEMENT

I would like to express profound gratitude to my guide Prof. Bruce Marks for his valuable support, encouragement, supervision, and useful suggestion throughout this project stage. His moral support and continuous guidance enabled me to complete my work successfully. I am grateful for the cooperation and constant encouragement from Head of Department Prof Garry Miller. I would also like to acknowledge his timely support and management during the project work. I attribute my heartiest thanks to all my friends Mr. Zubair, Mr. Akhil, and Miss Kimaya Mulay for their valuable advice throughout my work. Last but not least, I am thankful and indebted to all those who helped me directly or indirectly in the completion of this project report.

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