

Analysing the risk in the supply chain of apparel industry during an epidemic outbreak

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Abstract

Companies try to continue in business but struggle because of disruptions they face in the supply chain (SC). In this research, it is explored the SC risks faced by the apparel industry during an epidemic outbreak. It aims to investigate what type of risks are associated during an epidemic outbreak and how it has affected the SC. Further, it is investigated which risks should be prioritized, how to develop a suitable model to identify the SC risks and vulnerabilities. The data is collected from literature, interviews and surveys from leading personnel in the Sri Lankan apparel industry. It is then mapped in a vulnerability matrix, tested and validated. In this study, it is identified that the loss of international key suppliers and order cancellations are the riskiest. A generalized vulnerability model is developed in this study considering cost and time factors, however, it can be customized using different factors and risks depending on the experience and needs of the company. The study can be further developed to identify the SC risk mitigation strategies that should be taken to mitigate the SC disruptions during an epidemic outbreak.

Keywords

Supply Chain Disruptions, Supply Chain Risks, Epidemic Outbreak, Risk Model, Vulnerability Model

1. Introduction

A supply chain (SC) disruption is any sudden change or crisis which negatively impacts the interconnectedness of a network of people, organizations, and activities where the movement of a product from a supplier to a final customer is affected (Meyer, 2020). This effect can be either local or global. "It's impossible to anticipate the arrival of global crises such as the coronavirus outbreak, but firms can mitigate their impacts by taking supply chain preparedness to a higher level", says James B. Rice, Jr. in an article published in Harvard Business Review (Rice, Jr., 2020).

Supply chain disruptions can occur in a company because of legal disputes, strikes, natural disasters such as the 2011 Japan Tsunami. It reduced Japan's exports between 0.5% to 1.6% (Escaith et al., 2011). Manmade catastrophes where a brake-fluid proportioning valve supplier was under fire on 1st February 1997 which led Toyota to shut down all its plants and assembly lines and caused a sales loss of 70,000 vehicles (Ziaul et al., 2015; Nishiguchi & Beaudet, 2002). And special cases like epidemic outbreak (Ebola, SARS, MERS, Swine flu, and coronavirus/ COVID-19) (Ivanov, 2020). Due to COVID-19, China's industrial production has decreased by 13.5% for the month of January and February 2020, compared to the previous year figures (Seric et al., 2020). More than 75% of U.S. businesses have experienced supply chain disruption as a result of the COVID-19 outbreak (Leonard, 2020; Meyer, 2020; Hobbs, 2020).

The apparel supply chain aims to provide the right fashion products, simultaneously to satisfy the market needs, with the lowest possible cost, fastest speed and maximized profit (Hui and Choi, 2016). "No-one wants to buy clothes to sit at home in," says Simon Wolfson (McIntosh, 2020). Due to the coronavirus the fashion industry has been negatively impacted on every imaginable level where production has ceased, retailers have closed and demand has plummeted to 34% in March because apparel is not a basic human need (McIntosh, 2020). Therefore, the demand for apparels during a pandemic was very low. However, its contribution to the economy is significant. In 2018, the global clothing and apparel market reached a value of \$758.4 billion and has been growing at a compound annual growth rate (CAGR) of 7.5% since 2014 (Businesswire, 2020). Moreover, the target for 2022 which was set before the onset of COVID-19 was a CAGR of 11.8% to nearly \$1,182.9 (Businesswire, 2020). Furthermore, the Sri Lankan apparel industry

which contributes 6% to its country’s GDP and 44% to its national export revenue, had set itself a target of \$8 billion export revenue by 2025, prior to the onset of COVID- 19 (BOI, 2020; EDB, 2020).

The experience the Sri Lankan apparel manufacturing companies faced was very similar to the global context as most of the apparel manufacturing companies were struggling without raw materials for the upcoming orders. With the spread of the virus for over 65 countries, lockdown procedures were taken place, including Sri Lanka where companies went through a temporary shutdown (Kilpatrick and Barter, 2020). Furthermore, due to the locked-down revenue wasn’t generating in companies, therefore, they went through a salary reduction and termination of temporary staff. According to Escaith et al. (2011); Ziaul et al. (2015); Nishiguchi & Beaudet (2002); Dmitry (2020); Hippold (2020); and Seric et al. (2020) supply chain disruption has negatively affected the world’s economy. Therefore, this study focuses on supply chain risks faced during an epidemic outbreak in order to handle and mitigate the effect which is caused by it. We have taken the step towards identifying the supply chain risks faced during an epidemic outbreak. Since the recent event of COVID-19 and the significant importance of the Sri Lankan’s apparel industry, the scope of this study is to identify supply chain risks during an epidemic outbreak in the context of the Sri Lankan apparel industry. The primary objective of this study is to identify the supply chain risks in order to be prepared, mitigate the effects and ensure business continuity. The study proposes a model to identify the supply chain risks and vulnerabilities during an epidemic outbreak, and which risks should be prioritized. It is also well explained as to which threats should prioritize to the addressee in order to mitigate the effects of the risks.

2. Literature Review

According to Xu (2008) managing supply chain disruptions revolves around, thoroughly understanding the identified risks and increasing the capacity of the supply chain. In this study, it is focused on supply chain risks which are occurred in the Sri Lankan apparel industry during an epidemic outbreak.

According to Abdel-Basset and Mohamed (2019) risk is based on the organization’s magnitude and risk management allows the company’s performance to be more confident in supply chain sustainability decisions. They have used a combination of plithogenic multi-criteria decision-making approach based on the Technique in Order of Preference by Similarity to Ideal Solution (TOPSIS) and Criteria Importance Through Inter-Criteria Correlation (CRITIC) methods for a real-world case study of the Telecommunications Equipment Company (Abdel-Basset and Mohamed 2019). The identified risks and categories are shown in figure 1. The results show that the financial risk criteria is the most important main criteria and we can consider it as the cost perspective for our study.

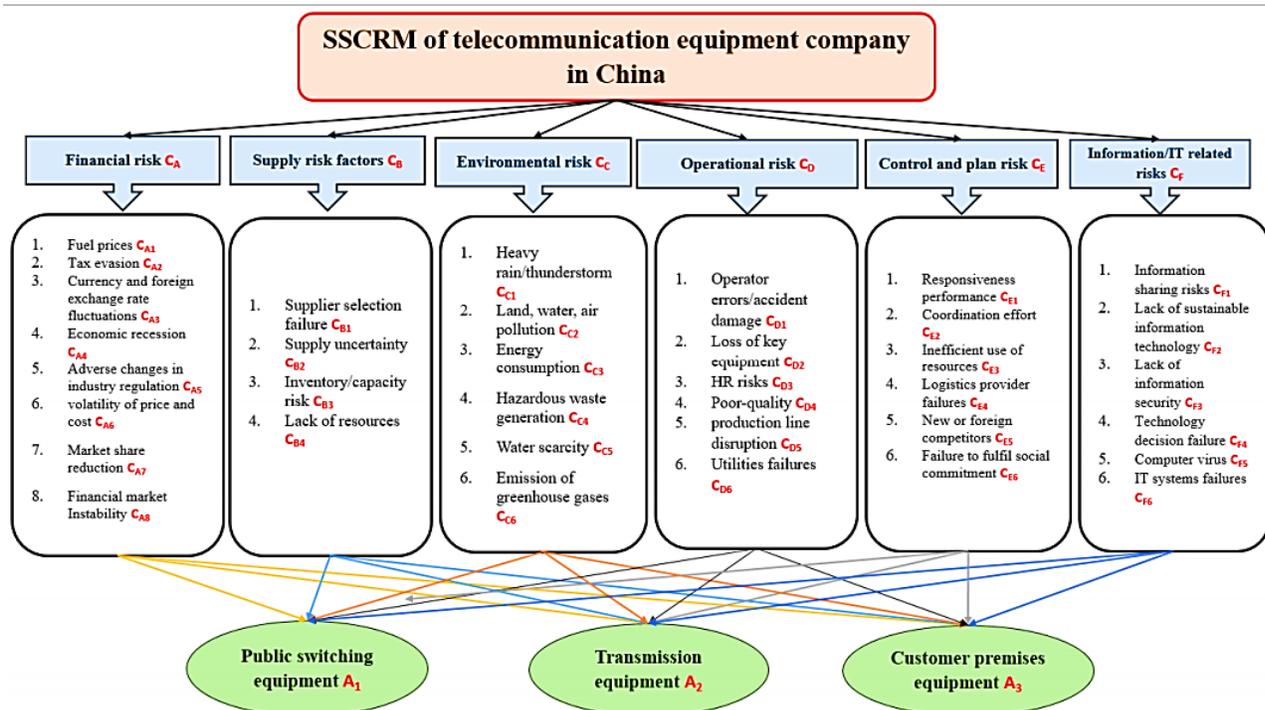


Figure 1: Risks and categories of a telecommunications equipment company (Abdel-Basset and Mohamed 2019)

According to a systematic literature analysis by Queiroz et al., (2020), COVID-19 outbreak can seriously wreak havoc on supply chains around the globe. Traditionally the interplay between supply chains and epidemic outbreaks has focused on resource allocation problems and supply medicals distribution, using optimization approaches and epidemic models. However, in the respect of the COVID-19 pandemic investigating the impacts of epidemic outbreaks should focus on robust research stream (Ivanov 2020; Queiroz et al. 2020).

According to McMaster et al. (2020) lean supply chain management is favored for its cost and waste reduction advantages, and limited by the lack of supply chain transparency that results increasing demand volatility. However, even though this problem exists in the agile supply chain, agile supply chains combat by focusing on enhancing communication and buyer-supplier relationships to improve information exchange which lead to an associated increase in inventory and inventory costs (McMaster et al. 2020). The COVID-19 pandemic has caused supply and demand disruptions which have resonating effects on supply chain activities and management, indicating a need to build flexibility to mitigate epidemic and demand risks (McMaster et al. 2020). Therefore, we have taken the first initiative of identifying the supply chain risks and classifying them.

Risk can be defined as “uncertainty of outcomes”, “probability of lost or lost occurrence”, “deviation of outcomes from expectation”, “change leading to loss” or “danger of harm loss” (Xu 2008). Using the mentioned risk definitions, Xu (2008) has identified the following basic risk characteristics; risk is an attitude towards future, rooted in uncertainty, occurred because of lack of information and disadvantage to the company. It means that time, uncertainty, information and loss are key factors. Moreover, Xu (2008); Sheffi and Rice Jr., (2005) have identified single port closure, multiple port closure, transportation link disruption, loss of key supplier, labor unrest, economic recession, visible quality problems, computer virus, workplace violence, flood, wind damage, IT system failure, accounting irregularity, earthquake, employee sabotage, technological change and product tampering as supply chain risks and developed a vulnerability matrix using disruption probability and consequences (shown in figure 1). Further, they have discussed that the supply chain could be resilient if the company follows a mixed approach of flexibility and redundancy.

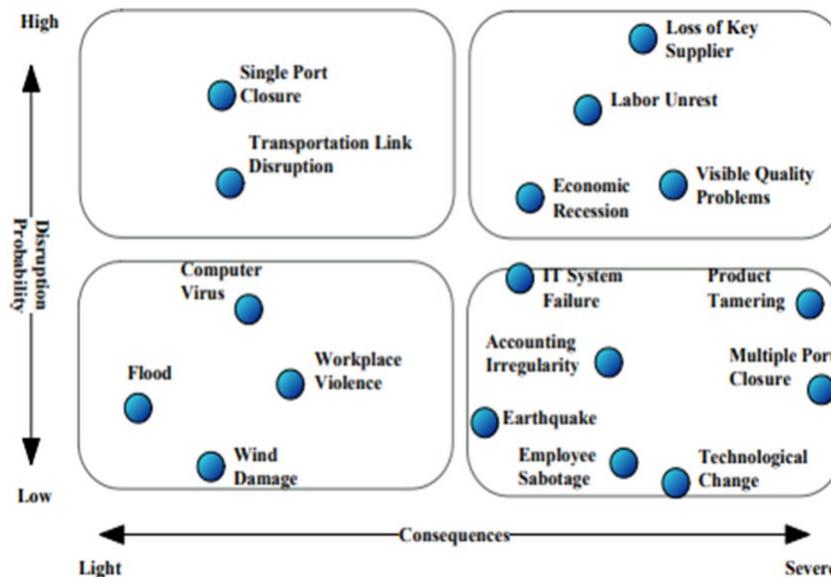


Figure 1: Vulnerability map for a single firm (Xu 2008; Sheffi and Rice Jr., 2005)

Venkatesh et al. (2015) have discussed, selected risks which are associated with the apparel retail supply chains in India by structural analysis of the controllable risks that are identified. The risks they have selected and the background of it are shown in table 1.

Table 1. Risk assumptions (Venkatesh et al. 2015)

Risk no.	Risk	Background of risks
R1	Globalization	Currency fluctuations; design transfers, competition; legal and political risk; policy changes; etc.
R2	Raw material and product quality standards	Retailers do not have the complete SOP of the product quality and it varies from season to season/ and product to product
R3	Scarcity of resources	Scarcity of raw material; power shortage; labor shortage; resource cost; the cost of technology etc.
R4	Supplier uncertainty	Failure to deliver on time; supplier bankruptcy; unreliable supplier; Cost and quality not reliable/ consistent; etc.
R5	Lack of co-ordination/ alignment	Lack of communication; no cross-functional teams; no transparency between partners/departments; etc.
R6	Behavioral aspect of employees	Employee disputes; inefficient/ unskilled employee; resistance to change; unavailability of labor due to absence; etc.
R7	Infrastructure risks	Transport breakdown; inadequate means of transport; inconsistent warehouse facility; IT failure; etc.
R8	Delay in schedule/ lead time	Order fulfillment error; change in production schedules; machine breakdown; delay in delivery; change in design; etc.
R9	Demand uncertainty	Error in demand forecast (short term or long term); bullwhip effect; short product life cycle; risk from new entrants; etc.
R10	Customer dissatisfaction	Product returns; customer complaints; reduced demand; stock out; poor quality; wrong product delivery; etc.
R11	Financial risk	High cash conversion cycle; low market share; low-profit margins; decreasing revenues; etc.
R12	Security and safety	Pilferages and shrinkage of the materials in the warehouse/losses in transit, performance of the product, cyber-attack; etc.

Venkatesh et al. (2015) has revealed the use of Interpretative Structural Modeling (ISM) to establish the interdependencies between the risks (table 1), spread across various supply chain functions where they have classified the risk factors based on their driving and dependence power (figure 2). They have identified that globalization, labor issues and security and safety of resources as the strong drivers of other supply chain uncertainties which will lead the company to a financial crisis (Venkatesh et al. 2015). The variables they have considered are limited, generic and the costs, frequency of occurrences of disruptions can be used to prioritize risk where strategies can be formulated to mitigate the risks.

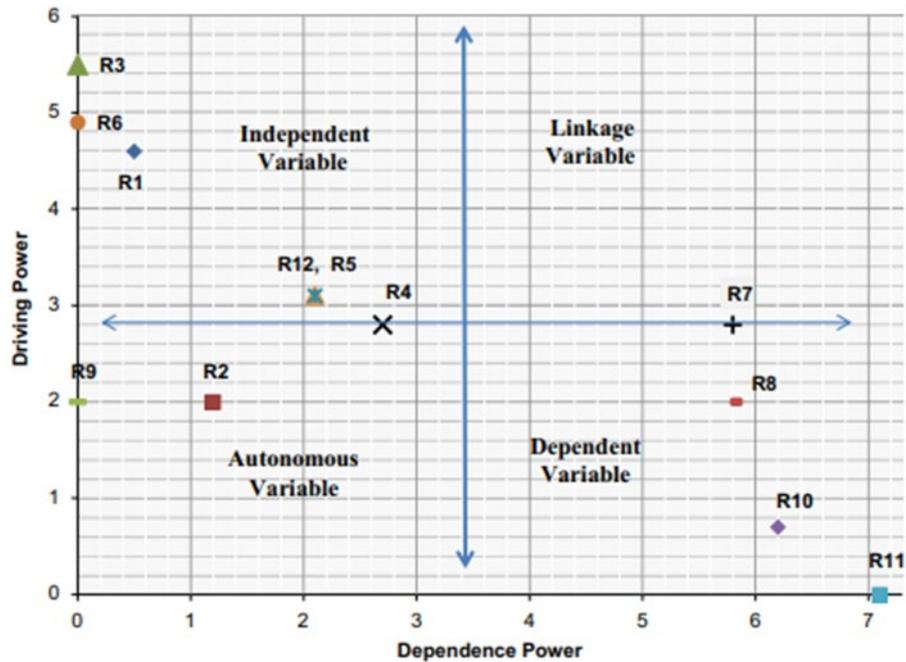


Figure 2: Cluster of risks (Venkatesh et al. 2015)

Tukamuhabwa et al. (2017) have used 45 face to face interviews with open-ended questions to analyse 20 manufacturing firms in Uganda. They have identified, classified the supply chain risks/ threats as Endogenous (supply-side, firm-level, demand-level), Exogenous (geopolitics, economic) using the collected data and it is shown in table 2. They have further analysed to identify the interconnectedness of supply chain threats, strategies and outcomes. However, considering the scope of our study we haven't taken the strategies and outcomes.

Table 2. Supply chain risks classification (Tukamuhabwa et al. 2017)

Category	Supply chain threats	Examples
Endogenous	Supply-side	Long-distance sourcing triggered threats, limited local supply market, product counterfeiting, poor-quality raw materials, dishonest suppliers, raw material delays and shortages, financial difficulties of suppliers, supplier delivery failure, reputational risk
	Firm-level	Machine breakdowns, owner management behaviour, dishonest employees, insufficient skilled manpower, poor internal coordination, poor-quality products, payment threat (to suppliers/ labour), Financial difficulties (focal firm), procurement risk, poor customer delivery performance
	Demand-side	Power asymmetries related threats (stronger customers), dishonest customers/ distributors, Payment threat (from customers), financial difficulties of customers, order cancellations, demand variations, customer characteristics, reputational risk
Exogenous	Geo-political	Political instabilities, geographical location (landlockedness), national politics, government policy, weak legal system, corruption, product counterfeiting, in-transit raw material theft, communication barriers, natural disasters
	Economic	Informal sector, unfair competition, poor transport infrastructure, unstable taxation, exchange rate fluctuations, power shortages

Ivanov (2020) has framed epidemic outbreaks as a unique type of supply chain disruption risk and used the example of coronavirus (COVID-19), anyLogistix simulation and optimization software to examine and predict the impacts of epidemic outbreaks on the supply chain performance. Ivanov and Dolgui (2019); Lückner et al. (2019); Schmitt et al. (2017); Ivanov (2020) have recognized lead-time, risk mitigation inventory and backup suppliers as crucial elements

affecting the supply chain reactions to disruptions. Moreover, geographic location data, lead-time data, and demand data are primarily needed to run the simulation models (Ivanov et al. 2014; Garvey et al. 2015; Pavlov et al., 2019; Dolgui et al. 2020; Li and Zobel, 2020; Anparasan and Lejeune 2018; Ivanov 2020). A guided framework is needed to develop pandemic plans for a company's supply chain because epidemic outbreaks create a lot of uncertainty. Therefore, we have taken the step towards developing a model to identify and analyse the supply chain risks which is faced during an epidemic outbreak.

3. Methodology

The prioritization of risk is essential as it acts as drivers to other risks, therefore, managers should focus on the few risks which act as drivers to other risks. The main purpose of this paper is to identify risk and vulnerability to analyse the costs and time associated with the supply chain risks and prioritize them. It is important to control these risks since it might lead companies to go through a temporary shutdown during an epidemic outbreak. This study is conducted in five steps to analyse the risks and vulnerability in the supply chain during an epidemic outbreak.

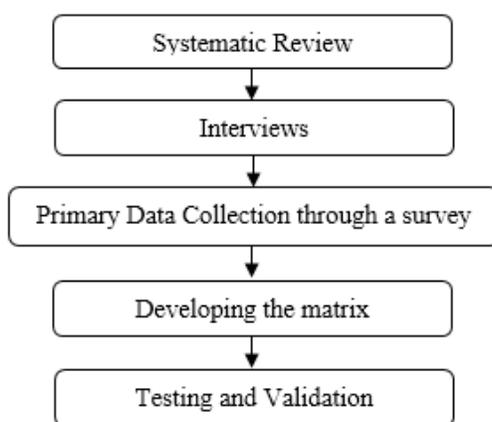


Figure 3: Flow Diagram of the Methodology

According to Xu (2008); Sheffi and Rice Jr., (2005); Venkatesh et al. (2015); Tukamuhabwa et al. (2017) supply chain risks are identified through the literature. Moreover, to further identify and verify the supply chain risks during an epidemic outbreak, we interviewed supply chain managers who have more than five years' experience (experts) in the apparel industry. The identified supply chain risks are,

- (R1)- Loss of local key supplier (Xu 2008; Venkatesh et al. 2015; Tukamuhabwa et al. 2017)
- (R2)- Loss of international key supplier (Xu 2008; Venkatesh et al. 2015; Tukamuhabwa et al. 2017)
- (R3)- Local port closure (Xu 2008)
- (R4)- International port closure (Xu 2008)
- (R5)- Transportation link disruption- other than ports (Xu 2008; Venkatesh et al. 2015; Tukamuhabwa et al. 2017)
- (R6)- Raw materials delays and shortages (Venkatesh et al. 2015; Tukamuhabwa et al., 2017)
- (R7)- Human Resource shortages (Venkatesh et al. 2015)
- (R8)- Product demand variations (Venkatesh et al. 2015; Tukamuhabwa et al., 2017)
- (R9)- Order cancellations (Venkatesh et al. 2015; Tukamuhabwa et al., 2017)
- (R10)- Lead time variations (Venkatesh et al. 2015; Ivanov 2020)

As of risk definitions and characteristics stated by Xu (2008), we have selected "risk is an attitude towards future", "disadvantage to the company" as the characteristics to develop the vulnerability matrix because most of the matrices related to risk are developed using likelihood of the risk/ disruption/ threat and its consequences (Xu 2008; Sheffi and Rice Jr., 2005; Kumar et al. 2014). However, our focus is to prioritize these risks in order to identify which risks should be addressed first and mitigate them, therefore, we developed the vulnerability matrix using time and loss factors. We used time factor as the time taken to address the risk and loss factor as the cost occurred to the company when the risks are not handled. A survey was sent to apparel industries to categorize the selected risks into time and

cost factors. We used convenience sampling to select the companies and random sampling to select supply chain-related managers. Using the Likert scale used in the survey, the model is developed. 80% of the data to develop the model and 20% of the data were used for testing and validation. Moreover, experts' opinions are taken to confirm the risk position in the vulnerability matrix.

4. Data Collection

Data is collected from the literature review and survey. The first step was to identify the related supply chain risks, therefore, the supply chain managers in the apparel industry were interviewed. The second step was to the model using experts' knowledge. Therefore, a five scale Likert scale was used to collect data (1- Strongly disagree, 2- Disagree, 3- Neither agree nor disagree, 4- Agree, 5- Strongly agree). The experts had to assume that the clients are international and suppliers are both local and international during the survey. The main two questions which were asked to identify the position of the risk in the vulnerability matrix are the time taken to mitigate the risk and the cost occurred to the company when the risks are not handled. There are 300-350 apparel manufacturing plants in Sri Lanka (EDB, 2020). However, there are less than 20 companies in the international businesses. Out of that, the data were collected from 8 leading apparel manufacturing companies. The companies were selected through convenience sampling. Moreover, 5 managers irrespective of their gender and who have more than 5 years' experience from each of the companies were selected using convenience sampling.

5. Results and Discussion

5.1 Numerical Results

The average results of the collected data are shown in table 3. The values shown under time and cost are the average value taken from the survey. The higher the time taken to mitigate the supply chain risk, the higher the risk. Likewise, the higher the cost occurred to the company when the supply chain risks are not handled, the higher the risk.

Table 3. Results of collected data from the survey

Supply Chain Risks	Time	Cost
(R1)- Loss of local key supplier	3.5	3
(R2)- Loss of international key supplier	4.5	4
(R3)- Local port closure	5	2
(R4)- International port closure	4.5	2
(R5)- Transportation link disruption- other than ports	3	2
(R6)- Raw materials delays and shortages	3.5	3
(R7)- Human Resource shortages	2	2
(R8)- Product demand variations	3.5	3.5
(R9)- Order cancellations	4.5	4
(R10)- Lead time variations	3.5	2.5

5.2 Graphical Results

According to the data collected from the experts through the survey, the supply chain risks are mapped in a vulnerability matrix and shown in figure 4. Figure 4 is drawn from time and cost values which are collected from the survey and shown in table 3.

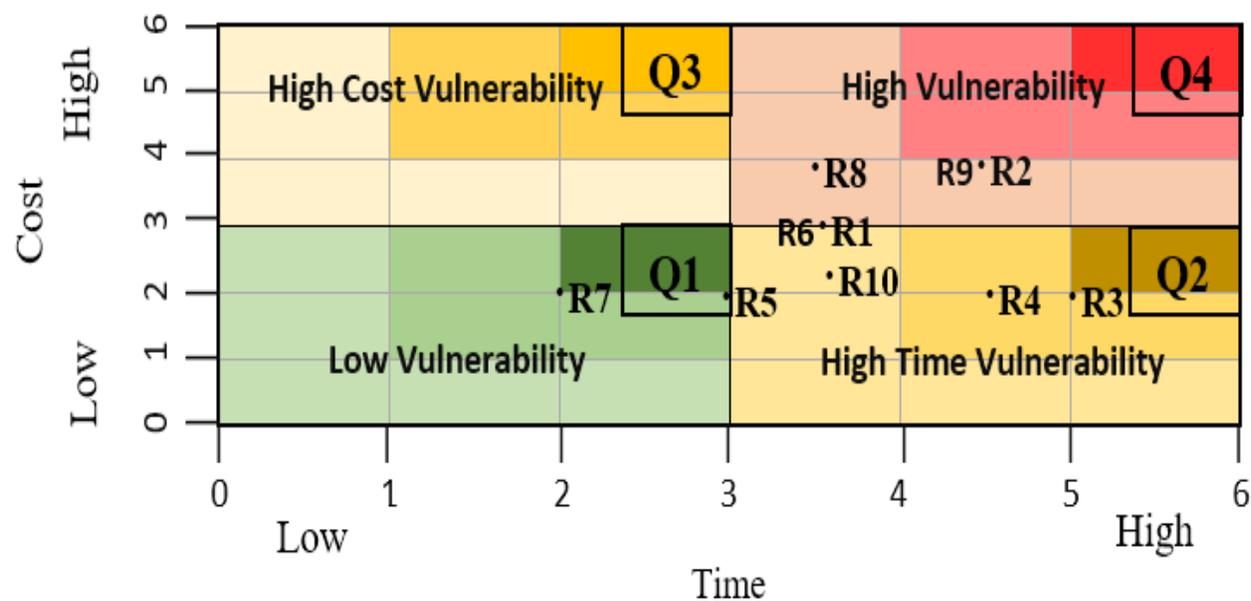


Figure 4: Risk assessment matrix on Cost and Time

The SC risks are mapped in a vulnerability matrix in this study (Figure 4). If the cost is high, then the risk is high, as the risk incur a cost to the company which might lead the company to go through a temporary shutdown if it's not handled or mitigated properly. These risks are shown in Quadrant 3 (Q3). If the time is high, it means that the risk is taking more time to handle or mitigate, therefore, the risk is also high which falls to Quadrant 2 (Q2). It is beneficial to focus on high vulnerability risks where the cost and time are both high, which means that the risk is very high compared to the other quadrants as shown in Quadrant 4 (Q4). A generalized vulnerability model is developed in this study considering cost and time factors, however, it can be customized using different factors and risks depending on the experience and needs of the company.

The weight for cost and time is measured on the same scale of Likert scale 1 to 5. According to the vulnerability matrix shown in figure 4, loss of international key supplier (R2) and order cancellations (R9) are further away in the matrix which means that the risk is high, because to resolve losing international key supplier and order cancellations take time and it's costly. International key suppliers are crucial when you consider the quality and cost aspect. Losing one of the key supplier, takes time and money when you have to find an alternative supplier and make agreements with them. During the interview with companies to identify the supply chain risks, they specifically mentioned that most of the key customers cancelled their orders, where some orders were not started at that time and some were ongoing orders. Getting orders cancelled during a crucial time like an epidemic outbreak is not profitable for a manufacturing company as they have to seek other orders or move into different products.

However, human resource shortages (R7) are towards the matrix which means the risk related to it is low compared to the other supply chain risks. It is because human resource shortage can be solved internally, quickly compared to the other risks, whereas, in the loss of international key suppliers, order cancellations are decided by external parties and cannot be handled internally as it takes time and resources to solve the issue.

During the interview experts said that they didn't have a specific model or a way to make decisions related to risk and strategies. In this study, we are addressing the gap of identifying the risk. Loss of international key supplier can be mitigated by having several suppliers from different regions. It may be costly, however, in order to mitigate the risk, you should at least have a minimum order from these suppliers. Order cancellation can be mitigated by having several customers and a variety of products. Moreover, during the epidemic outbreak, the manufacturers should switch to products such as personal protective equipment, masks, etc.

6. Conclusion

It is difficult to anticipate the arrival of an epidemic outbreak, however, companies can identify the SC risks and be prepared for it now rather than waiting for it to occur. In this paper, we empirically investigated the supply chain risks under time and cost categories. The results provide several insights for theory and practice. It is recommended to focus

on the high vulnerability quadrant in the vulnerability matrix (Figure 4) as its risk is high compared to other quadrants. If it's not mitigated the business might have to temporarily shut down due to the disruption caused.

This study is an attempt to contribute to identify supply chain risks during an epidemic outbreak literature and request scholars for more empirical research on the topic. This research also contributes to organizational theory by building a matrix to prioritize the supply chain risks they face during an epidemic outbreak in order to focus and mitigate them. Loss of international key supplier (R2) and order cancellations (R9) are further away in the matrix which means that the risk is high. However, human resource shortages (R7) are towards the matrix which means the risk related to it is low compared to the other supply chain risks.

The limitation of this study was that an assumption was given to collect data from the same domain. The assumption was that the clients are international and suppliers are both local and international. Further studies can be conducted considering many domains. Moreover, the weightage given to cost and time is equal. Moreover, this study can further develop to identify the weightage to be given for the cost and time factors. As for future work, this study can be extended to identify the strategies which should be taken in order to mitigate the supply chain disruptions. These outcomes of the research allow managers to evaluate the course of action that they should take concerning the SC disruption that they experience during an epidemic outbreak.

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Biographies

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Annista Wijayanayake received her Doctor of Engineering and Master of Engineering in Industrial Engineering and Management, specializing in Financial Engineering from Tokyo Institute of Technology Japan, respectively in 2001 and 1998. Currently she is serving as a Senior Lecturer at the Department of Industrial Management, University of Kelaniya- Sri Lanka. She had served as a honorary Research Fellow at Royal Melbourne Institute of Technology (RMIT) Australia in 2004 and as a lecturer, at the Faculty of Economics and Business and Faculty of Information Technology Monash University-Australia from 20017-2019. Also, she had served as an Academic Advisor for B.Sc. in Management and Information Technology degree programme, University of Kelaniya from 2003-2008. She won many international awards for her research and teachings. She received the academic excellence award for her Master’s degree by research by Tokyo Foundation- Japan for Inbound Students. She also received the 2019 teaching

excellence award from the Department of Econometrics and Business Statistics - Monash University for her teachings. She had worked as the co-investigator of international research on unnatural deaths among women and girls in Sri Lanka, which is funded by United Nation Population fund. Her research has been featured in prestigious journals such as Mathematical Programming, International Journal of Theoretical and Applied Finance, Journal of Global Optimization and in many International Conference Proceedings.

Suren Peter is a Senior Lecturer and the Head of the Department, of the Department of Industrial Management, University of Kelaniya, Sri Lanka. His research interests are behavior of capital markets, privatization and corporate restructuring, portfolio management and learning. He has over 25 years of teaching, research and consulting experience and has served as a National Consultant on a number of projects for the United Nations (UNIDO and UNDP) and has been involved in consulting with a number of international development organizations, government, local and private sector companies. He also serves on the Board of Directors in a number of companies engaged in finance and leasing, microfinance, real estate development and health and fitness.