A Structural Model for Investigating the Driving and Dependence Power of Supply Chain Risks in the Readymade Garment Industry

Nighat Afroz Chowdhury
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
Email: promy.ipe11@gmail.com

Dr. Syed Mithun Ali
Associate Professor
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
Email: syed.mithun@gmail.com

Zuhayer Mahtab
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
Email: mahtabzuhayer@gmail.com

Towfique Rahman
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
Email: towfique.rahman.bd@gmail.com

Dr. Golam Kabir*
Assistant Professor
Industrial Systems Engineering, Faculty of Engineering and Applied Science
University of Regina
E-mail: golam.kabir@uregina.ca

Dr. Sanjoy Kumar Paul
Lecturer
UTS Business School, University of Technology Sydney, Australia
Email: sanjoy.paul@uts.edu.au

*Corresponding author: golam.kabir@uregina.ca

A Structural Model for Investigating the Driving and Dependence Power of Supply Chain Risks in the Readymade Garment Industry

ABSTRACT

In today's business world, supply chain networks are becoming increasingly prone to uncertainties and complexities. The supply chain network of the ready-made garment (RMG) industry in Bangladesh is global in nature and is therefore vulnerable to increased risks and disruptions. This paper identifies potential supply chain risks and analyzes the interactions. To achieve this, a hierarchical structural model was developed through the application of an interpretive structural modeling (ISM) approach. Moreover, MICMAC (Matriced' Impacts Cruoses Multiplication Applique a un Classement) analysis was conducted to classify the risks based on driving and dependence power. Findings revealed that disruption risk was the most influential risk in the RMG industry. The results of this study will guide industrial managers to take remedial measures to mitigate the supply chain risks in the apparel industry.

Keywords: Supply chain; Supply chain risk management; ISM; MICMAC; Readymade garment industry.

1. INTRODUCTION

In today's market, the competition among firms is increasing within an ever-changing business environment (Banerjee & Mishra, 2017). Among the tools available to executives to gain competitive advantages in global trade, supply chain management (SCM) is one of the most useful strategies (Lambert, Cooper, & Pagh, 1998; Wu, Tseng, Chiu, & Lim, 2017).Thus, the supply chain is now considered a powerful tool to secure market position (Banerjee & Mishra 2017; ; Tang, 2006). However, the supply chain is prone to many risks and uncertainties that are hindrance to the development of SCM (Heckmann, Comes, & Nickel, 2015). One major area of SCM is solely devoted to anticipating uncertainties and mitigating risks for effective supply chain risk management (SCRM) (Vanany, Zailani, Pujawan, Sains, & Pujawan, 2009). Despite the emerging awareness among executives and academics, there are still many unanswered questions regarding the mechanism and implementation of SCM (Brandenburg et al. 2014; Flynn, Huo, & Zhao, 2010; Govindan et al. 2017). Most countries are not aware of the need for an effective supply chain structure. Some countries have begun to realize, but the overall environment must first be visualized for better context, which aids in the in-depth analysis of those risks.

The field of risk analysis is gradually increasing with the increase of exigency for mitigating risks (Jüttner, 2005; Manuj & Mentzer, 2008). Many have focused on domain-specific risk analysis, such as within the food industry (Mangla et al., 2018; Rueda, Garrett, & Lambin, 2017), the apparel and fashion industry (Turker & Altuntas, 2014), the chemical industry (Cohen & Kunreuther, 2009), the electronics industry (Rajesh & Ravi, 2015), and the automobile industry (Sharma & Bhat, 2014). Other studies have concentrated on domain-specific SCRM from a geographical perspective, due to the variation of risks from one location to another (Govindan, Kannan, Mathiyazhagan, Jabbour, & Jabbour, 2013; Venkatesh, Rathi, & Patwa, 2015).

This research work focuses on the ready-made garment (RMG) sector of Bangladesh. The RMG industry of Bangladesh plays a significant role in shaping the economic structure of the country. The RMG industry contributed to 12.36% of the total gross domestic product (GDP) of Bangladesh in the financial year of 2016-2017 and constituted 80.7% of the total export earnings. In the same financial year, the industry generated $28.14 billion (source: thefinancialexpress.com.bd). Industrial policy predicts that the industry's share of the GDP will be 40% by 2021 and will employ 25% of the total labor force in Bangladesh (Yunus & Yamagata, 2012).

Thus, the RMG industry of Bangladesh is playing a pivotal role in the global apparel retail supply chain. Bangladesh is doing well in competing with other emerging markets such as China, Vietnam and Cambodia. In 2016, Bangladesh became the second largest apparel exporter right after China reflecting the enormous growth of the industry. Whereas, Bangladesh was sixth back in 2006. The European Union (EU) is the largest apparel importer from Bangladesh. The EU imported $5.36 billion worth of apparel, having a 50% share in all apparel exports of Bangladesh. The USA is the second largest market of Bangladeshi apparel products having a 47% share in the total apparel export and generating $2.42 billion of revenue for Bangladesh. According to McKinsey and Company report, Bangladesh is destined to become the new China as apparel importers are moving away from China due to labor wage rise and considering Bangladesh as the next hot spot. These data reveal the importance of the RMG sector of Bangladesh in the global apparel retail. Therefore, to sustain economic growth, it is crucial that the RMG sector be effective and efficient. The objective of this paper is to diagnose supply chain risks in the context of Bangladeshi RMG sector and to identify the interactions among those risks. This research will help Bangladeshi firms and organizations manage and mitigate risks related to SCM.

Apparel industry is characterized by its competitive nature and high profit margin (Pentecost & Andrews, 2010). The increasing competitive nature of the industry has led to highly complex supply chains (Perry & Towers, 2009). This complexity has in turn increased the risks in RMG supply chain. To identify the risks inherent in the RMG supply chain in Bangladesh, interpretive structural modeling (ISM) was used. ISM explores the interrelationships and ranks factors according to dominancy over one another. Initially 17 risks were identified from a literature review. Using expert opinion, the 10 most significant risks were selected and contextual relationships were established for further analysis. ISM was followed by MICMAC analysis, which categorized the risks according to driving and dependence power. This research attempts to answer the following questions:

Q1. What are the major risks involved in in managing supply chains?
Q2a. What is the hierarchical relationship among the identified risks from the perspective of the Bangladeshi RMG industry?
Q2b. How can interdependency and dominancy affect overall supply chain performance?
Q3. What should managers do to mitigate such risks related to this context?

The structure of this paper is as follows. Section 2 focuses on relevant literature. The research methodology is described in Section 3. Section 4 highlights framework development for the concerned study. Discussions and findings are presented in Section 5. Conclusions, managerial implications, and recommendations for future study are given in Section 6.

2. LITERATURE REVIEW

This section briefly discusses the context of SCM practices, potential risks involved, risk mitigation strategies, and the methodology to address SCM risks.

2.1 Background of SCM

SCM is the management of resources, processes, and economic flow through a network of interconnected organizations with an aim to increase profit and customer satisfaction

(Brandenburg, Govindan, Sarkis, & Seuring, 2014). Over time, the perspectives of SCM have changed, due to changes in the key functions of a supply chain. A number of achievements in SCM have caused its primary and secondary stakeholders to conceptualize supply chain issues differently (Brindley, 2017). Christopher and Peck (2004) redefined SCM as the management of relationships with customers and suppliers through upstream and downstream communication with a goal of profitability for all members of the supply chain network.

2.2 Foundation and Recognition of Supply Chain Risks

Risk is a term that was originally based on the concept of variance and has many definitions depending on the field of research (Aven, 2012; Chiu & Choi, 2016). According to March and Shapira (1987), risk is the variation in the distribution of outcome and the probability of occurrence. Therefore, risks are often considered to be based on two aspects – the "likelihood" of occurrence and the "impact" of that occurrence (Christopher & Peck, 2004; Tang & Tomlin, 2008). Therefore, to find an effective way to mitigate risks, it is important to determine the severity and consequences of the risks. Different risks are inherent in the supply chain and the type of risks are dramatically increasing with globalization (Kumar, Tiwari, & Babiceanu, 2010; Wiengarten, Humphreys, Gimenez, & McIvor, 2016). According to Christopher (2016), all risks associated with material, cash, and information flow can be defined as supply chain risks.

Tang (2006) categorized supply chain risks into operational risks and disruption risks. Operational risks are those arising from the problems of coordinating demand and supply, cost uncertainties, and internal factors (Ali et al. 2018; Cohen & Kunreuther, 2009). For example, according to Chopra and Sodhi (2004), Cisco Systems Inc. (a major telecommunication device manufacturer) has capacity to assemble high-value, high-cost items in the USA in order to increase responsiveness to domestic customers. However, Cisco has an inventory of low-value, low-cost, high-demand products located overseas, thereby reducing both delay and inventory risks. However, disruption risks may arise from natural disasters, labor or political strikes, economic uncertainties, and from acts of purposeful agents, including terrorists (Kauppi, Longoni, Caniato, & Kuula, 2016; Kleindorfer & Saad, 2005). For example, the collapse of the Rana plaza building on April 24, 2013 was one of the worst industrial accidents in history, and caused many firms to move sourcing out of Bangladesh or other low-cost countries (Jacobs & Singhal, 2017). Such an event caused great financial and reputational damage to the Bangladesh RMG sector. These tragic events clearly demonstrated that a disruption affecting a component of the supply chain can have a direct impact on an organization's ability to continue production and operations (Alsamawi, Murray, Lenzen, & Reyes, 2017).

From the related literature, the various supply chain risks were identified, which are shown in Table 1.

Table 1: Risks involved in supply chains

No.	Risks	Brief Description	Literature
1	Disruption	Natural and man-made disasters induce disruption risk in supply chains.	(Ivanov, Dolgui, Sokolov, & Ivanova, 2017; Snyder et al., 2016)
2	Demand	This risk is associated with frequent fluctuations in the forecasted demand from the actual demand. Deviations are due to shorter product life cycle, high product variety, seasonal demand, long lead times, new product launch, sales promotion and bull-whip effect. This risk results in either undesired inventory or shortage.	(Ali, Arafin, Moktadir, Rahman, & Zahan, 2018; Yan, Jin, Liu, & Yang, 2018)
3	Supplier performance	This risk is associated with failure of supplier in fulfilling demand in terms of quality, quantity and time. Manufacturers depends on suppliers to meet demands. As such, poor supplier performance can hamper the manufacturer's supply chain performance greatly.	(Chen, Sohal, & Prajogo, 2013; Venkatesh et al., 2015)
4	Capacity	Capacity can either be increased or decreased. Excess capacity is often considered strategically suitable, but it can be a risk in case of financial performance. Low capacity is also a risk when demand increases and leads to opportunity cost.	(Fahimnia & Jabbarzadeh, 2016; Mohammaditabar, Ghodsypour, & Hafezalkotob, 2016)
5	Transportation	Failure in transportation system affects lead time, product life cycle, customer demand, inventories and shortages thereby causing inefficiencies in the supply chain	(Ko, Tu, & Ho, 2017; Qi & Lee, 2015)
6	Quality	Quality risks are in place due to low visibility across the supply chain. Factors such as low quality material from supplier, failure in inspection from manufacturer, contamination or damage of products during logistics operations are the major causes of quality risk.	(Brindley, 2017; Tse & Tan, 2012)
7	Delay/lead time	Failure to respond to fluctuations in demand from the customer side causes delay in delivery which in turn creates bull-whip effect and affects inventory cost.	(Bandaly, Satir, & Shanker, 2016; Fattahi, Govindan, & Keyvanshokooh, 2017)

8	Market	This risk is associated with failure in identifying potential market opportunities and response to market volatility.	(Christopher & Peck, 2004; Vinayak & Mackenzie, 2018)
9	Inventory	High value, high obsolescence rate and demand-supply uncertainty often initiates piling up or stock out inventory that results in either excess holding cost or lost opportunity cost of the supplier or retailer.	(Ghadge, Dani, & Kalawsky, 2012; Lai, Debo, & Sycara, 2009)
10	Information	This risk is involved with upstream and downstream information sharing. Trust, cheap talk, power, commitment, reciprocity as well as bullwhip effect are the main reasons for this risk that is leading to increase in inventories and shortages.	(Baruah, Chinnam, Korostelev, & Dalkiran, 2016; Prajogo & Olhager, 2012)
11	Supply chain network design	This risk is associated with planning problem in supply chain network. Several uncertain parameters such as cost, demand, supply and severe man-made or natural disruptions are responsible for this risk.	(Govindan et al., 2017; Qazi, Dickson, Quigley, & Gaudenzi, 2018)
12	Price fluctuation	Price fluctuation occurs due to short-term and long-term fluctuations in demand and supply, input and energy cost, and technological change, or as a result of disruptions in supply chains.	(Costantino, Pellegrino, & Tauro, 2016; Ghadge, Dani, Ojha, & Caldwell, 2017)
13	Exchange rate	Changes in exchange rates increase the operating cost of products thereby weakening the financial performance of the organization.	(Cruz, 2013; Heckmann et al., 2015)
14	Reputation	Corporate social responsibilities affect decision-making, reputation and financial values of an organization.	(Lemke & Petersen, 2013; Roehrich, Grosvold, & Hoejmose, 2014)
15	Environment and safety	Operational errors, lack of safety measurements and effluent treatment plant lead to industrial accidents and severe health problems.	(Jacobs & Singhal, 2017; Nath & Ramanathan, 2016)
16	Machine breakdown and facility failure	Breakdown of machines in production line or failure of facilities can lead to increase in lead time, decrease of supplier performance or fall of quality.	(Bakshi & Kleindorfer, 2009; Thun & Hoenig, 2011)
17	Job dissatisfaction and employee turnover	Lack of application of global labor standards, proper wages and working conditions may trigger considerable shortages and increasing delay time in executing supply chain functions.	(Dubey, Gunasekaran, Altay, Childe, & Papadopoulos, 2016; Jiang, Baker, & Frazier, 2009)

2.3 Related Studies on SCRM strategies

SCRM has been defined by many scholars as the coordination among partners of the supply chain to minimize risk and ensure profitability. Chopra and Sodhi (2004) constructed an SCRM strategy to mitigate risks by identifying risks and the drivers that cause the same. Tang (2006) reviewed various SCRM strategies for managing supply chain risks. Kumar et al. (2010) formulated a global supply chain model where every element of the supply chain was located in a different country. Sodhi, Son, and Tang (2012) presented a study on diversified research from the perspective of operations and supply chain management.

2.4 Basis for the Proposed Methodology

Previous studies have focused on many methodologies to determine the crucial risks barriers to SCM and possible approaches for mitigation. Some of these studies on SCRM are summarized in Table 2.

These studies employed systematic methods, probabilistic graphical approaches, analytical, and structural techniques. ISM is a well-established mechanism for performing the structural analysis of a complex issue or system containing a large number of factors and it graphically presents correlations based on mathematical means (Khan & Rahman, 2015). The application of the ISM method is gaining popularity among supply chain researchers. For example, Jharkharia and Shankar (2005) used ISM to identify the barriers to enablement of information technology to increase supply chain effectiveness and understand the mutual influences.

Table 2: Summary of studies on supply chain risks and concerned methodologies.

No.	Sources	Objectives	Methodology used
1	(Qazi et al., 2018)	To develop a supply chain risk network management process to determine degree of dependency among risks, several performance measurement criteria and how to mitigate them.	Bayesian Belief Network
2	(Jahre, 2017)	To provide a better insight of supply chain risk mitigation strategies in humanitarian supply chain	Systematic literature review of strategies
3	(Giannakis & Papadopoulos, 2016)	To develop a risk management process towards sustainability from operational perspective of supply chain.	Failure mode and effect analysis
4	(Zhao, Huo, Sun, & Zhao, 2013)	To investigate the effect risks on supply chain performance.	Structural equation modeling (SEM)
5	(Wieland & Marcus Wallenburg, 2012)	To explore the effects of SCRM on supply chain performance.	Structural equation modeling
6	(Ghadge et al., 2012)	To outline opportunities of research in SCRM.	Systematic literature review
7	(Manuj & Mentzer, 2008)	To propose global supply chain risk mitigation framework.	Systematic literature review

8	(Kleindorfer & Saad, 2005)	To propose a framework for mitigating disruption risks.	Empirical and literature review
9	(Jüttner, Peck, & Christopher, 2003)	To outline scopes of future research on SCRM.	Systematic literature review and semi-structured interview

Faisal, Banwet, and Shankar (2006) built a supply chain risk mitigation model by investigating various enablers and understanding the mechanism at work. Grzybowska (2012) applied this methodology to explore sustainability in supply chains by identifying different enablers and analyzing the mutual relationships. Govindan et al. (2013) analyzed barriers to green supply chain implementation through the application of ISM. Azevedo et al. (2013) used this methodology to evaluate the performance of an automotive supply chain by identifying and ranking various supply chain performance measurements. Venkatesh et al. (2015) performed a structural analysis of various types of risks in the Indian apparel retail supply chain through the application of the ISM method. Ali et al. (2018) deployed this methodology to examine the interrelationships among barriers to reverse logistics in a computer supply chain. Mor, Bhardwaj, and Singh (2018) identified several key performance criteria in the Indian dairy supply chain and examined the interdependent relationships with the help of an ISM approach. As it has been a useful mathematical tool for researchers and academics of many disciplines, the ISM methodology was adopted in this study.

3. STRUCTURE OF THE ISM METHODOLOGY

The ISM technique, first proposed by Warfield (1974), is a qualitative approach to decomposing a complex system into several elements or sub-systems and constructing a comprehensible multilevel structural model based on expert opinion. It is used to portray the elements of a complicated system in a structural relationship diagram (Khan & Rahman, 2015; Sharma et al. 2018). It is also referred to as a mental map based on an interactive learning process that helps to understand the interrelationships among various elements (Faisal et al., 2006). The configuration of the ISM technique is illustrated in Figure 1.

The following steps contributed to the development of the ISM:

Step-1: The factors related to the study were identified through an extensive literature review. Through a brainstorming session with experts, interactions among these factors were identified.

Step-2: The contextual relationships among factors were identified and represented using a structural self-interaction matrix (SSIM).

The following four symbols were used to represent the direction of the relationship between two corresponding factors (i and j):

a) V: Factor i affects factor j
b) A: Factor i is affected by factor j
c) X:. Factors i and j affect each other
d) O: Factors i and j are unrelated

Step-3: This phase of the ISM approach was associated with developing a reachability matrix of the system variables. For this, the four symbols (i.e., V, A, X or O) of the SSIM were replaced with a 1 or 0 to convert the SSIM into a reachability matrix. The rules for this substitution are shown in the Table 3.

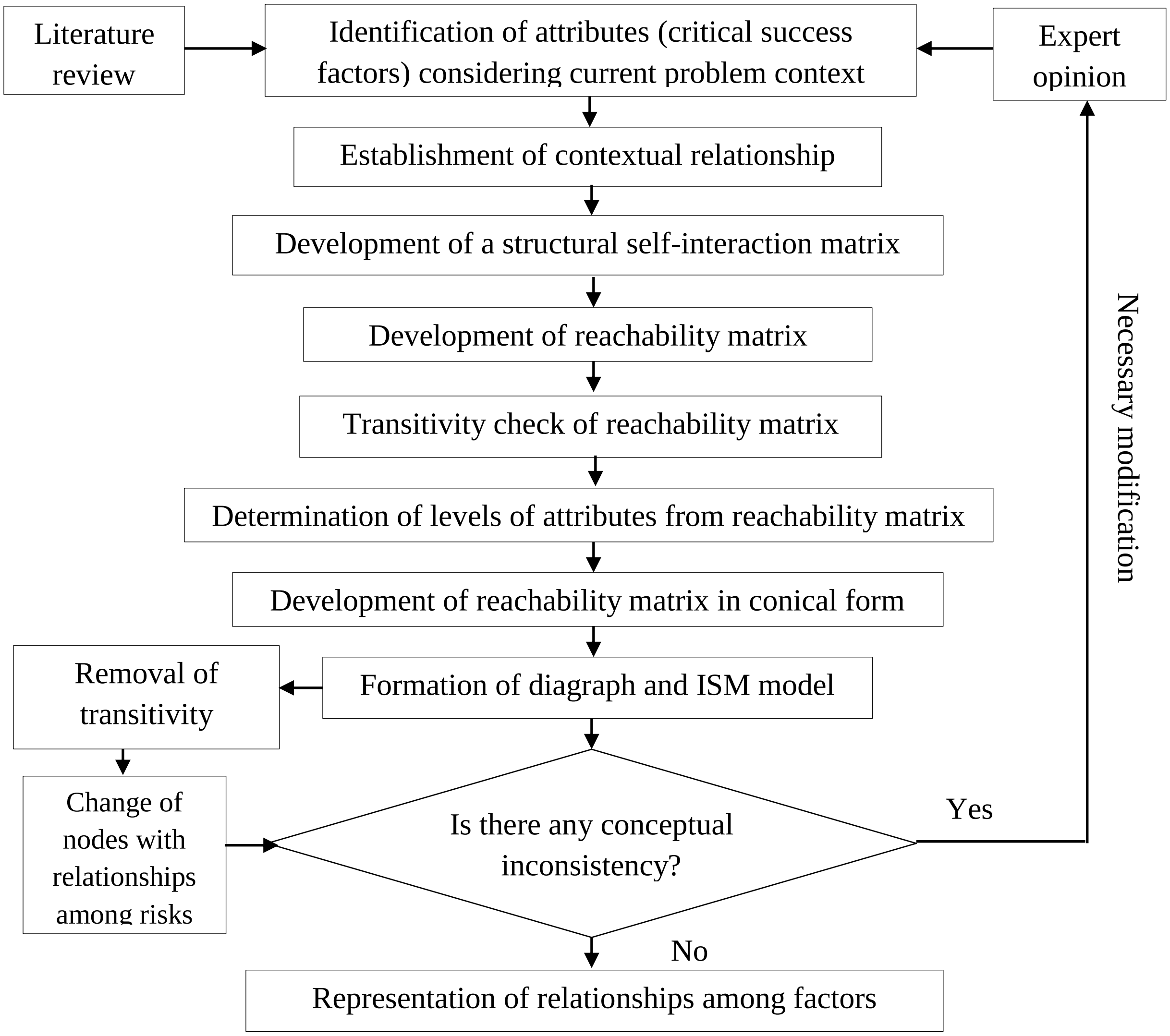

Figure 1: Flow diagram for ISM model formulation

Table 3: Rules of Substitution

SSIM	**(i, j)**	**(j, i)**
V	1	0
A	0	1
X	1	1
O	0	0

Step-4: Once the reachability matrix was complete, transitivity was checked among the factors and a matrix model was developed by following the transitivity rule. This matrix is referred to as the final reachability matrix or the transitivity matrix. According to this rule, if two variables have a 0 entry in the relationship matrix, then both are related to another factor Y, which indicates an embedded relationship with one another. For example, if a certain variable X affects Y and Y affects Z, then X affects Z. 1* entries are included in the matrix to incorporate transitivity among the variables with the help of expert opinion collected during the development of the SSIM. This matrix also shows the driving and dependence power of each variable or risk. The driving power of a particular variable is the accumulated number of all the variables it may influence. The dependence power of a particular variable is the accumulated number of all the variables by which it is influenced.

Step-5: The factors are partitioned into different levels using the reachability and antecedent set from the reachability matrix. The reachability set of a factor is the collection of all other factors that are affected by the factor in consideration and the factor itself. The antecedent set is the collection of all factors that affect the factor in consideration and the factor itself. An intersection set was developed, which is a collection of factors that are common to both the reachability and the antecedent set. The factors having similar reachability and intersection sets were placed at the top level and removed from further iterations. The process was repeated and continued for all factors.

Step-6: A conical matrix was formed arranging the variables in different levels according to the driving and dependence power along the rows and columns of the matrix. For example, the first level was arranged first across both the first row and column, and then the next levels were positioned similarly until all variables were positioned in the matrix. The driving and dependence power were then ranked by assigning the highest rank to the variable that had the maximum number of 1s along the rows and columns.

Step-7: In this step, a relationship diagram, termed a diagraph, was drawn based on the SSIM and reachability matrices. In a digraph, factors are placed top to bottom in descending order of level.

Step-8: In the final stage, the structural ISM was obtained with the help of the digraph.

4. An Example Application of the Proposed Framework

To check the validity of the proposed framework, two companies related to the apparel sector were chosen. These companies are well-known throughout the RMG industry in Bangladesh. However, both are facing several issues in implementing SCM practices successfully into the business, due to various risks involved in this process. Therefore, experts from different divisions of these firms acted as the respondents to this research, including operational process managers from the purchasing and supply division, supply production leaders, and production executives. The experts continuously evaluated the processes involved in developing the ISM. To avoid bias, opinions were collected and monitored separately.

4.1 ISM Analysis

The phases of the ISM process are described below in detail.

Phase 1: Identification of supply chain risk variables

The key risk variables identified through a survey of related literature are given in Table 2. Using experts' opinions (Appendix A), a set of 10 important supply chain risks in the RMG industry was finalized. These variables are presented in Table 4.

Table 4: Variables (risks) for ISM

Risks	Risk variable notation
Demand	R1
Delay/ Lead time	R2
Supplier performance	R3
Disruption	R4
Supply network design	R5
Transportation	R6
Price fluctuation	R7
Quality	R8
Machine Breakdown & facility failure	R9
Environment & safety	R10

Phase 2: Structural self-interaction matrix (SSIM)

Using the notations defined in section 3, a contextual relationship matrix, or SSIM, was developed for the current problem context. The SSIM was simultaneously discussed with the experts to obtain a general concord. Based on expert consensus, the SSIM matrix was finalized. For this research, the SSIM matrix is summarized in Table 5.

Table 5: Structural self-interaction matrix (SSIM)

Risk j / Risk i	R10	R9	R8	R7	R6	R5	R4	R3	R2	R1
R1	O	O	O	A	O	V	A	A	O	-
R2	A	A	O	O	A	V	A	A	-	
R3	A	A	A	O	O	V	A	-		
R4	O	V	O	V	V	V	-			
R5	A	O	A	A	A	-				
R6	V	O	V	V	-					
R7	O	O	V	-						
R8	O	A	-							
R9	V	-								
R10	-									

Phase 3: Reachability matrix

In this step, the SSIM was transformed into a reachability matrix showing the binary relationships. Following the rules of substitution, the reachability matrix was prepared, as shown in Table 6.

Table 6: Reachability matrix

Risk j / Risk i	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	1	0	0	0	1	0	0	0	0	0
R2	0	1	0	0	1	0	0	0	0	0
R3	1	1	1	0	1	0	0	0	0	0
R4	1	1	1	1	1	1	1	0	1	0
R5	0	0	0	0	1	0	0	0	0	0
R6	0	1	0	0	1	1	1	1	0	1
R7	1	0	0	0	1	0	1	1	0	0
R8	0	0	1	0	1	0	0	1	0	0
R9	0	1	1	0	0	0	0	1	1	1
R10	0	1	1	0	1	0	0	0	0	1

Phase 4: Transitivity check

This step was concerned with checking the transitivity in the reachability matrix. Following the rules described in section 3, the transitivity matrix for the supply chain risks is shown in Table 7.

Table 7: Transitivity matrix

Risk j / Risk i	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Driving power
R1	1	0	0	0	1	0	0	0	0	0	2
R2	0	1	0	0	1	0	0	0	0	0	2
R3	1	1	1	0	1	0	0	0	0	0	4
R4	1	1	1	1	1	1	1	1*	1	1*	10
R5	0	0	0	0	1	0	0	0	0	0	1
R6	1*	1	1*	0	1	1	1	1	0	1	8
R7	1	0	1*	0	1	0	1	1	0	0	5
R8	1*	1*	1	0	1	0	0	1	0	0	5
R9	1*	1	1	0	1*	0	0	1	1	1	7
R10	1*	1	1	0	1	0	0	0	0	1	5
Dependence power	8	7	7	1	10	2	3	5	2	4	49

Phase 5: Level partitions

After determining the transitivity matrix, the necessary steps were followed to identify the levels of the ISM. The detailed iterations involved in the level partitioning process of the ISM are presented in the Appendix (see Table A2). The summary of level partitions is shown in Table 8.

Table 8: Levels of SCM risks

Variables	Reachability set	Antecedent set	Intersection set	Level
R5	5	1,2,3,4,5,6,7,8,9,10	5	I
R1	1	1,2,3,4,6,7,8,9,10	1	II
R2	2	2,3,4,6,8,9,10	2	II
R3	3	3,4,6,7,8,9,10	3	III
R8	8	4,6,7,8,9	8	IV
R10	10	4,6,9,10	10	IV
R7	7	4,6,7	7	V
R9	9	4,9	9	V
R6	6	4,6	6	VI
R4	4	4	4	VII

Phase 6: Conical matrix

A conical matrix of SCM risks was formed according to the levels found in the previous phase. This matrix is shown in Table 9. The driving power and dependence power of the risks were also calculated considering transitivity.

Table 9: Conical matrix

Variables	R5	R1	R2	R3	R8	R10	R7	R9	R6	R4	Driving power	Level
R5	1	0	0	0	0	0	0	0	0	0	1	I
R1	1	1	0	0	0	0	0	0	0	0	2	II
R2	1	0	1	0	0	0	0	0	0	0	2	
R3	1	1	1	1	0	0	0	0	0	0	4	III
R8	1	1*	1*	1	1	0	0	0	0	0	5	IV
R10	1	1*	1	1	0	1	0	0	0	0	5	
R7	1	1	0	1*	1	0	1	0	0	0	5	V
R9	1*	1*	1	1	1	1	0	1	0	0	7	
R6	1	1*	1	1*	1	1	1	0	1	0	8	VI
R4	1	1	1	1	1*	1*	1	1	1	1	10	VII
Dependence power	10	8	7	7	5	4	3	2	2	1	49	

Phase 7: Diagraph

Based on the concept of portraying relationships in terms of nodes and edges, a diagraph was formed including the supply chain risks of the Bangladesh RMG sector. This diagraph is demonstrated in Figure 2.

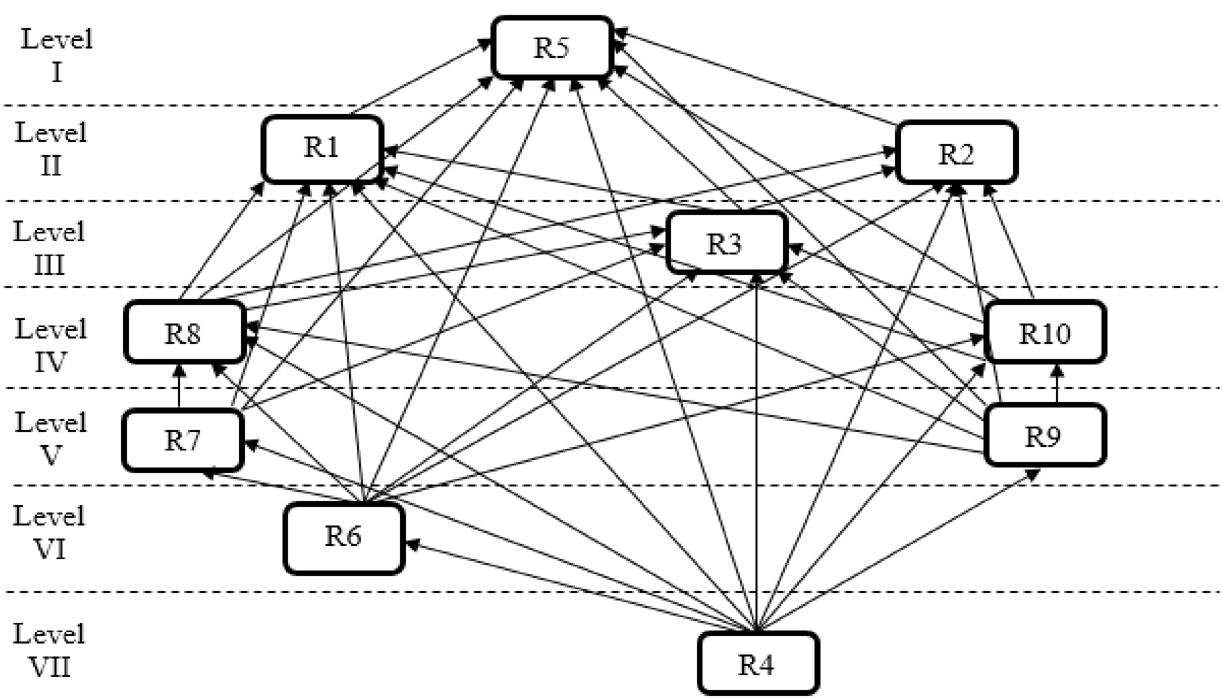

Figure 2: Final digraph

Phase 8: ISM model

The digraph was converted into an ISM by replacing the nodes of the factors with statements. The final ISM is illustrated in Figure 3.

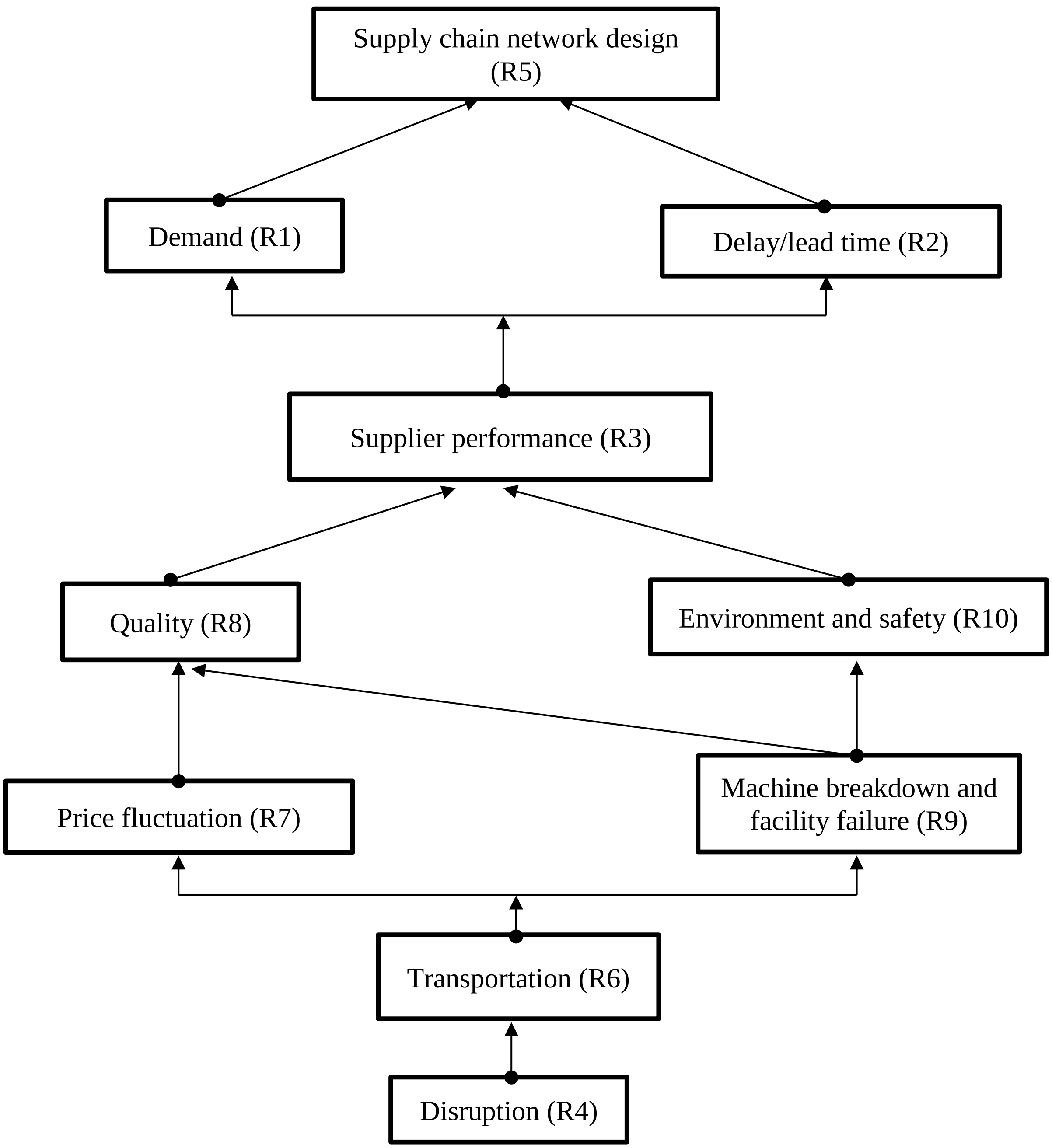

Figure 3: Proposed ISM model for supply chain risks

4.2 MICMAC Analysis

At this point in the process MICMAC analysis was performed to determine the degree of impact of the risks and to classify risks based on driving and dependence power. MICMAC analysis is a graphical representation similar to the ISM methodology, however, there is a significant difference. ISM only shows the nature or direction of influence among the variables, but MICMAC analysis portrays the extent to which the variables have influence over one another (Ali et al., 2018).

With the help of the driving and dependent power calculated in both the transitivity and the conical matrices (see Tables 6 and 9), a graph was constructed to categorize the supply chain risks. The graph was divided into four quadrants denoted as autonomous variables, dependent variables, linkage variables, and independent variables.

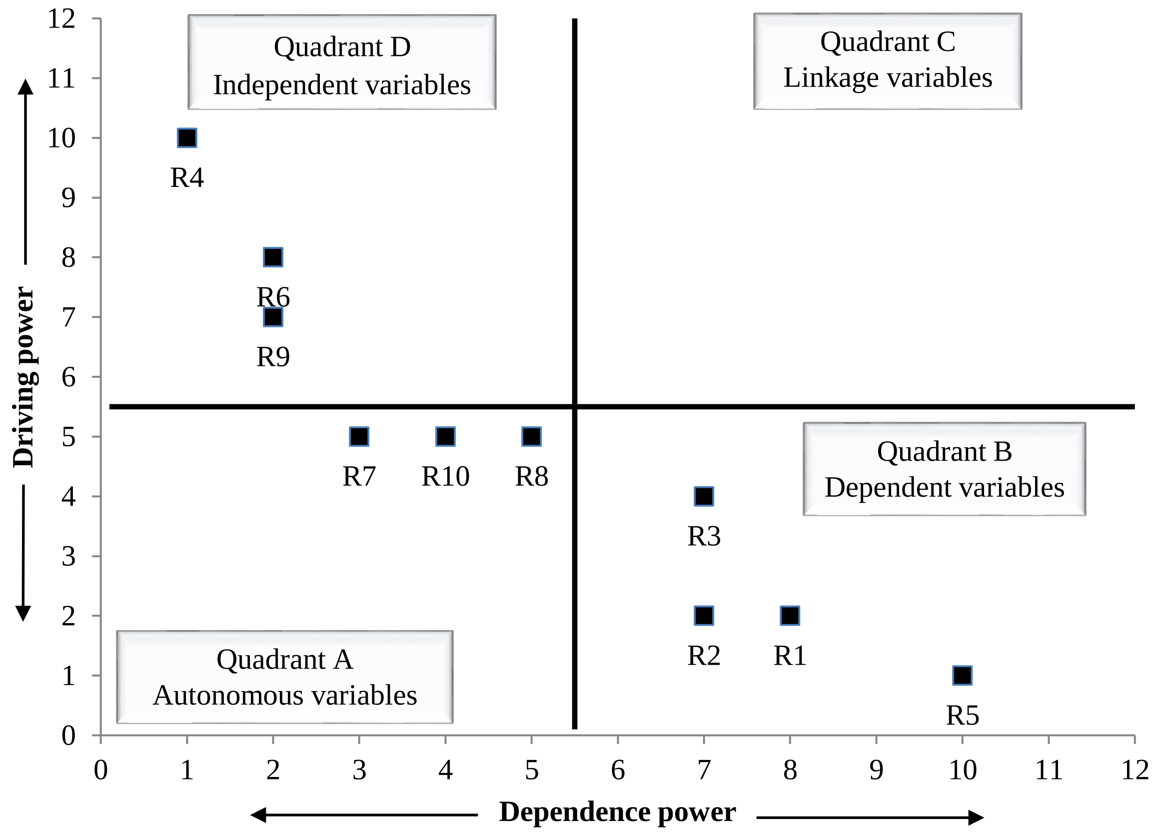

Figure 4: Driving power and dependency diagram of risks

The first quarter (quadrant A) consisted of autonomous variables. These variables have low driving and dependence power. In this study, three autonomous variables were found: price fluctuation (R7), environment and safety (R10), and quality (R8).

The second quarter (quadrant B) contained dependent variables that had a lower driving power and a higher dependence power. In this case, demand (R1), delay/lead time (R2), supplier performance (R3), and supply chain network design (R5) were found as dependent variables. Among these variables, supply chain network design (R5) had the strongest dependency. It was driven by all other risks mentioned in this study.

The next quarter (quadrant C) represented the linkage variables that were characterized by high driving power and dependency. This section did not contain any variables.

Finally, the last quarter (quadrant D) included independent variables characterized by higher driving power and lower dependency. Disruption (R4), transportation (R6), and machine breakdown and facility failure (R9) were identified as the independent variables. Among these, the disruption risk (R4) had the highest driving power, meaning it drove all other risks. Therefore, the managers of the Bangladeshi RMG industry should pay close attention to these risks.

5. Findings and Discussions

It is crucial to analyze and prioritize supply chain risks in order to compete in the global apparel market. Due to geographical, demographical, and socio-political situations, supply chain risks vary from country to country. The ISM model provided the most critical supply chain risks that deteriorated the performance of the Bangladeshi ready-made garment industry. Disruption (R4) had the highest driving power and the lowest dependence power. Disruption is an uncertain situation that can drive all other supply chain risks, which is why it occupied the level VII position in the ISM framework. Chopra and Sodhi (2004) cited disruption risk to be one of the most significant risks in the supply chain. Due to disruptions, the quality, transportation, and price of the product may fluctuate, which in turn can impact the demand of the apparel products. Tang (2006b) provided various strategies for mitigating disruption risks.

In level VI, transportation risk (R6) was found with high driving power. According to Ho, Zheng, Yildiz, & Talluri (2015), transportation risk, an important supply chain risk factor, is overlooked in the literature. Berle, Norstad, & Asbjørnslett (2013) mentioned that removing bottlenecks from transportation system will significantly improve the performance of a supply chain. Transportation is especially crucial to export-oriented apparel companies in developing countries like Bangladesh where timely delivery is utmost important. Lack of transportation infrastructure, political turmoil, labor unrest, traffic jams, and rising fuel costs have all made transportation a pivotal risk factor in the apparel industry.

Price fluctuation (R7) and machine breakdown and facility failure (R9) were stationed in level V, due to having a moderate degree of driving and dependence power. Fluctuation in the quality of raw materials, machine, and labor availability, as well as utilities and fuel prices, can all result in quality risks and demand shifting. Price fluctuation also affects supplier performance, since suppliers try to maintain a profit margin even when the raw material prices are lower. Costantino et al. (2016) stated that all organizations, private, non-profit and government, are exposed to price fluctuation risk and it can severely hinder the performance of the supply chain. Ghadge et al. (2017) said that reducing demand fluctuation and increasing responsiveness to price fluctuations are the two most important requirements in modern supply chain practices. In level IV, quality (R8) and environment and safety (R10) risks were found. Tse and Tan (2012) asserted that managing product quality risk in a complex multi-layered supply chain is absolutely necessary as substandard quality products can raise questions regarding manufacturer performance and eventually can shift demand, due to customer dissatisfaction. Environment and safety issues are major concerns for suppliers and can create disruptions in the supply network. The critical nature of this risk factor was highlighted after the Rana Plaza tragedy in 2013 in Savar, Bangladesh. After the collapse, many American and European buyers moved a business to Vietnam, China, India, and Cambodia (Jacobs & Singhal, 2017). They also stated that buyers had to take the most blame for this horrendous accident and thus they are much more wary of health and safety issues in RMG factories.

Supplier performance (R3) in level III was highly dependent on and can be influenced by the risk factors discussed above. In level II, demand (R1) and delay/lead time (R2), and in level, I supply network design (R5) had high dependence power and less driving power. If risks with high driving power and low dependence power were eliminated, level I and II risk categories could be mitigated. Therefore, managers from the apparel industry of Bangladesh should focus on mitigating disruption, transportation, and price fluctuation to lessen the impact of other highly dependent risks. Moreover, the MICMAC analysis helped provide insight into the strength of these risks. In the MICMAC analysis, the nature of the influence and the dependency of the risks were obtained through a graph. The autonomous risks should be dealt with separately, due to low driving and dependence power. The dependent risks were highly dependent on linking and independent risks. No linking variables were found; therefore, the main focus should be on the independent risks, which will eventually mitigate the effects of the dependent risks. The most influential risk was disruption, which highly influenced all other risks. The RMG sector of Bangladesh is vulnerable to natural and man-made disasters, which also give rise to other risks (Jacobs & Singhal, 2017). Therefore, concerned industry personnel should be highly vigilant about this risk and should find a solution in order to minimize the potential after-effects caused by this problem.

6. Model Implications

The implications and contributions of this study for theory and for practice are summarized in this section.

6.1 Implications for Theory

This paper provides two major theoretical implications. The first major implication is that this study provides a comprehensive framework for identifying the risks and their interdependencies by identifying the driving and dependence power of those risks. Due to limitations in organizational resources, managers are often reluctant in allocating resources for reducing risks in the supply chain. They need to know which risks are the most significant and hence requires the most attention. The framework developed in this study will help them in this regard. The ISM-based approach provides managers with a decision-making tool that will help them in prioritizing risks and formulate strategies to mitigate them. Thus, managers can allocate resources optimally.

The second major implication is that the results of this study differ from risk assessment studies in the existing literature. Whereas ‘Disruption’ was found to be the most significant risk in the RMG supply chain of Bangladesh, Moktadir et al. (2018) found ‘fluctuation in the arrival of imports’ to be the most significant risk in the pharmaceutical supply chain. Although both industries have some common risks such as supplier performance, machine or equipment failure, quality, and demand uncertainty, many risks are unique to this study. For example, risks such as power failure, bullwhip effects, competitive risks are unique to only the pharmaceutical industry and are not significant in the RMG industry. A risk assessment study on the automobile industry by Prakash, Agarwal, & Kumar (2018) found demand risk to be the most significant followed by process risk. Within demand risk, demand shift was the most important subcategory. Financial risk was found to be the least significant in the automobile industry in their research. On the other hand, production and warehousing disruption were the most important risks in the supply chains of non-perishable goods in a study by Abdel-Basset, Gunasekaran, Mohamed, & Chilamkurti (2019). Lack of integration and lack of information sharing were other significant risks in their study.

It is evident from these comparisons that risk assessment studies are highly industry and geography specific. Findings of a risk assessment study in a specific industry and specific country may not be applicable to some other industries in some other countries. Therefore, industry and country-specific risk assessment should be performed to help executives and managers gain knowledge about the supply chain risks existing in their organizations. However, this study helps researchers in other countries build supply chain risk assessment theory building as it has presented the mainstream of literature and the generic steps to building structural risk assessment framework.

6.2 Implications for Practice

This study identified the supply chain risks and determined their interrelationships by using an ISM based framework. As such, this study provides managers and supply chain practitioners some important insights. The results show that ‘Disruption’ is the most significant risk in SCM. Managers can use flexible manufacturing and supply base which means managers can use multiple smaller facilities instead of a larger one to reduce the damage due to disruption risks (Tang, 2006b). Multiple facilities will allow for continuous operations even if one or some facilities get disrupted due to natural and manmade disasters.

Transportation risk is the second most important risk found in this study. Managers can use flexible transportation such as multiple transportation modes and multiple routes to reduce transportation-related risks. Implementing multiple transportation modes will reduce the impact of a sudden transportation failure. Especially in developing countries like Bangladesh, political and labor unrest often lead to roadblocks, road transportation strike, and vandalism. Using air, rail or water transport may work for mitigating this risk. Similarly, using multiple routes and using multiple providers/carriers will also reduce transportation risks (Tang, 2006b).

Transportation risk is followed by price fluctuation, which is one of the most significant risks in a supply chain. Managers can use safety stock to reduce demand fluctuation and use multiple suppliers to reduce supply fluctuation both of which contribute to price fluctuations. Another important strategy in mitigating price fluctuation risk is signing long term risk sharing contracts with supply chain partners e.g. distributors and suppliers (Ghadge et al., 2017). Trading in a predefined price severely reduces the impacts of price fluctuations. Machine breakdown and facility failure are the next significant risk. Robust manufacturing systems using standby machines can help managers reduce this risk. The flexible manufacturing, preventive maintenance, and supply base strategy also can be applied in this case.

Poor quality is another important risk. Various quality assurance strategies such as total productive maintenance (TPM) total quality management (TQM) (Raj & Attri, 2010), lean six sigma (Snee, 2010) and supplier development can help managers ensure quality products and service. Environment and safety risk is a significant risk and it is gaining importance day by day (Beus, McCord, & Zohar, 2016). Managers should make use of industry standards and follow government regulations and ensure a safe environment for their employees and workers.

Demand risks, delay/lead time risks, and network design risks are lower level risks and hence not significant. These risks have high dependence power and thus highly driven by other risks. Managers should not focus on these risks first. Mitigating other higher-level risks will automatically reduce these lower level risks.

7. Conclusions, Limitations and Future Research Agenda

Supply chain risks are interdependent in nature and can cause a ripple effect by interacting with each other. Thus, the main objective of this paper was to examine the interactions among supply chain risks in the RMG industry of Bangladesh. This paper presented an ISM model that evaluated the contextual relationships among the supply chain risks in the RMG industry. Further, MICMAC analysis was conducted to explore the driving power and dependence among the supply chain risks.

Research findings demonstrated that disruption risk fell into the lowest level of the ISM, whereas supply chain network design was on the top of the proposed hierarchical structure. Thus, the disruption risk is critical, and influences all other risks, ultimately hindering the successful implementation of SCM practices. Hence, the disruption risk should be given top priority. SCM managers working in the RMG sector of Bangladesh can adopt this approach to apply SCM practices to the business model. The focus should be on addressing these crucial risks in the supply chain to achieve competitive success in terms of profitability.

This research has some limitations. The ISM model was based on the opinions of experts', and is therefore subject to individual bias. In this research, data were collected from the ready-made garment industry of Bangladesh. Even though the methodology of this study can be applied to investigate the driving and dependence power of supply chain risks for any industry sector from any region, however, the findings of this study are mostly applicable for the ready-made garment industry sector in the emerging economy like Bangladesh.

A statistical approach, such as structural equation modeling (SEM), could be linked to the ISM to reduce bias. In this case, a weighted ISM model could be applied to rank the factors under consideration on the basis of a Likert scale (Gothwal & Raj, 2017). The ISM model could also be extended using the total interpretive structural modeling approach (Shibin, Gunasekaran, & Dubey, 2017; Shibin et al., 2016) as it captures the nodes and links of the ISM. Total interpretive structural modeling (TISM) can better explain the relationships among the supply chain risk factors in the RMG industry's supply chain. Future research could build the TISM model of supply chain risks in a similar fashion. A fuzzy MICMAC analysis could be employed to determine the strength of the relationships among the attributes (Venkatesh et al., 2015). Fuzzy MICMAC uses a defined scale of values between zero and one to represent the intensity of the mutual relationships. Therefore, researchers could then clearly grasp the nature of the dependency of the factors.

References

Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Chilamkurti, N. (2019). A framework for risk assessment, management and evaluation: Economic tool for quantifying risks in supply

chain. *Future Generation Computer Systems*, *90*, 489–502. https://doi.org/https://doi.org/10.1016/j.future.2018.08.035
Ali, S. M., Arafin, A., Moktadir, M. A., Rahman, T., & Zahan, N. (2018). Barriers to Reverse Logistics in the Computer Supply Chain Using Interpretive Structural Model. *Global Journal of Flexible Systems Management*, *19*, 53–68. https://doi.org/10.1007/s40171-017-0176-2
Alsamawi, A., Murray, J., Lenzen, M., & Reyes, R. C. (2017). Trade in occupational safety and health: Tracing the embodied human and economic harm in labour along the global supply chain. *Journal of Cleaner Production*, *147*, 187–196.
Attri, R., Nikhil Dev, N., & Sharma, V. (2013). Interpretive Structural Modelling (ISM) approach: An Overview. *Research Journal of Management Sciences*, *2*(2), 3–8. Retrieved from http://www.isca.in/IJMS/Archive/v2/i2/2.ISCA-RJMS-2012-054.pdf
Aven, T. (2012). The risk concept-historical and recent development trends. *Reliability Engineering and System Safety*, *99*(0951), 33–44. https://doi.org/10.1016/j.ress.2011.11.006
Azevedo, S., Carvalho, H., & Cruz-Machado, V. (2013). Using interpretive structural modelling to identify and rank performance measures: An application in the automotive supply chain. *Baltic Journal of Management*, *8*(2), 208–230. https://doi.org/10.1108/17465261311310027
Bakshi, N., & Kleindorfer, P. (2009). Coopetition and investment for supply-chain resilience. *Production and Operations Management*, *18*(6), 583–603. https://doi.org/10.1111/j.1937-5956.2009.01031.x
Bandaly, D., Satir, A., & Shanker, L. (2016). Impact of lead time variability in supply chain risk management. *International Journal of Production Economics*, *180*, 88–100. https://doi.org/10.1016/j.ijpe.2016.07.014
Baruah, P., Chinnam, R. B., Korostelev, A., & Dalkiran, E. (2016). Optimal soft-order revisions under demand and supply uncertainty and upstream information. *International Journal of Production Economics*, *182*, 14–25. https://doi.org/10.1016/j.ijpe.2016.08.009
Berle, Ø., Norstad, I., & Asbjørnslett, B. E. (2013). Optimization, risk assessment and resilience in LNG transportation systems. *Supply Chain Management*, *18*(3), 253–264. https://doi.org/10.1108/SCM-03-2012-0109
Beus, J. M., McCord, M. A., & Zohar, D. (2016). Workplace safety: A review and research synthesis. *Organizational Psychology Review*, *6*(4), 352–381. https://doi.org/10.1177/2041386615626243
Brandenburg, M., Govindan, K., Sarkis, J., & Seuring, S. (2014). Quantitative models for sustainable supply chain management: Developments and directions. *European Journal of Operational Research*, *233*(2), 299–312. https://doi.org/10.1016/j.ejor.2013.09.032
Brindley, C. (2017). *Supply chain risk*. Routledge.
Bruce, M., Daly, L., & Towers, N. (2004). Lean or agile: A solution for supply chain management in the textiles and clothing industry? *International Journal of Operations and Production Management*, *24*(1–2), 151–170. https://doi.org/10.1108/01443570410514867
Chen, J., Sohal, A. S., & Prajogo, D. I. (2013). Supply chain operational risk mitigation: A collaborative approach. *International Journal of Production Research*, *51*(7), 2186–2199. https://doi.org/10.1080/00207543.2012.727490
Chiu, C. H., & Choi, T. M. (2016). Supply chain risk analysis with mean-variance models: a technical review. *Annals of Operations Research*, *240*(2), 489–507. https://doi.org/10.1007/s10479-013-1386-4
Chopra, S., & Sodhi, M. S. (2004). Managing Risk To Avoid Supply-Chain Breakdown. *MIT*

Sloan Management Review, *46*(46109), 53–61. https://doi.org/10.1108/IJOPM-10-2012-0449
Christopher, M. (2016). *Logistics & supply chain management*. Pearson UK.
Christopher, M., & Peck, H. (2004). *International Journal of Logistics Management , Vol. 15, No. 2, pp1-13, 2004*. *15*(2), 1–13. https://doi.org/10.1108/09574090410700275
Cohen, M. A., & Kunreuther, H. (2007). Operations risk management: Overview of Paul Kleindorfer's contributions. *Production and Operations Management*, *16*(5), 525–541.
Cohen, M. A., & Kunreuther, H. (2009). Operations Risk Management: Overview of Paul Kleindorfer's Contributions. *Production and Operations Management*, *16*(5), 525–541. https://doi.org/10.1111/j.1937-5956.2007.tb00278.x
Costantino, N., Pellegrino, R., & Tauro, D. (2016). Commodity Price Volatility mitigation in Supply Chain Risk Management: Real options to assess the value of flexibility-driven strategies. *IEEE International Conference on Industrial Engineering and Engineering Management*, *2016–Decem*, 129–133. https://doi.org/10.1109/IEEM.2016.7797850
Cruz, J. M. (2013). Mitigating global supply chain risks through corporate social responsibility. *International Journal of Production Research*, *51*(13), 3995–4010. https://doi.org/10.1080/00207543.2012.762134
Diabat, A., Govindan, K., & Panicker, V. V. (2012). Supply chain risk management and its mitigation in a food industry. *International Journal of Production Research*, *50*(11), 3039–3050.
Dubey, R., Gunasekaran, A., Altay, N., Childe, S. J., & Papadopoulos, T. (2016). Understanding employee turnover in humanitarian organizations. *Industrial and Commercial Training*, *48*(4), 208–214. https://doi.org/10.1108/ICT-10-2015-0067
Fahimnia, B., & Jabbarzadeh, A. (2016). Marrying supply chain sustainability and resilience: A match made in heaven. *Transportation Research Part E: Logistics and Transportation Review*, *91*, 306–324. https://doi.org/10.1016/j.tre.2016.02.007
Fattahi, M., Govindan, K., & Keyvanshokooh, E. (2017). Responsive and resilient supply chain network design under operational and disruption risks with delivery lead-time sensitive customers. *Transportation Research Part E: Logistics and Transportation Review*, *101*, 176–200. https://doi.org/10.1016/j.tre.2017.02.004
Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management*, *28*(1), 58–71.
Franca, R. B., Jones, E. C., Richards, C. N., & Carlson, J. P. (2010). Multi-objective stochastic supply chain modeling to evaluate tradeoffs between profit and quality. *International Journal of Production Economics*, *127*(2), 292–299. https://doi.org/10.1016/j.ijpe.2009.09.005
Frohlich, M. T. (2002). e-Integration in the Supply Chain: Barriers and Performance. *Decision Sciences*, *33*(4), 537–556. https://doi.org/10.1111/j.1540-5915.2002.tb01655.x
Ghadge, A., Dani, S., & Kalawsky, R. (2012). Supply chain risk management: Present and future scope. *The International Journal of Logistics Management*, Vol. 23, pp. 313–339. https://doi.org/10.1108/09574091211289200
Ghadge, A., Dani, S., Ojha, R., & Caldwell, N. (2017). Using risk sharing contracts for supply chain risk mitigation: A buyer-supplier power and dependence perspective. *Computers and Industrial Engineering*, *103*, 262–270. https://doi.org/10.1016/j.cie.2016.11.034
Giannakis, M., & Papadopoulos, T. (2016). Supply chain sustainability: A risk management

approach. *International Journal of Production Economics*, *171*, 455–470. https://doi.org/10.1016/j.ijpe.2015.06.032
Gothwal, S., & Raj, T. (2017). Analyzing the factors affecting the flexibility in FMS using weighted interpretive structural modeling (WISM) approach. *International Journal of Systems Assurance Engineering and Management*, *8*(2), 408–422. https://doi.org/10.1007/s13198-016-0443-1
Govindan, K., Fattahi, M., & Keyvanshokooh, E. (2017). Supply chain network design under uncertainty: A comprehensive review and future research directions. *European Journal of Operational Research*, *263*(1), 108–141. https://doi.org/10.1016/j.ejor.2017.04.009
Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A. B. L. de S., & Jabbour, C. J. C. (2013). Analysing green supply chain management practices in Brazil's electrical/electronics industry using interpretive structural modelling. *International Journal of Environmental Studies*, *70*(4), 477–493. https://doi.org/10.1080/00207233.2013.798494
Grzybowska, K. (2012). Sustainability in the supply chain: Analysing the enablers. In *Environmental issues in supply chain management* (pp. 25–40). Springer.
Heckmann, I., Comes, T., & Nickel, S. (2015). A critical review on supply chain risk - Definition, measure and modeling. *Omega (United Kingdom)*, *52*, 119–132. https://doi.org/10.1016/j.omega.2014.10.004
Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: A literature review. *International Journal of Production Research*, *53*(16), 5031–5069. https://doi.org/10.1080/00207543.2015.1030467
Ivanov, D., Dolgui, A., Sokolov, B., & Ivanova, M. (2017). Literature review on disruption recovery in the supply chain*. *International Journal of Production Research*, *55*(20), 6158–6174. https://doi.org/10.1080/00207543.2017.1330572
Jacobs, B. W., & Singhal, V. R. (2017). The effect of the Rana Plaza disaster on shareholder wealth of retailers: Implications for sourcing strategies and supply chain governance. *Journal of Operations Management*, *49–51*, 52–66. https://doi.org/10.1016/j.jom.2017.01.002
Jahre, M. (2017). Humanitarian supply chain strategies – a review of how actors mitigate supply chain risks. *Journal of Humanitarian Logistics and Supply Chain Management*, *7*(2), 82–101. https://doi.org/10.1108/JHLSCM-12-2016-0043
Jharkharia, S., & Shankar, R. (2005). IT-enablement of supply chains: understanding the barriers. *Journal of Enterprise Information Management*, *18*(1), 11–27.
Jiang, B. ., Baker, R. C. ., & Frazier, G. V. . (2009). An analysis of job dissatisfaction and turnover to reduce global supply chain risk: Evidence from China. *Journal of Operations Management*, *27*(2), 169–184. https://doi.org/10.1016/j.jom.2007.09.002
Jüttner, U. (2005). Supply chain risk management: Understanding the business requirements from a practitioner perspective. *The International Journal of Logistics Management*, *16*(1), 120–141. https://doi.org/10.1108/09574090510617385
Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics: Research and Applications*, *6*(4), 197–210.
Kauppi, K., Longoni, A., Caniato, F., & Kuula, M. (2016). Managing country disruption risks and improving operational performance: risk management along integrated supply chains. *International Journal of Production Economics*, *182*(July 2015), 484–495. https://doi.org/10.1016/j.ijpe.2016.10.006

Keay, S., & Callander, C. (2004). The safe use of infusion devices. *Continuing Education in Anaesthesia, Critical Care and Pain*, *4*(3), 81–85. https://doi.org/10.1093/bjaceaccp/mkh022

Khalid, Z. Bin, Mufti, N. A., & Ahmad, Y. (2016). IDENTIFYING AND MODELING BARRIERS TO COLLABORATION AMONG AUTO-PARTS MANUFACTURING SMEs. *Pakistan Business Review*, *18*(2), 487–507.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management*, *14*(1), 53–68. https://doi.org/10.1111/j.1937-5956.2005.tb00009.x

Ko, M.-D., Tu, M., & Ho, T.-C. (2017). Supply chain inventory model considering transportation risk and cost. *Industrial Engineering and Applications (ICIEA), 2017 4th International Conference On*, 126–130. IEEE.

Kumar, S. K., Tiwari, M. K., & Babiceanu, R. F. (2010). Minimisation of supply chain cost with embedded risk using computational intelligence approaches. *International Journal of Production Research*, *48*(13), 3717–3739. https://doi.org/10.1080/00207540902893425

Lai, G., Debo, L. G., & Sycara, K. (2009). Sharing inventory risk in supply chain: The implication of financial constraint. *Omega*, *37*(4), 811–825.

Lambert, D. M., Cooper, M. C., & Pagh, J. D. (1998). Supply chain management: implementation issues and research opportunities. *The International Journal of Logistics Management*, *9*(2), 1–20.

Lemke, F., & Petersen, H. L. (2013). Teaching reputational risk management in the supply chain. *Supply Chain Management*, *18*(4), 413–429. https://doi.org/10.1108/SCM-06-2012-0222

Liu, Z., & Nagurney, A. (2011). Supply chain outsourcing under exchange rate risk and competition. *Omega*, *39*(5), 539–549. https://doi.org/10.1016/j.omega.2010.11.003

Mangla, S. K., Luthra, S., Rich, N., Kumar, D., Rana, N. P., & Dwivedi, Y. K. (2018). Enablers to implement sustainable initiatives in agri-food supply chains. *International Journal of Production Economics*, *203*(July), 379–393. https://doi.org/10.1016/j.ijpe.2018.07.012

Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management. *Journal of Business Logistics*, *29*(1), 133–155.

March, J. G., & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science*, *33*(11), 1404–1418.

Mohammaditabar, D., Ghodsypour, S. H., & Hafezalkotob, A. (2016). A game theoretic analysis in capacity-constrained supplier-selection and cooperation by considering the total supply chain inventory costs. *International Journal of Production Economics*, *181*, 87–97. https://doi.org/10.1016/j.ijpe.2015.11.016

Moktadir, M. A., Ali, S. M., Mangla, S. K., Sharmy, T. A., Luthra, S., Mishra, N., & Garza-Reyes, J. A. (2018). Decision modeling of risks in pharmaceutical supply chains. *Industrial Management & Data Systems*, *118*(7), 1388–1412.

Nath, P., & Ramanathan, R. (2016). Environmental management practices, environmental technology portfolio, and environmental commitment: A content analytic approach for UK manufacturing firms. *International Journal of Production Economics*, *171*, 427–437. https://doi.org/10.1016/j.ijpe.2015.09.040

Nishat Faisal, M., Banwet, D. K., & Shankar, R. (2006). Supply chain risk mitigation: modeling the enablers. *Business Process Management Journal*, *12*(4), 535–552.

Pentecost, R., & Andrews, L. (2010). Fashion retailing and the bottom line: The effects of generational cohorts, gender, fashion fanship, attitudes and impulse buying on fashion expenditure. *Journal of Retailing and Consumer Services*, *17*(1), 43–52. https://doi.org/https://doi.org/10.1016/j.jretconser.2009.09.003

Perry, P., & Towers, N. (2009). Determining the antecedents for a strategy of corporate social responsibility by small- and medium-sized enterprises in the UK fashion apparel industry. *Journal of Retailing and Consumer Services*, *16*(5), 377–385. https://doi.org/https://doi.org/10.1016/j.jretconser.2009.05.003

Power, D. (2005). Supply chain management integration and implementation: A literature review. *Supply Chain Management*, *10*(4), 252–263. https://doi.org/10.1108/13598540510612721

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics*, *135*(1), 514–522. https://doi.org/10.1016/j.ijpe.2011.09.001

Prakash, A., Agarwal, A., & Kumar, A. (2018). Risk Assessment in Automobile Supply Chain. *Materials Today: Proceedings*, *5*(2, Part 1), 3571–3580. https://doi.org/https://doi.org/10.1016/j.matpr.2017.11.606

Qazi, A., Dickson, A., Quigley, J., & Gaudenzi, B. (2018). Supply chain risk network management: A Bayesian belief network and expected utility based approach for managing supply chain risks. *International Journal of Production Economics*, *196*, 24–42. https://doi.org/10.1016/j.ijpe.2017.11.008

Qi, L., & Lee, K. (2015). Supply chain risk mitigations with expedited shipping. *Omega (United Kingdom)*, *57*, 98–113. https://doi.org/10.1016/j.omega.2014.07.010

Rahul S Mor, Arvind Bhardwaj, S. S. (2018). Benchmarking the interactions among Barriers in Dairy Supply Chain: An ISM approach. *International Journal for Quality Research*, *12*(1), 385–404. https://doi.org/10.18421/IJQR12.02-06

Raj, T., & Attri, R. (2010). Quantifying barriers to implementing Total Quality Management (TQM). *European Journal of Industrial Engineering*, *4*(3), 308–335. https://doi.org/10.1504/EJIE.2010.033333

Rajesh, R., & Ravi, V. (2015). Modeling enablers of supply chain risk mitigation in electronic supply chains: A Grey-DEMATEL approach. *Computers and Industrial Engineering*, *87*, 126–139. https://doi.org/10.1016/j.cie.2015.04.028

Ravi, V., Shankar, R., & Tiwari, M. K. (2005). Productivity improvement of a computer hardware supply chain. *International Journal of Productivity and Performance Management*, *54*(4), 239–255. https://doi.org/10.1108/17410400510593802

Roehrich, J. K., Grosvold, J., & Hoejmose, S. U. (2014). Reputational risks and sustainable supply chain management: Decision making under bounded rationality. *International Journal of Operations and Production Management*, *34*(5), 695–719. https://doi.org/10.1108/IJOPM-10-2012-0449

Rueda, X., Garrett, R. D., & Lambin, E. F. (2017). Corporate investments in supply chain sustainability: Selecting instruments in the agri-food industry. *Journal of Cleaner Production*, *142*, 2480–2492. https://doi.org/10.1016/j.jclepro.2016.11.026

Sharma, S. K., & Bhat, A. (2014). Supply chain risk management dimensions in indian automobile industry: A cluster analysis approach. *Benchmarking*, *21*(6), 1023–1040. https://doi.org/10.1108/BIJ-02-2013-0023

Shibin, K. T., Gunasekaran, A., & Dubey, R. (2017). Explaining sustainable supply chain performance using a total interpretive structural modeling approach. *Sustainable Production*

and Consumption, *12*, 104–118. https://doi.org/10.1016/j.spc.2017.06.003
Shibin, K. T., Gunasekaran, A., Papadopoulos, T., Dubey, R., Singh, M., & Wamba, S. F. (2016). Enablers and barriers of flexible green supply chain management: A total interpretive structural modeling approach. *Global Journal of Flexible Systems Management*, *17*(2), 171–188.
Simangunsong, E., Hendry, L. C., & Stevenson, M. (2012). Supply-chain uncertainty: A review and theoretical foundation for future research. *International Journal of Production Research*, Vol. 50, pp. 4493–4523. https://doi.org/10.1080/00207543.2011.613864
Snee, R. D. (2010). Lean Six Sigma – getting better all the time. *International Journal of Lean Six Sigma*, *1*(1), 9–29. https://doi.org/10.1108/20401461011033130
Snyder, L. V, Atan, Z., Peng, P., Rong, Y., Schmitt, A. J., & Sinsoysal, B. (2016). OR/MS models for supply chain disruptions: A review. *IIE Transactions*, *48*(2), 89–109.
Sodhi, M. S., & Lee, S. (2007). An analysis of sources of risk in the consumer electronics industry. *Journal of the Operational Research Society*, *58*(11), 1430–1439. https://doi.org/10.1057/palgrave.jors.2602410
Sodhi, M. S., Son, B., & Tang, C. S. (2012). Researchers' perspectives on supply chain risk management. *Production and Operations Management*, *21*(1), 1–13.
Sushil. (2012). Interpreting the interpretive structural model. *Global Journal of Flexible Systems Management*, *13*(2), 87–106. https://doi.org/10.1007/S40171-012-0008-3
Tang, C. S. (2006a). Perspectives in Supply Chain Risk Management: A Review. *Ssrn*, *103*, 451–488. https://doi.org/10.2139/ssrn.925274
Tang, C. S. (2006b). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics Research and Applications*. https://doi.org/10.1080/13675560500405584
Tang, C., & Tomlin, B. (2008). The power of flexibility for mitigating supply chain risks. *International Journal of Production Economics*, *116*(1), 12–27.
Thun, J.-H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. *International Journal of Production Economics*, *131*(1), 242–249. https://doi.org/10.1016/J.IJPE.2009.10.010
Tse, Y. K., & Tan, K. H. (2012). Managing product quality risk and visibility in multi-layer supply chain. *International Journal of Production Economics*, *139*(1), 49–57. https://doi.org/10.1016/j.ijpe.2011.10.031
Turker, D., & Altuntas, C. (2014). Sustainable supply chain management in the fast fashion industry: An analysis of corporate reports. *European Management Journal*, *32*(5), 837–849. https://doi.org/10.1016/j.emj.2014.02.001
Vanany, I., Zailani, S., Pujawan, N., Sains, U., & Pujawan, N. (2009). Supply Chain Risk Management Literature Review and Future Research. *International Journal of Information System and Supply Chain Managment*, *2*(2), 16–33. https://doi.org/10.4018/jisscm.2009010102
Venkatesh, V. G., Rathi, S., & Patwa, S. (2015). Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. *Journal of Retailing and Consumer Services*, *26*, 153–167. https://doi.org/10.1016/j.jretconser.2015.06.001
Vinayak, A., & Mackenzie, C. A. (2018). A Quantitative Model for Analyzing Market Response During Supply Chain Disruptions. In *Supply Chain Risk Management* (pp. 139–153). Springer.

Warfield, J. N. (1974). Developing interconnection matrices in structural modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, (1), 81–87.
Wieland, A., & Marcus Wallenburg, C. (2012). Dealing with supply chain risks: Linking risk management practices and strategies to performance. *International Journal of Physical Distribution & Logistics Management*, *42*(10), 887–905. https://doi.org/10.1108/09600031211281411
Wiengarten, F., Humphreys, P., Gimenez, C., & McIvor, R. (2016). Risk, risk management practices, and the success of supply chain integration. *International Journal of Production Economics*, *171*, 361–370. https://doi.org/10.1016/j.ijpe.2015.03.020
Wu, K. J., Tseng, M. L., Chiu, A. S. F., & Lim, M. K. (2017). Achieving competitive advantage through supply chain agility under uncertainty: A novel multi-criteria decision-making structure. *International Journal of Production Economics*, *190*, 96–107. https://doi.org/10.1016/j.ijpe.2016.08.027
Yan, B., Jin, Z., Liu, Y., & Yang, J. (2018). Decision on risk-averse dual-channel supply chain under demand disruption. *Communications in Nonlinear Science and Numerical Simulation*, *55*, 206–224. https://doi.org/10.1016/j.cnsns.2017.07.003
Yunus, M., & Yamagata, T. (2012). The garment industry in Bangladesh. *Dyamics of the Garment Industry in Low-Income Countries*, 1–28. Retrieved from http://www.ide.go.jp/library/English/Publish/Download/Report/2011/pdf/410_ch6.pdf%0A papers://941fa284-6a3f-4661-b517-cb0b4edbed82/Paper/p1819
Zhao, li, Huo, B., Sun, L., & Zhao, X. (2013). The impact of supply chain risk on supply chain integration and company performance: a global investigation. *Supply Chain Management: An International Journal*, *18*(2), 115–131. https://doi.org/10.1108/13598541311318773

Appendix

Table A1: Expert opinion for selection of supply chain risks

Risks	Expert's opinion						Sum	Priority	Risk No
	Academician	Operational process manager (purchase)	Operational process manager (supply)	Supply production leader	Production executive (1)	Production executive (2)			
Disruption	1	2	10	7	7	6	33	4	R4
Demand	5	4	2	2	13	1	27	1	R1
Supply	2	3	5	6	4	12	32	3	R3
Capacity	11	8	4	16	12	15	66	12	R12
Transportation	10	11	5	9	2	8	45	6	R6
Quality	4	14	7	5	9	9	48	8	R8
Delay/ Lead time	3	15	1	4	5	2	30	2	R2
Market	14	9	14	12	11	7	67	14	R14
Inventory	13	10	9	14	6	14	66	13	R13
Information	12	7	11	1	10	17	58	11	R11
Supply network design	15	1	8	10	1	4	39	5	R5
Price fluctuation	6	5	12	15	3	5	46	7	R7
Exchange rate	16	16	17	13	16	16	94	16	R16
Reputation	17	17	16	3	17	13	83	17	R17
Environment & safety	7	13	13	11	8	3	55	10	R10
Machine Breakdown & facility failure	8	6	6	8	14	11	53	9	R9
Job satisfaction & employee turnover	9	12	15	17	15	10	78	15	R15

Table A2: Iterations of level partitions in ISM

Variables	Reachability set	Antecedent set	Intersection set	Level
Iteration 1				
R1	1,5	1,3,4,6,7,8,9,10	1	
R2	2,5	2,3,4,6,8,9,10	2	
R3	1,2,3,5	3,4,6,7,8,9,10	3	
R4	1,2,3,4,5,6,7,8,9,10	4	4	
R5	5	1,2,3,4,5,6,7,8,9,10	5	I
R6	1,2,3,5,6,7,8,10	4,6	6	
R7	1,3,5,7,8	4,6,7	7	
R8	1,2,3,5,8	4,6,7,8,9	8	
R9	1,2,3,5,8,9,10	4,9	9	
R10	1,2,3,5,10	4,6,9,10	10	
Iteration 2				
R1	1	1,2,3,4,6,7,8,9,10	1	II
R2	2	2,3,4,6,8,9,10	2	II
R3	1,2,3	3,4,6,7,8,9,10	3	
R4	1,2,3,4,6,7,8,9,10	4	4	
R6	1,2,3,6,7,8,10	4,6	6	
R7	1,3,7,8	4,6,7	7	
R8	1,2,3,8	4,6,7,8,9	8	
R9	1,2,3,8,9,10	4,9	9	
R10	1,2,3,10	4,6,9,10	10	
Iteration 3				
R3	3	3,4,6,7,8,9,10	3	III
R4	3,4,6,7,8,9,10	4	4	
R6	3,6,7,8,10	4,6	6	
R7	3,7,8	4,6,7	7	
R8	3,8	4,6,7,8,9	8	
R9	3,8,9,10	4,9	9	
R10	3,10	4,6,9,10	10	
Iteration 4				
R4	4,6,7,8,9,10	4	4	
R6	6,7,8,10	4,6	6	
R7	7,8	4,6,7	7	
R8	8	4,6,7,8,9	8	IV
R9	8,9,10	4,9	9	

R10	10	4,6,9,10	10	IV
Iteration 5				
R4	4,6,7,9	4	4	
R6	6,7	4,6	6	
R7	7	4,6,7	7	V
R9	9	4,9	9	V
Iteration 6				
R4	4,6	4	4	
R6	6	4,6	6	VI
Iteration 7				
R4	4	4	4	VII