SUPPLY CHAIN RISK ASSESSMENT IN THE HOME APPLIANCE INDUSTRY: A CASE STUDY.

by

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DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING (IPE)
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

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A project submitted to the Department of Industrial & Production Engineering, Bangladesh University of Engineering and Technology, in the partial fulfillment requirements for the degree of Master of Engineering in Advanced Engineering Management

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CERTIFICATE OF APPROVAL

The project titled "SUPPLY CHAIN RISK ASSESSMENT IN THE HOME APPLIANCE INDUSTRY: A CASE STUDY" submitted by Palash Kanti Dey, Roll No. 1014082111, Session October, 2014 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Master of Engineering in Advanced Engineering Management** on 28th September, 2021.

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It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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DEDICATION

To my loving parents and my sweet family for their constant support throughout my career.

ACKNOWLEDGEMENT

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Finally, I am grateful to Almighty for giving me the strength, guidance, and determination to achieve this success. I am also thankful to my parents for their unfailing support and encouragement to me to complete this project work.

ABSTRACT

Currently, home appliance industries of Bangladesh are growing very fast and productively. Bangladesh manufactures and assembles various consumer electronic home appliances in local manufacturing plants. Some of our products are even exported worldwide and the market is increasing. But most of the parts for this manufacturing must be imported globally. This requires a smooth and sustainable supply chain practice. There are several risks that threatens the smooth operation of this industry. It is essential to identify and prioritize the risks that affect the overall supply chain of the industry. These risks are not similar for all other industries.

In this study, there were 23 risks identified through detailed literature review and profound survey on home appliance industry. From these risks, using Delphi method 15 were found to be the most relatable and affecting the home appliance industry. These risks were ranked using TOPSIS method considering 8 impact criteria having weightages for their affect. The result of the thesis aims to support the home appliance industry in such a way that the supply chain professionals and industrial engineers can easily identify most influential risks towards an unencumbered supply chain process.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Supply chain management (SCM) is the flow of goods and services from procurement to customer. The process includes all the processes that transform raw materials into final products and deliver final products to the customer via a distributor or retailer. Production planning, production process, distribution, and shipment of products and services are monitored by Supply chain management. SCM plays a crucial role in the sustainable development of the manufacturing industry. It is an integrated process to maximize the profit of the industry. Such an increase in supply chain activities plays an essential role in the home appliance industry also. To minimize the cost of the entire production and processes to deliver the final products to the consumers are very much crucial in gaining profits. The risks associated with the supply chain in this sector needs to be briefly analyzed. To make that supply chain reliable and effective most of the home appliance manufacturing industries are putting a significant amount of efforts and resources in this matter.

The selection of the supplier is generally considered to be one of the most important activities for the supply chain administration of the products required, considering that it has a strong effect on reducing the total cost of improving company profitability by using an appropriate selection method. The problem of the selection of suppliers has now become an active research area. Efficient supplier selection plays a key role in supply chain management (SCM). It is designed to assess, identify and select the best option for a pool of potential suppliers, particularly in the presence of conflicting criteria.

There has been much debate on the different sources and impacts of threats likely to affect global supply chains in the 21st century. Increasing complexity due to globalization and lean structures and processes are significant drivers of supply chain risks and hence vulnerability in the supply chain (Norrman & Jansson, 2004). Also, different stakeholders involved in operating supply chains, such as suppliers, manufacturers, retailers, logistics service providers, infrastructure providers like port authorities, as well as national and international governmental institutions exploit to the complication and susceptibility of supply chains. Consequently, disruptions to global flows of goods and related states of affairs around the world have drawn companies' and governments' attention to such situations (Kungwalsong, 2013). The causes of such disruptions include natural catastrophes (e.g. flood or earthquake), man-made accidents (e.g. technological breakdowns), or intentional man-made attacks (e.g. theft or terrorism). Usually, a common understanding or consensus does not exist about the problems as well as the sources and impacts that cause risks in supply chains(Dixon et al., 2007). Furthermore, man-made risks in global supply chains are uncertain in terms of type, location, and affected supply chain partners and are, therefore, inherently "wicked" issues(Lodge, 2009). A wicked problem is defined as an issue that is multidimensional with often unpalatable trade-offs. As described by Camillus(Camillus, 2008), "a wicked problem has innumerable causes, is tough to describe, and doesn't have a right answer". A wicked issue often involves multiple stakeholders with different perceptions of the problem, different perceptions of the appropriate procedure to solve the problem, and different perceptions of how the results and success of the solution should be evaluated(Lowenthal, 1992). In such uncertain wicked environments, it is difficult for relevant stakeholders to process information and make effective decisions (Gnatzy & Moser, 2012).

Stakeholders from different regions and cultures often have different perceptions of situations and risks which could affect security in supply chains, depending on national or cultural backgrounds, their own position within the value chain, their experience, and so on (Slovic, 1986). In such situations, it is common to accidentally neglect relevant factors and important information or draw misleading conclusions (Tihanyi & Thomas, 2005).

In order to be better prepared for the future, we need to systematically consider different stakeholder conditions, contexts and limitations in order to gain a complete perspective of the wicked problem: supply chain security (SCS) (Lodge, 2009). An appropriate procedure which collects and evaluates all stakeholder aspects, including stakeholders' images of the future and opinions of the greatest challenges in SCS needs to be applied (Markmann et al., 2013).

In the present paper, analysis of the existing supply chain practices in the home appliance industry and the categorization of the home appliance industry according to the power consumption is done. The Delphi method is used to find out the most relevant risks and assess them according to their significance and nature in affecting the supply chain. The Multiple Criteria Decision Making (MCDM) method TOPSIS is done for prioritizing the risks incorporating the determined weights of the risk associated with the supply chain. The normalized decision matrix is taken to decide, and the relative closeness to the positive ideal determined the rank preference of the risks.

1.2 Objectives of the Thesis

The overall aim of this thesis is to identify the most influential risks in supply chain management practices in the home appliance industry of Bangladesh. The specific objectives of this thesis are as follows:

1. To identify the most relevant risks in supply chain management practices for a home appliance industry in Bangladesh using the Delphi method
2. To evaluate and analyze the identified risks with the help of an MCDM TOPSIS method
3. To determine the rank preference of the risks associated with supply chain

1.3 Outline of Methodology

The proposed research methodology is outlined below:

- Analysis of the existing supply chain practices in the home appliance industry.
- Categorization of the Home appliance industry according to power consumption.
- The Delphi method will be used to find out the most relevant risks associated with the Home Appliance industry supply chain.
- To use the TOPSIS method for prioritizing the risks, need to Construct the decision matrixes and determine the weights of criteria for decision-

makers to calculate the normalized decision matrix for each decision-maker.

- Determination of the positive ideal and negative ideal solutions for each decision-maker needs to be done.
- Then after calculating the relative closeness to the positive ideal solution, rank preference of the risks will be determined.

1.4 Organization of the Thesis

The thesis consists of six chapters. Chapter 1 represents the notion of the supply chain, the current situation of the study, the study's research gap and the study's purposes.

The rest of the thesis is organized as follows: Chapter 2 presents the literature review of supply chain management, current supply chain practices, categorization of the industry based on power consumption and an overview of home appliance industry of Bangladesh.

Research methodology, Delphi method projection formulation, a proposed mathematical MCDM TOPSIS method, solution matrixes formulation and decision-making criteria according to the risks rank preference; furthermore, decision-making methodology is presented in Chapter 3.

Chapter 4 describes a real case application of Bangladeshi home appliance industry to identify and prioritize risks to mitigate those risks in supply chain management practices.

Chapter 5 incorporates results and discussions on findings of this study, and sensitivity analysis is also given in Chapter 5.

Finally, conclusions and recommendations are presented in Chapter 6. References and appendix are presented at the end of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Supply Chain Management

A supply chain is a dynamic activity and involves the constant flow of materials, information, and funds. Therefore, supply chain management is the management of materials, information, and funds as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management involves coordinating and integrating these flows among different companies. Supply chain management helps to increase the profit of an organization as well as proper utilization of resources. The main objective of supply chain management is to maximize the profit of the industry. Hence supply chain success depends on the overall profitability of a supply chain. Successful supply chain requires many decisions relating to the decision of flow of materials, information, and funds. Therefore, supply chain management helps to manage such kinds of thing. Over the past decade, the traditional purchasing and logistics functions have evolved into a broader strategic approach to materials and distribution management known as supply chain management. Supplier selection to delivery of the final product includes a wide range of quality management. So, ensuring quality and selecting the right supply chain method also plays a significant role in the quality of the total process. It is proved that the supply chain and supply chain management have played an important role in business efficiency and have attracted the attention of numerous academicians over the last few years. Supply chain management activity is the root of maximizing profit of any kinds of industrial fields as well as service organizations. Therefore, it is necessary to improve the supply chain management activities for the successful business.

2.2 Supply Chain Risk Management

Having uncertainties in supply chains is – as the name suggests – unfavorable for running stable processes. Therefore, uncertainties in supply chains are commonly described as risks and require more specific information regarding the probability of occurrence and potential consequences. Furthermore, risks usually refer to a certain event or development, which disrupts the ordinary course of action by inducing exceptional conditions and scenario (Tuncel & Alpan, 2010). The scope of such disruptive events can range from high-probability, low-impact events (e.g. a screw missing in the production process) to low-probability, high-impact events (e.g. nuclear contamination of an entire region). The risk may also pertain to natural disasters and man-made accidents or attacks.

Supply chain risk management refers to reducing supply chain vulnerability by ensuring business continuity via planning. The discipline analyses to what extent the supply chain is susceptible to disruptions and thereby could be potentially harmful to a company's overall profitability and performance (Giunipero & Eltantawy, 2004). SCS management, in turn, is an element of supply chain risk management and seeks to prevent man-made attacks such as theft and damage to or destruction of products and assets (Sheffi, 2001). This new field of study identifies the deficiencies of existing logistics networks, develops security concepts within companies (Autry & Michelle Bobbitt, 2008) and analyzes maritime, rail, road and air transportation security, as well as the roles of law enforcement, security technologies and corporate security training. Lee and Wolfe (Wolfe, 2003) linked the topic to established quality management concepts and proposed an approach for prevention, process control and design improvements. Williams et al. (Williams et al., 2008) provided an extensive literature review, in which they demonstrate the main challenges in the field and concluded that SCS research lacks in portraying intra-organizational activities, the interaction among supply chain partners, and the role of the government, as well as quantitative assessments, to better understand the rationale, targets, sources and causes of SCS initiatives.

However, risk analysis methods have several shortcomings when applied to the context of global, far-reaching, and relatively unknown situations (Turoff et al., 2011). The quality of risk analysis is strongly dependent on the availability and actuality of information, as well as on the experience of the risk assessor (Slovic, 1986). In general, there is a lack of up-to-date information and experienced advisors. Risks are usually analyzed and evaluated by a small group of people who have just a fraction of the globally available information and experience in the topic. Therefore, it is difficult to evaluate such circumstances and appropriately prepare for emergency settings.

Furthermore, risk analysis is subjective. Risk assessment varies according to the risk perception of the assessor (Slovic, 1986). Since it is not possible to determine the "right" perception of risk or to accurately weight different risks, multiple perspectives should be surveyed and integrated (Bowonder & Linstone, 1987) continually (Turoff et al., 2011).

2.3 Overview of the Home Appliance Industry

Bangladesh manufactures several consumer electronics products, but in the majority of the cases, the manufacturing companies import different parts from abroad and assemble those in their factories.

According to the CEO, Business Initiative Leading Development, the electronics goods have a large increasing domestic market, which has more than 3000 units in operation. With the consultation with the representatives of government bodies and different consumer electronics companies, it was found that the market size of electronic industry is around 4 billion USD in 2017 and it is expected to have a yearly growth rate of 15%. Based on the growth rate, the market size is estimated to be around 12 billion USD in 2025. It should be noted that this number includes both consumer electronic products and industrial electronic products. It was also found that the total market of consumer electronics is around 1.8 billion USD.

Bangladesh is consuming and opting to produce a higher quantity of electricity than ever. From 2009, 7,000 MW of electricity was added to the national grid, and the government's Power System Master Plan (PSMP) targets to provide undisrupted power supply while increasing capacity to 34,000 Megawatts by 2030.

According to data from the World Bank, only 21.6% of the population had access to electricity in 1990. This figure tripled in 2012, with 58% of the population gaining access to electricity. Today, Bangladesh has the world's largest and most successful base of solar home systems (SHS), installed in 4.5 million off-grid residences (LIGHTCASTLE ANALYTICS WING, n.d.).

Urban areas have seen a rise in the number of nuclear family structure and many working couples, which has influenced the demand for refrigerators and other home appliances. Alongside, growing electrification rate has spearhead demand in the rural markets. Although many local brands are entering the electronics market, the majority of consumers still prefer international brands over local ones, due to perceived quality parameters. However, consumers in low-income households, in general, are more price-sensitive and are willing to purchase local brands at affordable pricing, instead of the longer warranty period and reliable after-sales services. So, where is this industry headed? Will the local brands surpass the international ones?

Although the majority of the population still lives in rural areas, the urban population is rising steadily. In 2005, 26.8% of the total population lived in urban areas; however, the number increased to 34.3% in 2015. Due to rapid urbanization, joint families are decreasing while nuclear families are gaining popularity. This trend is increasing in demand for housing and subsequently, consumer electronics items such as TVs, A/Cs and refrigerators.

It was found that Bangladesh imported both consumer and industrial electronic products worth of around 2.2 billion USD in 2016 (Bangladesh Bank). The trend analysis based on the import value from 2012-2016 shows that the total import value of electronic products will be around 5.2 billion USD.

Table 2.1: Import values of selected consumer electronics products from fiscal years 2012 to 2017 (in million USD)

Year	**2012**	**2013**	**2014**	**2015**	**2016**
Fans	13.17	11.53	18.77	10.81	9.58
Air Conditioner	30.59	22.7	29.5	28.69	47.13
Washing Machine	4.76	2.79	3.09	4.51	3.96
Microwave Oven	3.2	2.24	3.38	4.09	5.69
Electrical Oven, cookers, cooking plate, etc.	4.31	4	5.56	7.48	10.08
LED Light	0.47	3.56	7.04	0.03	0.1
Refrigerator	5.94	7.45	17.25	28.49	31.33
Parts of Television	6.36	8.09	3.93	3.17	2.92
UPS/IPS	5.93	5.81	6.67	6.97	8.41

Lead Acid Battery	5.36	5.04	0.1	1.59	6.9

*Source: National Board of Revenue (NBR)

It should be noted that neither the government bodies nor the associations were able to provide any import data for a vacuum cleaner, different kitchen appliances (blender, mixer, grinder, cooking range, and rice cooker), inverter and stabilizer. Therefore, it was not possible to identify the import values for the above-mentioned consumer electronics products.

The major consumer electronics products exported by Bangladesh are parts of television, air conditioner, refrigerator, washing machine, electro-mechanical domestic appliance and battery. Table 2.4 represents the item-wise export values selected for the study from the year 2012 to 2016. The major destination countries are the United Arab Emirates, Japan, Singapore & USA.

Table 2.2: Export values of selected consumer electronics products from fiscal years 2012 to 2017 (in million USD)

Year	**2012**	**2013**	**2014**	**2015**	**2016**
Air conditioner	0.08	0.05	0.00	0.08	0.15
Fan	1.17	2.97	5.55	1.58	5.57
Refrigerator	0.24	0.18	0.02	0.08	0.25
Washing Machines	0.00	0.02	0.00	0.00	0.00
Primary batteries	0.00	0.04	0.00	0.25	0.33
Electro-mechanical domestic appliance including food grinder, mixer& blender	0.00	0.00	0.00	0.00	0.00
Parts of Television (television receivers including video monitors, and video projectors)	2.00	0.00	0.00	0.00	1.00
Oven and rice cooker	0.01	0.00	0.00	0.05	0.14
LED Light	0.05	0.04	0.20	0.23	0.30
Vacuum Cleaner	0.00	0.00	0.00	0.15	0.00

It should be noted that neither the government bodies nor the associations were able to provide any export data for the food processor, blender, cooking range, inverter and stabilizer. Therefore, we couldn't identify the export values for the consumer mentioned above electronics products.

2.4 Existing Supply Chain Practices

Supply Chain is a systematic integrating process that involves different parties and entities to satisfy client's solicitation effectively and proficiently. It includes all parties legitimately or indirectly, which incorporates manufacturer, suppliers, transporters, distribution centers, retailers and even clients themselves.

It is an end-to-end process where the demand of customer is at one end, and the fulfilment of that demand is at the other terminal. Supply chain management at home appliance industries tries to coordinate all the processes to fulfil the customer's request.

Based on aggregate demand planning, further production, processing, and distributional planning are initiated.

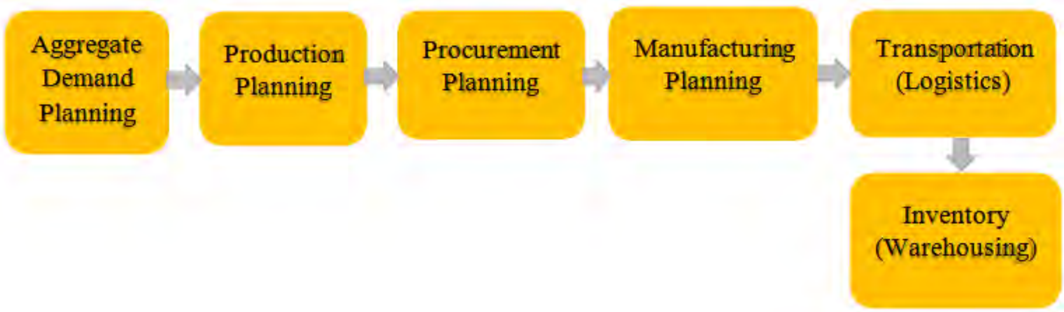

Figure 2.1: Supply Chain Management Planning

Alternative production procedures are assessed to deliver the ideal amount at a lower cost. Appropriate generation planning prompts to procurement order cycle/planning. Valuable suppliers are consulted with for the required fundamentals of manufacturing. Toward the end, the requested item is fabricated and circulated as needs be to the client.

The overall supply chain process goes through the following chain:

Figure 2.2: Supply Chain Management Factors

To meet the customer demand and deliver it at the lowest cost possible industries are following some supply chain management trends. In this chapter, these practices will be discussed. These practices are more or less of the same category for different industries. But home appliance industry supply chain practices are focused here.

2.4.1 Collaborative Demand Planning and Replenishment

Retailers and manufacturers study together to assess customer demand and work accordingly to create and develop the best supply chain strategy to meet the demand. This practice develops a replenished approach to attain the goal to fulfil the demand at the lowest cost. Firstly, the manufacturers gain tentative demand data according to the demand forecast from the retailers. Retailers hold the POS data and backroom inventory data which they use to project the future demand. According to this data, manufacturers order raw materials and manufacture the product in a certain time frame to avoid overspending on inventory and early production

2.4.2 Collaborative Production

Supplier and manufacture work together to reduce the inventory of raw materials and finished products stock level along the supply chain. This increases the responsiveness among the different parties related to meet customer demand. From the start of manufacturing, the raw material in house status is a big issue to reduce the overall cost of the production. Collaboration with the supplier of raw materials and finished products can lead to the successful execution of the supply chain. Because knowing the stock level of the raw materials and planning the production accordingly can save lost time and also save the inventory cost.

2.4.3 Collaborative Logistics Planning

The third area of the supply chain is related to the transportation of goods between stages in the supply chain. In the past, every party of the supply chain managed its own transport. Due to technological advancement in logistics and ICT enable the development of new paradigms based on cooperation. This facilitates to enable the scope of integration of raw materials and finished goods in the same chain, which decreases costs and increases responsiveness. By using the manufacturer's transportation, the supplier can send in the raw materials if it's available to use. Likewise, this cooperation between parties reduces the cost of the overall supply chain.

2.5 Categorization According to Power Consumption

Home appliances are electrical/mechanical machines which achieve some family unit capacities, for example, cooking, cleaning, or nourishment safeguarding.

Home appliances can be categorized into three groups, which are:

1. Major appliances, or white goods
2. Small appliances,
3. Consumer electronics, or brown goods

This division is mainly based on their power consumption and the extent to their usage. All the home appliances don't have the same use, and the capacity of that device varies too.

2.5.1 Major appliances

A major appliance, or residential apparatus, is a vast machine in-home apparatus utilized for routine housekeeping errands, for example, cooking, washing clothing, or sustenance conservation. Major appliances contrast from little appliances since they are greater and not compact. Usually, the power consumption of a washing machine is between 400 to 1300 watts whereas for a cooker it is 1000 to 5000 watts. But this two is considered in the same group for their frequency of use. The appliances in this group have a power consumption of around 150 to 1500 watts except for the cooker.

Major appliances are Refrigerator, Freezer, Water cooler, Cooker, Microwave oven, Washing machine, Clothes dryer, Dishwasher, Air conditioner, Water heater.

2.5.2 Small Appliances

Small appliances are typically small household electrical machines, also very useful and easily carried and installed. Yet another category is used in the kitchen, including juicers, electric mixers, meat grinders, coffee grinders, deep fryers, herb grinders, food processors, electric kettles, waffle irons, coffee makers, blenders and dough blenders, rice cookers, toasters and exhaust hoods.

Entertainment and information appliances such as home electronics, TV sets, CD, VCRs and DVD players, camcorders, still cameras, clocks, alarm clocks, computers, video game consoles, HiFi and home cinema, telephones and answering machines are classified as "brown goods". Some such appliances were traditionally finished with genuine or imitation wood. This has become rare, but the name has stuck, even for goods that are unlikely ever to have had a wooden case (e.g. camcorders). Generally, the power consumption of this category is around 60 to 700 watts. Exceptions are electric kettle, toaster which is at the higher end of consumption and clocks, HiFi, camcorders are at the lower end of the power consumption.

2.5.3 Consumer Appliances

Consumer appliances or home appliances are electronic (analogue or digital) equipment intended for everyday use, typically in private homes. Consumer electronics include devices used for entertainment (flat-screen TVs, DVD players, video games, remote control cars, etc.), communications (telephones, cell phones, e-mail-capable laptops, etc.), and home-office activities (e.g., desktop computers, printers, paper shredders, etc.). In British English, they are often called brown goods by producers and sellers, to distinguish them from "white goods" which are meant for housekeeping tasks, such as washing machines and refrigerators. In the 2010s, this distinction is not always present in large big-box consumer electronics stores, such as Samsung, which sells entertainment, communication, and home office devices and kitchen appliances such as refrigerators. These devices have very low power consumption. The value is around 100 watts.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This thesis aims to find out the most significant supply chain risk in the context of the Home Appliance industry in Bangladesh. As stated earlier in this thesis, firstly Delphi Survey method is used to identify the major risks associated with the supply chain. Secondly, to rank this risks TOPSIS method is introduced to divide them according to their rank preference.

To do so first, the survey on the different risks is done to find out the relevant and affecting ones in the context of SCM. Identification of the risks was based on the literature review and expert's opinion of Home Appliance industry. Furthermore, the most common and probable risks are identified. Then the TOPSIS method is used to rank among those risks in their rank order. This method is carried out in 6 steps. Each of these steps is discussed in the latter part of this chapter. Figure 3 portrays the overall approach of the thesis and methodology.

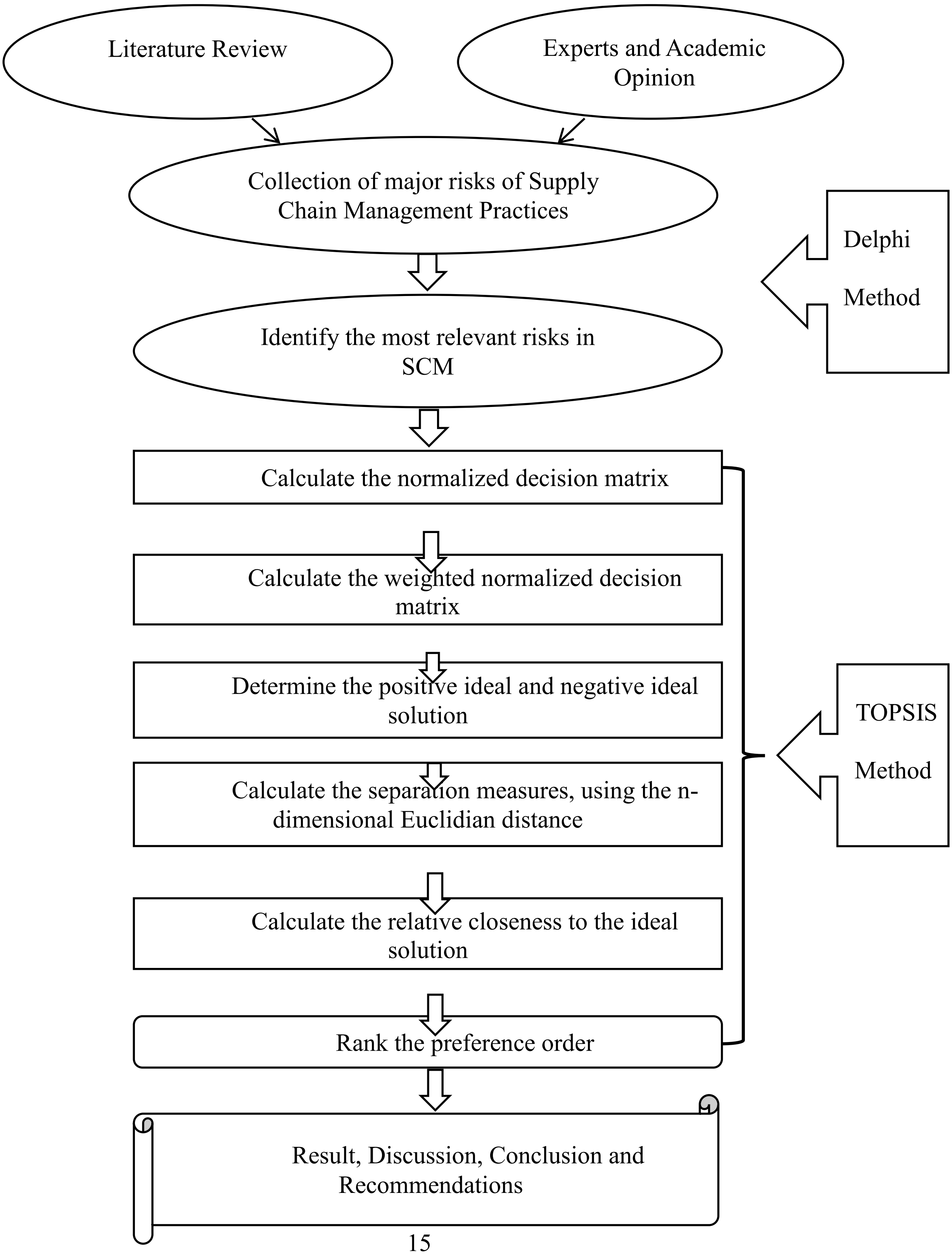
Literature Review
Experts and Academic Opinion
Collection of major risks of Supply Chain Management Practices
Identify the most relevant risks in SCM
Delphi Method
Calculate the normalized decision matrix
Calculate the weighted normalized decision matrix
Determine the positive ideal and negative ideal solution
Calculate the separation measures, using the n-dimensional Euclidian distance
Calculate the relative closeness to the ideal solution
Rank the preference order
TOPSIS Method
Result, Discussion, Conclusion and Recommendations

Figure 3.1: Conceptual Framework of the Thesis

3.2 Delphi Survey Method

The Delphi method has proven to be an efficient survey method when only a limited amount of data on a topic is available. The major aim of the approach is to assist and create a group communication procedure. Different experts from industry and scholars in the supply chain field participated in the survey to identify the existing and future risks in this sector. The assessment is done based on the consensus of the participants, and the dissent is taken accounted for to identify and select the most relevant events.

As this method strived to gain an in-depth assessment of arguments with a variety of perspectives on the topic from a wide range of experts, we conducted our research in the form of a real-time Delphi on the Internet. Recent research has proven that both conventional ground-based, as well as modern real-time Delphi methods, lead to comparable results. In the real-time data survey, the clarity of the survey is significant, and the experts get the feedback instantly right after one round is completed (Lee et al., 2009). This makes the participants available for the next round and prevents mortality of the group over various survey rounds.

Four central phases constitute this Delphi process. First, intensive literature, database and desk research were done on potential risks for the current and future supply chain management. The result is a long list of issues. During workshops with a mixed delegation of researchers and industry experts, the list was consolidated into a short-list of strategic issues, which are considered to be particularly relevant for SCS (Kannan et al., 2013). Strategic issues included both scientific as well as practical relevance. Second, we identified and invited experts with an appropriate level of expertise in the field to participate. In a third step, we facilitated the Delphi survey process by sending participants regular reminders and invitations to participate in the survey. In the last step, we analyzed the quantitative and qualitative data in various ways to identify the contribution of the survey to the field of SCS.

3.3 TOPSIS Method

In this study, according to proposed research methodology after applying the Delphi method on the found potential risks the TOPSIS method is implemented on the short-listed risks. TOPSIS method is used to make the most preferable choice among multi-criteria models in making complex decisions and multiple attribute models.

Decision-making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem (Saghafian & Hejazi, 2005). Multiple criteria decision making may be considered as a complex and dynamic process including one managerial level and one engineering level. The managerial level defines the goals, and chooses the final "optimal" alternative. The multi-criteria nature of decisions is emphasized at this managerial level, at which public officials called ',,decision makers‟‟ have the power to accept or reject the solution proposed by the engineering level. A MCDM problem can be concisely expressed in matrix format as

	C_1	C_2	...	C_n
A_1	X_{11}	X_{12}	...	X_{1n}
A_2	X_{21}	X_{22}	...	X_{2n}
A_m	X_{m1}	X_{m2}	...	X_{mn}

$W = [\, w_1, w_2, \ldots, w_n]$

where $A_1, A_2, \ldots, A_m$ are possible alternatives among which decision makers have to choose, $C_1, C_2, \ldots, C_n$ are criteria with which alternative performance are measured, ij is the rating of alternative A_i with respect to criterion C_j, w_j is the weight of criterion C_j.

Technique for order performance by similarity to ideal solution (TOPSIS), one of known classical MCDM method, was first developed by Hwang and Yoon (Parida & Sahoo, 2013) for solving a MCDM problem. It is based upon the concept that the chosen alternative should have the shorter distance from the positive ideal solution and the farthest from the negative ideal solution. A similar concept has also been pointed out by Zeleny (Liu et al., 2012). In the process of TOPSIS, the performance ratings and the weights of the criteria are given as exact values.

TOPSIS (technique for order preference by similarity to an ideal solution) method is presented in Chen and Hwang, with reference to Hwang and Yoon (Baykasoğlu et al., 2013). TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution (M. Amiri, M. Zandieh, B. Vahdani, M. Yazdani and R. Soltani, n.d.). The procedure to implement the TOPSIS method is as follows,

Step 1: Calculate the normalized decision matrix. The normalized value x_{ij} is calculated as

$$n_{ij} = x_{ij} \Big/ \sqrt{\sum_{j=1}^{m} x_{ij}^2} \quad , \; j = 1 , \ldots , \text{m}, \; i = 1 , \ldots , \text{n} \tag{3.1}$$

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as

$$v_{ij} = w_i n_{ij} \; , \quad j = 1 , \ldots , \text{m}, \; i = 1 , \ldots , \text{n} \tag{3.2}$$

where w_i is the weight of the ith attribute or criterion, and $\sum_{i=1}^{n} w_i = 1$.

Step 3: Determine the positive ideal and negative ideal solution.

$$A^+ = \{ v_1^+, \ldots, v_n^+ \} = \{(\max_j \; v_{ij} | i \in I) , (\min_j \; v_{ij} \, | i \in J)\} , \tag{3.3}$$

$$A^- = \{ v_1^-, \ldots, v_n^- \} = \{(\min_j \; v_{ij} | i \in I) , (\max_j \; v_{ij} \, | i \in J)\} , \tag{3.4}$$

where I is associated with benefit criteria, and J is associated with cost criteria.

Step 4: Calculate the separation measures, using the n-dimensional Euclidean distance.

The separation of each alternative from the positive ideal solution is given as

$$d_j^+ = \{ \sum_{i=1}^{n} \left(v_{ij} - v_i^+ \right)^2 \}^{\frac{1}{2}} \quad , \quad j = 1 , \ldots , \text{m.} \tag{3.5}$$

Similarly, the separation from the negative ideal solution is given as

$$d_j^- = \{ \sum_{i=1}^{n} \left(v_{ij} - v_i^- \right)^2 \}^{\frac{1}{2}} \quad , \quad j = 1 , \ldots , \text{m.} \tag{3.6}$$

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_j with respect to A^+ is defined as

$$R_j = d_j^- / (d_j^+ + d_j^-) \ , , \quad j = 1 , \ldots , \text{m.} \tag{3.7}$$

Since $d_j^- \geq 0$ and $d_j^+ \geq 0$, then clearly, $R_j \in [0,1]$.

Step 6: Finally, ranking the preference order according to the value of R_j. The R_j value of alternative that is closer to 1 implies the higher priority of the jth alternative.

The basic principle of the TOPSIS method is that the chosen alternative should have the „shortest distance" from the positive ideal solution and the „farthest distance" from the negative ideal solution. The TOPSIS method introduces two „reference" points, but it does not consider the relative importance of the distances from these points.

CHAPTER 4

A CASE STUDY

4.1 Application of the proposed research framework

The proposed research framework is applied in a home appliance factory in Bangladesh. The case of the home appliance factory is shown as a representative case selected for implementation of MCDM method Delphi and TOPSIS. Here the selected factory is XYZ which is an export-oriented home appliance manufacturing factory of Bangladesh. The products of the factory are exported in many developed countries and meets the demand of their own brand in the local market in Bangladesh. The factory has a vast network of supply chain activity throughout their operation as they are operating globally for sourcing raw material as well as exporting the final products. There are many variables that can cause a delay and hamper the overall flow of supply chain. So, the importance of identifying the risks and ranking them to focus on those factors specifically to increase the overall supply chain efficiency is significant. To implement the proposed research methodology in the context of XYZ factory is their top most concern.

The factory has been facing some serious issues in the supply chain department about the sudden changes of the factors related to the effectiveness of the overall supply chain. The risk factors affecting the supply chain cannot be identified at right time that"s why the loses are taking a toll on the overall performance of the factory. So, they want to be specific about the risk factors and want to have the clear insight about the top most risks related to their supply chain. This study helps to find out the most common risks to establish an efficient network for the home appliance factory supply chain.

The proposed research methodology requires firstly to identify the major risks among the existing common risks found from the literature reviews. To do that Delphi method was implemented and then among those results found from Delphi process, risk ranking was done using TOPSIS method.

4.2 Data Collection

For collection of data for this study firstly an extensive literature review was done to identify the common risks associated with the supply chain. To get the real review and experience about those risks projections Delphi panel was chosen and their opinions were evaluated to rank order the risks implementing TOPSIS method. Data was collected from the industry experts, teachers and supply chain experts to be more accurate about the real scenario.

Step 1: Selection of Risk Projections

The Delphi projections were developed through studies about the literature and practical issues in the industry. Projection identification for the Delphi survey was difficult as many varying elements are involved in the supply chain such as government, region, transportation and route, technologies used etc. The studied information needed to be put as a risk factor linguistic value for a better understanding of the survey participants. For that, the projection was simplified and presented to the experts and other participants. Therefore, the main focus was to make the projections based on the commonly searched or matched language terms.

Step 2: Delphi Panel Selection

The selection process was rigorous to select a suitable Delphi panel. The panel was grouped with supply chain management managerial level, teachers, government experts, students, suppliers, transportation and logistics organization personnel. The idea was to get the information from as much relevant source as possible. Contributing from all their opinion, the research gap could be mitigated. We were able to identify 85 potential SCS experts for our survey. These participants presented us with the diversified information about the risk assessment. Their area of experience and area of expertise are presented in Table 4.1 in a cluster form.

Table 4.1: Profile of Delphi panel members

Academics	Research areas	Affiliation
Professor, Assistant Professor	Supply Chain Risk Management	BUET, RUET, AUST, KUET
Manager, Head of the Department	Supply Chain	Walton, LG, Samsung, Bangla CAT, Navana Motors
Assistant Manager	Production	Hero MotoCorp, LG, Runner
Senior Executive officer	Local and foreign dispatch	Inventory and production
Government Officials	Customs & Law	Government export import operation, Law enforcement agency

Step 3: Analysis of the Delphi findings

The participants were sent the invitation of survey questionnaires through a hyperlink via email. In this link, they had the chance to access the survey questionnaire any time in the period of two months. The selection criteria of the risks were based on Likert scale rating criteria.

Table 4.2: Linguistic assessment and related LIKERT scale

Linguistic assessment	Related LIKERT scale value
Very Low	1
Low	2
Moderate	3
High	4
Very High	5

Among the 85 participants 45 (52.94%) participated in the survey, of which 31 (68.88%) were industry, 8 (17.77%) were engineering study background, and 6 (13.33%) came from the law or other association. The participants were sent a reminder to take the survey. After their assessment, the data was saved, and they had the chance to review their choice, and the overall result of the survey was displayed. The participants were given a chance to revise their opinion based on the final result if they felt like. In the survey management and related personnel from 5 home appliances industry were included to focus on the different perspective of view about the supply chain risks. Because of the diversification of the Delphi panel, we were able to achieve a multi-stakeholder view on the topic and generate a controversial discussion among the participants. As the participant number crossed the minimum of participants' number 30, it can be said the quality and the robustness of the survey has increased.

The initial list contained 23 supply chain risks which were further analyzed and refined by the experts in different sessions of workshops. The Delphi survey method contributed by facilitating further information to short-list the risks. After the opinion from the experts, the risks were condensed down to several 15. These risks relate to one way or other in the home appliance industry as the maximum number of participants was from this industry. These risks are listed below:

Table 4.3: Final list of risks to implement TOPSIS

Short-listed Risks found Applying Delphi	
1. Manufacturing lead time (A_1)	9. High transportation cost (A_9)
2. Product delivery lead time (A_2)	10. Natural disaster (A_{10})
3. Sourcing lead time (A_3)	11. Sales withdrawal (A_{11})
4. Inventory level (A_4)	12. Lack of material quality (A_{12})
5. Damage in inventory (A_5)	13. Inbound supply delay (A_{13})
6. Changes in market demand (A_6)	14. Flow of information gap (A_{14})
7. Raw material purchasing price (A_7)	15. Regulatory and bureaucratic risks (A_{15})
8. Transport delay (A_8)	

These risks are marked based on their survey risks preference assessment marking

	Product Cost (C_1)	**Sales Growth** (C_2)	**The Ratio of net Profit** (C_3)	**Market Share** (C_4)	**Order Fill Rate** (C_5)	**Relationship with Customers** (C_6)	**On time Delivery** (C_7)	**Occurrence Frequency** (C_8)

process where the marking was based on Likert scale. According to the survey, the risks with the maximum marking of low and very low risks were eliminated. The survey results and the responses of the participants are shown in the latter part of the thesis.

Step 4: The identified risk alternatives obtained from the Delphi method is evaluated in terms criteria to rank order preference those risks by TOPSIS method. For evaluating risks, a linguistic assessment scale is defined and for evaluating alternatives with respect to each risk a ranking scale is defined. These scales are introduced to the decision maker to evaluate risks and alternatives. The rating scale for evaluating risk alternatives and the found risk alternatives are shown in Table 4.2 and Table 4.3 respectively.

Step 5: The attributes of the alternatives are set considering the relation of the alternatives with criteria with the help of academic and industry experts. The value was taken on a scale of 1-10 to mark the relation with criteria. The impact of the risk alternatives is tested on 8 criteria. The attributes values and the criteria matrix are shown in the Table 4.4. In the row the risk alternatives and in the column the impact criteria are shown.

Step 6: With the help of a group of decision-makers, the specific weights of criteria and aggregated ranking of alternatives are constructed. Then the normalized decision matrix is constructed and shown in Table 4.5.

1.Manufacturing lead time (A_1)	7	5	6	3	8	9	8	7
2.Product delivery lead time (A_2)	4	8	5	3	10	10	10	8
3.Sourcing lead time (A_3)	9	7	4	5	9	3	7	7
4.Inventory level (A_4)	9	6	7	5	9	5	8	8
5.Damage in inventory (A_5)	9	4	8	5	8	5	9	4
6.Changes in market demand (A_6)	8	9	7	8	6	5	4	8
7.Raw material purchasing price (A_7)	9	8	8	6	5	1	4	9
8.Transport delay (A_8)	7	5	7	4	9	8	9	7
9.High transportation cost (A_9)	6	7	8	7	8	6	7	8
10.Natural disaster (A_{10})	5	8	9	8	9	7	10	4
11.Sales withdrawal (A_{11})	9	8	8	6	7	9	2	5
12.Lack of material quality (A_{12})	8	10	7	7	2	10	3	5
13.Inbound supply delay (A_{13})	9	6	9	8	6	7	9	4
14.Flow of information gap (A_{14})	4	9	7	5	9	6	8	6
15.Regulatory and bureaucratic risks (A_{15})	9	8	8	9	6	3	8	7

Table 4.4: Impact criteria relation matrix for the risk alternatives

Table 4.5: Normalized Decision Matrix

	(C_1)	(C_2)	(C_3)	(C_4)	(C_5)	(C_6)	(C_7)	(C_8)

(A_1)	0.398862	0.362738	0.4353	0.3111	0.405096	0.580947	0.422813	0.449977
(A_2)	0.227921	0.580381	0.3627	0.3111	0.50637	0.645497	0.528516	0.514259
(A_3)	0.512823	0.507833	0.2902	0.5185	0.455733	0.193649	0.369961	0.449977
(A_4)	0.512823	0.435285	0.5078	0.5185	0.455733	0.322748	0.422813	0.514259
(A_5)	0.512823	0.290190	0.5804	0.5185	0.405096	0.322748	0.475664	0.25713
(A_6)	0.445132	0.573819	0.4913	0.6576	0.315353	0.368604	0.227184	0.499026
(A_7)	0.456906	0.510061	0.5143	0.4536	0.295141	0.108465	0.266076	0.54371
(A_8)	0.370999	0.335578	0.4221	0.3105	0.531253	0.676123	0.560315	0.422885
(A_9)	0.340229	0.456629	0.4698	0.5078	0.486864	0.488273	0.449052	0.483298
(A_{10})	0.313112	0.475550	0.5137	0.5287	0.531253	0.529150	0.617802	0.241649
(A_{11})	0.545705	0.490511	0.4458	0.4232	0.404145	0.592156	0.126491	0.326164
(A_{12})	0.500979	0.575435	0.3995	0.4785	0.119737	0.550481	0.192450	0.373718
(A_{13})	0.531253	0.339140	0.4888	0.4942	0.392232	0.394405	0.577350	0.331042
(A_{14})	0.244796	0.484543	0.3889	0.3241	0.568075	0.338061	0.498058	0.552345
(A_{15})	0.500773	0.430705	0.4566	0.5636	0.41804	0.180906	0.536924	0.569652

Step 7: After getting the normalized decision matrix, the weighted normalized decision matrix is constructed. The weights of the criteria are shown in the Table 4.6.

The normalized decision matrix is shown in the Table 4.7. These weights are multiplied with the value of n_{ij} and the value matrix is shown in the table 4.8.

Table 4.5: Weights of the impact criteria

Impact Criteria	**Weights**
Product cost (C_1)	0.17
Sales growth (C_2)	0.13
The ratio of net profit (C_3)	0.13
Market share (C_4)	0.11
Order fill rate (C_5)	0.1
Relationship with customers (C_6)	0.1
On time delivery (C_7)	0.14
Occurrence Frequency (C_8)	0.12

Table 4.6: Weighted Normalized Decision Matrix

Step 8: To compare the values of the weighted normalized decision matrix a positive ideal solution (A^{+}) and a negative ideal solution (A^{-}) is determined taking the

	(C_1)	(C_2)	(C_3)	(C_4)	(C_5)	(C_6)	(C_7)	(C_8)
(A_1)	0.067807	0.047156	0.056674	0.034248	0.04051	0.058094	0.059193	0.053997
(A_2)	0.038747	0.075449	0.047213	0.034256	0.050637	0.064549	0.073992	0.061711
(A_3)	0.08718	0.066018	0.037754	0.057586	0.045573	0.019364	0.051794	0.053997
(A_4)	0.08718	0.056587	0.066224	0.057356	0.045573	0.032274	0.059193	0.061711
(A_5)	0.08718	0.037724	0.075465	0.057254	0.04051	0.032274	0.066593	0.030856
(A_6)	0.075672	0.074596	0.063945	0.072356	0.031535	0.036860	0.031805	0.059883
(A_7)	0.077674	0.066308	0.066936	0.049923	0.029514	0.010846	0.037250	0.065245
(A_8)	0.06307	0.043625	0.054965	0.034269	0.053125	0.067612	0.078444	0.050746
(A_9)	0.057839	0.059361	0.061168	0.055947	0.048686	0.048827	0.062867	0.057996
(A_{10})	0.053229	0.061821	0.066854	0.058286	0.053125	0.052915	0.086492	0.028998
(A_{11})	0.09277	0.063766	0.058587	0.046647	0.040415	0.059215	0.017708	0.03914
(A_{12})	0.085167	0.074806	0.051954	0.052686	0.011974	0.055048	0.026943	0.044846
(A_{13})	0.090313	0.044088	0.063514	0.054487	0.039223	0.039440	0.080829	0.039725
(A_{14})	0.041615	0.062990	0.050645	0.035712	0.056807	0.033806	0.069728	0.066281
(A_{15})	0.085131	0.055991	0.059414	0.062557	0.041804	0.018090	0.075169	0.068358

maximum value for positive ideal solution and taking the minimum value for negative ideal solution from the data range.

Table 4.7: Positive and Negative Ideal Solution

Criteria	(C_1)	(C_2)	(C_3)	(C_4)	(C_5)	(C_6)	(C_7)	(C_8)
(A^+)	0.0927	0.0754	0.0754	0.0723	0.0568	0.0676	0.0864	0.0683
(A^-)	0.0387	0.0377	0.0377	0.0341	0.0119	0.0108	0.0177	0.0290

Step 9: The separation measures for each of the risk alternatives are calculated using the formula stated in equation 3.5 and 3.6. The separation (d_j^+) of each alternative from positive ideal solution and separation (d_j^-) from negative ideal solution is calculated.

Table 4.8: Separation Values from Positive and Negative Ideal Solution

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
d_j^+	.0673	.0736	.0751	.0536	.0707	.0712	.0853	.0645	.0551	.0616	.0838	.0852	.0583	.0785	.0600
d_j^-	.0817	.1006	.0815	.0916	.0892	.0841	.0737	.0999	.0867	.1020	.0860	.0797	.0971	.0862	.0975

Step 10: To calculate the relative closeness of the alternatives to the ideal solution equation 3.7 is followed. This relative closeness values determines the decision-making priority. The closer the value to 1 the more the priority becomes. The alternatives are ranked according to this rule and ranking is discussed in the later part of this thesis.

Table 4.9: Relative Closeness of the Alternatives to the ideal Solution

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R_j	.5481	.5775	.5206	.6309	.5577	.5414	.4632	.6077	.6112	.6231	.5065	.4834	.6245	.5235	.6189

CHAPTER 5

RESULT AND DISCUSSIONS

5.1 Results and Discussions

Major risks related to supply chain are identified and the risks are ranked for smooth supply chain operation in "XYZ" home appliance manufacturing factory in this study.

The proposed methodology has been systematically implemented to evaluate and rank the risks associated with the supply chain.

Table 5.1: Ranking Decision Making from the Risk Alternatives

dj+	**dj-**	**Rj**	**Rank**	**Risk Alternatives**
0.053614439	0.091678485	0.630990709	1	**(A4)**
0.058386139	0.097130812	0.624567364	2	**(A13)**
0.061679958	0.102003911	0.62317632	3	**(A10)**
0.060071323	0.097579816	0.618960424	4	**(A15)**
0.055149651	0.086715649	0.611253417	5	**(A9)**
0.064535196	0.099990839	0.607750857	6	**(A8)**
0.073619091	0.100642878	0.577537821	7	**(A2)**
0.070748731	0.089213833	0.557716949	8	**(A5)**
0.067379334	0.081742862	0.548160262	9	**(A1)**
0.071231598	0.084123052	0.541490403	10	**(A6)**
0.078521776	0.086294676	0.523580476	11	**(A14)**
0.075111454	0.081597724	0.520695243	12	**(A3)**
0.083853242	0.086088045	0.50657522	13	**(A11)**
0.085240967	0.079773308	0.48343277	14	**(A12)**
0.085386214	0.073702282	0.463278514	15	**(A7)**

The Table 5.1 shows the ranking according to the relative closeness to the ideal solution of main supply chain risks. Based on the normalized decision matrix and weighted normalized decision matrix value calculated and obtained from Table 4.4 & Table 4.6, the value of the Table 5.1 is calculated to rank the main supply chain risks to ensure the smooth operation of supply chain for the case factory. The ranking is done according to the impact of the risk and the importance of the associated criteria. The final ranking is as follow:

Inventory Level (A4)>Inbound Supply Delay (A13)>Natural Disaster (A10)>Regulatory and Bureaucratic risks (A15)>High Transportation Cost (A9)>Transport Delay (A8)>Product Delivery Lead Time (A2)>Damage in Inventory (A5)>Manufacturing Lead Time (A1)>Changes in Market Demand (A6)>Flow of Information Gap (A14)>Sourcing Lead Time (A3)>Sales Withdrawal (A11)>Lack of Material Quality (A12)>Raw Material Purchasing Price (A7).

The identified results of this study are shown to the industry experts and the accepted the major identified risks and the appreciated the risk ranking as well. Inventory level gained the first position with the R_j value of (0.63099). This seems to be a huge issue to consider as the forecasting of demand is very much related to the inventory level. Unwanted inventory is a burden to a company and poses a huge opportunity and financial loss. Second comes the inbound supply delay risk with a score of (0.62456), for which the material required and ordered for the factory is delayed to arrive hence the production gets delayed and the overall cost increases. Natural disaster comes third with a score of (0.62317). Supply chain operations are affected drastically for natural disasters and the cost gets out of control. Sudden uncertainty is a big challenge and it‟s impact is fair high.

Fourth is the Regulatory and Bureaucratic rules (0.61896) that implies on the policy of the supply chain operations like purchasing tax, freight charge, documentation rigidness etc. As a result, the cost gets high and challenging to meet the required deadline. High Transpiration Cost (0.61125) and Transport delay (0.60775) is fifth and sixth on the list respectively. Transport or logistics is an important part of the supply chain which ensures the overall smooth and efficient flow of operation. Well organized supply chain network can mitigate the uncertainty about cost and time.

In number seven, eight and nine are the Product Delivery Lead Time (0.57753), Damage in Inventory (0.55771) and Manufacturing Lead Time (0.54816). These are the risks that are mainly related to the production. On time delivery of the finished product is the main challenge to satisfy the customer for which the sales growth and market share is directly related. Damage in the inventory of raw material and finished goods is devastating to the financial gain for the company as the work need to be done again. Manufacturing of a particular goods within the given lead time and delivering it on time without damaging is the main objective of the production facility.

Changes in Market Demand (0.54149) is at number ten on the list. The industry experts shared their views about the issue. The demand variation needed to be studied closely and the forecasting should be near accurate to obtain an efficient supply chain. Flow of Information Gap (0.52358) ranked eleventh. The information requirement and changes of specific details needed to be carried out to the responsible persons on time without delay and distortion. Information gets manipulated and the flow gets slower which causes a big loss.

Sourcing Lead Time (0.52069), Sales Withdrawal (0.50657), Lack of Material Quality (0.48343) and Raw Material Purchasing Price (0.46327) are the last four risks of the list. These four risks are associated with the material sourcing. The sourcing and procurement team face difficulties to maintain overcome these challenges due to uncertainty from the supplier end and the supplier selection is also very difficult.

5.2 Sensitivity Analysis

To check the robustness of the proposed methodology sensitivity analysis is done and the changes in the results are shown. The weight of impact criteria is different based on the opinion of different experts and different factory. In this study, we use archetypal sensitivity analysis by assigning separate weightings to different criteria identified by the experts and academics. To check the validation of the evaluation criteria of this study the calculation and evaluation of the major identified risks the TOPSIS method is tested again based on the varied weight factors of the impact criteria. The changed weight of the impact criteria is shown in Table 5.2.

Table 5.2: Changed Weights of Impact Criteria

Impact Criteria	**Weights**
Product cost (C_1)	0.13

Sales growth (C_2)	0.11
The ratio of net profit (C_3)	0.14

	(C_1)	(C_2)	(C_3)	(C_4)	(C_5)	(C_6)	(C_7)	(C_8)

Market share (C_4)	0.11
Order fill rate (C_5)	0.12
Relationship with customers (C_6)	0.11
On time delivery (C_7)	0.14
Occurrence Frequency (C_8)	0.14

For analyzing the changes in the decision matrix, the weighted normalized decision matrix is constructed according to the new weights of the criteria which is shown in the Table 5.3. The normalized decision matrix is unchanged as the attributes value of the risk alternatives is not changed. The comparison of the values of weighted normalized decision matrix with the positive ideal solution and negative ideal solution is calculated. The result is shown in the Table 5.4. Following the formula of equation 3.5 and 3.6 the separation values from the positive and negative ideal solution is measured.

After getting the separation values, relative closeness to the ideal solution is calculated and compared to the closeness to the value 1. The closer the value of R_j to 1 the more important the risk criteria on basis of the impact criteria. The values are then ranked according to their performance values based on the values of separation measures (d_j^+, d_j^-) and relative closeness values R_j are shown in the Table 5.5.

(A_1)	0.05185	0.03990	0.06094	0.03422	0.04861	0.06390	0.05919	0.06299
(A_2)	0.02963	0.06384	0.05078	0.03422	0.06076	0.07100	0.07399	0.07199
(A_3)	0.06666	0.05586	0.04062	0.05703	0.05469	0.02130	0.05179	0.06299
(A_4)	0.06666	0.04788	0.07109	0.05703	0.05469	0.03550	0.05919	0.07199
(A_5)	0.06666	0.03192	0.08125	0.05703	0.04861	0.03550	0.06659	0.03599
(A_6)	0.05786	0.06312	0.06878	0.07234	0.03784	0.04054	0.03180	0.06986
(A_7)	0.05939	0.05610	0.07199	0.04989	0.03542	0.01193	0.03725	0.07611
(A_8)	0.04823	0.03691	0.05909	0.03415	0.06375	0.07437	0.07844	0.05920
(A_9)	0.04423	0.05022	0.06576	0.05586	0.05842	0.05371	0.06286	0.06766
(A_{10})	0.04070	0.05231	0.07191	0.05815	0.06375	0.05820	0.08649	0.03383
(A_{11})	0.07094	0.05395	0.06241	0.04655	0.0485	0.06513	0.01770	0.04566
(A_{12})	0.06512	0.06329	0.05593	0.05264	0.01437	0.06055	0.02694	0.05232
(A_{13})	0.06906	0.03730	0.06843	0.05437	0.04707	0.04338	0.08082	0.04634
(A_{14})	0.03182	0.05329	0.05444	0.03565	0.06817	0.03718	0.06972	0.07732
(A_{15})	0.06510	0.04737	0.06392	0.06201	0.05016	0.01989	0.07516	0.07975

Table 5.3: Weighted Normalized Decision Matrix based on Changed Weights of Impact Criteria

Table 5.4: Positive and Negative Ideal Solution

Criteria	(C1)	(C2)	(C3)	(C4)	(C5)	(C6)	(C7)	(C8)
(A^{+})	0.07094	0.06384	0.08125	0.07234	0.06817	0.07437	0.08649	0.07975
(A^{-})	0.02963	0.03192	0.04063	0.03415	0.01437	0.01193	0.01770	0.03383

Table 5.5: Ranking Decision Making from the Risk Alternatives

dj+	dj-	Rj	Rank	Risk Alternatives
0.051345	0.092315	0.642595	1	A4
0.060799	0.106688	0.636993	2	A13
0.061035	0.106791	0.636321	3	A10
0.055753	0.091855	0.62229	4	A15
0.06611	0.106718	0.617483	5	A9
0.061225	0.094685	0.607305	6	A8
0.064282	0.097829	0.603466	7	A2
0.065735	0.086114	0.567103	8	A1
0.073318	0.093731	0.561097	9	A14
0.073995	0.087569	0.542011	10	A5
0.074022	0.082997	0.528578	11	A6
0.08031	0.078705	0.494952	12	A3
0.086503	0.083405	0.490883	13	A11
0.09191	0.074912	0.449053	14	A12
0.090511	0.072912	0.446155	15	A7

The ranking of the risk alternatives according to the changed weights of the impact criteria is as follow:

Inventory Level (A4)>Inbound Supply Delay (A13)>Natural Disaster (A10)>Regulatory and Bureaucratic risks (A15)>High Transportation Cost (A9)>Transport Delay (A8)>Product Delivery Lead Time (A2)> Manufacturing Lead Time (A1)>Flow of Information Gap (A14)> Damage in Inventory (A5)>Changes in Market Demand (A6)> Sourcing Lead Time (A3)>Sales Withdrawal (A11)>Lack of Material Quality (A12)>Raw Material Purchasing Price (A7).

From the above ranking found based on the change weightings it is clear that there is no major change in ranking among various risk alternatives during sensitivity analysis. These results show the same priority ranking order for the risk alternatives considering the impact criteria weightings changes except a minor order variation in the ranking. So, it can be said that there is no serious change in the ranking for sensitivity analysis. Therefore, the applied sensitivity analysis technique ensures the robustness of obtained final results.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The global competition of the industries is based on different types of challenges arisen with the advancement and globalization of the industry. The fast-increasing challenges like global competition, raw material‟s dependency, increased product diversity, demanding customer and globalization have a key impact on the home appliance industry. The home appliance industry of Bangladesh is vulnerable to a lot of risks related to supply chain. The risk can originate from various sources and can abate the overall efficiency of the supply chain. The home appliance industry is facing numerous risks and dealing with the risks are getting difficult. Identification of the risks related to the supply chain is very important and to tackle these risks systematically they needed to be ranked.

The goal of this thesis work was to identify and analyze the supply chain risks that have a vital role in affecting the smooth and efficient operation of chain management practices in home appliance industry. To identify the risks primarily extensive literature review is done and then Delphi method is used to short list those risks with the help of opinions of industry experts and academics. There were 23 risks found initially from the existing literature review and discussion with industry experts. Among those 15 of the risks are found to be most related and affecting to the home appliance industry of Bangladesh after applying Delphi method. These risks are then ranked systematically using the TOPSIS method incorporating 8 impact criteria. The attributes of the risk alternatives and weightings of the criteria are set discussing with the selected Delphi panel members. The risk ranking results are discussed in the result part of this study. To implement a smooth and efficient supply chain management in context to home appliance industry the ranking will serve as an action plan summary. The ranking reduces the uncertainty of the risk encounter and the impact of the risk can be mitigated by handling the top ranked risks systematically.

6.2 Recommendations

In this thesis, to identify and short-list the supply chain risks Delphi method is used and to rank those risks a multiple criterion decision-making tool TOPSIS method is proposed. Also, a real-life industrial case study is discussed to present the way of testing proposed research methodology in context to Bangladesh. The prospect of this thesis is, it will help to identify and evaluate the supply chain risks in other industrial fields of Bangladesh to implement a smooth and efficient supply chain. The findings from this thesis could be used in the growing industrial sector of Bangladesh like leather goods, garments, food processing, polymer, footwear, mining, chemical, pharmaceutical etc. All of these industrial sectors have a vast channel of supply chain activity and vulnerable to various types of risk factors which increases the overall cost of an industry. This thesis will help the persons in the industry who are responsible for achieving overall SCM activity efficiently. All the risks factors are not covered in this study as one industry is not ideal for identifying all sorts of risks. To implement this methodology in other sectors the relevant factors needed to be considered. Other MCDM tools like Fuzzy-VIKOR, Fuzzy-DEMATEL Fuzzy-AHP, ANP, ISM, ELECTRE III, Fuzzy TOPSIS can be used for analysis of SCR to evaluate most influential SCR to obtain a successful supply chain system.

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APPENDICES

Appendix A: Survey form to identify prioritized risk associated with supply chain to implement Delphi Method.

Appendix B: Survey form responses