Analysis of Barriers in Implementing Green Supply Chain Management in Plastic Industry

Towfique Rahman

A thesis submitted in partial fulfillment of the requirement for the degree of

MASTER OF ENGINEERING IN ADVANCED ENGINEERING MANAGEMENT

Department of Industrial and Production Engineering

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CERTIFICATE OF APPROVAL

The thesis titled "Analysis of Barriers in Implementing Green Supply Chain Management in Plastic Industry" submitted by Towfique Rahman, Student No. 1015082114 P, Session - October 2015, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management on 05 March, 2018.

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

Towfique Rahman

Date: 05 March, 2018

Towfique Rahman

This Work is Dedicated to My

Parents

Md. Abdur Razzaque & Latifa Khatun

For their endless love, support and encouragement

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List of Abbreviations

BPGMA:	Bangladesh Plastic Goods Manufacturing Association
BNP:	Best Non-fuzzy Performance
COA:	Center of Area
EPB:	Export Promotion Bureau
FS :	Fuzzy Set
GSCM:	Green Supply Chain Management
MCDA:	Multi Criteria Decision Analysis
MOM:	Mean of Maximal
PVC :	Polyvinyl Chloride
PC:	Personal Computer
PET:	Polyethylene Terephthalate
TFN:	Triangular Fuzzy Number

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Abstract

Researchers and practitioners have given much importance to green supply chain management (GSCM), an interdisciplinary field, as a proactive approach to accelerate awareness and mitigate environmental impacts. Understanding and application of various sustainability practices into traditional supply chain management and relating them to environmental issues and performance have been heavily scrutinized in the last couple of years. Ecological sustainability initiatives are gaining popularity as a result of increasing environmental problems, competitive advantages, legislative bindings, international pressures, financial benefits and societal issues. Due to the increased pressures from various advocacy groups and governments for firms to mitigate environment impacts from their supply chains, companies have started incorporating green initiatives into their supply chains. Yet, there are some difficulties faced by some companies especially those in the plastic industry of Bangladesh to implement GSCM. This study therefore attempted to examine the barriers to implementing GSCM in the plastic industry of Bangladesh. The study used a combination of literature review and opinions of some selected managers from the plastic industry of Bangladesh to identify four main-barriers and twenty-five sub-barriers relevant to GSCM implementation, and proposed four alternative action plans to help mitigate these barriers. Fuzzy-VIKOR approach was applied to aid in the evaluation of the barriers and action plans in the plastic industry of Bangladesh. The findings of the study shows that, the order/rank of intensity and severity of the main-barriers to implementing GSCM initiatives in the plastic industry of Bangladesh are as follows: “inadequate knowledge and support” “insufficient technology and infrastructure” “financial constraints” and “unsupportive organizational and operational policies”. The results also show the rankings of the su -barriers under each main barrier and that of the four alternative action plans for the smooth implementation of GSCM practices. This study can provide managers with a better understanding of the barriers to implementing GSCM practices and insights for developing strategies for implementing GSCM practices in the plastic industry of Bangladesh.

Chapter 1

Introduction

1.1. Introduction

Environmental damage and degradation, the negative impacts of human activities has received growing attention over the last few decades. Sustainable development through green activities has gained considerable attention due to global pressure, business to business demand, legislature consumers‟ awareness environmental policies and societal issues [1–3]. International organizations, national policies, industries, academicians are giving importance to green innovations to reduce environmental degradation and energy wastage. Incorporating green activities into the existing supply chains is a growing trend. The goal of green activities is to help organizations reduce energy waste, conserve biodiversity and eco-system and also protect the environment. Green supply chain activities are gaining popularity in current industrial setting. Manufacturing organizations are incorporating green activities into their supply chains to protect the environment, ensure a promising profit and increase production to gain acceptance, popularity and reliability in the highly competitive local and global business environment. GSCM (green supply chain management) can be defined as the process of using eco-friendly inputs or green materials, and converting these inputs into green outputs that can be retrieved and reused at the end of their life cycle thus, creating a promising and eco-friendly supply chains [4–6]. This eco-materials transformation into green outputs retrievable or reusable at end-of-life stages are supported by green equipment and green technology manufacturing or production processes which ensure less emission of carbon dioxide and less energy loss. GSCM is important in reducing the total negative environmental impact of any manufacturing plant involved in supply chain activities which can contribute to sustainable development and ensure performance enhancement [7]. Incorporating green supply chains concept into the traditional operational activities is challenging. Greening the supply chains involve all the activities of the operations which include: sourcing, transportation, logistics, packaging, distribution, warehouse, production, materials, infrastructure etc. [7]. Greening all these parts of the chain of a company increases the competitiveness in the market. Companies can build a good reputation and image by implementing green activities in their management and supply chain. GSCM practices ensure economic benefits for the manufacturers and companies.

1.2. Motivations

Green practices in the supply chain have enormous benefits for the manufacturers and companies. Green supply chain and operations initiatives are very famous in the developed. In some cases, adopting GSCM practices is a legislative requirement in the developed countries [8]. However, in the developing country, adopting green practices in the supply chains is still in the embryonic stage. In Bangladesh, green activities of the supply chains are not well practiced. Yet due to glo al pressure investors" pressure government legislation, changing corporate philosophy, the manufacturing industries of Bangladesh have started to adopt green practices in their management, operations and supply chains. However, there are many difficulties faced by these organizations in an attempt to fully implement these GSCM practices. These difficulties results in failures posing serious barriers to GSCM implementation. Identifying these barriers is an important and initial step to take. Understanding them and their severities can help clarify and aid in their removal and management of these barriers. The following research questions are the basis for the objectives of this study:

1. What are the current supply chain structures of the plastic industry of Bangladesh?
2. What are the barriers to implementing GSCM in the plastic industry of Bangladesh?
3. How can these barriers to GSCM practices implementation be evaluated and ranked?

Many researches and studies have been conducted on the barriers to implementing GSCM practices in different industries and countries. For example, Jayant et al., [9] investigated the barriers to the implementation of GSCM practices in the Indian manufacturing industry whereas Mehrabi et al., [12] studied the barriers to GSCM implementation in the petrochemical industry among others. Yet, literature and expert opinions have shown that green concepts are not well practiced in the plastic manufacturing sector of Bangladesh. There are several barriers to implementing GSCM in the plastic industries of Bangladesh. These barriers are making GSCM implementation in the manufacturing plants of plastic industries a difficult task. Yet, no research has been conducted to identify and propose an approach to dealing with these barriers when implementing GSCM practices in the plastic industries of Bangladesh. To address this research gap in literature and practice, this study focuses on determining and ranking the barriers to implementing GSCM practices in the plastic industries of Bangladesh.

1.3. Contributions

The contributions of this study are justified by the specific objectives and findings of this study and uniqueness of the research process as compared to other research conducted in the context of Bangladesh. A case manufacturing company of the plastic industry in Bangladesh is considered in this study. The barriers were identified through a combination of literature review and expert opinions. In Bangladeshi context, no research has been conducted concerning barriers in implementing GSCM in the plastic industry using fuzzy-VIKOR approach. Additionally, no study has been carried out on the action plans in implementing GSCM practices in the plastic industry of Bangladesh. This study ranks the identified barriers and their sub-barriers in order of severity for removing them and also evaluates and ranks the action plans for smooth implementation of GSCM practices in the plastic industries of Bangladesh.

So, the specific objectives of this study are summarized as follows:

1. To identify significant barriers to implementing GSCM practices for a plastic manufacturing factory in Bangladesh.
2. To evaluate and rank the barriers by using a fuzzy-VIKOR approach.
3. To assess and rank the alternative action plans for the smooth implementation of GSCM in the case company.

1.4. Organization of the Thesis

To fulfill the objectives of this study, this research work is prepared as follows: Chapter 2 describes the brief of green supply chain management, plastics industries of Bangladesh, reviews of the existing works and the brief of barriers. Proposed research methodology with the solution methodology is presented in Chapter 3. An industrial case study with an application of the fuzzy-VIKOR method is given in Chapter 4. Results and discussions are explained in Chapter 5. Finally, the conclusion along with the managerial implications and future directions of the study is drawn in Chapter 6.

Chapter 2
Literature Review

In this section the literature review on GSCM, practices of GSCM in plastic manufacturing industry, existing works on barriers analysis and the barriers to GSCM implementation are presented.

2.1. Green Supply Chain Management (GSCM)

Environmental sustainability and ecological balance have been prime concern among environmentalists, researchers and practitioners. Due to the emerging degradation of the environment and wastage of energy, the industries and manufacturing plants are encouranged to adopt green and sustainable measures to protect the environment. The term „green‟ has been aligned with the emerging trend „sustaina ili ty‟ concepts. Green activities focus on the environmental conditions which promote sustainable development [4–6]. Economic growth, rapid industrialization and new technology usage result in an increased waste generation and inadequate disposal system. These conditions are the causes of air pollution, deforestation, land degradation, an imbalance in bio-diversity etc. [11]. These environmental degradation and energy wastage have a tremendous impact on environment i.e. poor health, less agriculture production, climate change etc. GSCM focuses on the reduction of the negative environmental impacts by redesigning procurement, manufacturing system and proper waste processing and reverse logistics infrastructure [11]. The industries and manufacturing plants are facing local and global pressures to adopt green features in the emerging supply chain structure and management. GSCM is a concept to facilitate the deployment of environmental initiatives into the supply chains from the organizational sourcing to the end product, ensuring less energy waste, less environmental degradation etc. GSCM ensures a promising and a long-term relationship with the suppliers and consumers with the long run commitment to promoting green activities. Incorporating green activities into the supply chains ensures reduction of wastage and energy loss [12]. The action plans of green supply chain belong to three areas – strategy, environment and logistics. The main concern of GSCM is the sustainability and protection of the environment. Logistics activities are considered vital part of green supply chain. Logistics activates such as selection of raw materials, distribution channel, warehouse, reverse logistics and waste processing management are the primary concerns of green activates of the whole supply chain. GSCM helps the industries increase efficiency by reducing resources and energy loss.

The present economy of the world is largely dependent on manufacturing and production. But due to the emerging needs, manufacturing plants are giving utmost priority to mass production giving less priority to the environmental sustainability. Yet, ecological balance is a must for the existence of human being. Energy is limited therefore reduction in energy use can result in dramatic positive consequences in the long run. Local and global organizations are very much concerned about the present condition of the world. Therefore, they are giving pressures to the industries to adopt GSCM practices in their management and operations.

Many studies and researches are being conducted on the concept of GSCM. But most of these works have been carried out in the context of developed countries [13]. These works can provide a framework for further study of GSCM practices in emerging economies context. Previous researchers have identified many dimensions of green supply chain concepts. Beamon[14] investigated the comparison between tradition supply chain and green supply chain. He argued that traditional supply chain is a one-directional strategy where raw materials are converted to final products for the end customers. He further stated that green supply chain is more focused on the environmental issues which are a multi-dimensional strategy. In their study, Govindan et al.[15] examined the barriers to implementing GSCM in Indian industries. Luthra et al.[16] investigated the barriers to implementing GSCM practices in the automobile industries. Ojo et al.[17] studied the substantial barriers to implementing GSCM in construction industries.

GSCM practices are of two categories including: internal GSCM practices and external GSCM collaboration practices. Green marketing and branding, green policy, green technology in production process, green shipping methods belong to the internal activities of GSCM. Collaboration with suppliers, customers and other parties regarding the long-term commitment of green activities are considered as external activities of GSCM [18,19]. Green design (eco-design), green packaging, green procurement, green sourcing, green production, green material selection, green supplier selection, green logistics i.e. green transportation, green warehouse, green recycling, green logistics, green purchasing, green marketing, green policy, green shipping, circular economy, waste processing facility are all modern concepts of GSCM.

Greening all these activities and contents of supply chain ensures the sustainability of the environment. Establishing internal and external practices of GSCM ensures the long-term relationship with the supplier for green sourcing of materials, smooth operations in the manufacturing plants to reduce energy waste, production of eco-friendly products for the consumers and also ensures guaranteed returns after the end of the product lifecycle all ensuring the survival of the initiative. Continuous improvement and innovations in greening the processes of the supply chains will help mitigate the environmental risks. There are lots of barriers which hinder the implementation of GSCM practices. Continuous research and needful actions will help industries handle the barriers and establish action plans for introducing green activities into their traditional supply chain.

2.2. The Current State and Practices of GSCM in the Plastic Industry of Bangladesh

The plastic industry has become an important industrial sector in Bangladesh for the last few decades. According to Bangladesh Plastic Goods Manufacturing Association (BPGMA), the journey of this industry started around the year 1960. There was significant growth of this industry during 1980-1990. Since then this industry has played and is playing a major role in the economy of Bangladesh. Due to the growth and export potential of this sector, Bangladesh government is facilitating the development of this area. The BPGMA report says that there are around 3000 small, medium and large size plastic goods manufacturing units in this country. This industry has a huge economic impact in Bangladesh with the current market size of around US$ 1 Billion of which US$ 714 Million pertain to domestic and the rest to the global market (Source: BPGMA). The report of Export Promotion Bureau (EPB) says Bangladesh earned around US$ 68 Million from plastic products export to the UK, USA, EU countries, Malaysia etc. The report also reveals that Bangladesh made US$ 50 Million in the year 2009-2010 and it was US$ 52 Million in the year 2008-2009. Plastics products are also exported to SAARC member countries i.e. India, Nepal, Sri-Lanka etc.

The supply chain of this industry includes sourcing of raw materials from home and abroad, production of different grade plastics and plastic goods, distribution to the end consumer. Plastic is a synthetic material composed of various grades of organic polymer i.e. polyethylene, PVC, nylon and other chemical elements. These plastic products are used for different purposes i.e. packaging, construction, garbage bag, toothbrush, artificial flowers, ball pen, PVC (polyvinyl chloride) pipes, electric switches, PC accessories, mobile and many useful things. They are used in different industries i.e. healthcare, construction, agriculture etc. According to a report of BPGMA about 0.75 million tons of plastic raw materials, mostly known as Resin, are needed for this industry in Bangladesh (BPGMA). At present most of the polymer demand is met through importation.

The supply chain structures of the plastic industries of Bangladesh need to be up to the mark to compete in the global market. Many toxic and hazardous chemicals i.e. dichloromethane, acetone, methylene chloride, methyl ethyl ketone, styrene, toluene, benzene, sulfur oxides, nitrous oxide, methanol, ethylene oxide are emitted during the production of plastic products [20]. They have hazardous impacts on the environment. The production of a PET (Polyethylene Terephthalate) bottle releases about 100 (hundred) times air pollutants than by the same amount of glass production. The green technologies and green activities need to be incorporated into the traditional supply chain for the sustainability of the environment. The used and expired products made of plastics also have a huge impact on the environment. There are some recycling units in Bangladesh. The total local recycled plastic waste is about 750,000 tons per year (Source: BPGMA). One study of BPGMA reveals that in the year 2010, 60% of the after-use plastic waste was recycled which resulted in a saving of US$600 of import of raw material. However, recycling units are not sufficient to collect and process all the plastic wastes. The industries of Bangladesh are facing pressure to adopt and enhance green supply chain practices in their whole production system to reduce hazardous impacts on the environment.

Green activities should be enhanced and incorporated into the traditional supply chain of the plastic industries of Bangladesh. Green initiatives can help the manufacturers select green materials from the right suppliers. It will also assist them to maintain a promising and long-term relationship with the suppliers concerning green activities. Green activities will also ensure less pollutant emission during the production because of adopting high-tech green innovation process in the production system [21]. Green logistics will also ensure the proper use of end-of-life plastics products either by proper disposal or recycling process which will increase the revenue of the industries. But there are lots of barriers to implementing the green concept into the traditional supply chain of plastic industries of Bangladesh. This study mainly focuses on the identification of barriers and ranking them and, finding out the suitable action plans for the smooth implementation of GSCM practices in the plastic industries of Bangladesh.

2.3. Review on Existing Works

Industries are facing obligations to adopt green activities in the supply chains due to the emerging pressure from government and international community to protect the environment. Green activities are widely practiced in the industries of the developed countries. Adopting green activities in the manufacturing sector of some developed countries is mandatory. Research on different aspects of green concepts of the supply chains is being conducted worldwide to flourish the green activities of the environment [21]. Green initiatives are not widely practiced in the manufacturing sector of Bangladesh. There is little or no significant research on GSCM practices in Bangladesh. The plastic industries deal with the production of plastic made products which include various grades of plastic elements. The industries pay little attention to the environmental pollution resulting from for example emission of hazardous gasses and elements. This demotivation may have resulted from some difficulties hindering these organizations initiatives to greening their operations and supply chains [22]. Rigorous research is needed to identify the barriers hindering the implementation of GSCM practices in the plastic industries of Bangladesh. This lack of research gap simulates this study to identify and analyze the barriers to implementing GSCM practices in the plastic industries of Bangladesh. To achieve the goal of this study, the concept of green and barriers to implementing GSCM practices need to be critically reviewed from previous researches. Previous research on green supply chains and barriers to implementing GSCM practices in other industries will set the stage for conducting research on GSCM practices in the plastic industries of Bangladesh context. Mathiyazhagan et al., (2016) identified most influential thirty-eight barriers to implementing GSCM practices in the plastic processing industries of India. Satapathy, (2017) investigated barriers for plastic recycling of the plastic industry of India. Muduli et al., (2013) addressed barriers to implementing GSCM in Indian mining industries in their research work. Beamon, (1999) discussed an overview of the design of GSCM practices in his study. Table 2.1 summarizes the existing works on the concepts of GSCM and barriers to implementing GSCM practices in other industries.

Table 2.1: Existing work on green supply chain barriers analysis

Authors	Contributions
Ahi and Searcy (2013)	This study identified and analyzed the published definitions of green supply chain management (GSCM) with highlighting 22 definitions for GSCM. The recognized definitions are explained with each other in this study.
Testa and Iraldo, (2010)	This research work assessed the determinants and effects of practices of GSCM in different issues.
Subramanian and Gunasekaran, (2015)	A cleaner supply chain management framework for the practice for green activities is discussed in this study. The importance of cleaner methods in the production, and green activities indifferent supply-chain stages, future topics in the area of cleaner management for GSCM researchers are highlighted in this study.
K Muduli et al., (2013)	Barriers to implementing GSCM in the mining industries of India are discussed in this research.
Raci and Shankar, (2005)	Analysis of interactions of barriers in implementing reverse logistics system in automobile industries is examined in this study.
Abdullah et al., (2016)	This study focuses on the barriers in introducing innovative green processes in the manufacturing units in the Malaysian context.
Ghazilla et al., (2015)	Drivers and barriers in implementing green manufacturing practices in the SMEs are discussed in this study in the Malaysian context.
Gleim et al., (2013)	This research investigated individual barriers that affect consumers' evaluations of the green products which are found in retail outlets.
Shen et al., (2017)	A comparative study on significant barriers to green procurement in Chinese real estate development is presented in this research.
Lintukangas et al., (2016)	This study describes the supply risks in GSCM adoption.
Mehrabi et al., (2012)	Barriers to implementing GSCM practices in petrochemical industries are highlighted in this study.

2.4. Barriers to Green Supply Chain Management Practices

Barriers in different aspects of technology, infrastructure, organizational policy, knowledge, financial matters are the main hindrance to implementing green activities along the supply chains of plastic industries of Bangladesh. This study mainly focuses on the identification and analysis of the barriers in different areas for implementing GSCM practices. Introducing green technologies and activities is a pressing need because of the immense local and global pressures. Green businesses are the solution to the present degradation of the environment. Going green reduces energy consumption and carbon-dioxide emission to the environment and ensures environmental sustainability. However, GSCM implementation in a comparatively new business environmental is somewhat arduous task [28]. Identifying the barriers that hinder the implementation of the GSCM practices in traditional supply chains can provide a solution to the industrial and decision-makers to initiate action plans for implementing GSCM practices smoothly. With a combination of literature reviews and opinions from relevant industrial experts, the most critical, main barriers and sub-barriers to implementing GSCM practices in the plastic industries of Bangladesh were identified. Four relevant industrial experts including supply chain manager with 15 years working experience, operations manager with 10 years working experience, logistics manager with 12 years working experience and technology manager with 14 years working experience from four different plastic manufacturing industries in Bangladesh were involved in the evaluation and refinement of the barriers. A brief of the characteristics of the managers is presented in Table A2 in Appendix. The identified barriers were listed and sent to these industrial experts for their opinions y putting „yes" (acceptance) or „no" (rejection). A threshold is agreed and any barrier that meets or exceeds the set threshold after the analysis will be maintained, otherwise deleted. On the basis of the expert opinions and analysis, the main barriers and sub-barriers were selected for the final evaluation. These barriers include four main barriers and twenty-five sub-barriers. The main barriers include "Insufficient Technology & Infrastructure (B1)"; "Inadequate Knowledge & Support (B2)"; "Unsupportive Organizational & Operational Policy (B3)"; and "Financial Constraints (B4)". We now overview these barriers based on literature review.

2.4.1. Insufficient Technology & Infrastructure (B1)

Green activities of supply chain require many innovative technologies and infrastructures. Green technologies in the supply chain are gaining popularity in the present time. Green manufacturing practice is an essential part of green supply chain practice. Insufficient green technology in the manufacturing processes can casue greater emission of hazardous elements, produce gases to the environment, and cause unnecessary energy loss. The lack of advanced technology (B11) can potentially hinder the implementation of GSCM practices. In Bangladesh, the adoption of GSCM is not mandatory for the manufacturing sector and that it‟s not well practiced in most of the manufacturing companies. This results in the lack of shared knowledge of the best GSCM practices (B12) among Bangladeshi manufacturing companies which is one of the barriers to the GSCM implementation. In the plastic industries of Bangladesh, there is a lack of R & D practices for product recovery system (B13) which is one of the potentially significant barriers to the implementation of GSCM practices [34, 35]. The lack of R & D facilities within these plastic industries of Bangladesh could prevent green solutions and initiatives development and hinder the implementation of GSCM practices. The lack of technical expertise (B14) is another critical barrier that could hinder the promotion of green initiatives and increase the level of complexity in recovery operations (B15) towards the implementation of GSCM practices in the plastic industries of Bangladesh. Many plastic manufacturing companies in Bangladesh do not use modern manufacturing technologies, storage and transportation facilities for their operations. The lack of modern technologies, facility of storage and transportation (B16) can significantly hinder the implementation of a comprehensive GSCM practices in the plastic industries of Bangladesh.

2.4.2. Inadequate Knowledge & Support (B2)

Introducing and practicing green initiatives in the traditional supply chains needs adequate knowledge on green supply chain concepts, proper training, and support. The lack of knowledge on green practices (B21) can significantly hinder the implementation of GSCM practices [10, 36]. The supply chain practitioners of the plastic industries of Bangladesh give relatively little attention and importance to environmental issues as a result of their current lack of knowledge on the importance of GSCM. Due to lack of environmental knowledge (B22) on green issues, the manufacturing sectors in Bangladesh are comfortable using environment polluting materials and processes, which does have serious economic repercussions. Many manufacturing companies from the Bangladeshi plastic industry are still using the most out moulded technologies for their operations which do have adverse effect on the environment. The plastic industries of Bangladesh provide little opportunity for employee training on GSCM practices limiting their knowledge-based to the traditional supply chain initiatives. This lack of employee training on GSCM practices (B23) in Bangladesh manufacturing sector is a serious hindrance to the implementation of GSCM practices in the plastic industry. This subsequently limits these employee capabilities and competences on green products awareness creation for customer patronage. The lack of customer awareness on green products (B24) is a significant barrier to green product patronage and sustenance and smooth implementation of GSCM practices. Due to the lack of tax knowledge on returned products (B25) by the plastic manufacturing sector of Bangladesh, they are not motivated to introduce re-manufacturing system into their supply chain operations to gain some financial benefits through the tax incentive to support the GSCM implementation. Another potential barrier to the successful implementation of GSCM practices in the plastic industries of Bangladesh is the lack of interest and support from top management to adopt GSCM (B26) within their supply chain operations. Top management support is one of the fundamental barriers in almost all companies and industries hindering the successful implementation of program.

2.4.3. Unsupportive Organizational & Operational Policy (B3)

Unsupportive organizational and operational policies can significantly hinder the implementation of new concepts and programs within the entire organization. Deficient organizational structure of the companies to adopt GSCM (B31) can potentially hinder the implementation of green practices in the supply chains [9, 36]. The lack of government supportive policies for GSCM (B32) implementation is another a rrier faced y Bangladeshi"s plastic manufacturing sector to implementing green practices in their supply chains. If stakeholders of supply chains do not support each other during the implementation of GSCM practices within their operations, then, it will be challenging for the individual companies to green their supply chains [37, 38]. The lack of support from supply chain stakeholders (B33) is another pressing barrier to the smooth implementation of GSCM practices. The plastics industries of Bangladesh have few recycling facilities within their business structure. As a result of the lack of recycling and reuse facilities of organizations (B34), the industries are unable to enjoy the profitability of green activities. In addition, the plastic industries of Bangladesh are not working within any international standard. Due to lack of international environmental certification (e.g. ISO 14001) (B35), the plastics industries are facing difficulties in achieving international recognition, thereby are unable to penetrate the international market and increase market share. Lack of standard practices for GSCM (B36) is another potential hindrance to the implementation of green activities in the supply chains. Current Bangladeshi government‟s rules and regulations do not support and motivate greening of organizations. This lack of legislation requirement (B37) is considered a potential barrier to implementing GSCM practices in the plastic industries of Bangladesh.

2.4.4. Financial Constraints (B4)

Greening the entire supply chain requires different modern high-tech green technologies, infrastructure and eco-designs which require huge financial investment. Financial constraint is considered a significant barrier to the implementation of GSCM practices in the plastic processing industries of Bangladesh. Due to cost implication (B41) involved in acquiring green technologies and modernizing their supply chains processes, the plastic manufacturing industries of Bangladesh are faced with difficulties in meeting their green agenda. The plastic industries of Bangladesh are facing immense difficulties to implementing GSCM practices due to the un-availability of bank loans to encourage green product (B42) for the consumers [39, 40]. Another potential hindrance faced y the Bangladeshi‟s plastic industries toward the implementation of GSCM practices is the uncertainty related to economic issues (B43). Cost of disposal of hazardous products (B44) is significantly huge, with this huge cost implication causing the uncertainty of implementing GSCM practices. The green supply chain concept is a novel phenomenon that the plastic industries of Bangladesh are not aware of and the associated economic benefits they seek to gain by greening their supply chains. This lack of knowledge of economic benefits (B45) that the companies seek to gain is considered one of the potential barriers hindering GSCM implementation. Organizations perceive GSCM implementation as a program with high initial and operating cost and so are not motivated to such initiative. The perceived high initial and operating cost (B46) of greening the supply chains is a significant barrier to implementing GSCM practices in the plastics industries of Bangladesh.

2.5. Alternative Action Plans for Smooth GSCM Implementation

For the smooth implementation of GSCM practices in the plastic industries of Bangladesh, four alternative action plans are proposed. Based on the study of barriers and success factors from the relevant literature and expert opinions, these alternative action plans are put together to aid in the smooth implementation of GSCM in the case company. The identified barriers are the weak points in case of implementing GSCM practices. Taking these barriers into account, the relevant action plans are determined which are almost opposite to the barriers. These action plans will strategically become the strong point for the smooth implementation of GSCM practices in the case company. The proposed action plans are as follows:

Action Plan 1- Top management"s full and continuous commitment and support and organizing awareness programs (A1)

Action Plan 2- Development and introduction of infrastructure and cleaner technology (A2)

Action Plan 3- Provision of substantial financial support to initiate GSCM programs implementation (A3)

Action Plan 4- Development of organizational and operational policies towards greening initiatives and practices (A4)

Top management continuous commitment and support will encourage industries to adopt GSCM practices and motivate them to organize various customer awareness programs for green products and green activities. Another important enabler of GSCM practices is the development and introduction of infrastructure and cleaner technology across the entire supply chains. Financial support plays a vital role in enabling the implementation of GSCM practices in more comprehensive manner and the development of organizational and operational policies to ensure the smooth implementation of GSCM initiatives and practices [41, 42].

Chapter 3
Methodology

3.1. Proposed Research Methodology

To fulfill the objectives of this study, at first the existing literature on GSCM practices was examined and a number of consultation sessions were arranged with experts from relevant industries. From the outcomes of reviewing the current literature and opinions from the experts of the relevant industries, the most influential barriers to GSCM practices were selected in the field of plastic industries of Bangladesh. In this research work, four evaluators were taken from two leading plastics processing industries. This study consists of four major barriers and twenty-five sub-barriers. The identified barriers to GSCM implementation are hierarchically ordered and presented in Chapter 4 in Fig 4.1.

The top level of the structure indicates the ultimate objective of this study. The second level of the structure consists of four identified major barriers. The third level reveals the decomposition of the main barriers into total twenty-five sub-barriers. Finally the fourth level denotes four alternative action plans for smooth GSCM implementation. Then by defining linguistic fuzzy scale to evaluate barriers and fuzzy ranking scale to evaluate alternatives, aggregated fuzzy weights of barriers and aggregated fuzzy ranking of alternatives are constructed to form fuzzy decision matrices. Then after the de-fuzzification of the aggregated fuzzy values of alternatives and after the finding of the relevant values, precise calculations are performed to get the ranking of the major barriers along with the individual ranking of the sub-barriers. The ranking of the alternative action plans is also developed. The systematic graphical research framework is illustrated in Fig 3.1.

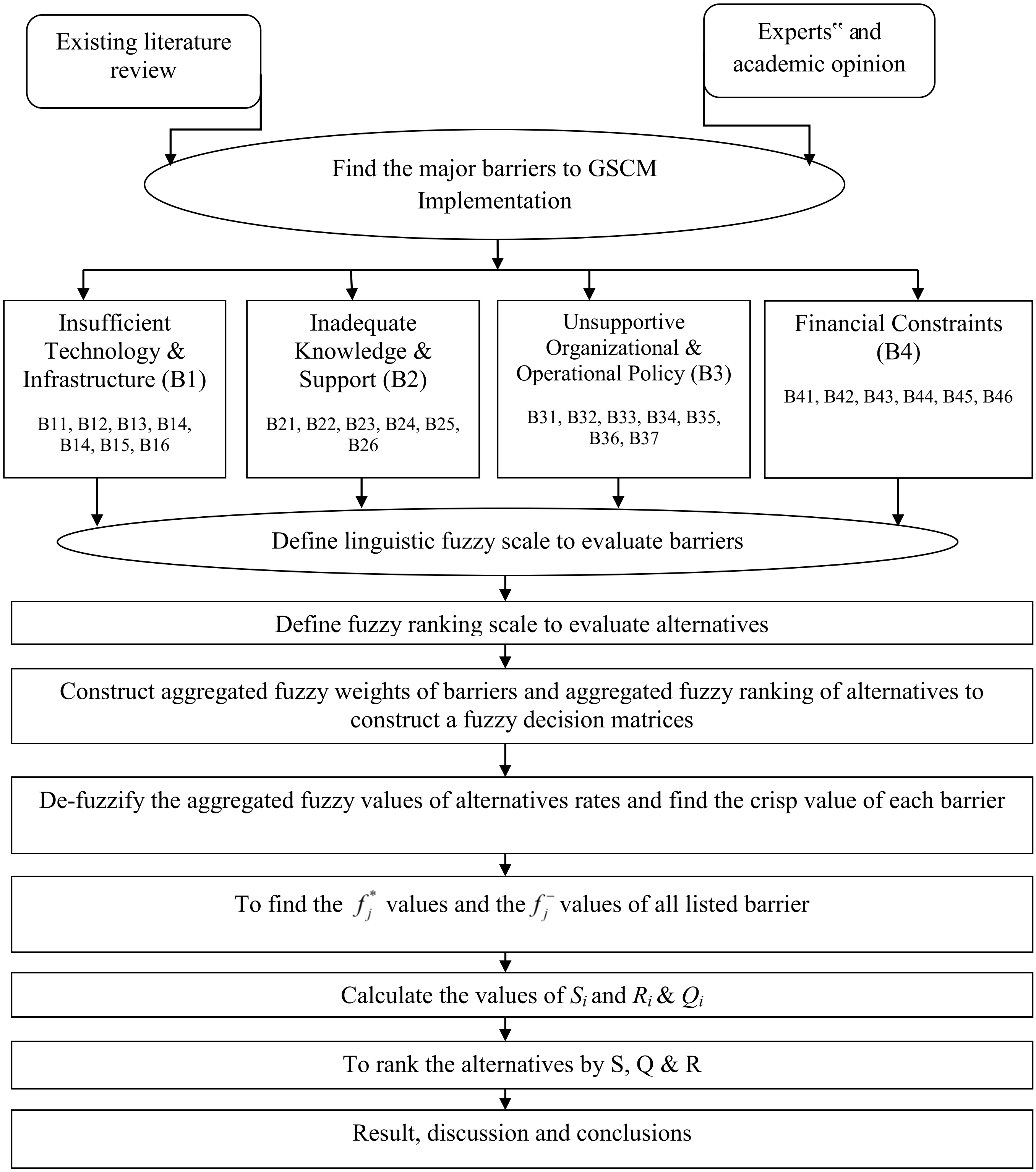

Fig. 3.1. Proposed research framework

3.2. Fuzzy-VIKOR Methodology

3.2.1. Fuzzy Set

In different conditions, in view of the imprecision, subjectivity what's more, inconclusive wellsprings of human perception, crisp numbered information are not adequate. Presented by [43, 44] fuzzy set (FS) theory was produced in view of the supposition that the fundamental factors in human perception and judgment are not numbers, but rather phonetic terms of the fuzzy set. FS theory was taken into account to settle the ambiguity and imprecision of human judgment by using linguistics scale. FS theory was first utilized by Bellman and Zadeh, (1970) in decision-making problems. Fuzzy based MCDA tools utilize the linguistic terms not the number for calculating vagueness of decision maker in terms of weights and finally converted it into a fuzzy number. FS theory gives more extensive results than classic set theory in real life decision-making problems [46–48]. FS theory is explained below to solve proposed decision-making problem.

Definition 1: (Fuzzy set): To begin with the fuzzy set, Z is assumed to be the universal set of discourse, $Z=\{z_1,z_2,z_3,......z_n\}$. A FS A of Z is a set of order pairs $\{(z_1,f_A(z_1)),(z_2,f_A(z_2)),(z_3,f_A(z_3)),........(z_n,f_A(z_n))\}$ where $f_A:Z\rightarrow[0,1]$ is the function of A, and $f_A(z_i)$ denotes for the membership degree of z_i in A.

Definition 2.(Fuzzy number): A tilde „~ " over a sym ol indicates the sym ol of a FS. TFNs are easy and realizable for DMs. Therefore, in this study, TFNs are used to evaluate the GSC implementing barriers. A TFN M is given in Fig. 3.2. A TFN is indicated as *(l, m, u)* where *l>m>u*. A TFN is simply written as *(l, m, u)*. *l* shows the smallest conceivable value, while *m* is the middle value, and *u* is the biggest conceivable value. Each TFN has linear portrayals to its left side and right side with the end goal that its membership function can be composed as Eq. (3.1):

$$\mu(z/\tilde{M}) = \begin{cases} 0, & z < l \\ (z-l)/(m-l), & l \le z \le m \\ (u-z)/(u-m), & m \le z \le u \\ 0, & z > u \end{cases} \tag{3.1}$$

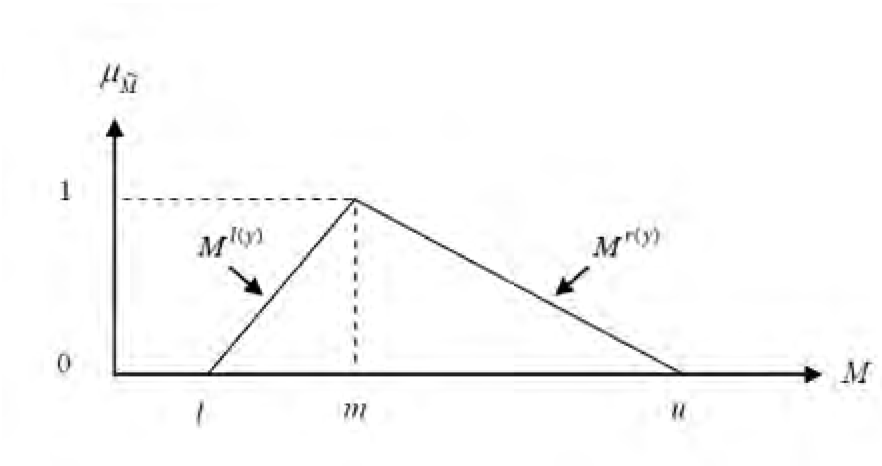

Fig. 3.2. Triangular Fuzzy Num e r M (Ashrafzadeh et al., 2012)

A fuzzy number can simply be given by its comparing left and right portrayal of every level of membership as appeared in Eq. (3.2):

$$\overline{M} = \overline{M}^{l(y)}, \overline{M}^{r(y)} = (l+(m-l)y, u+(m-u)y), y \in [0,1] \tag{3.2}$$

Definition 3. *Let* G = (l,m,u) *and* $H = (o,p,q)$ are two TFNs. Then the basic mathematical operations of TFN are explained as follows:

$$G + H = (l,m,u) + (o,p,q) = (l+o, m+p, u+q) \tag{3.3}$$

$$G - H = (l,m,u) - (o,p,q) = (l-o, m-p, u-q) \tag{3.4}$$

$$G \times H = (l,m,u) \times (o,p,q) = (lo, mp, uq) \tag{3.5}$$

$$G \div H = \frac{(l,m,u)}{(o,p,q)} = \left(\frac{l}{q}, \frac{m}{p}, \frac{u}{o}\right) \tag{3.6}$$

$$(k,k,k)\times(l,m,u)=(kl,km,ku),k>0,k\in R. \tag{3.7}$$

$$G^{-1}=\left(l,m,u\right)^{-1}=\left(\frac{1}{u},\frac{1}{m},\frac{1}{l}\right) \tag{3.8}$$

Definition 4. *Let* G $=\left(l,m,u\right)$ *and* $H=\left(o,p,q\right)$ are two TFNs (see Fig. 3.3). The distance between fuzzy numbers A and B is computed as follows:

$$d(G,H)=\sqrt{\frac{1}{3}\left[(l-o)^2+(m-p)^2+(u-q)^2\right]} \tag{3.9}$$

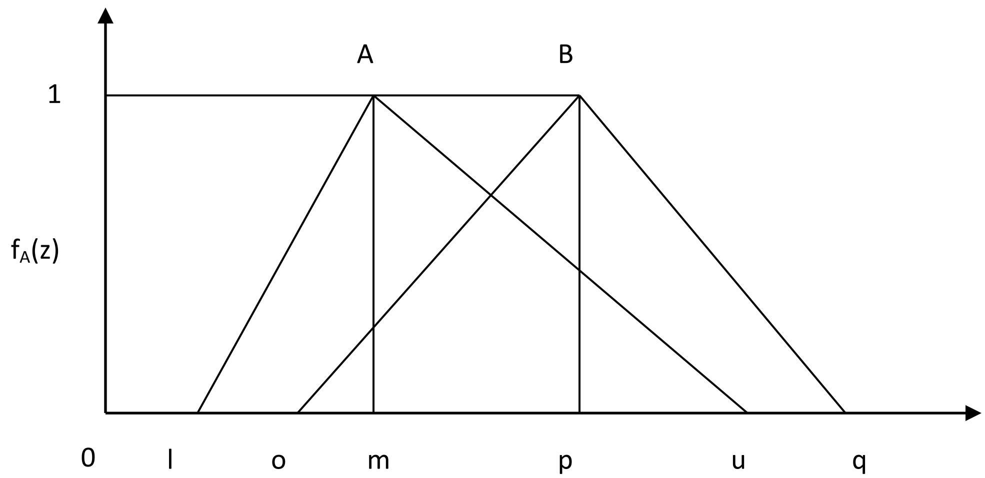

Fig. 3.3. Two triangular fuzzy numbers

Definition 5. Let, a group of decision-making has K evaluator, and the fuzzy rating of evaluator D_k (k = 1,2,. ., K) can be denoted as a positive TFN R_k (k = 1,2,. .,K) with membership function FR_k (z). Therefore, the aggregated fuzzy rating can be explained as:

$$R=(l,m,u);k=1,2,3,.....K \tag{3.10}$$

$$where, l=\min_k\{l_k\}_k, m=1/k\sum_{k=1}^{k}m_k, u=\max_k\{u_k\}_k.$$

3.3. The VIKOR Method

In VIKOR methodology, to evaluate the ranking of MCDA problems, ($L_{1,i}$ *as* S_i) and ($L_{\infty,I}$ *as* R_i) are utilized. The Lp-matric is given below:

$$L_{pi} = \left\{ \sum_{j=1}^{n} W_j \left[\left(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right) \right] \right\}^{1/p} \quad 1 \le p \le +\alpha; i = 1,2,3,....I. \tag{3.11}$$

The result acquired by min S_i is with a maximum group utility ("majority" rule) and the result acquired by min R_i *i*s with a minimum individual regret of the "opponent" [50]. The algorithm of fuzzy VIKOR method can be explained by following steps [51–54].

Step 1. Fix the research objectives of MCDA problems and define the existing problem to validate the research objectives. In this research, the research objective is to examine and ranking GSCM implementing barriers concerning plastic processing industry by taking relevant case factory.

Step 2. For the purpose of the study, decision groups are formed with four decision maker from relevant case factory and fix the finite set of attributes (Barriers). In this study, four main categories of GSCM implementing barriers, twenty-five sub barriers under the main category of barriers and four alternatives have been taken. The identified major GSCM implementing barriers and sub-barriers are given in the literature review which is tabulated in Table A1 in Appendix.

Step 3. To evaluating barriers define a linguistic fuzzy scale and for evaluating alternatives respect to each barrier define the fuzzy ranking scale. These scales are introduced to the decision maker to evaluate barriers and alternatives. Fuzzy decision-making scale and fuzzy rating scale are shown in Fig. 3.4 and Fig. 3.5 subsequently.

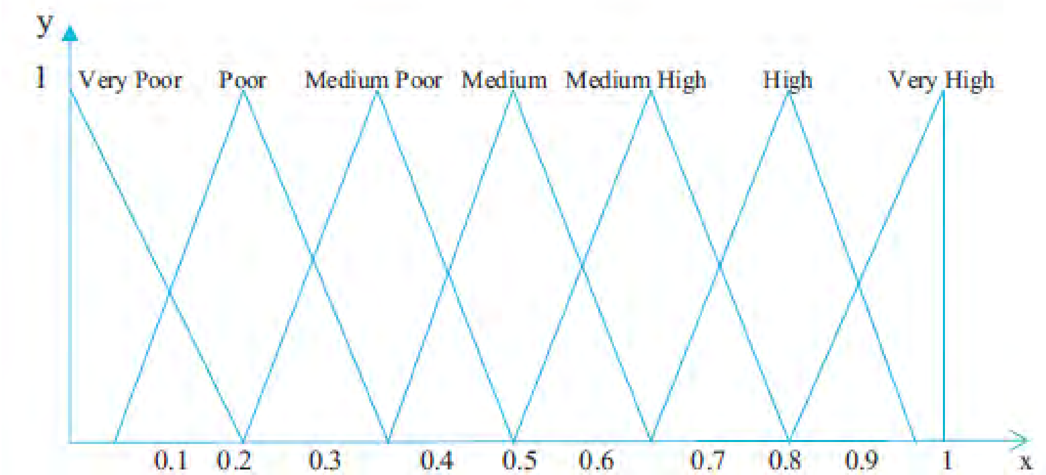

Fig. 3.4. Linguistic variables for importance weight of each criterion[55].

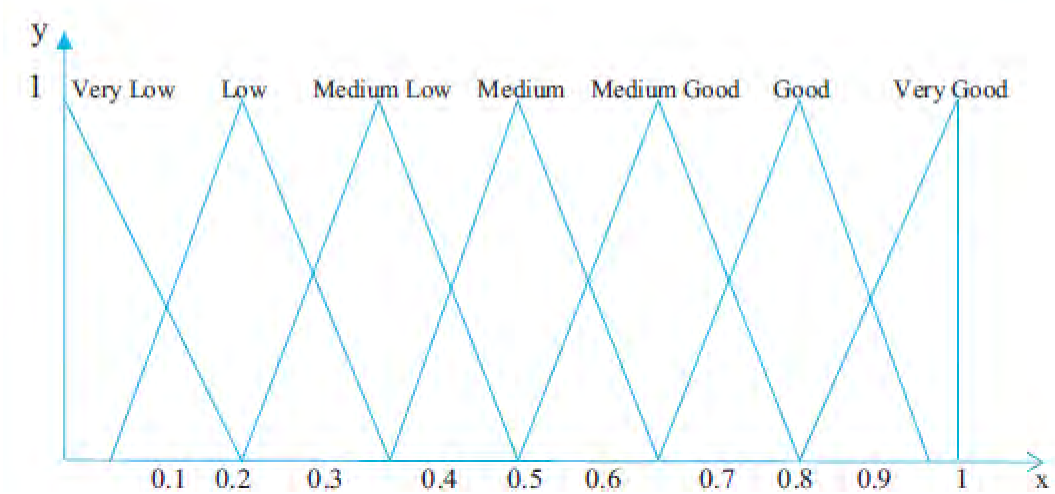

Fig. 3.5. Linguistic scale for variables [55]

Step 4. With the help of a group of decision-makers, the aggregated fuzzy weights of barriers and aggregated fuzzy ranking of alternatives are constructed. Then, a fuzzy decision matrix is constructed. The aggregate fuzzy rating (x_{ij}) of alternatives concerning each barrier is evaluated as follows:

$$x_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}) \tag{3.12}$$

Where, $x_{ij1} = \min\{x_{ij1}\}_k, x_{ij3} = \max\{x_{ij3}\}_k$ and the aggregated fuzzy weights w_j of each barrier can be computed as follows:

$$W = (\overline{w}_1, \overline{w}_2, \overline{w}_3) \tag{3.13}$$

Where,

$$w_{j1} = \min\{w_{jk1}\}_k, w_{j2} = 1/k\sum_{k}^{k} w_{jk2}, w_{j3} = \max\{w_{jk3}\}_k$$

A decision matrix, D, of $m \times n$ dimension is defined as in Eq. (3.14):

$$D = A_i \begin{pmatrix} A_i\overline{x}_{11} & \overline{x}_{1j} & \overline{x}_{1n} \\ \vdots & \ddots & \vdots \\ A_i\overline{x}_{m1} & \overline{x}_{mj} & \overline{x}_{mn} \end{pmatrix} \tag{3.14}$$

Where, $x_{ij}, \forall_{ij}$ maybe crisp or fuzzy. If x_{ij} is fuzzy, it is showed by a TFN as $\overline{x}_{ij} = l_{ij}, m_{ij}, u_{ij}$ .The fuzzy weights can be explained by the Eq. (3.15):

$$W = (\overline{w}_1 ... \overline{w}_j ... \overline{w}_n); \overline{w}_j = \overline{\alpha}_1, \overline{\beta}_j, \overline{\chi}_n \tag{3.15}$$

Step 5. The fuzzy decision matrixes de-fuzzify and find the crisp value of each barrier. In this research work, defuzzification process was used to locate the best non-fuzzy performance (BNP) value. In general, mean of maximal (MOM), center of area (COA), and α -cut are three basic methods of BNP. The COA method is a practically applicable and simple. In COA method, there is no need any evaluator to perform the basic operations. COA methods of triangular fuzzy performance score $\overline{h}_{ai} = (lh_{ai}, mh_{ai}, uh_{ai})$ can be used to evaluate BNP value and given equation is applied to assess BNP value:

$$\text{BNP: } x_{ai} = lh_{ai} + \frac{(uh_{ai} - lh_{ai}) + (mh_{ai} - lh_{ai})}{3}, \forall a \tag{3.16}$$

Step 6. Find the f_j^* values and the f_j^- values of all listed barrier ratings, $j = 1, 2, \ldots, n$.

$$f_j^* = \max\{f_{ij}\} \tag{3.17}$$

$$f_j^- = \min\{f_{ij}\} \tag{3.18}$$

Where, f_j^* is the positive value for the j^{th} barrier, and f_j^- is the negative value for the j^{th} barrier. If one associates all f_j^*, it will have the ideal mix, which gets the most noteworthy scores comparable as f_j^-.

Step 7. Calculate the values of S_i and R_i $(i=1, 2, \ldots m)$ using following Eqs.:

$$S_i = \sum_{j=1}^{n} W_j \left[\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right] \tag{3.19}$$

$$R_i = \max_j \left[W_j \left(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right) \right] \tag{3.20}$$

Where S_i indicates the distance of i^{th} alternative to the positive result, and R_i indicates the distance of i^{th} alternative to the negative result. Likewise, W_j are the weights of criteria, which are communicated in their relative significance

Step 8. Calculate the values of Q_i $(i = 1,2, \ldots, m$ using Eq. (3.21):

$$Q_i = v\frac{S_i - S^*}{S^- - S^*} + (1-v)\frac{R_i - R^*}{R^- - R^*} \tag{3.21}$$

Where, $S^- = \max_i S_i, R^- = \max_i R_i, S^* = \min_i S_i, R^* = \min_i R_i$ and v is the weight of strategy of the majority of criteria or the maximum group utility. In this research, consider that $v = 0.5$.

Step 9. This step ranks the alternative action plans. With the help of step (8) calculated Q_i value help to rank the action plan and regarding this rank, a decision can be formulated.

Step 10. On the off chance that the accompanying two conditions are fulfilled agree recently, at that point the plan with a minimum estimation of Q in positioning is considered as the ideal trade-off solution. For instance;

C1. The alternative $Q(A^{(1)})$ has a satisfactory preferred standpoint if $Q(A^{(2)}) - Q(A^{(1)}) \geq 1/n-1$ where $A^{(2)}$ is the option with the second position in the positioning rundown and n is the number of alternatives

C2. The alternative $Q(A^{(1)}$ is steady inside the decision-making process on the off chance that it is likewise best positioned in S_i and R_i.

Step 11. Select the best alternative by picking $Q(A^{(m)})$ as a best trade-off arrangement with the base estimation of Q_i in regards to above conditions

Chapter 4

A Case Study

4.1. An Industrial Case Study with the Application of Fuzzy –VIKOR Method

The developed methodology and framework has been applied to a real case study and used to rank the major barriers with the sub-barriers to implementing GSCM practices in one plastic manufacturing factory in Bangladesh. The plastic manufacturing factory „ABC" is facing numerous obstacles in implementing green activities in its traditional supply chain. The case factory demands the identification of major barriers to implementing GSCM practices and the ranking of the barriers with strategic action plans for the smooth implementation. In this study, the major barriers are identified by the relevant literature and the previous studies. Four evaluators, who are expert in the relevant field, are hired for the evaluation of the barriers and the ranking of the barriers with a fuzzy-VIKOR approach.

The applications of the proposed method are explained below:

Step 1: The main objectives are defined that is evaluating most influential GSCM implementing barriers in the context of plastic processing factory. The listed major barriers appear in Table A1 in Appendix and the framework of the goal of the research appears in Fig. 4.1.

Step 2: To evaluate the importance of each GSCM implementing barriers and rating of the alternatives, in this research, five experts are employed with the help of a seven-point scale given in Fig. 3.3 and 3.4 respectively. The provided fuzzy based linguistic scale is triangular fuzzy number.

Step 3: In this step, with the help of four decision maker evaluate the barriers, sub-barriers and alternatives comparisons concerning the main barriers. The evaluation of barriers is given in Tables 4.1 and 4.2.

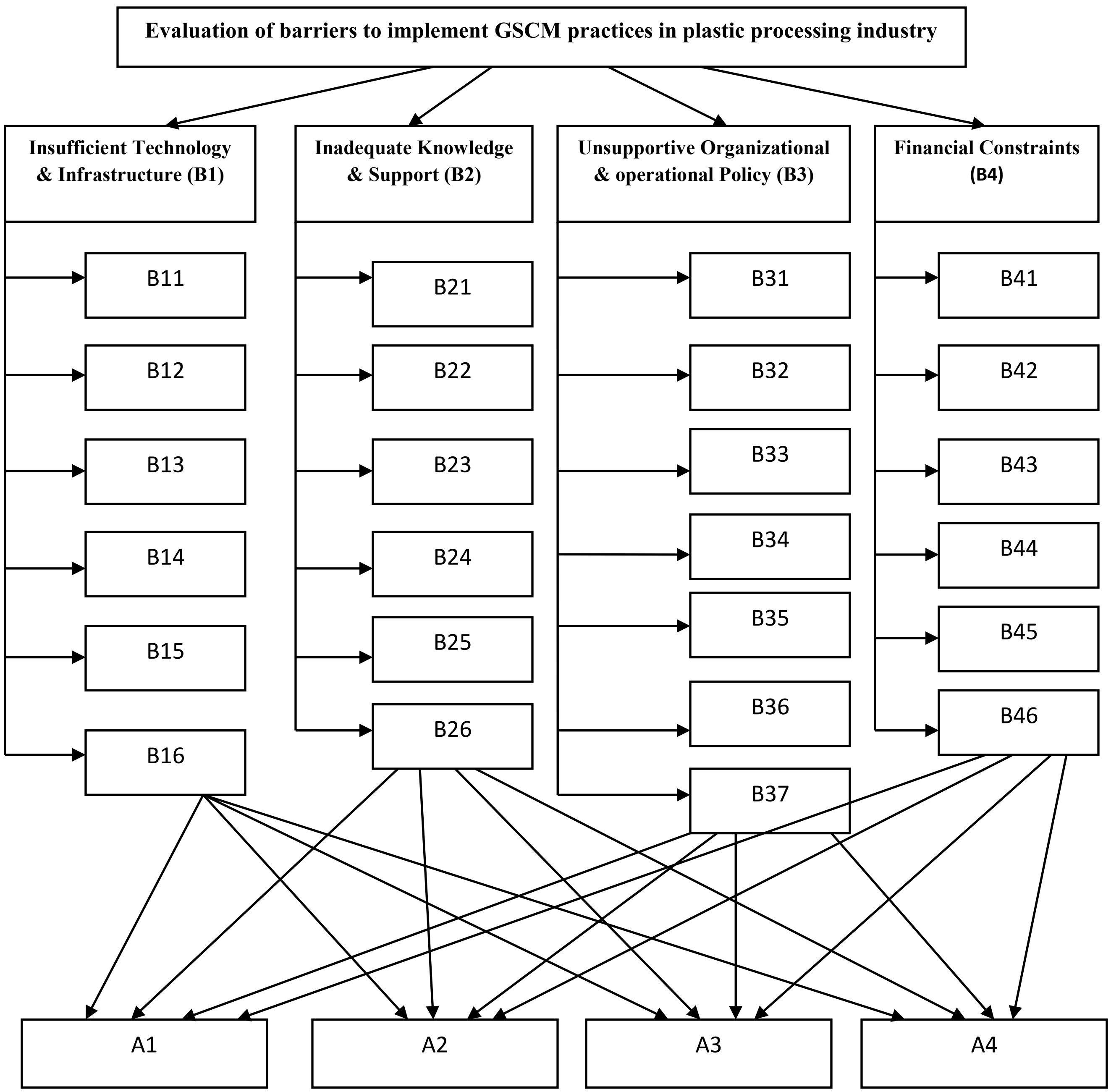

Fig. 4.1: Framework of the goal of the present work

Table 4.1: Important weight of barriers and sub-barriers from four evaluators.

Barriers	**Decision Maker**			
	E1	**E2**	**E3**	**E4**
B1	H	H	VH	H
B2	VH	VH	VH	H
B3	MH	M	MH	M
B4	VH	H	MH	MH
B11	VH	VH	H	VH
B12	H	H	VH	H
B13	M	M	MH	M
B14	MH	MH	M	MH
B15	M	M	H	M
B16	M	M	M	M
B21	VH	VH	VH	VH
B22	MH	VH	MH	H
B23	MH	H	H	MH
B24	MH	MH	M	H
B25	M	MH	M	MH
B26	VH	VH	H	VH
B31	H	VH	VH	H
B32	VH	VH	H	VH
B33	H	H	VH	H
B34	M	M	M	MH
B35	MH	M	MH	M
B36	H	H	H	H
B37	MH	MH	MH	H
B41	VH	H	VH	H
B42	H	H	H	MH
B43	VH	VH	VH	H
B44	MH	M	MH	M
B45	MH	H	MH	MH
B46	MH	MH	MH	MH

Step 4: The matrix of fuzzy evaluation for the barriers weights and action plan are obtained as in Tables 4.3 and 4.4. The fuzzy values of the sub-barriers are shown in Table 4.5. Then, with the help of Eqs. (3.12) and (3.13), fuzzy aggregated values of action plan and linguistic importance weights are evaluated as in Table 4.6.

Table 4.2: Ratings of the alternatives with respect to the main barriers assessed by evaluators

		B1	B2	B3	B4
E1	**A1**	MG	G	MG	MG
	A2	G	G	MG	G
	A3	ML	MG	MG	M
	A4	MG	MG	M	MG
E2	**A1**	G	MG	G	MG
	A2	G	G	G	MG
	A3	ML	MG	MG	M
	A4	MG	MG	MG	M
E3	**A1**	G	G	MG	G
	A2	G	G	G	G
	A3	MG	ML	M	MG
	A4	MG	G	MG	G
E4	**A1**	MG	G	G	G
	A2	G	G	G	MG
	A3	ML	MG	M	ML
	A4	MG	G	G	MG

Table 4.3: Important weight of barriers and sub-barriers from four evaluators (Fuzzy Value)

Barriers	E1	E2	E3	E4
B1	(0.7, 0.8,0.9)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.7,0.8,0.9)
B2	(0.8,0.9,1)	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)
B3	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B4	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B11	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.8,0.9,1)
B12	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.7,0.8,0.9)
B13	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B14	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
B15	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.35,0.5,0.65)
B16	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B21	(0.8,0.9,1)	(0.8,0.9,1)	(0.8,0.9,1)	(0.8,0.9,1)
B22	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B23	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B24	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
B25	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B26	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.8,0.9,1)
B31	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)
B32	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.8,0.9,1)

Table 4.3 Continued				
Barriers	**E1**	**E2**	**E3**	**E4**
B33	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.7,0.8,0.9)
B34	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B35	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B36	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B37	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B41	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B42	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B43	(0.8,0.9,1)	(0.8,0.9,1)	(0.8,0.9,1)	(0.7,0.8,0.9)
B44	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B45	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B46	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)

Table 4.4: Ratings of the alternatives with respect to the main barriers assessed by evaluators (Fuzzy values)

		B1	**B2**	**B3**	**B4**
E1	**A1**	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
	A2	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
	A3	(0.2,0.3,0.4)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
	A4	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
E2	**A1**	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
	A2	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
	A3	(0.2,0.3,0.4)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
	A4	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
E3	**A1**	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
	A2	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
	A3	(0.6,0.7,0.8)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
	A4	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
E4	**A1**	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
	A2	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
	A3	(0.2,0.3,0.4)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
	A4	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)

Table 4.5: Ratings of the alternatives with respect to the sub-barriers assessed by evaluator (E1)

E1					
		A1	**A2**	**A3**	**A4**
B11		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B12		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)

Table 4.5 Continued					
		A1	**A2**	**A3**	**A4**
B13		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B14		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B15		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B16		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B21		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B22		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.70.8)
B23		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B24		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B25		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B26		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B31		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B32		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B33		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B34		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B35		(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B36		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B37		(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B41		(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B42		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B43		(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B44		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B45		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B46		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)

Table 4.5: Ratings of the alternatives with respect to the sub-barriers assessed by evaluator (E2)

E2					
		A1	**A2**	**A3**	**A4**
B11		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B12		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B13		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B14		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B15		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B16		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B21		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B22		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B23		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B24		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.6,0.7,0.8)
B25		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)

Table 4.5 Continued					
		A1	**A2**	**A3**	**A4**
B26		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B31		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B32		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B33		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B34		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B35		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B36		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B37		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B41		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B42		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B43		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B44		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B45		(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.3,0.5,0.65)	(0.35,0.5,0.65)
B46		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)

Table 4.5: Ratings of the alternatives with respect to the sub-barriers assessed by evaluator (E3)

E3					
		A1	**A2**	**A3**	**A4**
B11		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B12		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B13		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B14		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B15		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B16		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B21		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B22		(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B23		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B24		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.3,0.4)
B25		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B26		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B31		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B32		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B33		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B34		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B35		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B36		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B37		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B41		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)

Table 4.5 Continued					
		A1	**A2**	**A3**	**A4**
B42		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B43		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
B44		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B45		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B46		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)

Table 4.5: Ratings of the alternatives with respect to the sub-barriers assessed by evaluator (E4)

E4					
		A1	**A2**	**A3**	**A4**
B11		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B12		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B13		(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.6,0.7,0.8)
B14		(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B15		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B16		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B21		(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B22		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B23		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B24		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.6,0.7,0.8)
B25		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B26		(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
B31		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B32		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
B33		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
B34		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)
B35		(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B36		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.3,0.4)
B37		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
B41		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B42		(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.3,0.4)
B43		(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
B44		(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.2,0.3,0.4)	(0.2,0.3,0.4)
B45		(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
B46		(0.2,0.3,0.4)	(0.2,0.3,0.4)	(0.35,0.5,0.65)	(0.35,0.5,0.65)

Table 4.6: Aggregated Fuzzy values of alternative rate and subjective importance weights

Barriers	W_j	A1	A2	A3	A4
B1	(0.7,0.825,1)	(0.6,0.75,0.9)	(0.7,0.8,0.9)	(0.2,0.4,0.8)	(0.6,0.7,0.8)
B2	(0.7,0.875,1)	(0.6,0.775,0.9)	(0.7,0.8,0.9)	(0.2,0.6,0.8)	(0.6,0.75,0.9)
B3	(0.35,0.6,0.8)	(0.6,0.75,0.9)	(0.6,0.775,0.9)	(0.35,0.6,0.8)	(0.35,0.675,0.9)
B4	(0.6,0.775,1)	(0.6,0.75,0.9)	(0.6,0.75,0.9)	(0.2,0.5,0.8)	(0.35,0.675,0.9)
B11	(0.7,0.875,1)	(0.6,0.775,0.9)	(0.6,0.775,0.9)	(0.6,0.775,0.9)	(0.6,0.775,0.9)
B12	(0.7,0.825,1)	(0.6,0.725,0.8)	(0.6,0.75,0.9)	(0.6,0.775,0.9)	(0.6,0.775,0.9)
B13	(0.35,0.55,0.8)	(0.2,0.35,0.65)	(0.2,0.4,0.65)	(0.2,0.4,0.65)	(0.2,0.5,0.8)
B14	(0.35,0.725,0.9)	(0.6,0.775,0.9)	(0.6,0.75,0.9)	(0.6,0.75,0.9)	(0.6,0.775,0.9)
B15	(0.35,0.575,0.9)	(0.2,0.4,0.65)	(0.35,0.5,0.65)	(0.2,0.4,0.65)	(0.2,0.4,0.65)
B16	(0.35,0.5,0.65)	(0.2,0.4,0.65)	(0.2,0.45,0.65)	(0.2,0.45,0.65)	(0.2,0.3,0.4)
B21	(0.8,0.9,1)	(0.6,0.775,0.9)	(0.7,0.8,0.9)	(0.6,0.775,0.9)	(0.6,0.775,0.9)
B22	(0.6,0.775,1)	(0.35,0.675,0.9)	(0.35,0.675,0.9)	(0.35,0.6,0.8)	(0.35,0.675,0.8)
B23	(0.6,0.75,0.9)	(0.2,0.5,0.8)	(0.35,0.5,0.6)5	(0.35,0.55,0.8)	(0.35,0.55,0.65)
B24	(0.35,0.675,0.9)	(0.2,0.5,0.8)	(0.35,0.5,0.65)	(0.2,0.45,0.65)	(0.2,0.6,0.8)
B25	(0.35,0.6,0.8)	(0.2,0.4,0.65)	(0.35,0.5,0.6)5	(0.2,0.45,0.65)	(0.2,0.4,0.65)
B26	(0.7,0.875,1)	(0.6,0.775,0.9)	(0.6,0.775,0.9)	(0.6,0.725,0.9)	(0.6,0.775,0.9)
B31	(0.7,0.85,1)	(0.2,0.4,0.65)	(0.2,0.45,0.65)	(0.35,0.5,0.65)	(0.2,0.35,0.65)
B32	(0.7,0.875,1)	(0.6,0.725,0.9)	(0.6,0.725,0.8)	(0.6,0.75,0.9)	(0.6,0.75,0.9)
B33	(0.7,0.825,1)	(0.6,0.75,0.9)	(0.6,0.725,0.9)	(0.6,0.775,0.9)	(0.6,0.75,0.9)
B34	(0.35,0.55,0.8)	(0.2,0.3,0.4)	(0.2,0.35,0.4)	(0.2,0.3,0.4)	(0.2,0.4,0.65)
B35	(0.35,0.6,0.8)	(0.2,0.45,0.65)	(0.2,0.35,0.4)	(0.2,0.4,0.65)	(0.2,0.3,0.4)
B36	(0.7,0.8,0.9)	(0.2,0.45,0.65)	(0.35,0.5,0.65)	(0.2,0.5,0.8)	(0.2,0.45,0.65)
B37	(0.6,0.725,0.9)	(0.35,0.65,0.8)	(0.35,0.65,0.8)	(0.35,0.65,0.8)	(0.35,0.6,0.8)
B41	(0.6,0.75,0.9)	(0.35,0.65,0.8)	(0.35,0.65,0.8)	(0.35,0.625,0.8)	(0.35,0.65,0.8)
B42	(0.6,0.775,0.9)	(0.2,0.45,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.2,0.35,0.4)
B43	(0.7,0.875,1)	(0.35,0.6,0.8)	(0.35,0.55,0.8)	(0.6,0.725,0.9)	(0.35,0.65,0.8)
B44	(0.35,0.6,0.8)	(0.2,0.3,0.4)	(0.2,0.35,0.65)	(0.2,0.4,0.65)	(0.2,0.3,0.4)
B45	(0.6,0.725,0.9)	(0.35,0.6,0.8)	(0.35,0.65,0.8)	(0.35,0.55,0.65)	(0.35,0.55,0.8)
B46	(0.6,0.7,0.8)	(0.2,0.4,0.65)	(0.2,0.45,0.65)	(0.2,0.4,0.65)	(0.2,0.35,0.65)

Step 5: In this step, the fuzzy aggregated values of action plans (alternatives) rates are de-fuzzified using Eq. (3.16). The obtained results are presented in Table 4.7.

Step 6: Using Eqs. (3.17) and (3.18), the best f_j^* and the worst f_j^- values are determined and are also shown in Table 4.7 (Columns 8 & 9 respectively).

Table 4.7: De-fuzzified Aggregated Fuzzy values of alternative rate

Barriers	**W_j**	**Normalized W_j**	**A1**	**A2**	**A3**	**A4**	**f_j***	**f_j^-**
B1	0.842	0.274	0.750	0.800	0.467	0.700	0.800	0.467
B2	0.858	0.279	0.758	0.800	0.533	0.750	0.800	0.533
B3	0.583	0.190	0.750	0.758	0.583	0.642	0.758	0.583
B4	0.792	0.257	0.750	0.750	0.500	0.642	0.750	0.500
B11	0.858	0.213	0.758	0.758	0.758	0.758	0.758	0.758
B12	0.842	0.209	0.708	0.750	0.758	0.758	0.758	0.708
B13	0.567	0.140	0.400	0.417	0.417	0.500	0.500	0.400
B14	0.658	0.163	0.758	0.750	0.750	0.758	0.758	0.750
B15	0.608	0.151	0.417	0.500	0.417	0.417	0.500	0.417
B16	0.500	0.124	0.417	0.433	0.433	0.300	0.433	0.300
B21	0.900	0.199	0.758	0.800	0.758	0.758	0.800	0.758
B22	0.792	0.175	0.642	0.642	0.583	0.608	0.642	0.583
B23	0.750	0.166	0.500	0.500	0.567	0.517	0.567	0.500
B24	0.642	0.142	0.500	0.500	0.433	0.533	0.533	0.433
B25	0.583	0.129	0.417	0.500	0.433	0.417	0.500	0.417
B26	0.858	0.190	0.758	0.758	0.742	0.758	0.758	0.742
B31	0.850	0.162	0.417	0.433	0.500	0.400	0.500	0.400
B32	0.858	0.164	0.742	0.708	0.750	0.750	0.750	0.708
B33	0.842	0.161	0.750	0.742	0.758	0.750	0.758	0.742
B34	0.567	0.108	0.300	0.317	0.300	0.417	0.417	0.300
B35	0.583	0.111	0.433	0.317	0.417	0.300	0.433	0.300
B36	0.800	0.153	0.433	0.500	0.500	0.433	0.500	0.433
B37	0.742	0.141	0.600	0.600	0.600	0.583	0.600	0.583
B41	0.750	0.171	0.600	0.600	0.592	0.600	0.600	0.592
B42	0.758	0.173	0.433	0.500	0.500	0.317	0.500	0.317
B43	0.858	0.195	0.583	0.567	0.742	0.600	0.742	0.567
B44	0.583	0.133	0.300	0.400	0.417	0.300	0.417	0.300
B45	0.742	0.169	0.583	0.600	0.517	0.567	0.600	0.517
B46	0.700	0.159	0.417	0.433	0.417	0.400	0.433	0.400

Step 7, 8 and 9: Using Eqs. (3.19-3.21) the values of S, R and Q for all the proposed action plans were determined and are shown in Table 4.8. In this study, the weight of the maximum group utility (v) is considered as 0.5.

Table 4.8: The values of S and R for all Alternatives

Alternatives	S	R		Q
A1	10.47438	0.9	S^*_j= 7.2975	0.851867
A2	7.29752	0.858333	S^-_J= 11.81181	0
A3	11.81181	0.9	R^*_j= 0.8583	1
A4	11.18094	0.9	R^-_j= 0.9	0.930125

Step 10: In this stage, final positioning of the action plans by *S, R* and *Q* in descending order are re-assessed and displayed in Table 4.9. In light of the crisp Q_i value, the positioning of the alternatives in descending order is completed as *A2> A1> A4 > A3*. In this stage, the best alternative is observed to be *A2*. Additionally, both *C1* and *C2* conditions are fulfilled, which implies that QA4-QA1≥1/4-1 and also *A2* is best positioned by *R* and *S.*

Table 4.9: The rankings of the alternatives by S, R and Q in ascending order.

Alternatives	S		R		Q	Ranking
A2	7.29752	**A2**	0.858333	**A2**	0	**1**
A1	10.47438	**A1**	0.9	**A1**	0.851867	**2**
A4	11.18094	**A4**	0.9	**A4**	0.930125	**3**
A3	11.81181	**A3**	0.9	**A3**	1	**4**

Step 11: According to importance weight of barriers and sub- barriers from four decision makers, *A2* is the best-selected action plan for implementing GSCM practices in plastic processing factory.

Chapter 5
Results and Discussions

5.1. Results and Discussions

Barriers to GSCM implementation are ranked and evaluated and the alternative action plans are ranked for smooth GSCM implementation for „ABC" plastic manufacturing factory in this study. The proposed methodology has been systematically implemented to evaluate and rank the barriers, sub-barriers to GSCM implementation and also to rank the alternative action plans.

Table 5.1: Final Evaluation of Ranking

Main Barriers	Main Barrier Ranking	Sub- Barriers	Sub Barriers	Normalized weight	Sub- Barrier Ranking
B1- Insufficient Technology & Infrastructure	2	B11	Lack of advanced technology	0.213	1
		B12	Lack of shared knowledge of the best GSCM practices	0.209	2
		B13	Lack of R & D practices for product recovery system	0.14	5
		B14	Lack of technical expertise	0.163	3
		B15	Complexity in recovery operations	0.151	4
		B16	Lack of facility of storage and transportation	0.124	6

Table 5.1 Continued					
B2- Inadequate Knowledge & Support	1	B21	Lack of knowledge on green practices	0.199	1
		B22	Lack of environmental knowledge	0.175	3
		B23	Lack of training on GSCM practices	0.166	4
		B24	Lack of awareness of customer about GSCM	0.142	5
		B25	Lack of tax knowledge on returned products	0.129	6
		B26	Lack of interest and support from top management to adopt GSCM	0.19	2
B3- Unsupportive Organizational & operational Policy	**4**	B31	Deficient structure of industries to adopt GSCM	0.162	2
		B32	Lack of Govt. supportive policies on GSCM	0.164	1
		B33	Lack of support from parties in supply chain	0.161	3
		B34	Lack of recycling and reuse facilities of organization	0.108	7
		B35	Lack of environmental certification (ISO 14001)	0.111	6
		B36	Lack of standard practices for GSCM	0.153	4
		B37	Lack of legislation	0.141	5
					`

Table 5.1 Continued

B4- Financial Constraints	3	B41	Cost implication	0.171	3
		B42	Non- availability of bank loans to encourage green products	0.173	2
		B43	Uncertainty related to economic issues	0.195	1
		B44	Cost of disposal of hazardous products	0.133	6
		B45	Less idea of economic profit	0.169	4
		B46	High initial and operating cost	0.159	5

The result shows the ranking of main barriers. Based on the normalized value calculated and obtained from Table 4.7 & Table 5.1, the main barriers to GSCM implementation for the case factory are ranked as follows: „inadequate knowledge & support (B2)‟ with the normalized value (0.279) has e en ranked in the first place as the most influential a rrier „insufficient technology & infrastructure (B1)‟ with the normalized value (0.274) is ranked in the second place in the sense of imposing a rrier with the normalized value (0.257) „financial constraints (B4)‟ is positioned in the third rank and finally „unsupportive organizational & operational policy (B3)‟ has been ranked in the fourth place with the normalized value (0.19). Final Evaluation of Ranking is presented in Table 5.1.

„Lack of advanced technology (B11)‟ with the normalized value (0.213) has gained the first position the main barrier group- „insufficient technology & infrastructure (B1)‟. This ranking reveals that lack of advanced technology is an influencing barrier that hinders the smooth implementation of GSCM practices in the case factory under this main barrier. With the normalized value (0.124) „lack of modern technologies facility of storage and transportation (B16)‟ gained the last place of this su -barrier list. The raking of the other influencing sub-barriers under this main barrier is presented in Table 5.1.

Table 5.1 also shows the details of the ranking of the sub-barriers under each main barrier. In the main barrier group- „inadequate knowledge & support (B2)‟ „lack of knowledge on green practices (B21)‟ with normalized value (0.199) earned the first position in this su -barrier group. That means lack of knowledge on green practices is the main hindrance in implementing GSCM practices in the case factory under this main arrier. In this group „lack of tax knowledge on returned products (B25)‟ with normalized value (0.129) is ranked in the last position. Though this sub-barrier is positioned in the last place, it hinders the implementation of GSCM practices in the case factory. Table 5.1 shows the ranking of all the sub-barriers under this group.

„Lack of government supportive policies for GSCM (B32)‟ is ranked in the first position of the main barrier group- „unsupportive organizational & operational policy (B3)‟ ecause the normalized value (0.164) of this sub- barrier is found to be the highest. The case factory is getting less support from the govt. and thus the operational policy is not favorable in regard to implementing GSCM practices. „Lack of recycling and reuse facilities of organizations (B34)‟ is ranked in the last of this sub-barrier list. Table 5.1 shows the ranking of the other sub-barriers under this main barrier.

In the main barrier group- „financial constraints (B4)‟ „uncertainty related to economic issues (B43)‟ with normalized value (0.195) is placed in the first position as the most influencing barrier under this main barrier. Implementing green activities in the traditional supply chain imposes many financial related uncertainties. These uncertainties are regarded as influential barriers of financial constraints. In the last of the sub-barrier list under this main barrier „cost of disposal of hazardous products (B44)‟ is positioned with lowest normalized value (0.133). Ranking of all other sub-barriers under this main barrier is presented in Table 5.1.

The ranking of the barriers and sub-barriers reveals the insights of the different hindrance of implementing GSCM practices in the case factory. For the smooth implementation of GSCM practices in the case factory four alternative action plans are evaluated. The evaluation of the four action plans can help the case factory implement GSCM practices smoothly. From the results presented in the Table 4.9, action plan 2- „development and introduction of infrastructure and cleaner technology (A2)‟ has e en ranked in the first position having the value (S=7.29752 R=0.858333, Q=0). Action plan 2is regarded as the most important action plan. In the second position of the ranking, action Plan 1- „top management‟s full and continuous commitment and support and organizing awareness programs (A1)‟ is placed ecause action plan 1 has the value (S=10.47438, R=0.9, Q=0.851867). With the calculated value (S=11.18094, R=0.9, Q=0.930125), action Plan 4- „development of organizational and operational policies towards greening initiatives and practices (A4)" is regarded as the third most important action plan and is placed in the third position. Finally, action Plan 3- „provision of su st antial financial support to initiate GSCM programs implementation (A3)" which has calculated value (S=11.81181 R=0.9 Q=1) is regarded as the fourth most important action plan and is placed in the fourth position of the ranking. Thus, the proposed methodology is implemented successfully to rank and evaluate the main barriers, their sub-barriers and evaluate the action plans in this research work. This research work will help the case factory learn insights of the barriers and action plans to implement GSCM practices in the operational activities.

Chapter 6

Conclusions, Managerial Implications and Recommendations

6.1. Conclusions

GSCM practices are gaining popularity widely in various manufacturing industries. Due to the emerging pressures from national and international organizations, the manufacturing industries have started to adopt green activities in their traditional supply chains. GSCM practices are widely practiced in the developed countries as against their counterparts in the emerging economies. The plastic manufacturing industry of Bangladesh is taking initiatives to incorporate green activities in their supply chains. Yet due to the lack of research and study on various obstacles and barriers that can hinder the smooth implementation of GSCM practices, the plastics industries of Bangladesh are facing numerous problems when implementing GSCM practices. This study was initiated to determine the influential barriers to GSCM implementation and propose potential action plans to mitigate these barriers. These barriers and action plans are ranked systematically using the fuzzy-VIKOR approach and appropriate action plans are linked to each barrier for mitigation. The result reveals the identified four major barriers including-insufficient technology and infrastructure, inadequate knowledge and support, unsupportive organizational and operational policy and financial constraints. However „inadequate knowledge and support‟ was found to e the most influential barrier among the four in implementing GSCM practices. The result also reveals the rankings of the sub-barriers under each major barriers and alternative action plans for the smooth implementation of GSCM practices for the plastic industry of Bangladesh. Development and introduction of infrastructure and cleaner technology was regarded as the most important action plan to support the implementation of GSCM practices in the plastics industries of Bangladesh. Green activities reduce energy loss and environmental degradation. Profitability is also ensured by adopting green activities and green technologies in the manufacturing plans.

6.2. Managerial Implications

This study‟s findings will therefore provide significant guidance to the plastic industries of Bangladesh when attempting to implement GSCM practices in their organizations. If the barriers are tackled strategically and the action plans are initiated systematically, the plastic industries of Bangladesh will be able to reduce the unnecessary energy loss and environmental degradation and make some financial gains. The intensity of the barriers significantly affects the successful implementation of GSCM practices. The meaning and insights of the identified barriers will assist the decision makers to either tackle the barriers or to take some precautions for the smooth implementation of GSCM practices. The action plans will assist the policy makers to formulate strategies to make the initiatives to implement GSCM practices. Thus, the insights of the barriers and course of the action plans will assist the policy makers to adopt green activities in their traditional supply chain and make better utilization of resources and energy which will lead to a promising profitability.

6.3. Recommendations for Future Study

Despite the contributions made by this study, a number of limitations and concerns do exist. Yet, these limitations do provide fertile grounds for future and additional empirical investigations. For example, the barriers in this study were identified using the extant literature review and industrial managers‟ opinions. A more scientific approach and empirical validation is required, especially in the plastic manufacturing industry of Bangladesh. Given that only a handful of managers were asked their opinion, a more robust and scientific evaluation covering a broader set of organizations, plastic manufacturing industries, and regions are necessary to ascertain how much of these barriers are really hindering the implementation of GSCM practices. Progressively, many new challenging barriers may hinder the implementation of GSCM practices. Those barriers can be taken into account and ranked systematically.

From a methodological perspective, this study used fuzzy-VIKOR to evaluate the barriers and action plans. These tools, although potentially useful, may require more thorough comparative analysis with other tools. For example, other weighting schemes/ models such as the Interpretive Structural Modelling (ISM), the Structural Equation Modelling (SEM) or the Graph Theory and Matrix Approach (GTMA), Analytic Hierarchy Process (AHP), the Fuzzy-AHP, the

Grey Relational Analysis, Elimination and Choice Expressing Reality (ELECTRE), and Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) can also be used to rank the barriers and action plans in the future and similar study, and compared. The methodology and framework developed in this study can be applied to other industries i.e. chemicals, leather, pharmaceuticals, automobile industries etc. to assess and rank the barriers to GSCM practices and potential action plans to mitigate these barriers.

We believe this study is one of the very first and few that focuses on the Bangladeshi plastic manufacturing industry. It sets the stage for additional and needed research investigation and practical application of the action plans to mitigate these barriers. Clearly more works in this area is required in the present economic, social and technological context of the country.

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Appendix

Table A1: Simplified meanings of each barrier with identification code

Major Barriers	*Sub-Barriers*	*Simplified Meanings*	*Relevant Literature*
1. Insufficient Technology & Infrastructure (B1)	1. Lack of advanced technology (B11)	Green manufacturing processes need lots of advanced and modern green technologies. Lack of advanced technologies hinder the implementation of GSCM practices	[1–3]
	2. Lack of shared knowledge of the best GSCM practices (B12)	The contemporary industries need to share their experience and expertise of the best practices of GSCM, without which implementation of GSCM in a new environment is difficult.	
	3. Lack of R & D practices for product recovery system (B13)	Lack of high-tech R&D facilities for reverse logistics and product recovery hinders the GSCM implementation.	
	4. Lack of technical expertise (B14)	Without proper technical knowledge gathered from experience and training, handling machines and other sophisticated technologies are difficult.	
	5. Complexity in recovery operations (B15)	Reverse logistics, waste management and recovery operations need sophisticated technology and its handling process is also complicated. This complicated process hinders GSCM practices.	
	6. Lack of facility of storage and transportation (B16)	GSCM needs green storage and green transportation system, without which its implementation is not possible.	

Table A1 Continued			
2. Inadequate Knowledge & Support (B2)	1. Lack of knowledge on green practices (B21)	Knowledge of green concepts of the supply chain is essential for GSCM practices. Lack of knowledge on green practices hinders its implementation smoothly.	[4–6]
	2. Lack of environmental knowledge (B22)	Environmental issues are important parts of GSCM practices. Without adequate knowledge on the environmental issue, it's hard to implement GSCM practices.	
	3. Lack of training on GSCM practices (B23)	Training from home and abroad on green issues of the supply chain is required for the smooth implementation of the GSCM practice. Lack of proper training hinders GSCM implementation.	
	4. Lack of awareness of customer about GSCM (B24)	Without customers‟ awareness about GSCM, its implementation is quickened and flourished.	
	5. Lack of tax knowledge on returned products (B25)	Reverse logistics and remanufacturing of returned products and reselling them have separate taxation structure. Lack of knowledge on the proper taxation system hinders the GSCM implementation.	
	6. Lack of interest and support from top management to adopt GSCM (B26)	Top management needs to take prompt actions and initiatives to foster green activities in the supply chain. Without top management‟s interest and support implementation of GSCM practices is difficult.	

Table A1 Continued			
3. Unsupportive organizational &operational Policy (B3)	1. Deficient structure of industries to adopt GSCM (B31)	Manufacturing industries need to incorporate favorable structure for GSCM implementation i.e. green warehouse, favorable organizational policies, without which smooth implementation of GSCM practices is difficult.	[3, 9, 56]
	2. Lack of Govt. supportive policies on GSCM (B32)	Government policies are the driving force to implement any rules and regulations strictly. Lack of govt. supportive policies on GSCM hinders the implementation of GSCM practices smoothly.	
	3. Lack of support from parties in supply chain (B33)	All the parties involved in the whole supply chain must take part in adopting green activities in the supply chain. Implementation of GSCM practices is difficult if any one of the parties lacks in supporting green activities.	
	4. Lack of recycling and reuse facilities of organization (B34)	Recycling and reuse facilities are essential parts of green activities. GSCM implementation is badly disrupted if the organizations don‟t give much effort in recycling and reuse facilities.	

Table A1 Continued			
	5. Lack of environmental certification (ISO 14001) (B35)	Manufacturing industries need to achieve sustainability certification i.e. ISO 14001 if they want to maintain the compliance of the international standard. Without this certification, manufacturers implement GSCM practices correctly.	
	6. Lack of standard practices for GSCM (B36)	Industries intending to implement GSCM practices need to know the standard practices of green activities. As the contemporary industries don"t practice green activities in a standard way, there is a knowledge gap of standard practices for GSCM.	
	7. Lack of legislation (B36)	Lack of govt. rules and regulations and organizational policies hinder the implementation of GSCM practices in the industries.	
4. Financial Constraints (B4)	1. Cost implication (B41)	Huge investment is needed to purchase & install technology, machine and construct green infrastructure for GSCM. This cost related constraint hinders the GSCM implementation.	[57–59]

Table A1 Continued			
	2. Non- availability of bank loans to encourage green products (B42)	Financial institutions i.e. banks are not aware of the profitability of green activities. Industries don‟t find loan facilities for green activities from the banks easily. This situation hinders GSCM practices severely.	
	3. Uncertainty related to economic issues (B43)	The profitability of green activities has not been assessed. But green activities lead to profitability. Industries are not yet aware of the profitability of green activities of the supply chain.	
	4. Cost of disposal of hazardous products (B44)	Disposal of dangerous products needs high-tech machine and experts. Due to the high cost of disposal of hazardous waste, GSCM implementation becomes uncertain.	
	5. Less idea of economic profit (B45)	Green activities lead to economic gain. But due to unavailability of assessment of the profitability of green businesses, industries have less idea of economic profit of GSCM practices	
	6. High initial and operating cost (B46)	For incorporating green activities into the traditional supply chain, the industries need to purchase high-tech technology, machine and build green infrastructure. All of these lead to high initial and operating cost which hinders the GSCM practices.	

Table A2: Characteristics of four respondent managers

Manager 1	
Position	Supply chain manager
Role of area	Procurement, sourcing, distribution
Working experiences	15 years' active working experiences
Type of the company	Plastics chair, table, bottle, plastic utensils manufacturing
Manager 2	
Position	Operations manager
Role of area	Manufacturing and production
Working experiences	10 years' active professional experiences
Type of the company	Plastic bottling (manufacturing) as third party
Manager 3	
Position	Logistics manager
Role of area	Transportation and distribution
Working experiences	12 years' professional experiences
Type of the company	Plastic utensils manufacturing and export
Manager 4	
Position	Technology manager
Role of area	Production, manufacturing and ERP
Working experiences	14 years' technical experiences
Type of the company	Plastic packaging manufacturing