Analysis of Barriers to Green Supply Chain Management Implementation in Leather Industry: A Case Study

Md. Shaif Uddin

Department of Industrial and Production Engineering

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

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by

Md. Shaif Uddin

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 to Green Supply Chain Management Implementation in Leather Industry: A Case Study" submitted by Md. Shaif Uddin, Student No. 0416082104F, Session –April 2016 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management on November 14, 2017.

BOARD OF EXAMINERS

1. Dr. Syed Mithun Ali — Chairman (Supervisor)
   Assistant Professor
   Department of Industrial & Production Engineering
   BUET, Dhaka.

2. Dr. Ferdous Sarwar — Member
   Associate Professor
   Department of Industrial & Production Engineering
   BUET, Dhaka.

3. Dr. Shuva Ghosh — Member
   Assistant Professor
   Department of Industrial & Production Engineering
   BUET, Dhaka.

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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.

Shaifu

November 14, 2017 Md. Shaif Uddin

This Work is Dedicated to My

Parents

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Nomenclature

AHP	:	Analytical Hierarchy Process
ANP	:	Analytic Network Process
BEPB	:	Bangladesh Export Promotion Bureau
BOD	:	Biological Oxygen Demand
CETP	:	Common Effluent Treatment Plant
COD	:	Chemical Oxygen Demand
DEMATEL	:	Decision-Making Trial and Evaluation Laboratory
ELECTRE	:	Elimination Et Choix Traduisant La Realite (ELimination and Choice Expressing Reality)
GSCM	:	Green Supply Chain Management
ISM	:	Interpretive Structural Modeling
MCDA	:	Multi-Criteria Decision Analysis
SMEs	:	Small and Medium Enterprises
TIA	:	Total Information Analysis
TOPSIS	:	Technique For Order of Preference By Similarity To Ideal Solution
C_{ab}	:	Concordance Interval Set
$\overline{C}$	:	Average Value of Concordance Index
CR	:	Consistency Ratio
CI	:	Consistency Index
D_{ab}	:	Discordance Interval Set
$\overline{D}$	:	Average Value of Discordance Index
E	:	Matrix of Concordance Index
F	:	Matrix of Discordance Index
G	:	General Matrix
G_s	:	Strictly Relation Graph

G_w	:	Weakly Relation Graph
n	:	Represents The Total Number of The Barriers
RI	:	Random Index
R_{ij}	:	Normalized Matrix
r_{ij}^{S}	:	Value of Strictly Relation Between A_i and A_j
r_{ij}^{W}	:	Value of Weakly Relation Between A_i and A_j
V_{ij}	:	Weighted Normalized Matrix
W	:	Weight Coefficient Vector of The Barriers
W_{max}	:	Maximal Eigen Vector of The Relationship Matrix
w_i	:	Represents The Weight of The Barriers
X	:	Relationship Matrix
x_{ij}	:	Comparative Significance of Barrier i Comparing With j
λ_{max}	:	Maximal Eigen Value of The Relationship Matrix

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Abstract

Leather processing industry is constantly polluting the environment in Bangladesh. As a result, stakeholders are continuously pressurizing managers working in leather processing industry to green leather processing activities. Thus, green concept is attracting significant attention to managers in Bangladeshi leather processing industry. The managers have toiled hard to execute the green idea in their supply chain management. However, the industry is struggling with many barriers to implementing green supply chain management (GSCM). This thesis entails the identification and prioritization of barriers and ranking the possible pathways to implement GSCM in Bangladeshi leather industry. Both from the reviews of analysts and literature, twelve barriers in four dimensions are identified. This thesis proposes a hybrid approach named analytical hierarchy process (AHP) and elimination et choix traduisant la realite (ELECTRE-I). AHP was used to calculate the weight and prioritize the barriers. ELECTRE-I was employed to rank the possible pathways to implement GSCM. We present an illustrative case to show the usefulness and validity of the proposed approach. A sensitivity analysis was done to investigate the strength of the outcome of the method. In this research, technology dimension has been occupied as first ranking and high cost of advanced technology was identified as most influential barrier. Green technology and techniques has been found as the most effective pathways. The findings of this research is hoped to support researchers and practitioners by giving insights on barriers and possible pathways to implement GSCM.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Leather processing industry is one of the primitive industries in Bangladesh. This sector has potential due to its remarkable contribution to the creation of national wealth as well as its worldwide status. Due to the natural grain surface, noble texture, identical fiber composition and fine touch, Bangladeshi leather has achieved a strong position all over the world (Paul et al., 2013). According to Bangladesh export promotion bureau (BEPB), the involvement of the tanning sector to the nation"s economy is US$ 43908758.39 in 2016-17 fiscal year. Furthermore, many industrially advanced countries have shown their interest to invest in Bangladeshi leather sector. This is due to low labor cost compared to developed countries. The process of leather tanning consists of various steps with the utilization of huge quantity of pure water and generates bulk amount of solid & liquid wastes. In most of the tanning process, chromium salt is used as a tanning agent because above 90% of the leather produced in Bangladesh is chrome tanned (Ahmed & Chowdhury, 2016). Many organic and inorganic compounds, such as ammonia, chloride, chromium, sulfates, dissolved and suspended solids and other heavy metals characterize the wastewater produced in the tanning process. With a high level of biological oxygen demand (BOD) & chemical oxygen demand (COD), generated wastewater is discharged into the sewerage system without any treatment. This leads to the extensive breakdown of ecosystem of river. It can also be noted that when chrome -III is oxidized into chrome-IV, it will turn into carcinogen (Chowdhury et al., 2013). There are about 200 tanneries in Bangladesh. One study shows that tanneries discharge about 20,000 m^3 of effluents and 232 tons of solid wastes per day. This huge amount of solid waste (sludge) is dumped into residential area, which causes serious air pollution. It also creates threat to human health. Besides, incineration of leather trimmings in an open place causing severe environmental pollution. The living condition of this area is below the satisfaction level (Azom et.al., 2012). It is worth pointing out that all tanneries in Hazaribag, Dhaka have already been transferred to a leather park at Savar with proposed high technical support. However, it is a matter of great regret that same scenario has been spotted like previous zone due to lack of advanced technology and under constructed as well as inappropriate infrastructure. This points out a challenge to the upcoming sustainability and cleaner production of leather sector with increasing number of barriers, including environmental legislature and eco-criteria derived from exclusive market of export.

Experts show that if environmental requirements are followed strongly, the export is expected to be increased by $5 billion (Report, 2016). GSCM enables such a firm to be more competitive in the global market (Rao & Holt, 2005). The literature provides masses of studies and associated proofs illuminating the benefits of environmental compliance for business (Stokes & Rutherfoord, 2000; Sarkis, 2003;Hsu & Hu, 2008). Common supply chain management has turned into GSCM by furnishing ecological necessities (Gandhi et al., 2015; Mathiyazhagan et al., 2014). GSCM is defined by the inclusion of green elements i.e., green supply and procurement, green plan, green process, green promotion & distribution, reverse logistics etc., in every functional stage of a supply chain (Min & Kim, 2012; Mohanty & Prakash, 2013). GSCM has contributed to the economic growth and development of a company with the care of environment (Vanpoucke, 2016). GSCM is participating to support the continuous sustainable improvement by playing a significant contribution through maintaining the total information analysis (TIA) report of any organization engaged in supply chain acts (Chin et al., 2015). While implementing GSCM into a field, a lot of barriers came to the management system and found areas to implement alternatives for improvement (Govindan et al., 2014; Wang & Chan, 2013).

The study has the purpose of analyzing such barriers and finding the possible pathways. Therefore, this study helps the firm to filtrate the major barriers to implementing GSCM through the hybrid multi-criteria decision analysis (MCDA) method namely AHP and ELECTRE-I. In various sector of study MCDA technique is extensively used. Many

MCDA approaches have been suggested by experts, such as AHP (Saaty 1980) and ELECTRE-I (Bernard Roy 1968). AHP has become an important technique in MCDA. In addition, the transparent construction process of AHP makes them easily understood by academics and practitioners. However, AHP is often criticized regarding their inability to process ambiguous variables. Chan and Kumar (2007) indicated that, due to the utilization of a scale with one to nine discrete values AHP cannot determine the uncertainty in calculating the weights of various characteristics. On the other hand, to reflect the stakeholder‟s choice, ELECTRE-I has been widely used as outranking technique in various sectors. This method also represents the priority of comparisons with criteria through outranking comparisons to lessen the bias of decision-makers (Pang et al., 2011).

1.2 Research Gap

The extant literature makes it evident that both academics and practitioners are paying attention towards barrier analysis to GSCM adoption. GSCM studies have shown significant progression in developed countries, more so than the developing ones. In spite of increasing awareness and concerns for environmental sustainability in the world, the Bangladeshi leather-processing industry has shown very little development regarding GSCM practices. Keeping in consideration that GSCM is a sought after tool to improve the supply chain and overall business operation, this study aims to provide a perspective for GSCM practices by reviewing the literature, which can utilize the practices in the leather industry of Bangladesh. As apparent from the above discussion, a significant quantity of studies regarding this research issue administered mostly in industrially developed countries. In Bangladesh, extensive study has not been taken place to emphasize barrier analysis and possible ways to implement GSCM in the leather processing industry of Bangladesh. This lack of research is the inspiration for this study. This study addresses the gap by using a hybrid method named AHP&ELECTRE-I.

1.3 Objectives of the Present Work

The overall aim of this research work is to identify most influential barriers and select most effective pathways to green supply chain management implementation in leather processing factory of Bangladesh. The specific objectives of this study are as follows.

1. To identify major barriers to implementation of green supply chain management for a leather processing factory in Bangladesh.
2. To prioritize influential barriers and rank possible pathways to green supply chain strategy with the application of the AHP and ELECTRE approach respectively.

1.4 Scope of the Thesis

The thesis is organized into six chapters including this one. The chapters are structured in the following way: Chapter 1 represents the prospect of leather processing industry, application of green supply chain management, advantages of AHP and ELECTRE-I method, the research gap of the study and objectives of the study.

The rest of the thesis is organized as follows; Chapter 2 presents the literature review of green supply chain management, barriers to GSCM implementation and possible pathways to implement GSCM.

Research methodology, application of MCDA technique and AHP and ELECTRE-I solution methodology are presented in Chapter 3.

Chapter 4 describes the real case application of Bangladeshi leather processing factory for modeling barriers to implementing green supply chain management.

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

Finally, Conclusions and managerial implications and recommendations for future research are presented in Chapter 6. References and appendix are presented at the end of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Green Supply Chain Management

Chowdhury, Upadhyay, Briggs and Belal (2016) addressed the idea of GSCM by using the hypothesis of reprocessing, recycling and reuse which expresses the concepts of reverse logistics as well. Srivastava (2007) described the GSCM as a tool of ensuring the sustainability of an environment through reducing the amount of waste and carbon emission. Srivastava (2007) also delineated that GSCM concept helps to improve the attitude on research in various industrial sectors. Perron (2005) proposed that the acknowledgment of availing of the ecological opportunities and achievement of industries is indispensable for circulating those opportunities in small and medium enterprises (SMEs) and large enterprises. Shipeng and Linna (2011) noticed that in all sorts of business enterprises, GSCM takes into account marking ecological problems in supply chain management. Wu, Tseng, and Vy (2011) founded GSCM as a helping hand to support the organization for gaining turnover and market share through reduction of their ecological hazards and influences while improving their productivity. Sembiring and Rambe (2016) noticed that greater part of GSCM has emerged as a key of management and viewpoint of unbeaten and top firms. Chowdhury et al. (2016) outlined that the theory of GSCM contributes to not only in processing area but also in technology improvement. Currently, it is applied in other sectors i.e., administration of the state, academic institutions and many service sectors. Hoque and Clarke (2013) proposed that the adoption of GSCM could improve the efficiency and security of the inherent environment. GSCM has remarkable possibility to help in monetary and ecological sustainability as well. Ali and Bentley (2015) suggested that practicing GSCM can help improving the employee morale, brand reputation, and profitability and thus enhancing the overall firm performance.

2.2 Barriers to GSCM Implementation

This subsection presents the literature related to barriers to implementing GSCM. After reviewing the literature, it can be noted that there are various studies on the proposed analysis specifically on the field of GSCM. It has also found that only few studies discussed GSCM barriers. Table 2.1 shows the studies that facilitated to analyze the barriers to implementing GSCM.

Table 2.1
Summary of barriers to GSCM implementation

Sl. No.	**Category of Barriers**	**Barriers to implementing GSCM**	**References**
01.	Technology	i) Reluctance to adopt advanced technology	Parmar (2016); Balon et al. (2016); Balaji et al. (2014)
		ii)Low level of technological know-how	Parmar (2016)
		iii)Apprehension of failing	Govindan et al. (2014); Rao & Holt (2005); Perron (2005)
		iv)Absence of expertise in technology	Stokes & Rutherfoord (2000); Van Hemel & Cramer(2002); (Mathiyazhagan et al. (2013)
		v)Organizational difficulties with environmental technology	Sarkis (2007)
		vi)Insufficient internal technological resources expertise on environment	Zhu & Geng (2013)

Table 2.1

Summary of barriers to GSCM implementation

(Continued)

Sl. No.	Category of Barriers	Barriers to implementing GSCM	References
02.	Financial	i) Unavailable bank loans for motivation of green product	Govindan et al. (2014); Parmar (2016)
		ii) High cost for hazardous waste disposal	Parmar (2016); Govindan et al. (2014); Zhu & Geng (2013)
		iii) Cost implication	Parmar (2016)
		iv) Financial constraints	Balon et al. (2016); Govindan et al. (2014); Mathiyazhagan et al. (2013)
		v) High cost for using environmental packaging	Zhu & Geng (2013); Wang et al. (2015)
		vi) High investment and fewer return-on-investments	Govindan et al. (2014); Mathiyazhagan et al. (2013)
03.	Knowledge	i) Lack of knowledge and experience	Balaji et al. (2014)
		ii) Disbelief about environmental benefits	Govindan et al. (2014); Mathiyazhagan et al. (2013); Stokes & Rutherfoord (2000); Wang et al. (2015)
		iii) Lack of professionals exposed to green systems	Mathiyazhagan et al. (2013); Govindan et al. (2014); Wang et al. (2015)
		iv) Perception of "out-of-responsibility" zone	Govindan et al. (2014); Mathiyazhagan et al. (2013)
		v) Lack of awareness about reverse logistics adoption	Woofi & Zailani (2010); Parmar (2016); Balon et al. (2016); Govindan et al. (2014); Wang et al. (2015); Mathiyazhagan et al. (2013)
		vi) Lack of environmental knowledge	Govindan et al. (2014); Mathiyazhagan et al. (2013)

Table 2.1
Summary of barriers to GSCM implementation

(Continued)

Sl. No.	Category of Barriers	Barriers to implementing GSCM	References
04.	Government support and policies	i) Lack of government support to adopt GSCM	Parmar (2016); Govindan et al. (2014); Wang et al. (2015); Mathiyazhagan et al. (2013)
		ii) Lack of government regulation and legislation	Balaji et al. (2014); Luthra et al. (2016); Balon et al. (2016)
		iii) Restrictive company policies towards product/process stewardship	Govindan et al. (2014); Mathiyazhagan et al. (2013); Stokes & Rutherfoord (2000)
		iv) Lack of rewards and encouragement programs	Luthra et al. (2016); Sarkis (2007); Mathiyazhagan et al. (2013); Govindan et al. (2014)
		v) Inefficient policy framing	Luthra et al. (2016)
		vi) Lack of promotion of ethical and safe practices	Luthra et al. (2016)
05.	Outsourcing	i) Complexity in measuring and monitoring suppliers' environmental practices (B2)	Govindan et al. (2014); Wang et al. (2015)
		ii) Problems in maintaining environmental suppliers	Wang et al. (2015); Govindan et al. (2014)
		iii) Lack of sustainability certification (ISO 14001)	Parmar (2016)
		iv) Lack of training courses/consultancy/institutions to train, monitor and mentor the progress specific to each industry	Mathiyazhagan et al. (2013); Govindan et al. (2014
		v) Lack of corporate social responsibility	Parmar (2016); Govindan et al. (2014); Mathiyazhagan et al. (2013); Balon et al. (2016)
		vi) Eco-literacy among supply chain partners	Balon et al. (2016)

2.3 Possible Pathways to Implement GSCM

There are some research articles relevant to pathways to implement GSCM. Researchers in various industrial applications and countries identify many pathways. Table 2.2depicts these pathways.

Table 2.2

Summary of possible pathways to GSCM implementation

Sl. No.	Category	Possible pathways to implementing GSCM	References
01.	Environmental	i) Environmental regulations	Chien et al. (2007); (Mudgal et al. (2009)
		ii)Eco-design	Zhu et al. (2010); Eltayeb et al. (2011)
		iii)Reverse logistics	Eltayeb et al. (2011)
		iv)Pollution prevention	Hosseini (2007)
		v)Cleaner technology	Hosseini (2007)
02.	Operational	i) Guide & benchmarking systems	Lam et al. (2010)
		ii) Green technology and techniques	Lam et al. (2010)
		iii) Reducing energy consumption	Diabat & Govindan (2011)
		iv) Reliability and quality specifications	Lam et al. (2010)
		v) Appropriate infrastructure	Paul et al. (2013)
03.	Management	i) Waste management	Udomleartprasert (2004)
		ii) Internal environment management	Zhu et al. (2010)
		iii) Leadership and responsibilities	Lam et al. (2010)
		iv) Certification to ISO: 14001 EMS	Mudgal et al. (2009)
		v) Supplier management	Hu et. al. (2012)

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This study presents a decision support framework for identifying the most influential barriers and selecting the most effective pathways to the implementation of GSCM in Bangladeshi leather industry. Fig. 3.1 illustrates this structure. The goal is to select the most influential barriers and most effective pathways to the implementation of GSCM. It consists of four steps as described below.

Step 1: Identify the suitable dimensions, major barriers, and pathways to implement GSCM

In this step, major barriers with suitable dimensions and possible pathways have been identified from literature review and experts input. It can be noted that thirty most common barriers with five dimensions and fifteen possible pathways were identified from existing literature.

Step 2: Determine the most influential barriers by applying AHP

The most influential barrier has been determined from major barriers, which were identified in Step 1. This step has been carried out by applying AHP method. The highest weighted barrier has been considered as the most influential barrier, which can be easily identified from global weights of specific barriers.

Step 3: Determine the relative priorities of pathways with respect to each barriers by applying AHP method

In this stage, the relative priorities of identified possible pathways concerning each of the major barriers have been determined by applying AHP technique. Decision-making matrix has been constructed in this step.

Step 4: Determine the most effective pathways by applying ELECTRE-I method

In the final step, the most effective pathway has been determined from general matrix G. This step has been carried out by applying ELECTRE-I method.

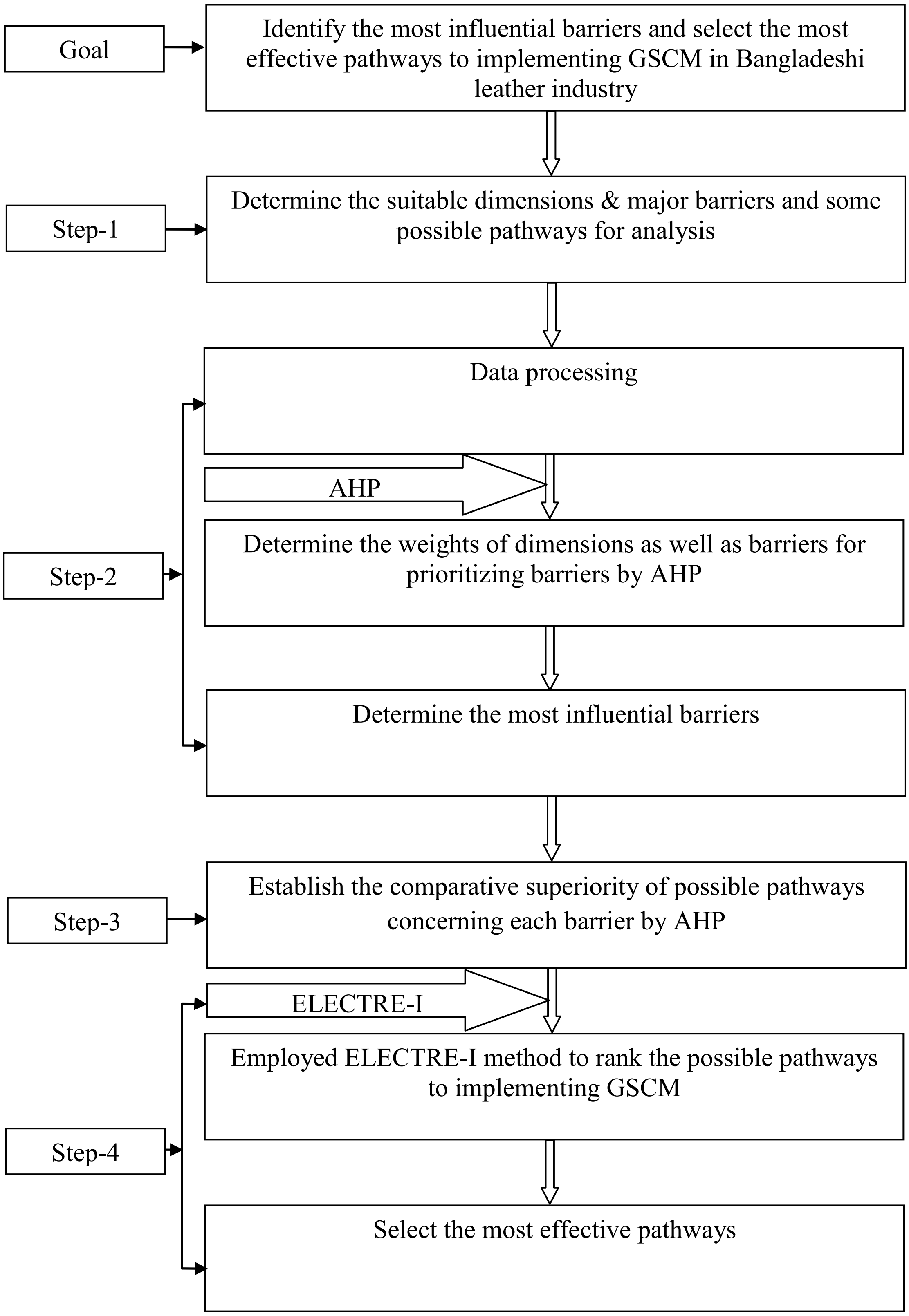

Fig. 3.1 Framework of the proposed method

3.1.1 Identification of major barriers with suitable dimensions and possible pathways

The major barriers to implementing GSCM in Bangladeshi leather industry have been identified from the literature and professionals' opinion. It is worth pointing out that the specific firm may have distinctive observation concerning barriers to implementing GSCM. Therefore, barriers defined for any firm might not be the same in others and may have discrete influences as well. Based on existing literature and experts‟ input, twelve major barriers and five possible pathways to the implementation of GSCM have been determined (detail of finalizing the barriers with suitable dimensions and possible pathways have been discussed in data collection section). It can be noted that experts verified these major barriers and possible pathways. Later, validated barriers have been categorized into four dimensions (technology; knowledge; government support and policies; and financial) by taking expert‟s approval. Table 3.1 and Table 3.2 show the list of major barriers with suitable dimensions and possible pathways respectively.

Table 3.1

Major barriers with suitable dimensions and possible pathways to implement GSCM in Bangladeshi leather processing industry

Sl. No.	Dimensions	Barriers	Notation
1.	Technology	i) High cost of advanced technology	T1
		ii) Apprehension of failing	T2
		iii) Organizational difficulties with environmental technology	T3
2.	Knowledge	i) Lack of knowledge and experience	K1
		ii) Lack of awareness about reverse logistics adoption	K2
		iii) Lack of professionals exposed to green systems	K3
3.	Government support and policies	i) Lack of government regulation and legislation	G1
		ii) Lack of rewards and encouragement programs	G2
		iii) Restrictive company policies towards product/process stewardship	G3
4.	Financial	i) High cost for hazardous waste disposal	F1
		ii) High cost for using environmental packaging	F2
		iii) Financial constraints	F3

Table 3.2
Possible pathways to implementing GSCM in Bangladeshi leather industry

Sl. No.	Possible Pathways	Notation
01.	Waste management	P1
02.	Appropriate infrastructure	P2
03.	Green technology and techniques	P3
04.	Cleaner technology	P4
05.	Supplier management	P5

3.2 Solution Methodology

The application of MCDA technique, procedures of AHP and ELECTRE-I method are presented in this section subsequently.

3.2.1 Application of MCDA technique

Barrier analysis to implementing GSCM, in which several barriers remain under certain dimensions, is a problem of MCDA. The establishment of the decision-making matrix is a precondition to accomplish the analysis.

According to Hajkowicz & Higgins (2008) MCDA has been commonly used to attain a fixed quantity of alternatives stand on a evaluation criteria set has a subsequent distinctiveness: a) capability to of decision framework management; b) ability to explain complicated criteria with the unit that does not have a common measure; and c) aiding in the process of making decisions (Mendoza & Martins, 2006). Furthermore, it helps in calculating various goals with contradictory standards or instinctive features (Teixeira de Almeida, 2007). Broad application of MCDA has occurred in many distinguishable challenges such as management of water resources, strategic technology development solutions of fuel cell in the industry of automotives, sustainibility assessment of biogas production, assesment of technologies relating to concentrated thermal and solar energy, management of natural resources, selection and evaluation of suppliers (An et al., 2017).

All problems in the process of making decisions are parallel to barrier analysis of GSCM in the leather industry.

Several MCDA methodologies have been published in the literature, such as interpretive structural modeling (ISM) (Parmar, 2016), AHP (Luthra et al., 2016), ELECTRE (Pang et al., 2011; An et al., 2017), technique for order of preference by similarity to ideal solution(TOPSIS) (Wang & Chan, 2013). In the midst of these, ELECTRE is one of the most commonly used methods for its many privileges (Pang et al., 2011). It is a widely recognized multi-standard approach standing on the research of dominating relations, which uses indexes of concordance and discordance to examine the outranking associations between the options (Teixeira de Almeida, 2007). Family procedures of ELECTRE consist of various privileges, considering the ELECTRE-I system as an instance, it can mirror the real qualities between each pair of two options (An et al., 2017). Therefore, ELECTRE family methods has also been broadly used, for example, water resource management (Zardari et. al., 2010), reliability design scheme for CNC machine (Pang et al., 2011), groundwater remediation (An et al., 2017), power management (Sánchez-Lozano et. al., 2016), and management of solid waste (Hokkanen et al., 1995), etc.

There are two most important branches in the matrix of making decisions i.e., a) the weights of the barriers to implementing GSCM and b) the weights of the possible pathways concerning each of the barriers to implementing GSCM. To determine the weights of the barriers, picking an appropriate method is a precondition to build right judgments. There are various ways to find out the weights of the barriers, i.e., the factual processes and the emotional processes. The factual methods, i.e., TOPSIS and entropy, can facilitate the decision-makers to find out the weights in relation to the features of the data of the possible pathways concerning the barriers neutrally. However, these equitable methods cannot indicate the likings and eagerness of the decision-maker. Consequently, the opinion-based weighting methods, i.e., AHP and Delphi, which can indicate the views of the stakeholders, are extensively used in establishing the weights of the factors or barriers in question. AHP, which is the most prominent emotional weighting process, can assist the decision-makers to find out the weights of the barriers by means of 1–9 scales and their reciprocals to set up the relationship matrix (Saaty, 1980). This method has been extensively used in many sectors due to the benefit of integrating the judgments of the decision-makers or stakeholders. i.e., mode of transport selection (Kuo & Tang, 2011), supplier selection (Dweiri et.al., 2016), hazardous waste recycling (Hatami et. al., 2013), health care system (Liberatore & Nydick, 2008) and maintenance engineering (Bevilacqua & Braglia, 2000) etc.

AHP method, which is developed by Saaty (1980), is used to find out both the weights of the barriers to implementing GSCM and the comparative precedence of the possible pathways concerning each of the barriers to implementing GSCM. It is obviously tricky to decision-makers to find out the precedence of the possible pathways concerning each barrier to GSCM implementation. There are mainly two causes: (1) rigorous ambiguity troubles existed in decision-making: the information of the possible pathways concerning the barriers to implementing GSCM cannot be achieved owing to different causes; (2) many flexible barriers cannot be illustrated in a straight line via quantitative techniques. After determining the decision-making matrix, the ELECTRE-I method is used to find out the precedence of the possible pathways to implementing GSCM in Bangladeshi leather processing industry. The following subsection describes the AHP and ELECTRE method.

3.2.2 Procedure of AHP method

In this research, the proposed method, AHP, determines the weights of barriers used in ELECTRE method. As declared above, the process is a decision investigation technique judging the quality-based as well as quantity-based data and mirrors the likings of the decision-makers. The utilization of the AHP setting offered by Saaty in 1978 to evaluate the criteria weightings in MCDA recently has become familiar in many sections of process engineering. The procedure of the AHP method is described as follows.

Step 1: Establish comparison matrix

Assume there are n numbers of barriers in a number of gradation, the pair-wise relationship technique suggested in 1980 by Saaty (see Table 3.3) can be applied to compute the matrix of comparison (indicated by matrix X), as displayed in Equation (3.1).

$$\mathrm{X} = \begin{bmatrix} 1 & x_{12} \ldots\ldots & x_{1n} \\ x_{21} & 1 & x_{2n} \\ \vdots & \cdots & \ddots \quad \vdots \\ x_{n1} & x_{n2} & \ldots.1 \end{bmatrix} \tag{3.1}$$

Where x_{ij} indicates the significance of barrier i compared to barrier j.

Equation (3.2) can calculate the significance of barrier j compared to barrier i.

$$x_{ji} = \frac{1}{x_{ij}},\ x_{ij} > 0,\ i,\ j = 1,\ 2,\ \ldots.n \tag{3.2}$$

Step 2: Calculation of weights

Through the relationship matrix, the weighting coefficients of each barrier can be obtained by computing the principal eigenvector of the relationship matrix, as exposed in Equation (3.3).

$$\begin{bmatrix} 1 & x_{12}\cdots & x_{1n} \\ x_{21} & 1\ldots. & x_{2n} \\ \vdots\ \cdots & \ddots & \vdots \\ x_{n1} & x_{n2}\ \ldots. & 1 \end{bmatrix} \begin{vmatrix} w_1 \\ w_1 \\ \\ \vdots \\ w_n \end{vmatrix} = \lambda \max \begin{vmatrix} w_1 \\ w_1 \\ \\ \vdots \\ w_n \end{vmatrix} \tag{3.3}$$

Table 3.3

Relationship scale in the Saaty method (An et al., 2017)

Scales	**Definition**	**Note**
1	Equal importance	i is equally important to j
3	Moderate importance	i is moderately important to j
5	Essential importance	i is essentially important to j
7	Very strong importance	i is very strongly important to j
9	Absolute importance	i is very absolutely important to j
2, 4, 6, 8	Intermediate value	The relative importance of i to j is between two adjacent judgment
Reciprocal	Reciprocals of above	The value had been assigned to i when compared to j, then j has the reciprocal value compared to i

Table 3.4

The value of the average random consistency index RI

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Where $(w_1, w_2, \cdot\cdot\cdot, w_n)^T$ is the maximal eigenvector of matrix X, λ_{max} is the maximal Eigen value of matrix X.

Equation (3.4) can determine the maximal eigenvector.

$$w_{max}, = [w_1, w_2, \cdot\cdot\cdot, w_n] \tag{3.4}$$

Where λ_{max} and W_{max} are the maximal Eigen value and the maximal Eigenvector of the relationship matrix respectively.

By normalizing, the maximal eigenvector of the weights of the barrier can be obtained, as presented in Equation (3.5).

$$W = \left(\frac{w_1}{\sum_{i=1}^{n} w_i}, \frac{w_2}{\sum_{i=1}^{n} w_i}, \ldots, \frac{w_n}{\sum_{i=1}^{n} w_i} \right)^T \tag{3.5}$$

Where W is the weight coefficient vector, w_i represents the weight of the barriers, and n represents the total number of the barriers.

Step 3: Consistency check

If $x_{ik}= x_{ij}x_{jk}$, j, k =1, 2, · · ·, n, then the relationship matrix X can be documented as a consistent matrix. Theory proves that if the n-dimensional comparison matrix is a consistent matrix, its maximal Eigen value must be equal to n. However, it is hard to set up a comparison matrix, which is consistent with matrix. In real cases, various comparison matrixes that satisfy the consistency check denote the consistent matrixes. By means of consistency ratio is a frequent way to evaluate whether a comparison matrix is consistent or not, as shown in Equation (3.6).

$$CR = \frac{CI}{RI} \tag{3.6}$$

Where CR denotes consistency ratio, CI denotes consistency index; RI indicates average random index with the same dimension with X.

The value of average random index can be obtained in Table 3.4. The consistency index can be calculated by Equation (3.7).

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3.7}$$

Where λ_{max} symbolizes the maximal Eigen value of the comparison matrix X, n symbolizes the dimension of this matrix.

When CR <0.1, the matrix can be acceptable as a consistent matrix, perversely CR ≥ 0.1, the matrix should be customized until a satisfactory one.

3.2.3 Procedure of ELECTRE-I method

By means of outranking relationships, ELECTRE technique reveals the superiority of relationships among different alternatives. Therefore, it is feasible that, these outranking relationships can differentiate among the alternatives. There are two types of indices used in ELECTRE method for pair wise comparison of alternatives. Indexes of concordance and discordance are the two indices (Pang et al., 2011). ELECTRE-I method was applied by analyzing these two indices to select the possible pathways in this thesis.

We assume that A_1, A_2,…, A_m are m possible pathways for GSCM implementation in the leather factory, C_1, C_2,…, C_n are barriers, which can describe the properties of possible pathways. x_{ij} defines the level of pathways Ai concerning barriers C_j. Again W_n denotes the weight of the significance of C_n, which is obtained from AHP method. The following paragraphs show the stepwise formulation of ELECTRE-I method.

Step 1: Determination of normalization matrix and weighted matrix

Considering concepts on the interval numbers of decision matrix, the normalized matrix of R_{ij} = [r_{ij}] is calculated by Equation (3.8).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \; i = 1, 2, \ldots, n \quad = 1, 2 \ldots m \tag{3.8}$$

Thus, Equation (3.9) shows the weighted matrix, which depends on normalized matrix, assigned to it.

$$V_{ij} = R \times R \times W = \begin{vmatrix} r_{11}.w_1 & r_{12}.w_2 & & r_{1n}.w_n \\ r_{21}.w_1 & r_{22}.w_2 & & r_{2n}.w_n \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1}.w_1 & r_{m2}.w_2 & & r_{mn}.w_n \end{vmatrix} \tag{3.9}$$

Where $0 \le w_1, w_2, \ldots, w_n \le 1$. These constants express the weights of the attributes. Besides, the correlation coefficients of normalized interval lie between zero and one.

Step 2: Ascertainment of concordance and discordance interval sets

Suppose selecting the effective possible pathways is a multiple criteria decision. By the use of information of preference, the decision-making system is obtained from the sets of intervals of the concordance and discordance. The sets of attributes may get past this system. Let A = {a, b, c...} signifies a finite set of alternatives. There are two different sets of concordance interval set (C_{ab}) and discordance interval set (D_{ab}). The concordance interval shows the dominancy if the requirement is met.

$$C_{ab} = \{j \mid x_{aj} \geq x_{bj}\} \tag{3.10}$$

On the other hand, we can establish the discordance interval set (D_{ab}) by using Equation (3.11).

$$D_{ab} = \{j \mid x_{aj} < x_{bj}\} = J - C_{ab} \tag{3.11}$$

Step 3: Calculation of the concordance interval matrix

Based on the preferences of the decision-makers for alternatives, the concordance interval index (C_{ab}) between A_a and A_b can be obtained by using Equation (3.12).

$$C_{ab} = \sum_{j \in C_{ab}} w_j \tag{3.12}$$

The concordance index shows the consent of the assertion “A outranks B.” Equation (3.13) shows the formulation of the concordance interval matrix.

$$C = \begin{vmatrix} - & c(1,2) \ldots\ldots\ldots\ldots c(1,m) \\ c(2,1) & - \ \ldots\ldots\ldots\ldots c(2,m) \\ \vdots & \vdots \quad \ddots \quad \vdots \\ c(m,1) & c(m,2) \ldots \quad - \end{vmatrix} \tag{3.13}$$

Step 4: Calculation of the discordance interval matrix

At the start, take the discordance index of d (a, b), which can be considered as the priority of dissatisfaction in the resolution of alternative a instead of alternative b. Equation (3.14) defines this preference more particularly.

$$d(a, b) = \frac{\underset{j \in D_{ab}}{\mathrm{Max}} \left| v_{aj} - v_{bj} \right|}{\underset{j \in J,\, m,\, n \in I}{\mathrm{Max}} \left| v_{mj} - v_{nj} \right|} \tag{3.14}$$

Here m and n help to calculate the weighted normalized value of all possible pathways. Therefore, we can establish discordance interval matrix by using discordance interval index sets.

Equation (3.15) shows this interval matrix.

$$D = \begin{vmatrix} -\,\ldots\ldots\ldots d(1,\, 2)\ldots\ldots\ldots\ldots d(1,\, m) \\ d(2,\, 1)\ldots\ldots\ldots -\,\ldots\ldots\ldots\ldots d(2,\, m) \\ \vdots \qquad \vdots \qquad \ddots \qquad \vdots \\ d(m,\, 1) \qquad d(m,\, 2) \qquad - \end{vmatrix} \tag{3.15}$$

Step 5: Determine the concordance index matrix

Equation (3.16) describes the concordance index for the measurement of satisfaction problem.

$$\bar{c} = \sum_{a=1}^{m} \sum_{b}^{m} c(a,\, b) / m(m-1) \tag{3.16}$$

Where $\bar{c}$ denotes the average value of concordance index.

Equation (3.17) describes the Boolean matrix (E) of the dominance index.

$$\begin{cases} e(a,\, b) = 1 & \text{if} \quad c(a,\, b) \geq \bar{c} \\ e(a,\, b) = 0 & \text{if} \quad c(a,\, b) < \bar{c} \end{cases} \tag{3.17}$$

If A_i is strictly preferred to A_j, we denote it by r_{ij}^{s} = 1, other-wise r_{ij}^{s} = 0 in the concordance index matrix. When r_{ij}^{s} = 1, then A_i and A_j will be linked by a directed path, then, in that way, the concordance index matrix can be transformed into a strictly relation graph. Strictly relation graph can be denoted by G_S

Where r_{ij}^{s} represents the value of strictly relation between A_i and A_j.

Step 6: Determine the discordance index matrix

In opposite, the index of discordance measures the level of the dissatisfaction. The discordance index follows Equation (3.18).

$$\bar{d} = \frac{\sum_{a=1}^{m}\sum_{b}^{m} d(a,\ b)}{m(m-1)} \tag{3.18}$$

According to the basis of the discordance index stated before, the matrix of discordance index (F) can be determined. Equation (3.19) shows the matrix (F).

$$\begin{cases} f(a,\ b) = 1 & \text{if} \quad d(a,\ b) \le \bar{d} \\ f(a,\ b) = 0 & \text{if} \quad d(a,\ b) > \bar{d} \end{cases} \tag{3.19}$$

If A_i is weakly preferred to A_j, we denote it by r_{ij}^{w} = 1, other-wise r_{ij}^{w} = 0 in discordance index matrix. When r_{ij}^{w} = 1, then A_i and A_j will be linked by a directed path, then, in that way, the discordance index matrix can be transformed into a weakly relation graph. Weakly relation graph can be denoted by G_w

Where r_{ij}^{w} represents the value of weakly relation between A_i and A_j.

Step 7: Construction of the general matrix

The general matrix G is computed by multiplying the peer-to-peer elements of matrix E and matrix F (Hatami-Marbini et al., 2013). The general matrix follows Equation (3.20).

$$G = E \times F \tag{3.20}$$

CHAPTER 4

A CASE STUDY

4.1 Case Company

The implementation of GSCM is a tricky mission due to the contradictory nature of the objectives. Organizations want extensive profits to be increased and negative environmental impacts to be diminished. For the time being, they disagreed to augment the expenditure to a large size. However, GSCM implementation can advance trade contribution. Here, a real life case apprehensive to a leather-processing factory (named ABC here) is presented to demonstrate how the proposed AHP & ELECTRE, a hybrid technique performs to aid decision-making. For the sake of confidentiality, the name of the company is not mentioned here.

The proposed method has been executed through a practical and sensible question. The selected firm trades with the production of crust and finished leather. The yearly production of this company is 32 million sq. meter. Table 4.1 shows the profile of the case company.

Table 4.1

Profile of the case company

Name of Company	Respondent	Years of experience& role of area	Types of products	Company size (Area, Employees, Annual sales turnover for FY-2016)
ABC Leather processing company	Production manager	(i) 41 years (ii) Procurement, Manufacturing, distribution	Cow full chrome, Cow semi chrome, Cow vegetable, Goat full chrome, Goat semi chrome and various types of finished leathers for shoes and leather goods	Area:3 acre, Employees-788, Annual sales turnover- USD $40 million

With the shifting of its facilities to the newly built government "Leather Economic Zone" with common effluent treatment plant (CETP),it has created a benchmark in the tannery sector. The new production unit has been built with the most modern and compliant factors in consideration. The new unit will not only improve efficiency in production but also increase in-house production capacity by at least 20%. By discussing with the firm‟s management, it is obvious that they have an outline to implement GSCM for improving their business performance**.** Above all, it comes in a common point to carry out the proposed framework to the selected firm. Therefore, a comprehensive process has been executed to determine the comparative significance of identified barriers and possible pathways associated with GSCM implementation.

4.2 Data Collection

In the process of data collection, a group of five experts, four from relevant industry and one from academic expert is constructed. Table 4.2 shows the profile of the experts. The required data have been collected from the industry professionals and academic expert. The process of data collection has been carried out in two phases as described below.

Phase-1: Finalize the major barriers with suitable dimensions and possible pathways to implementation of GSCM

At first, thirty common barriers with many dimensions have been identified through a survey of existing literature and investigate the relevant sector. To identify major barriers with suitable dimensions and possible pathways in the context of Bangladeshi leather industry, the experts were asked to add or delete any barriers and possible pathways to implementation of GSCM. In this study, responses from expert have been collected and then arranged several discussion sessions to finalize the major barriers and possible pathways. Therefore, twelve barriers and five possible pathways were identified for this study. It can be noted here that "reluctance to adopt advanced technology" barrier has been substituted by "high cost of advanced technology" according to experts‟ opinion. Experts opined that, managers are reluctant to adopt advanced technology as the cost is high. Further, the twelve barriers have been categorized into four dimensions by taking experts‟ opinion.

In addition, it is important to be noted that, to determine the most influential barriers hindering the implementation of GSCM and select the most effective pathways to implementing GSCM in leather industry, a standard questionnaire was designed consisting of common barriers and fifteen possible pathways collected from a literature review as per the Bangladeshi perspective (see in Appendix, Table A4). A survey was conducted by sending the questionnaire by mail and personal contacts to different experts. The survey was conducted from May to October in 2017 and was a Yes or No type format. The major barriers and five possible pathways were then collected.

Phase-2: Evaluation of comparison among dimensions, identified barriers and possible pathways

This phase has been carried out by taking experts‟ input for the purpose of developing a hybrid methodology named AHP and ELECTRE-I. To support the analysis and to set up the decision-making matrix correctly, the experts have been requested to contribute to a focus group meeting. A number of literature regarding some information of the twelve barriers and five possible pathways concerning each barrier for implementing GSCM rose to these experts. The objectives along with brief methodology also have been presented to the expert panel and they were requested to fill pair-wise matrices. A synchronizer has been allotted to direct the meeting for shaping every one of the comparison matrices. It is important to note that, there were frequently various debates in the discussion, and the synchronizer had to synchronize the discussion to arrive at a harmony for each comparison matrix.

Table 4.2
Profile of experts

Name of experts	Position	Years of experience	Academic qualification
X1	Assistant professor	10 years	Doctor of Philosophy (Ph.D.), majoring in supply chain management
X2	Executive director	25 years	Master of Business Administration(MBA)
X3	Production manager	17 years	MBA
X4	Leather engineer	12 years	B.Sc. in Leather Engineering
X5	Leather engineer	10 years	B.Sc. in Leather Engineering

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Data Analysis

The collected data has been analyzed through inputting the data into AHP and ELECTRE-I formulation. All required matrices have been obtained to determine the most influential barriers and most effective pathways. Firstly, AHP technique has been applied to determine the most influential barriers. According to AHP technique the computation of the weights of the four dimensions, (technology; knowledge; government support and policies; and financial dimensions) is considered. For an instance the specialists apprehended the view that the comparative significance of technology issue evaluated with knowledge issue is in „moderate importance"(scale 3) so the number „3" is placed in the cell (1,2) of the relationship matrix to compare the comparative significance of these four dimensions. Similarly, all the other inputs in this matrix can also be found, as shown in the Table 5.1.With the help of AHP technique, it can be shown From Table 5.1 that, the maximal Eigen value of the relationship matrix, (λ_{max}) is 4.186, CI, which denotes the consistency index, is 0.062, and CR, which denotes the consistency ratio, is 0.069. It is noticeable that, the computed value of CR is less than 0.01, which implies that for consistency check the relationship matrix is acceptable. In the same way, the local weights of the barriers in each dimension can also be established, as shown in Table 5.2-5.5.

Table 5.1

Relationship matrix to obtain the weights of four dimensions (technology, knowledge, government support and policies and financial)

	Technology	knowledge	Government support and policies	Financial	weights
Technology	1	3	2	1	0.362
knowledge	1/3	1	2	1	0.209
Government support and policies	1/2	1/2	1	1/3	0.124
Financial	1	1	3	1	0.305

λ_{max}= 4.186, CI = 0.062, CR = 0.069<0.1

Table 5.2

Relationship matrix of barriers belongs to technology dimension

	T1	T2	T3	Weights
T1	1	3	5	0.648
T2	1/3	1	2	0.230
T3	1/5	1/2	1	0.122

λ_{max} = 3.004, CI = 0.002, CR = 0.003<0.1

Table 5.3

Relationship matrix of barriers belongs to knowledge dimension

	K1	K2	K3	Weights
K1	1	3	7	0.649
K2	1/3	1	5	0.279
K3	1/7	1/5	1	0.072

λ_{max} = 3.065, CI = 0.032, CR = 0.056<0.1

Table 5.4

Relationship matrix of barriers belongs to government support and policies dimension

	G1	G2	G3	Weights
G1	1	5	9	0.751
G2	1/5	1	3	0.178
G3	1/9	1/3	1	0.070

λ_{max} = 3.029, CI = 0.015, CR = 0.025<0.1

Table 5.5

Relationship matrix of barriers belongs to financial dimension

	F1	F2	F3	Weights
F1	1	2	7	0.592
F2	1/2	1	5	0.333
F3	1/7	1/5	1	0.075

λ_{max} = 3.014, CI = 0.007, CR = 0.012<0.1

For determining the global weight of each barrier to implementing GSCM the local weight of every barrier is multiplied by parallel dimension's weight with which it is associated. The global weight of each barrier has been shown in Table 5.6.

Table 5.6

Global weights of the barriers to implementing GSCM in Bangladeshi leather industry

Dimensions	**Weights of Dimensions**	**Barriers**	**Weights of Barriers**	**Global Weights**	**Overall Priority/sequence**
Technology	0.3620	T1	0.6483	0.2347	1
		T2	0.2297	0.0831	6
		T3	0.1220	0.0442	8
Knowledge	0.2090	K1	0.6491	0.1356	3
		K2	0.2790	0.0583	7
		K3	0.0719	0.0150	11
Government support and policies	0.1239	G1	0.7514	0.0931	5
		G2	0.1782	0.0221	10
		G3	0.0704	0.0087	12
Financial	0.3051	F1	0.5917	0.1806	2
		F2	0.3332	0.1017	4
		F3	0.0751	0.0229	9

With the global weight of each barrier shown in Table 5.6, the ranking of the barrier dimension in the downward array is technology > finance > knowledge > government support and policies. Technology category has been accepted as the most influential barrier dimension in which specific barrier “High cost of advanced technology” is ranked first.

The comparative superiorities of five possible pathways concerning each barrier have been computed by the same method of regulating the local weight of each barrier with the help of AHP technique. It can also be noted down that preferences of experts are needed to run this comparison. Then outcomes have been arranged in Table 5.7 to 5.18. It is important to say that all matrices have been normalized.

Table 5.7

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning T1

T1	P1	P2	P3	P4	P5	Weights
P1	1	2	1/2	1	3	0.207
P2	1/2	1	1/3	2	2	0.153
P3	2	3	1	5	4	0.432
P4	1	1/2	1/2	1	2	0.144
P5	1/3	1/5	1/4	1/2	1	0.064

$\lambda_{max} = 5.277$, $CI = 0.069$, $CR = 0.062<0.1$

Table 5.8

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning T2

T2	P1	P2	P3	P4	P5	Weights
P1	1	1	5	5	7	0.399
P2	1	1	7	4	5	0.382
P3	1/5	1/7	1	3	1	0.087
P4	1/5	1/4	1/5	1	2	0.065
P5	1/7	1/3	1	1/2	1	0.067

$\lambda_{max} = 5.243$, $CI = 0.061$, $CR = 0.054<0.1$

Table 5.9

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning T3

T3	P1	P2	P3	P4	P5	Weights
P1	1	2	1	5	3	0.323
P2	1/2	1	1/3	3	2	0.164
P3	1	3	1	8	2	0.355
P4	1/5	1/3	1/2	1	1	0.083
P5	1/3	1/8	1/2	1	1	0.075

$\lambda_{max} = 5.391$, $CI = 0.098$, $CR = 0.087<0.1$

Table 5.10

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning K1

K1	P1	P2	P3	P4	P5	Weights
P1	1	3	2	3	5	0.391
P2	1/3	1	1/3	1/3	4	0.109
P3	1/2	3	1	3	7	0.317
P4	1/3	3	1/4	1	1	0.121
P5	1/5	1/3	1/7	1	1	0.063

$\lambda_{max} = 5.362$, CI = 0.090, CR = 0.081<0.1

Table 5.11

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning K2

K2	P1	P2	P3	P4	P5	Weights
P1	1	1	2	7	7	0.378
P2	1	1	2	5	3	0.298
P3	1/2	1/2	1	7	2	0.194
P4	1/7	1/5	1/3	1	1/7	0.040
P5	1/7	1/7	1/2	7	1	0.089

$\lambda_{max} = 5.295$, CI = 0.074, CR = 0.066<0.1

Table 5.12

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning K3

K3	P1	P2	P3	P4	P5	Weights
P1	1	2	1/4	2	5	0.186
P2	1/2	1	1/7	1	1	0.079
P3	4	7	1	5	9	0.561
P4	1/2	1	1	1	2	0.135
P5	1/5	1/5	1/9	1/2	1	0.040

$\lambda_{max} = 5.435$, CI = 0.109, CR = 0.097<0.1

Table 5.13

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning G1

G1	P1	P2	P3	P4	P5	Weights
P1	1	3	2	4	3	0.378
P2	1/3	1	1/2	2	3	0.161
P3	1/2	2	1	6	4	0.304
P4	1/4	1/2	1/3	1	2	0.098
P5	1/3	1/6	1/4	1/2	1	0.060

$\lambda_{max} = 5.320$, CI = 0.080, CR = 0.071<0.1

Table 5.14

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning G2

G2	P1	P2	P3	P4	P5	Weights
P1	1	1/3	2	3	3	0.225
P2	3	1	5	3	5	0.464
P3	1/2	1/5	1	5	2	0.157
P4	1/3	1/3	1/5	1	2	0.084
P5	1/3	1/5	1/2	1/2	1	0.069

$\lambda_{max} = 5.444$, CI = 0.111, CR = 0.099<0.1

Table 5.15

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning G3

G3	P1	P2	P3	P4	P5	Weights
P1	1	2	2	4	3	0.354
P2	1/2	1	2	3	8	0.308
P3	1/2	1/2	1	2	4	0.187
P4	1/4	1/3	1/8	1	2	0.075
P5	1/3	1/2	1/4	1/2	1	0.075

$\lambda_{max} = 5.401$, CI = 0.100, CR = 0.090<0.1

Table 5.16

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning F1

F1	P1	P2	P3	P4	P5	Weights
P1	1	1	2	8	3	0.336
P2	1	1	3	3	7	0.355
P3	1/2	1/3	1	4	3	0.178
P4	1/8	1/3	1/7	1	4	0.073
P5	1/3	1/4	1/3	1/4	1	0.057

$\lambda_{max} = 5.408$, CI = 0.102, CR = 0.091<0.1

Table 5.17

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning F2

F2	P1	P2	P3	P4	P5	Weights
P1	1	3	1	4	3	0.327
P2	1/3	1	1/3	2	5	0.163
P3	1	3	1	4	5	0.363
P4	1/4	1/2	1/5	1	1	0.076
P5	1/3	1/4	1/5	1	1	0.070

$\lambda_{max} = 5.185$, CI = 0.046, CR = 0.041<0.1

Table 5.18

Relationship matrix to establish the comparative superiority of the five possible pathways for effective implementation of GSCM concerning F3

F3	P1	P2	P3	P4	P5	Weights
P1	1	1/2	2	1	3	0.220
P2	2	1	3	5	2	0.400
P3	1/2	1/3	1	3	1	0.154
P4	1	1/5	1/2	1	2	0.128
P5	1/3	1/3	1	1/2	1	0.099

$\lambda_{max} = 5.393$, CI = 0.098, CR = 0.088<0.1

Both the global weight of each barrier to implementing GSCM and the comparative superiorities of five possible pathways concerning each barrier in a matrix are arranged. This matrix implies the decision-making matrix. Table 5.19 presents the matrix.

Table 5.19

Decision-making matrix/normalizing the decision matrix for ranking the possible pathways

Barriers	**T1**	**T2**	**T3**	**K1**	**K2**	**K3**	**G1**	**G2**	**G3**	**F1**	**F2**	**F3**
Weights	0.2347	0.0831	0.0442	0.1356	0.0583	0.0150	0.0931	0.0221	0.0087	0.1806	0.1017	0.0229
P1	0.2067	0.3991	0.3231	0.3911	0.3780	0.1856	0.3782	0.2249	0.3539	0.3362	0.3273	0.2197
P2	0.1530	0.3817	0.1636	0.1085	0.2983	0.0794	0.1608	0.4643	0.3081	0.3550	0.1632	0.4000
P3	0.4322	0.0869	0.3549	0.3171	0.1941	0.5609	0.3036	0.1572	0.1875	0.1781	0.3625	0.1535
P4	0.1444	0.0650	0.0829	0.1205	0.0404	0.1345	0.0978	0.0843	0.0752	0.0734	0.0764	0.1278
P5	0.0637	0.0673	0.0754	0.0627	0.0891	0.0396	0.0595	0.0693	0.0752	0.0574	0.0705	0.0989

To obtain the rank of five possible pathways to implementing GSCM, ELECTRE-I is applied. At first, the weighted normalized matrix has been acquired by finding the product of the global weight of each barrier and the corresponding comparative priorities of five possible pathways. Table 5.20 presents the computed weighted normalized matrix.

Table 5.20

Weighted normalized matrix

Barriers	T1	T2	T3	K1	K2	K3	G1	G2	G3	F1	F2	F3
Weights	0.2347	0.0831	0.0442	0.1356	0.0583	0.0150	0.0931	0.0221	0.0087	0.1806	0.1017	0.0229
P1	0.0485	0.0332	0.0143	0.0531	0.0220	0.0028	0.0352	0.0050	0.0031	0.0607	0.0333	0.0050
P2	0.0359	0.0317	0.0072	0.0147	0.0174	0.0012	0.0150	0.0103	0.0027	0.0641	0.0166	0.0092
P3	0.1014	0.0072	0.0157	0.0430	0.0113	0.0084	0.0283	0.0035	0.0016	0.0321	0.0369	0.0035
P4	0.0339	0.0054	0.0037	0.0163	0.0024	0.0020	0.0091	0.0019	0.0007	0.0133	0.0078	0.0029
P5	0.0149	0.0056	0.0033	0.0085	0.0052	0.0006	0.0055	0.0015	0.0007	0.0104	0.0072	0.0023

The concordance index matrix and the discordance index matrix of five possible pathways have been computed by means of concordance interval matrix and discordance interval matrix (see Table A1 and Table A2 in Appendix A). The concordance and discordance interval matrix have been obtained from concordance and discordance interval sets (see Table A1 and Table A3 in Appendix A). Table 5.21 and 5.22 respectively shows the concordance index matrix and discordance index matrix respectively.

Table 5.21

Determine the concordance index matrix (Boolean matrix)

Pathways	P1	P2	P3	P4	P5
P1	0	1	1	1	1
P2	1	0	1	1	1
P3	1	1	0	0	0
P4	0	0	0	0	0
P5	0	0	0	0	0

C Bar = 0.194788

Table 5.22

Determine the discordance index matrix (Boolean matrix)

Pathways	P1	P2	P3	P4	P5
P1	0	1	0	1	1
P2	0	0	0	1	1
P3	1	1	0	1	1
P4	0	0	0	0	1
P5	0	0	0	0	0

D Bar = 0.616027

To establish the general matrix, we then aggregated these two Boolean matrices by multiplying their peer-to-peer elements. The constructed general matrix is shown in Table 5.23. From the general matrix presented in Table 5.23, we get the final sequence of five possible pathways.

The strictly relation graph and weakly relation graph of possible pathways have been drawn from the concordance index matrix and discordance index matrix respectively. The strictly relation graph and weakly relation graph have been pointed out in red color. Fig. 5.1 and Fig 5.2 represent the strictly relation graph and weakly relation graph accordingly.

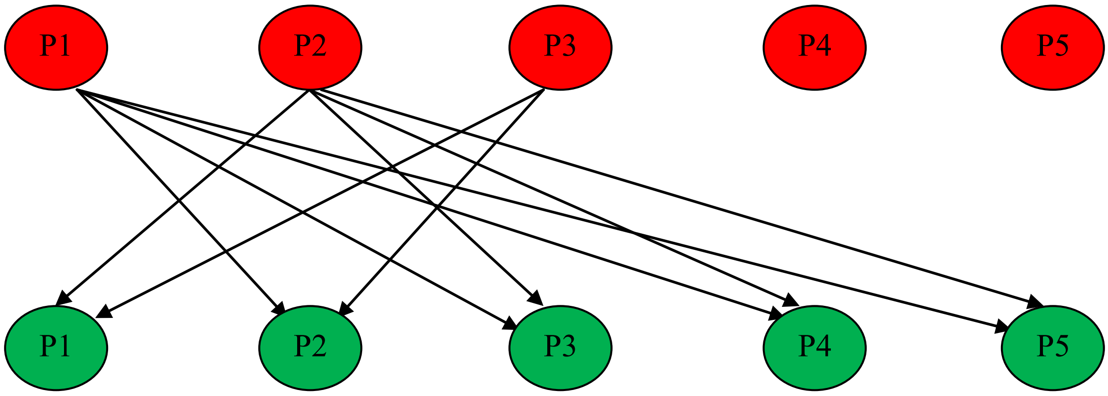

Fig. 5.1 Strictly relation graph (G_s) of possible pathways

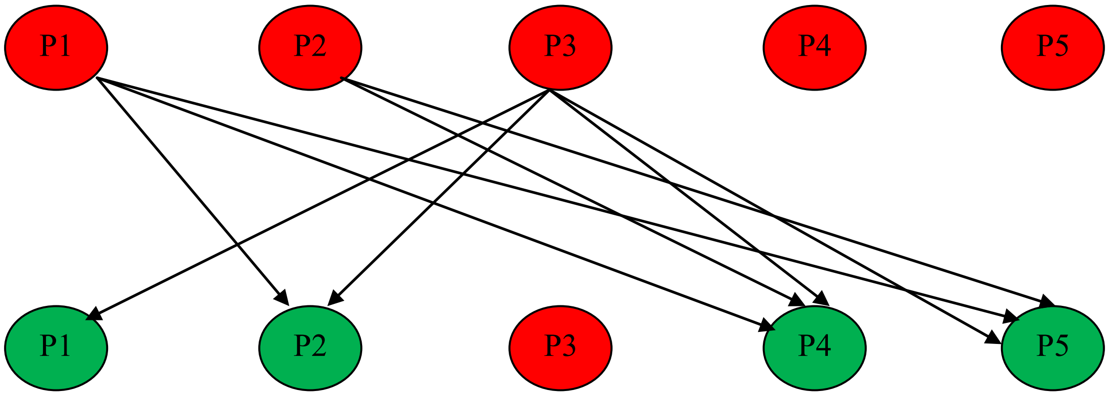

Fig. 5.2 Weakly relation graph (G_w) of possible pathways

Table 5.23

General matrix

Pathways	P1	P2	P3	P4	P5
P1	0	1	0	1	1
P2	0	0	0	1	1
P3	1	1	0	0	0
P4	0	0	0	0	0
P5	0	0	0	0	0

The resultant order of five possible pathways is P3 > P1 > P2 > P4 > P5. Green technology and techniques (P3) has been recognized as the most effective possible pathway to implementing GSCM. The next ranking is followed by thewaste management (P1), appropriate infrastructure (P2), cleaner technology (P4), and supplier management (P5).

5.2 Sensitivity Analysis

A sensitivity analysis is usually done to examine the strength of the outcomes (An et al., 2017; Kaya & Kahraman, 2011; Agrebi et al., 2017). In fact, the investigation deals with one query i.e., "How responsive is the final result to tiny alterations in the each weight obtained through the pair wise evaluation method?" (Agrebi et al., 2017).This question can be answered by carrying out the sensitivity analysis. To validate the proposed method, this investigation is carried out (Govindan et al., 2014). The barrier with the highest weight should be identified first. In this research, this process is done by putting different value to the barriers. Thirteen events have been studied which are shown in Table 5.24. The definition of an event is given below:

(1) Identical significance: putting the same weight of 0.2347 in every barrier (Event-1).

(2) A leading and other equal significance circumstances (Events 2–13): this implies that a leading weight is putted to a barrier, and the same weight is putted to the remaining barriers. For event k (k = 2, 3, ..., 13), a leading weight of 1 is putted to the $(k\text{-}1)^{th}$ barrier (according to the priority sequence of every barrier shown in Table 5.6) and the same weight of 0.2 to the remaining barriers. Considering Event 2 as an instance, a leading weight of 1 is putted to „resistance to advance technology adoption" and the weight of 0.2

to the remaining eleven barriers. Similarly all the events have been done. Table 5.24 shows the outcomes of total events.

Table 5.24
Sensitivity Analysis

Events \ Pathways	P1	P2	P3	P4	P5
Base Event	2	3	1	4	4
Event -1	Not available	Not available	Not available	Not available	Not available
Event -2	2	2	1	3	3
Event -3	Not available	Not available	Not available	Not available	Not available
Event -4	1	2	1	3	3
Event -5	1	2	1	3	3
Event -6	1	2	1	3	3
Event -7	1	1	2	2	2
Event -8	Not available	Not available	Not available	Not available	Not available
Event -9	1	2	1	3	3
Event -10	2	1	3	3	3
Event -11	2	1	3	3	3
Event -12	2	3	1	4	4
Event -13	Not available	Not available	Not available	Not available	Not available

According to Table 5.24, it is apparent that the ranking of pathways may alter when the weights of the barrier have been adjusted. In addition, ELECTRE-I cannot differentiate among five possible pathways in several events. Therefore, it may be concluded that the ranking of possible pathways is not identical if the experts have been altered. There are two reasons for this deviation: i) as the experts have dissimilar likings and motivation, the weights of the barriers for GSCM implementation are altered; ii) ranking of possible pathways concerning individual barrier to implementing GSCM obtained by individual expert may have distinctive priority. Overall, individual expert can decide distinctive relationship or comparative matrices that may direct to characteristic outcomes.

CHAPTER 6

CONCLUSIONS, MANAGERIAL IMPLICATIONS AND RECOMMENDATIONS

6.1 Conclusions

In the advancement of products and processes, GSCM is acting as an important tool for fulfilling the ecological criteria. It is also facilitating the improvement of productivity, brand reputation, and profitability and thus increasing the overall firm performance. For having different properties of the barriers, identifying major barriers to implementing GSCM has become a complex task. This study has tried to design a standard framework to lessen the complexities involved with the major barriers identification. This study will also make the attempts of managers easier towards the improvement of the environment. The existence of the relevant studies within different organization has been proven by the literature review. Throughout this study, we have obtained the capability to find the most influential barriers and most effective pathways, which can accelerate the GSCM implementation in Bangladeshi leather processing industry.

Twelve major barriers and five possible pathways have been identified from the literature review and experts input. The hybrid method named AHP & ELECTRE has been applied to prioritize these twelve barriers and five possible pathways respectively. The dimension of technology has been exposed as the major dimension from AHP outcome. Therefore, it can easily be said that, the most significant barrier is the lack of technology in the implementation of GSCM, followed by finance, knowledge, and government support and policies dimensions. It is evident that, the dimension of government support and policies holds the last priority. This priority discloses that, organizations are still now facing major gap, even though, they are engaged in the stimulation of the system for GSCM implementation. However, according to the judgments of experts, in contrast of the dimension of technology, the government support and policies dimension is not vital. In the same way, the ranking of the specific barriers are determined from the global weights of barriers. After analyzing the global weights of barriers, it is declared that, High cost of advanced technology barrier is the important one when comparing with the other barriers. Therefore, High cost of advanced technology needs more focus. Note that the dimension “government support and policies” has shown lower weight than the remaining dimensions. It can be proposed that, all barriers under the dimension of government support and policies could be removed easily.

On the other hand, ELECTRE-I result shows that green technology and techniques is the most effective pathway to accelerate the process of GSCM implementation. Waste management, appropriate infrastructure, cleaner technology and supplier management pathways are the next rankings. Although appropriate infrastructure is ranked as third, the flow of liquid waste generated during the various chemical process for converting raw hides and skins into finished leather is more critical to handle.

To explore the alteration of the base position of effective pathways a sensitivity analysis has been carried out. It showed that, when the weights of the barriers were changed from 0.2 to 1.0 then the base ranking were also altered significantly. The investigation makes it evident that the specific barriers control the ranking of the possible pathways.

The study has provided an effective way out for leather industries to detect major barriers and possible pathways for implementing GSCM. It has presented a framework, which can support the industry in the period of GSCM implementation. This analysis has exposed that Bangladeshi leather industry is now trying to give more attention for upgrading ecological efficiency besides the economic enhancement. Besides, majority of the industries are trying to get monetary aid to enhance the ecological efficiency. However, they have lowered their attention to the revision of ecological knowledge and technologies. Nevertheless, the positive side is that industries are trying to enhance the ecological efficiency by implementing GSCM.

6.2 Managerial Implications

While implementing GSCM, it is not feasible to eliminate all barriers identified immediately. That is why; managers have to determine a barrier which occupies the first priority among barriers to implementing GSCM. As technology dimension is ranked first as a barrier, they should be kept more focus on the technology issues. In addition, they have to show positive sense about advanced technology. Managers need to capable of choosing most fitted advanced technology at minimum cost.

Managers can accelerate the implementation process of GSCM by selecting an effective pathway. This research reveals that green technology and techniques is the most effective pathways. Therefore, managers can execute green technology and techniques such as green purchasing, green manufacturing and green distribution in their system. If they can introduce green strategy in their system then it will fruitful to implement GSCM. It can also help improving cleaner production, transport system and increasing the performance of CETP.

6.3 Recommendations

This research presents a hybrid technique by the combination of AHP and ELECTRE. The ranking of barriers and pathways to implement GSCM determined by various experts showed partiality due to the presence of distinctive consent of individual expert. In addition, AHP cannot determine the uncertainty in calculating the weights of various attributes. In this study, all barriers and pathways were examined without considering any uncertainties. Therefore, the future work can be focused on barrier analysis to implement GSCM under uncertainties. This study can be further explained by using other MCDA methods such as analytic network process (ANP), Fuzzy-AHP, ISM, decision-making trial and evaluation laboratory (DEMATEL).

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Appendix A

Table A1

Concordance interval index and interval set

Pathways	P1	P2	P3	P4	P5
P1	0	0.7745	0.6045	0.6045	0.5213
P2	0.2255	0	0.3757	0.3757	0.2926
P3	0.395535	0.6243	0	0	0
P4	0	0.0000	0.0000	0	0.0000
P5	0	0.0583	0.0583	0.0251	0
	0.621075	1.457078	1.038453	3.11660537	
	C Bar	0.194788			

Table A2

Discordance interval index

Pathways	P1	P2	P3	P4	P5
P1	0	0.1379	1.8537	0.0162	0.0436
P2	7.250708	0	2.051243	0.03195721	0.011108
P3	0.539465	0.4875	0	0.00871834	0.011325
P4	61.79739	31.29184	114.7008	0	0.150038
P5	22.94635	90.02325	88.30298	6.66498026	0
	7.790173	0.625427	3.90493	12.3205301	
	D Bar	0.616027			

Table A3

Discordance sets

Barriers	T1	T2	T3	K1	K2	K3	G1	G2	G3	F1	F2	F3
Weights	0.2347	0.0831	0.0442	0.1356	0.0583	0.0150	0.0931	0.0221	0.0087	0.1806	0.1017	0.0229
P1	0.0485	0.0332	0.0143	0.0531	0.0220	0.0028	0.0352	0.0050	0.0031	0.0607	0.0333	0.0050
P2	0.0359	0.0317	0.0072	0.0147	0.0174	0.0012	0.0150	0.0103	0.0027	0.0641	0.0166	0.0092
P3	0.1014	0.0072	0.0157	0.0430	0.0113	0.0084	0.0283	0.0035	0.0016	0.0321	0.0369	0.0035
P4	0.0339	0.0054	0.0037	0.0163	0.0024	0.0020	0.0091	0.0019	0.0007	0.0133	0.0078	0.0029
P5	0.0149	0.0056	0.0033	0.0085	0.0052	0.0006	0.0055	0.0015	0.0007	0.0104	0.0072	0.0023
P1-P2	0.0126	0.0014	0.0070	0.0383	0.0046	0.0016	0.0202	-0.0053	0.0004	-0.0034	0.0167	-0.0041
P1-P3	-0.0529	0.0260	-0.0014	0.0100	0.0107	-0.0056	0.0069	0.0015	0.0015	0.0286	-0.0036	0.0015
P1-P4	0.0146	0.0278	0.0106	0.0367	0.0197	0.0008	0.0261	0.0031	0.0024	0.0474	0.0255	0.0021
P1-P5	0.0336	0.0276	0.0109	0.0446	0.0168	0.0022	0.0297	0.0034	0.0024	0.0503	0.0261	0.0028
P2-P1	-0.0126	-0.0014	-0.0070	-0.0383	-0.0046	-0.0016	-0.0202	0.0053	-0.0004	0.0034	-0.0167	0.0041
P2-P3	-0.0655	0.0245	-0.0084	-0.0283	0.0061	-0.0072	-0.0133	0.0068	0.0011	0.0319	-0.0203	0.0056
P2-P4	0.0020	0.0263	0.0036	-0.0016	0.0150	-0.0008	0.0059	0.0084	0.0020	0.0508	0.0088	0.0062
P2-P5	0.0210	0.0261	0.0039	0.0062	0.0122	0.0006	0.0094	0.0087	0.0020	0.0537	0.0094	0.0069

Table A3

Discordance sets

(Continued)

Barriers	T1	T2	T3	K1	K2	K3	G1	G2	G3	F1	F2	F3
P3-P1	0.0529	-0.0260	0.0014	-0.0100	-0.0107	0.0056	-0.0069	-0.0015	-0.0015	-0.0286	0.0036	-0.0015
P3-P2	0.0655	-0.0245	0.0084	0.0283	-0.0061	0.0072	0.0133	-0.0068	-0.0011	-0.0319	0.0203	-0.0056
P3-P4	0.0675	0.0018	0.0120	0.0267	0.0090	0.0064	0.0192	0.0016	0.0010	0.0189	0.0291	0.0006
P3-P5	0.0865	0.0016	0.0123	0.0345	0.0061	0.0078	0.0227	0.0019	0.0010	0.0218	0.0297	0.0013
P4-P1	-0.0146	-0.0278	-0.0106	-0.0367	-0.0197	-0.0008	-0.0261	-0.0031	-0.0024	-0.0474	-0.0255	-0.0021
P4-P2	-0.0020	-0.0263	-0.0036	0.0016	-0.0150	0.0008	-0.0059	-0.0084	-0.0020	-0.0508	-0.0088	-0.0062
P4-P3	-0.0675	-0.0018	-0.0120	-0.0267	-0.0090	-0.0064	-0.0192	-0.0016	-0.0010	-0.0189	-0.0291	-0.0006
P4-P5	0.0189	-0.0002	0.0003	0.0078	-0.0028	0.0014	0.0036	0.0003	0.0000	0.0029	0.0006	0.0007
P5-P1	-0.0336	-0.0276	-0.0109	-0.0446	-0.0168	-0.0022	-0.0297	-0.0034	-0.0024	-0.0503	-0.0261	-0.0028
P5-P2	-0.0210	-0.0261	-0.0039	-0.0062	-0.0122	-0.0006	-0.0094	-0.0087	-0.0020	-0.0537	-0.0094	-0.0069
P5-P3	-0.0865	-0.0016	-0.0123	-0.0345	-0.0061	-0.0078	-0.0227	-0.0019	-0.0010	-0.0218	-0.0297	-0.0013
P5-P4	-0.0189	0.0002	-0.0003	-0.0078	0.0028	-0.0014	-0.0036	-0.0003	0.0000	-0.0029	-0.0006	-0.0007

Table A4

Questionnaire

Sl. No.	Questionnaire	Yes/ No
1	Does the manager show reluctance to adopt advanced technology due to high cost?	
2	Are there any organizational difficulties with environmental technology and apprehension of failing to implement GSCM?	
3	Are there any lacking of technological know-how and resources?	
4	Are the cost of hazardous waste disposal and environmental packages high?	
5	Are there fewer return-on-investments?	
6	Does the financial constraint seem to be more critical barrier?	
7	Is the awareness about reverse logistics adoption unsatisfactory?	
8	Does the absence of professionals hinder the acceleration of green system?	
9	Can the reward and encouragement programs accelerate the GSCM Implementation?	
10	Do you think government needs to revise regulation and legislation about environment?	
11	Are there any restrictive company policies towards product or process stewardship?	
12	Can the green technology and techniques accelerate the implementation process?	
13	Does the management of waste and appropriate infrastructure make the GSCM implementation process easier?	
14	Do you think supplier management and cleaner technology can influence the GSCM implementation process effectively?	