Cogent Business & Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/oabm20

Study of the interplay among internal and external barriers to GSCM in the Indian leather industry using the total ISM and MICMAC methodology

Manoj Kumar & Rao T Joji

To cite this article: Manoj Kumar & Rao T Joji (2023) Study of the interplay among internal and external barriers to GSCM in the Indian leather industry using the total ISM and MICMAC methodology, Cogent Business & Management, 10:2, 2234697, DOI: 10.1080/23311975.2023.2234697

To link to this article: https://doi.org/10.1080/23311975.2023.2234697

Published online: 21 Jul 2023.

Kumar & Joji, *Cogent Business & Management* (2023), 10: 2234697
https://doi.org/10.1080/23311975.2023.2234697

cogent business & management

MANAGEMENT | RESEARCH ARTICLE

Study of the interplay among internal and external barriers to GSCM in the Indian leather industry using the total ISM and MICMAC methodology

Manoj Kumar[1*] and Rao T Joji[2]

Received: 02 February 2023
Accepted: 13 May 2023

*Corresponding author: Manoj Kumar, School of bussiness, University of Petroleum and Energy Studies, A 83 Pushpanjali Upvan, Mathura - 281004, Uttar Pradesh, India
E-mail: manoj88.iaf@gmail.com

Reviewing editor:
Nitika Sharma, International Management Institute, New Delhi, India

Additional information is available at the end of the article

Abstract: Green Supply Chain Management (GSCM) has received growing attention in the last few years. Due to public awareness, economic, environmental, or legislative reasons, the requirement of GSCM has increased. The Indian leather industry is considered to be the most polluted industry in India in terms of all forms of pollution, i.e. water, land, and air. In the recent past, the Indian leather industry has been changing basic assumptions. The world's largest exporter of leather is currently becoming a net importer of the bovine hide. Manufacturing industries have started adopting the green concept in their supply chain management recently to focus on environmental issues. However, industries still struggle to identify the relationship between internal and external barriers hindering green supply chain management implementation. In this context, this study aims to develop

Manoj Kumar

ABOUT THE AUTHORS

Manoj Kumar holds his Master of Business Administration (MBA) in Manufacturing Management from BITS Pilani, India. His research interests are green supply chain management inventory and supply chain modeling and optimization. In addition, he is pursuing his Ph.D. in Logistics and supply chain management from the University of Petroleum and Energy Studies, India.
Rao specialization is Finance and Energy Risk Management. Dr. Rao's academic experience encompasses 18 years of teaching and research. Dr. Rao served organizations namely St Stephens (Delhi), Hindustan Times Ltd, and Sintex Industries Ltd (International Division). Dr. Rao holds a strong flare for research and his research has been published in leading global journals such as Renewable and Sustainable Energy Review, Energy Policy, Energy Strategy Review, Energy Research & Social Science, Journal of Scientific & Engineering Research, and Journal of Risk Finance to name a few. He was awarded the Best Researcher Award (2017) by CIMA (London) & UPES for his contribution to the field of Energy Research.

PUBLIC INTEREST STATEMENT

Environmental pollution is a major concern for humankind as it not only affects the current lifestyle of human beings but also threatens the future of human life on this planet. Development plays a vital role in the progress of humans and enables them to achieve impossible milestones in life. , however, any progress has its disadvantages. The Indian Leather industry is one of the most unorganized sectors in India and getting the finished product in hand demands tons of environmental waste in all possible forms, i.e. water, land, and air pollution. GSCM is the best answer to these concerns as it encompasses everything from sourcing to the final product and its disposal too. GSCM seems very easy to implement but always finds roadblocks in terms of internal and external barriers. Understanding these barriers will surely help the high-demanding Indian leather industry curb the concern raised above.

a structural model between internal and external barriers to implementing GSCM in the Indian leather industry. To assess the link between internal and external barriers to GSCM in the Indian leather sector, empirical research was carried out utilizing a Multi-Criteria Decision Making (MCDM) method called Interpretive Structural Modeling (ISM). ISM is a useful approach for understanding the complex relationships between various internal and external barriers and their hierarchies in the context of green supply chain management (GSCM) adoption. It can be used to identify the key barriers that influence the effective adoption of GSCM in the Indian leather industry, as well as the interdependencies between these barriers. This can help GSCM decision-makers in the Indian leather industry to better understand the challenges and opportunities for implementing sustainable practices throughout their supply chain and to develop effective strategies for addressing them. Additionally, ISM can be used to identify the key drivers and barriers to GSCM adoption, which can inform the development of targeted interventions to promote sustainable practices in the Indian leather sector. The findings indicate that inconsistent quality and lack of motivational laws are the most crucial barriers to overcoming the remaining obstacles and implementing GSCM successfully in the Indian leather sector.

Subjects: Resource Management - Environmental Studies; Environmental History; Environmental Ethics; Environmental health; Administration and Management; Management & Organization;

Keywords: green supply chain management; barriers to implementing GSCM; interpretive structural modeling

1. Introduction

The Indian leather industry dates back to 3000 BC, making it the country's oldest manufacturing sector. According to claims, leather was tanned utilizing domestic methods such as fat scrubbing, fumigation, and dyeing and was mostly utilized for practical items including clothes, tents, footwear, and chairs (2018). Moktadir et al. (2018) Jumping ahead to the 19th century, the British colonial era, they developed the first shoe factory (1880) at Kanpur, after which they introduced the most cutting-edge chrome tanning technology (1857). A total of 24 tanneries were approved for operation by 1913 in various locations throughout India, taking into account the expanding demand.

A significant development for the leather sector was the founding of the Central Leather Research Institute in independent India in 1948. India strategically forbids the export of unprocessed hides and skins, reserving the manufacturing of leather and its related products solely for the small-scale industry. In 1972, a group headed by Dr. A Seetharamiah suggested that exports be restricted to finished leather and other items with value-added. The 1990s saw the full development of forex markets in terms of trade liberalization, able to dictate actions at multiple levels, namely national and global. Committee (2012). It was believed that trade liberalization would help a variety of developing nations that have comparative advantages in the exploitation of natural resources and the production of labor-intensive goods. As the Indian government has always given this sector a high priority. Efforts like (the Working Group Report GOI, 2011; Foreign Trade Policy 2010–15, published in 2009; Government of India, 5 years plan 2012–17, published in 2011) have demonstrated to be a very consistent foreign exchange earner for our country, making it the top sector for creating jobs and the leading foreign exchange earner (Bechtsis et al., 2018)

The Indian leather, leather products, and footwear industries are important to the Indian economy. This sector is well-known for its consistently high export revenues and is one of the country's top 10 foreign exchange-earners. During the 2020–21 fiscal year, India exported $3.68 billion in footwear, leather, and leather products. The sector has an abundance of raw materials because India has 20% of the world's cow and buffalo population and 11% of the world's goat and sheep population. Added to this are the advantages of trained labor, new technology, increased industrial compliance with international environmental standards, and the unwavering support of linked industries. The leather industry is an employment-intensive sector, employing over 4.42 million people, the majority of whom come from lower-income families. Women make up 30% of the workforce in the leather products business. India is the world's second-largest exporter of leather garments, the third-largest exporter of saddlery and harnesses, and fourth largest exporter of leather goods.

All industries have experienced an increased drive to include green practices in their daily operations in recent decades. In the area of green supply chain management, pressure on the industry to implement environmental efforts is growing. From the moment an idea is conceived until the finished product is delivered to the consumer, GSCM is used. All essential supply chain operations, including process design, purchasing, production, logistics, disposal, recovery, and reuse, as well as worker health and safety, must incorporate GSCM. Therefore, a wide viewpoint is necessary to achieve social and economic sustainability for all participants in the food chain and to make it a norm in society (Mohanty & Prakash, 2014)

The positive application of GSCM in the Indian leather industry is always hindered by the various barriers faced on the ground by various leather industries. Understanding various internal and external barriers is much needed and it needs hours. Understanding the relationship between various internal and external barriers will help the Indian leather industry successfully implement GSCM (Shao et al., 2016).

Organizations like the Network of Professional Social Workers(NPSW) which is an International Association of professional Social Workers can play a vital role in establishing green supply chain management practices on the ground. NPSW connects with Social Workers across the globe beyond national and regional boundaries. Social Workers from any part of the world, working with any population, organization, and setting are welcome to join hands with this global professional association.

2. GSCM barriers classification

There are many barriers to GSCM implementation, and they can be divided into external, internal, and individual factors. External factors might include inadequate infrastructure, lack of resources, or geopolitical events such as trade tensions. Internal factors could be related to poor communication, inadequate forecasting and planning, and differences in legal and regulatory requirements. Finally, individual factors might involve a lack of knowledge or skills, a lack of motivation, or the prioritization of other tasks.

The Indian leather industry faces several barriers to implementing GSCM practices, including a lack of awareness, inadequate government policies, and a lack of resources. Let's consider a case study on the barriers to GSCM in the Indian leather industry. A leather goods manufacturer in India is looking to implement GSCM practices to reduce its environmental footprint and improve its sustainability. However, it faces several barriers to achieving this goal. A small case study was conducted through online interviews of experts in the field of the Indian leather industry and the following major barriers are reflected in the study: -

(1) **Lack of knowledge**. The manufacturer faces a lack of knowledge about GSCM practices and their benefits among its suppliers and employees. Many of them are not aware of the environmental impact of their actions or the importance of adopting sustainable practices.

(2) **Inadequate Government Policies**.The Indian government has not yet implemented sufficient policies to encourage the adoption of GSCM practices. This lack of regulatory support makes it challenging for companies to invest in sustainable practices.

(3) **Economics-related issues**.Implementing GSCM practices can require significant investments in technology, infrastructure, and human resources. Many small and medium-sized enterprises in the Indian leather industry may face Economics related issues to implement these practices.

(4) **Technology and infrastructure**. Technology and infrastructure can play a crucial role in promoting Green Supply Chain Management (GSCM) in the Indian leather industry. Energy-efficient technologies such as LED lighting, efficient motors, and advanced control systems can help reduce energy consumption and greenhouse gas emissions.

(5) **Market and Competitors**. The market and competitors for Green Supply Chain Management (GSCM) in the Indian leather industry are constantly evolving. As environmental concerns continue to rise, there is growing demand for environmentally sustainable products and supply chain practices.

(6) **Top management involvement**. The top management involvement is critical for the success of GSCM practices in the Indian leather industry. They should provide leadership, allocate resources, monitor and evaluate, collaborate, and promote training and awareness to promote sustainable practices in the supply chain.

Further to the above case study and after conducting a thorough review of the literature on GSCM barriers, 25 carriers can be grouped into seven separate categories. These include technology and infrastructure-linked issues (T & I), governance and supply chain process-linked issues (G & SC), economic-linked issues (E), knowledge-linked issues (K), policy-linked issues (P), market and competitors-linked issues, and management-linked issues. Each of these categories has issues that could hinder the successful implementation of GSCM. Knowing this will help organizations, as they look to develop more effective GSCM strategies.

GSCM barriers classification. Sources: (Bouzon et al., 2015; Dhillon et al., 2016; Lahane & Kant, 2021; Muduli et al., 2013).The below Table 1 is made with two columns indicating classification and barriers. The variables here are the barriers to GSCM, and they are further classified as internal and external barriers. (IN) denotes the internal barriers and (EX) denotes the external barriers. For GSM implementation in the Indian leather industry.

3. Research highlights

A systematic literature review was undertaken to understand various barriers to GSCM. Various barriers play a major roadblock in the successful implementation of GSCM in the Indian leather industry. Although there might be various other reasons like social, economic, and environmental reasons for non-implementation various internal and external barriers play a major role in non-implementation. Notwithstanding the above, the Indian government is working very closely with various agencies to implement GSCM for the Indian industry.

However, the Indian industry faces the challenge of ground logistics groundwork and the government is pushing for GSCM at the ground level. Furthermore, to the best of our knowledge, very few or no GSCM published in various Peer-English-speaking publications in the Indian setting have examined the link between various internal and external obstacles. In light of this, we outline the proposed solution approach, Interpretive Structural Modeling (ISM), and study findings.

4. Research gaps

The following are the gaps that emerge post an extensive Literature review: -

(1) A thorough assessment of the literature revealed that the majority of GSCM investigations, regardless of a sub-category, were done in Western countries, China, and Southeast Asia.

Table 1. Classification and barriers

Classification	Barriers
Technology and infrastructure (T&I)	T&I-1(IN). Absence of personnel technical skills T&I-2(IN). Absence of IT systems standards T&I-3(IN). Absence of latest technologies T&I-4(IN). Absence of in-house facilities (infrastructure) T&I-5(IN). Technology and the R&D issues linked to product recovery
Governance and supply chain process linked concerns (G&SC)	G&SC-1(EX). Difficulties with supply chain members (poor coordination) G&SC-2(IN). Inadequate forecasting and planning G&SC-3(IN). Unreliable quality
Economic associated matters (E)	E-1(IN). Absence of initial capital E-2(EX). Absence of financial support for investments in return monitoring system/storage and handling E-3(EX). Uncertainty linked to economic issues E-4(IN). Absence of economy of scale
Knowledge allied concerns (K)	K-1(IN). Absence of knowledge on GSCM practices K-2(EX). Absence of information on take back channels K-3(EX). Absence of awareness concerning GSCM and its benefits K-4(IN). Absence of taxation knowledge on returned products
Policy linked problems (P)	*P*-1(EX). Absence of specific laws *P*-2(EX). Absence of waste management practices *P*-3(EX). Absence of inter-ministerial communication *P*-4(EX). Absence of motivation laws
Market and competitors (M&C)	M&C-1(EX). Perception of a poorer quality product M&C-2(EX). Undeveloped recovery marketplaces M&C-3(EX). Little recognition of GSCM competitive advantage
Management correlated problems(M)	*M*-1(IN). Low importance of GSCM relative to other issues *M*-2(IN). Low involvement of top management and strategic planning

There has been very little work publicized and done for the Indian leather sector in particular.

(2) Majorly recent research papers talk about the environmental concerns caused by vehicle industries, pulp and paper, electrical and electronic industries, logistics services (3PL), retail sectors, infrastructure, and so on. There is a major lack in the sector of the Indian leather industry. The findings and relationships between internal and external barriers are yet to be established.

(3) This study mainly attempts to address the above gaps by using ISM as a methodology.

5. Solution methodology

The main objective of this work is to determine the relationship between internal and external barriers in GSCM implementation for the Indian leather industry. This objective is being achieved by investigating international peer-reviewed articles to select various internal and external barriers and finally classifying them into various categories. Furthermore, utilizing ISM, rigorous and empirical research was conducted to assess the link between internal and external barriers to GSCM adoption.

A detailed study was conducted looking at the barriers to GSCM implementation in the Indian leather sector. Interpretive Structural Modeling (ISM) is used to explore the bilateral consequences of the barrier categories and identify internal driving barrier categories that can exacerbate other

barrier categories. This is an important step in understanding the complexity of GSCM implementation and developing effective strategies to overcome the barriers (Luthra et al., 2011)

6. Data collection

This research project sought information on barriers to GSCM adoption in the Indian leather industry context: consequently, the target audience should be aware of GSCM practices and barriers, as well as specialists in the Indian leather sector. Since this study is the first to look at how internal and external barriers to the Indian leather industry relate to one another. The development of knowledge on the subject and the accuracy of the data gathered so become increasingly significant and pertinent.

Experts were chosen for their understanding of the GSCM in the Indian leather industry and their availability to answer inquiries. The list of chosen experts, years of experience, and justification for our choice are given in Table 2. The researchers have chosen two major Indian leather factories to serve as illustrations of this industry sector. Both businesses have GSCM programs in place. The environmental specialist and sustainability manager were recommended by the logistics managers at each of the organizations as experts who could best respond to the research questions. Academicians who have expertise in the GSCM sector and were available to respond to the queries were nominated.

First, the potential respondents were called by phone, and an in-person interview was set up. Second, throughout the structured interviews, clarifications on GSCM obstacles were provided to ensure the best appreciation of the terminology used. Pair-wise comparison questions were utilized to study the link between GSCM implementation barriers.

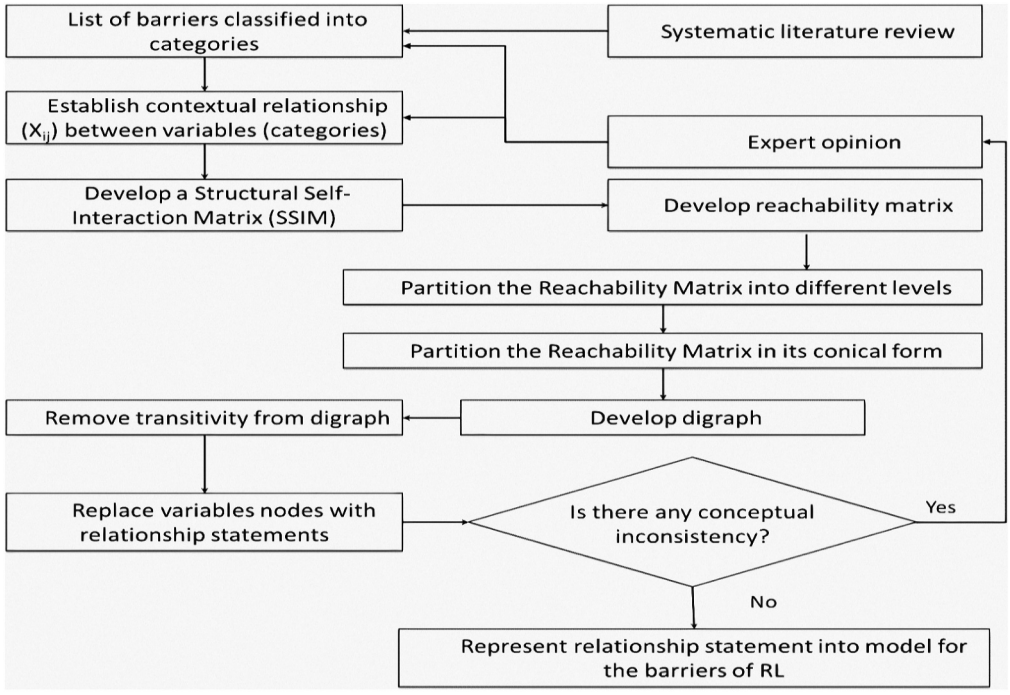
The data collected vide the above process is analyzed and put into thought before placing for the Interpretive structuring modeling (ISM) method to generate the relationship between internal and external barriers. The self-structural matrix is generated using this data, which will be the basis for ISM methodology at large. The relationship thereon found post-ISM will be analyzed by industry experts and researchers in the field for better understanding and apprehension.

The basic flow chart for ISM implementation and application is shown below for a better and clear understanding (Figure 1).

Table 2. Experts' description and choice justification

Expert	Expert Experience in the field	Justification
Environmental Specialist	5 years	Responsible for researching whether firm actions are appropriate in light of the state waste management regulation
Sustainability manager	3.5 years	In charge of overseeing and managing the company's GSCM program
Doctorate researcher on GSCM	7 years	Researchers developing studies on product return, remanufacturing, and reverse logistics. Transversal knowledge by having worked in the field in many industries in India
Full Professor on Supply ChainManagement Management	11 years	Researchers who have worked on the extensive literature on GSCM and RL at many Indian companies that manufacture machinery

Figure 1. Flow chart for ISM.



The above figure reflects the detailed procedure to be followed in this study for understanding the relationship between internal and external barriers to the successful implementation of GSCM in the Indian leather industry.

The graphic depicts the steps used to obtain the outcome using the Interpretive structural modeling (ISM) approach. The creation of a structural self-interaction matrix is critical in variable analysis using ISM methodology. For a better understanding of the link among various factors in the research, a reachability matrix will be necessary

7. Literature of review (Step 1)

To better establish the research gap, global peer-reviewed journals on the GSCM were discovered to determine the GSCM barriers, both internal and external. ISI Web of Science, Scopus, Science Direct, Springer, and Google Scholar was among the bibliographic databases searched. “GSCM” and “barriers” are the keywords used to retrieve the papers from the title, keywords, or abstract. Phatak & Sople (2018) analyzed data from Advanced Micro Devices (AMD), a multinational company with operations across various nations, to assess the operational components of environmental supply-chain management.

Branded and non-branded goods and services are contrasted in terms of green supply chain management strategies and are then assessed and discussed. Using the empirical study of 89 automotive firms in China, (Zhu et al., 2007)investigated the GSCM pressures/drivers (motivators), efforts, and performance of the automotive supply chain. The findings demonstrate that Chinese car supply chain firms have faced substantial and rising regulatory and market constraints while also having strong internal motivations for GSCM practice adoption. Further, the closed-loop supply chain with multi-stage products under quality control and green policies has been well explained (Abolfazl Gharaei et al., 2021). Through factor analysis (Lu et al., 2007), looked at the consistency approaches that affect the adoption and use of green supply chain management in the Taiwanese electronics industry. Nine electronic firms are utilized to rank the relative importance of four variables and twenty procedures using the fuzzy analytic hierarchy process method. The statistics indicate that these companies prioritize effective supplier management while implementing GSCM.

In addition, there is work undertaken in the field of integrated inventory management that focuses on multi-level supply chains: and advocates the null-space method for saving inventory costs (Gharaei et al., 2022).

The implementation of GSCM in the sugar industry of India was thoroughly studied by Kumar. Et. al and they have surveyed some 30 sugar mills in the Indian state of Uttar Pradesh. The environmental impact caused by the source of leather can be best understood from (Gharaei etal., 2022) work which highlighted the optimal economic growth quantity considering the carbon emissions for the whole process. Empirical research was carried out to look at the GSCM techniques used by the Indian manufacturing industry. They provided 59 survey items. Their study produced green manufacturing, green design, green procurement, and economic performance. They found that the adoption of GSCM in India is still in its infancy.

Through detailed literature and discussions with industry experts, 45 barriers have been identified and categorized based on their meaning and similarities. Barriers with sources are illustrated in Table 3. Those with more than 10 years of experience in purchasing, supply chain management, and working in environmental management departments of the industry were chosen as experts and targeted for this study.

8. List of barriers and their categories (Step-2)

The most common barriers are identified through a questionnaire survey from various industrial sectors. Hence, this study offers a novel approach to understanding the barriers to GSCM implementation from an Indian leather industry perspective. The 25 identified barriers were classified into seven categories as reflected below: -

a. Technology and infrastructure-related issues (T&I): this category includes information technology barriers, technical skills issues, and barriers related to lack of infrastructure for RL development.
b. Governance and supply chain process-related issues (G&SC): this category refers to reverse SC barriers, cooperation issues, and performance measurement.
c. Economic related issues (E): this category includes financial and economic barriers related to RL.
d. Knowledge-related issues (K): this category refers to information flows and RL awareness in companies.
e. Policy-related issues (P): this category includes issues on regulations and laws concerning product takeback and RL.
f. Market and competitors-related issues (M&C): this category includes competition advantage reasons and recovery market issues.
g. Management-related issues (M): this category includes issues such as managers' posture concerning RL and the relative importance of RL compared to other activities.
h. These categories were used as the variables for the contextual relationship in the next steps of the ISM methodology.

Keeping all players at a common platform where an integrated multi-product, the multi-buyer supply chain for green, quality control policies, and a vendor-managed inventory with consignment stock agreement is explained by (Gharaei, 2021). Inventory management plays a great barrier in GSCM implementation and integrated lot size will help in mitigating this constraint (Gharaei et al., 2022). Integration of various resources and various EOQ models is a stepping stone toward GSCM for any active industry and the same was explained under the separability approach (Abolfazl Gharaei (2021)).

Table 3. Description of green supply chain management barriers

Barriers	Description	Sources
Outsourcing		
(1) Problem in maintaining environmental suppliers	Due to traditional mindsets, suppliers' interests different from others in the total supply chain network.	Sarkar and Mohapatra (2006), Mudgal et al. (2010), and Ninlawan et al. (2010).
(2) Complexity in measuring and monitoring suppliers' environmental practices	Metrics misalignment thought to be primary source of inefficiency and disruption in supply chain interactions.	Faisal et al. (2000), Mudgal et al. (2010), Hervani et al. (2005) and Björklund et al. (2012).
(3) Lack of an environmental partnership with suppliers	With environmental consciousness, industries find it difficult to maintain partnerships with suppliers.	Hamner (2006) and Wolf and Seuring (2010).
(4) Products potentially conflict with laws	Most industries' products fail to conform to environmental laws.	Zhu and Sarkis (2006).
(5) Lack of government support to adopt Environmental friendly policies	Government regulations are not strong enough to force industries to adopt environmental friendly policies.	AlKhidir and Zailani (2009) and Zhu et al. (2012).
(6) No proper training/reward system for suppliers	Industries neither train/reward suppliers for adopting environment friendly concepts	Massoud et al. (2010).
Technology		
(7) Fear of failure	Fear of failure in adopting green supply chain; that firms could suffer monetary losses/product failure, lead to loss of competitive advantage.	Rao and Holt (2005), Perron (2005) and Revell and Rutherfoord (2003).
(8) Lack of effective environmental measures	Industries reluctant to implement effective environmental measures.	Rao and Holt (2005).
(9) Lack of human resources	Lack of enough laborers in the organization and/or their quality. Basically, the fundamental obstacle to improving environmental performance of SMEs is lack of human resources.	Perron (2005) and Hillary (2004).
(10) Difficulty in transforming positive environmental attitudes into action	Though industries have positive environmental attitudes, they find it difficult to put them into action.	Revell and Rutherfoord (2003), and Hillary (2004) and Perron (2005).
(11) Lack of technical expertise	Inability to find an alternative to design a pollution free product to fulfill environmental requirements.	Perron (2005) and Revell and Rutherfoord (2003).
(12) Complexity of design to reuse/recycle used products	Design of recycling used products difficult	Beamon (1999).
(13) Complexity of design to reduce consumption of resource/energy	Inability of design technology to reduce usage of resource/energy. Present industrial practices incapable of switching to new systems.	Russel (1998) and Perron (2005). Revell and Rutherfoord (2003).
(14) Lack of new technology, materials and processes	Non-availability of appropriate technology/process within organizations to adopt green supply chain. All materials not very eco-friendly.	Perron (2005).

(*Continued*)

Table 3. (*Continued*)

Barriers	Description	Sources
(15) Lack of awareness about reverse logistics adoption	Industries generally unaware of reverse logistics practices	Ravi and Shankar (2005), Meade et al. (2007) and Mudgal et al. (2010).
Knowledge		
(16) Disbelief about environmental benefits	Industries lack belief in environmental benefits for implementing green concept.	Revell and Rutherfoord (2003) and Walker et al. (2008).
(17) Perception of "out-of-responsibility" zone	Perception of organizations that taking steps for environmental good-will is not their responsibility.	Shen and Tam (2002).
(18) Difficulty in identifying environmental opportunities	Industries inefficient to identify environmental opportunities.	Theyel (2000).
(19) Lack of Eco-literacy amongst supply chain members	Supply chain members lack knowledge about Eco-literacy.	Theyel (2000), Ravi and Shankar (2005), Mudgal et al. (2010) and Revell and Rutherfoord (2003).
(20) Lack of Environmental Knowledge	Lack of awareness of environmental legislations and ignorant of environmental impact on the organization's activities and benefits of adopting green supply chain.	Shen and Tam (2002).
(21) Lack of green system exposure to professionals	SMEs known to lack human resources both in quantity and quality to pursue environmental management.	Yu Lin and Hui Ho (2008).
(22) Complexity in identifying third parties to recollect used products	Identifying third parties to recollect used products not easy for industries.	Our contributed barrier
(23) No specific environmental goals	Industries lack well set environmental goals.	Theyel. (2000).
(24) Difficulty in obtaining information on potential environmental improvements	Industries struggle to get information on potential environmental improvements/ inability to get correct feedback.	Perron (2005).
(25) Hesitation/fear to convert to new systems	Industries fear adopting new systems.	Revell and Rutherfoord (2003).
(26) High investments and less return-on-Investments	High investment-low returns in implementing green concept.	Our contributed barrier
Financial		
(27) Expenditure in collecting used products	Collection of used products expensive.	Our contributed barrier
(28) Cost of environment friendly packaging	High cost of eco-friendly packaging.	Walker et al. (2008).
(29) Non-availability of bank loans to encourage green products/ processes	Industries struggle to get bank loans for environment related initiatives.	Our contributed barrier
(30) Risk in hazardous material inventory	Maintaining hazardous materials inventory involves high probability of financial loss.	Our contributed barrier

(*Continued*)

Barriers	Description	Sources
(31) Financial constraints	Finance plays major role in green supply chain management implementation; has many constraints.	Ravi and Shankar (2005), Hervani et al. (2005) and AlKhidir and Zailani (2009).
(32) Need for extra human resources	More human resource needed to adopt/maintain GSCM in environmental systems.	Our contributed barrier
(33) High cost of hazardous waste disposal	Disposal of hazardous costly due to threats involved.	Our contributed barrier
(34) Cost of switching to new system	Adoption of new system costly.	Mudgal et al. (2010).
(35) Lack of training courses/consultancy/institutions to train, monitor/mentor progress specific to each industry	Industry professionals need training to adopt GSCM in their units and to monitor progress from consultancy or institutions.	Carter and Dresner (2001).
Involvement and support		
(36) Lack of customer awareness and pressure about GSCM	Low demand from customers for eco-friendly products due to lack of GSCM awareness. lack of GSCM awareness.	Chen et al. (2006) and Mudgal et al. (2010).
(37) Lack of Corporate Social Responsibility	Corporate social responsibility suggests firms are willing to go beyond simple compliance. Willing to consider public consequences of organizational actions but industries fail to adopt it.	Mudgal et al. (2010).
(38) Not much involvement in environmental related programs/meetings	Lack of participation in conferences/seminars related to green supply chain conducted by government/organizations which successfully adopted this concept. Hence, less exposure to top management.	Perron (2005).
(39) Restrictive company policies towards product/process stewardship	Lack of importance attached to product and process stewardship and management's inattention detrimental to GSCM.	Beamon (1999), Revell and Rutherfoord (2003) and AlKhidir and Zailani (2009).
(40) Poor supplier commitment/unwilling to exchange information	Suppliers unwilling to exchange environment related information with industries, fearing end product being affected.	Sarkis (2003), Hong et al. (2009).
(41) Lack of Inter-departmental co-operation in communication	Restriction in information flow across organization hierarchy makes GSCM implementation unfeasible.	Ravi and Shankar (2005).
(42) Lack of involvement of top management in adopting green supply chain management	Resistance of top management to change existing investments, information systems and habits make switchover to a new supply chain system challenging.	Ghobadian et al. (1998), Hillary (2004), Yu Lin and Hui Ho (2008), Ravi and Shankar (2005), Zhu et al. (2007)
(43) Lack of awareness of the environmental impacts on business	Top management lacks awareness of environmental impacts on their business	Mudgal et al. (2010).
(44) Inadequate management capacity	Management capacity is poor/unstable.	Beamon (1999).

(*Continued*)

Table 3. (*Continued*)

Barriers	Description	Sources
(45) Market competition and uncertainty	Implementation of GSCM is time consuming and affects staid industries.	Mudgal et al. (2010).
(46) Lack of support and guidance from regulatory authorities	Regulatory authorities fail to extend proper support to maintain a green environment.	Perron (2005).

9. Establish contextual relationships between variables (Step 3) and develop structural self-interaction matrix (SSIM) (Step 4)

To decide which pairings of categories should be studied (Step 3), a contextual relationship is constructed among the categories based on the variables found in Step 2. Variables (categories) are developed into a structural self-interaction matrix (SSIM) Table 4, which illustrates pairwise interactions between variables in the system. A "has an effect on" type contextual relationship is used to analyze the barrier categories. In other words, one category affects another category. As a result, the contextual relationships (barrier categories) between the variables are developed using the following classification:

Type V: Category Xi has an impact on classification Xj;

Type A: Category Xj has an impact on Category Xi;

Type X: Category Xi has an impact on Category Xj;

Type O: Category Xi has an impact on Category Xj and vice versa

10. Reachability matrix (RM) (Step 5)

Now SSIM has been transformed into the binary matrix, which is called the initial reachability matrix (Table 5) by substituting V, A, X, and O into the binary numbers 0 and 1, as per the rules. The following algorithm has been done based on the following rules.

- If the value of (i, j) in the matrix is V, the entry of (i, j) in the initial reachability matrix will be 1 and the entry of (j, i) will be 0.
- If the value of (i, j) in the matrix is A, the entry of (i, j) in the initial reachability matrix will be 0 and the entry of (j, i) will be 1.
- •If the value of (i, j) in the matrix is X, the entry of (i, j) in the initial reachability matrix will be 1 and the entry of (j, i) will be 1.
- If the value of (i, j) in the matrix is O, the entry of (i, j) in the initial reachability matrix will be 0 and the entry of (j, i) will be 0.

11. Final reachability matrix (FRM) (Step 6)

The final reachability matrix is shown in Table 6 and is derived from the initial reachability matrix using the transitivity rule, which states that if a variable "1" is connected to "2" and "2" is related to "3", then "1" is surely related to "3".

11.1. Level partitioning (LP)

The above-mentioned reachability matrix was divided up into layers. The data in the Table 7 were used to generate the reachability and antecedent sets for each category. The reachability set for an individual category includes the category itself as well as any additional categories that may influence it. An individual category's antecedent set is the collection of categories that may influence it. For each category, the intersection of these sets was calculated.

Table 4. Structural Self-Interaction Matrix (Ssim)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TI-1(IN). Lack of personnel technical skills		X	A	O	A	O	O	V	O	O	O	O	X	O	O	O	O	O	O	O	V	O	O	O	O
TI-2(IN). Lack of IT systems standards			V	X	V	O	O	O	O	O	O	O	O	O	O	O	O	O	O	V	O	O	O	O	O
TI-3(IN). Lack of latest technologies				O	V	O	V	V	O	V	O	O	O	O	O	O	O	O	O	V	A	O	O	O	O
TI-4(IN). Lack of in-house facilities (infrastructure)					V	O	O	V	X	X	A	X	O	O	O	O	O	O	O	O	A	O	O	O	O
TI-5(IN). Technology and the RD issues related to product recovery						X	O	O	O	O	O	O	X	X	X	X	A	V	O	O	O	A	O	O	A
GSC-1(EX). Difficulties with supply chain members (poor coordination)							V	O	O	A	O	O	O	A	O	A	O	O	O	O	O	O	O	O	A
GSC-2(IN). Limited forecasting and planning								V	V	O	A	A	O	X	A	O	A	O	O	O	O	O	O	O	X
GSC-3(IN). Inconsistent quality									O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	A
E-1(IN). Lack of initial capital										V	O	V	O	O	O	O	O	O	O	O	O	O	O	O	V
E-2(EX). Lack of financial support for invest in return monitoring sys/storage and handling											O	O	A	O	A	A	A	A	A	O	O	A	O	A	A
E-3(EX). Uncertainty related to economic issues												X	O	O	O	O	O	O	O	V	O	O	O	O	V
E-4(IN). Lack of economy of scale													O	O	O	O	O	O	O	O	O	O	O	O	A
K-1(IN). Lack of knowledge on GSCM practices														X	X	X	X	A	O	O	O	O	V	A	A
K-2(EX). Lack of information on take back channels															A	A	A	A	O	O	O	A	A	O	A
K-3(EX). Lack of awareness concerning GSCM and its benefits																V	V	V	O	O	O	O	A	A	O
K-4(IN). Lack of taxation knowledge on returned products																	A	O	X	O	O	O	O	O	A
P-1(EX). Lack of specific laws																		V	A	V	O	O	V	V	V
P-2(EX). Lack of waste management practices																			O	O	O	A	O	A	A
P-3(EX). Lack of inter-ministerial communication																				O	O	V	V	V	O
P-4(EX). Lack of motivation laws																					O	O	O	A	O
MC-1(EX). Perception of a poorer quality product																						O	O	A	O
MC-2(EX). Undeveloped recovery marketplaces																							O	A	O
MC-3(EX). Little recognition of GSCM competitive advantage																								A	O
M-1(IN). Low importance of GSCM relative to other issues																									A
M-2(IN). Low involvement of top management and strategic																									

Table 5. Reachability matrix (Rm)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Driving Power
TI-1(IN). Lack of personnel technical skills	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	5
TI-2(IN). Lack of IT systems standards	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6
TI-3(IN). Lack of latest technologies	1	0	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
TI-4(IN). Lack of in-house facilities (infrastructure)	0	1	0	1	1	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
TI-5(IN). Technology and the RD issues related to product recovery	1	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	8
GSC-1(EX). Difficulties with supply chain members (poor coordination)	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
GSC-2(IN). Limited forecasting and planning	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5
GSC-3(IN). Inconsistent quality	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
E-1(IN). Lack of initial capital	0	0	0	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	5
E-2(EX). Lack of financial support for invest in return monitoring sys/storage and handling	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E-3(EX). Uncertainty related to economic issues	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	6
E-4(IN). Lack of economy of scale	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
K-1(IN). Lack of knowledge on GSCM practices	1	0	0	0	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	0	0	9
K-2(EX). Lack of information on take back channels	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	5
K-3(EX). Lack of awareness concerning GSCM and its benefits	0	0	0	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	9
K-4(IN). Lack of taxation knowledge on returned products	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	7
P-1(EX). Lack of specific laws	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0	1	1	1	0	1	0	0	1	1	1	12
P-2(EX). Lack of waste management practices	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	4
P-3(EX). Lack of inter-ministerial communication	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	1	1	1	0	7
P-4(EX). Lack of motivation laws	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
MC-1(EX). Perception of a poorer quality product	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3

(*Continued*)

Table 5. (*Continued*)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Driving Power
MC-2(EX). Undeveloped recovery marketplaces	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	5
MC-3(EX). Little recognition of GSCM competitive advantage	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	3
M-1(IN). Low importance of GSCM relative to other issues	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	1	1	1	1	1	0	9
M-2(IN). Low involvement of top management and strategic	0	0	0	0	1	1	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	0	0	1	1	12
Dependence Power	5	3	3	7	12	6	9	6	3	13	2	5	10	11	5	7	4	7	2	6	3	3	5	4	5	

cogent business & management

Table 6. Final reachability matrix (Frm)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Driving Power
TI-1(IN). Lack of personnel technical skills	1	1	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	25
TI-2(IN). Lack of IT systems standards	1	1	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	25
TI-3(IN). Lack of latest technologies	1	1*	1	1*	1	1*	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	25
TI-4(IN). Lack of in-house facilities (infrastructure)	1*	1	1*	1	1	1*	1*	1	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25
TI-5(IN). Technology and the RD issues related to product recovery	1	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1	1	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	25
GSC-1(EX). Difficulties with supply chain members (poor coordination)	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25
GSC-2(IN). Limited forecasting and planning	1*	1*	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	25
GSC-3(IN). Inconsistent quality	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
E-1(IN). Lack of initial capital	1*	1*	1*	1	1*	1*	1*	1*	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	25
E-2(EX). Lack of financial support for invest in return monitoring sys/storage and handling	1*	1*	1*	1	1*	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25
E-3(EX). Uncertainty related to economic issues	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1	25
E-4(IN). Lack of economy of scale	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25
K-1(IN). Lack of knowledge on GSCM practices	1	1*	1*	1*	1	1*	1*	1*	1*	1	1*	1*	1	1	1	1	1	1*	1*	1*	1*	1*	1	1*	1*	25
K-2(EX). Lack of information on take back channels	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25
K-3(EX). Lack of awareness concerning GSCM and its benefits	1*	1*	1*	1*	1	1*	1	1*	1*	1	1*	1*	1	1	1	1	1	1	1*	1*	1*	1*	1*	1*	1*	25
K-4(IN). Lack of taxation knowledge on returned products	1*	1*	1*	1*	1	1	1*	1*	1*	1	1*	1*	1	1	1*	1	1*	1*	1	1*	1*	1*	1*	1*	1*	25
P-1(EX). Lack of specific laws	1*	1*	1*	1*	1	1*	1	1*	1*	1	1*	1*	1	1	1*	1	1	1	1*	1	1*	1*	1	1	1	25
P-2(EX). Lack of waste management practices	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	25

(*Continued*)

Table 6. (*Continued*)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Driving Power
P-3(EX). Lack of inter-ministerial communication	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1	1*	1	1*	1*	1	1	1	1*	25
P-4(EX). Lack of motivation laws	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
MC-1(EX). Perception of a poorer quality product	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	25
MC-2(EX). Undeveloped recovery marketplaces	1*	1*	1*	1*	1	1*	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1*	25
MC-3(EX). Little recognition of GSCM competitive advantage	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	25
M-1(IN). Low importance of GSCM relative to other issues	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1	1*	1	1*	1*	1	1*	1	1	1	1	1	1*	25
M-2(IN). Low involvement of top management and strategic	1*	1*	1*	1*	1	1	1	1	1*	1	1*	1	1	1	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1	25
Dependence Power	23	23	23	23	23	23	23	24	23	23	23	23	23	23	23	23	23	23	23	24	23	23	23	23	23	

11.2. Level partitioning iterations

The antecedent set A and intersection set R are now finally adjusted to the final level and the common level in the previous step is clubbed together to decide the top level in this case. Level partitioning interactions (Table 8) are formulated to get the top level among various levels to formulate the conical matrix in the next step.

12. Conical matrix (CM) creation (Step 7) ISM model construction (Steps 8, 9, 10, 11)

The partitioned reachability matrix is reorganized by their members according to their level to produce the conical matrix (Table 9), which indicates that all elements with the same level are pooled. A digraph is a resultant graph. When the transitivity is eliminated, the digraph is eventually turned into the ISM model, as described in the ISM technique.

12.1. Driving power and matrix

The subcategories are divided into four clusters or sectors according to Figure 2 autonomous, independent, dependent, and linked. Sector-I depicts, a low driving power and low reliance type of barrier composes the sector. Because this area did not receive any barrier categories, they are all connected. Depending barrier types make up Sector II, which has low driving power but high dependence power and we have inconsistency quality (8) and lack of motivational law (20) in this Sector . Sector III will be composed of barriers with both high driving power and strong reliance power and we have almost all barrier falling into this sector barring inconsistence quality (8) and lack of motivational law (20). Sector-IV depicts barriers with high driving power and low dependence power and we have no barrier in this sector

Sector I—Autonomous category, Sector II—Dominated/Dependent category

Sector III_ Relay/Linkage category, Sector IV- Dominant/independent category

13. Micmac analysis

MICMAC (Matrice d'Impacts Croisés-Multiplication Appliquée à un Classement) analysis is a tool used to identify the interdependencies among the various factors affecting a particular industry. It helps in identifying the driving factors and their impact on the industry as well as the factors that are dependent on other factors. According to the experts' responses, the following are the finding:-

a. All barrier types fall into the third Sector, demonstrating that maximum obstacles have a strong dependence power and driving power in total.
b. Furthermore, expect inconsistent quality and a lack of motivating laws. All other variables are interconnected and impact one another.
c. The only inconsistency in quality and a lack of motivation laws come into the second Sector, which has a high dependence power and a low driving power; nonetheless, these two obstacles are interconnected to all other factors. The proposed study couldn't investigate any possible association between these two factors. The management of these two factors would be critical for any top management or top leader to effectively adopt GSCM in India's leather industry.

14. Findings and managerial implications

Green Supply Chain Management (GSCM) refers to the integration of environmental concerns into the supply chain management process. In the Indian leather industry, there are both internal and external barriers that can affect GSCM. Understanding various barriers and their relationships will help the various stakeholders in the system to enhance the adoption of GSCM. The adoption will not only help the company follow the GSCM norms within the company but also help the supply chain outside the core supply chain. There were 13 internal barriers and 12 external barriers, which were studied in this work in detail. Out of these variables, only two were found to be highly related

Table 7. Level partitioning(LP)

Level	Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)
1	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
2	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
3	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
4	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
5	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
6	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
7	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
8	8,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	8,	1
9	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
10	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
11	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
12	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
13	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
14	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2

(Continued)

Table 7. (Continued)

Level	Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)
15	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
16	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
17	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
18	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
19	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
20	20,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	20,	1
21	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
22	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
23	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
24	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2
25	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	2

Table 8. Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
8	8,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	8,	1
9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	

(Continued)

Table 8. (*Continued*)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
17	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
19	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
20	20,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	20,	1
21	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
22	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
24	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
25	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25,	
12				

Table 9. Conical matrix (Cm)

Variables	8	20	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	Driving Power	Level
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	25	2
2	1*	1	1	1	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
3	1	1	1	1*	1	1*	1	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
4	1	1*	1*	1	1*	1	1	1*	1*	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
5	1*	1*	1	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1	1	1	1	1*	1	1*	1*	1*	1*	1*	1*	25	2
6	1*	1*	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
7	1	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	25	2
9	1*	1*	1*	1*	1*	1	1*	1*	1*	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	25	2
10	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
11	1*	1	1*	1*	1*	1	1*	1*	1	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	25	2
12	1*	1*	1*	1*	1*	1	1*	1*	1	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
13	1*	1*	1	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1	1	1	1	1	1*	1*	1*	1*	1	1*	1*	25	2
14	1*	1*	1*	1*	1*	1*	1	1	1	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	25	2
15	1*	1*	1*	1*	1*	1*	1	1*	1	1*	1	1*	1*	1	1	1	1	1	1	1*	1*	1*	1*	1*	1*	25	2
16	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1	1*	1*	1	1	1*	1	1*	1*	1	1*	1*	1*	1*	1*	25	2
17	1*	1	1*	1*	1*	1*	1	1*	1	1*	1	1*	1*	1	1	1*	1	1	1	1*	1*	1*	1	1	1	25	2
18	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	25	2
19	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1	1*	1	1*	1	1	1	1*	25	2
21	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	25	2
22	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	25	2
23	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1	1*	1*	25	2
24	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1	1*	1	1*	1*	1	1*	1	1	1	1	1*	25	2
25	1	1*	1*	1*	1*	1*	1	1	1	1*	1	1*	1	1	1	1*	1	1*	1	1*	1*	1*	1*	1	1	25	2
Dependence Power	24	24	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23		
Level	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		

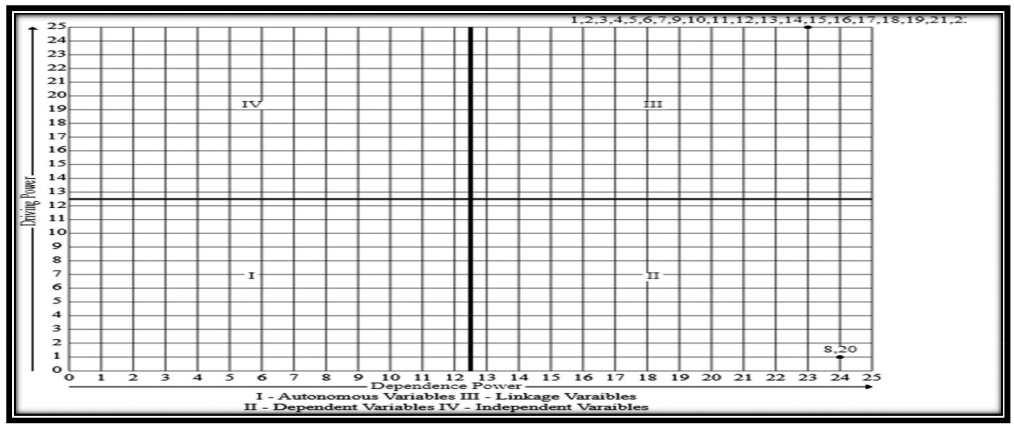


Figure 2. Driving power and dependence diagram.

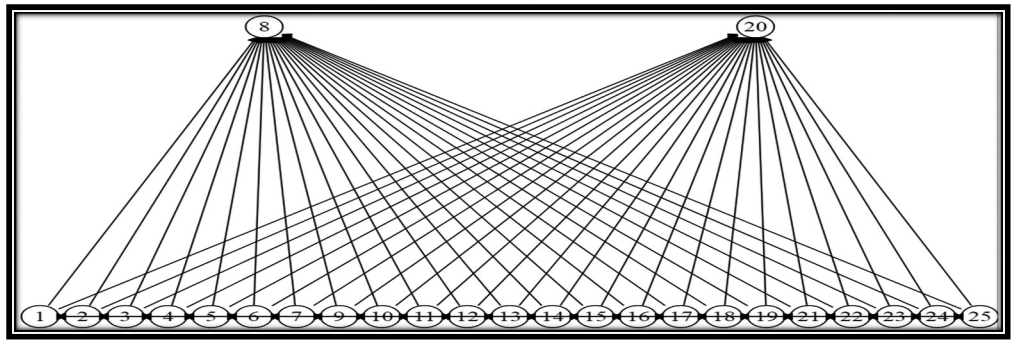


Figure 3. Interpretive structural modeling for barrier classification affecting GSCM.

to all other variables, the rest 12 internal and 11 external barriers were found with strong and high dependence and high driving power for GSCM implementation in green supply chain management.

15. The following are some managerial insights that appear from the present research

The interrelation depicted in this study indicates that all internal and external variables except Inconsistent quality and the lack of motivation laws depicts the interrelationship of multiple variables as reflected in Figure 3. The effective implementation of GSCM in the Indian leather industry depends on both factors. In the end, the consumer's approval of the product is influenced by the inconsistent quality. A wide range of stakeholders must be encouraged to embrace GSCM for it to be adopted. The industry's adoption will be hampered by the lack of motivation. Both variables show a strong reliance on power and little influence from other factors. The leather industry needs to pay attention to these two variables if it is to implement GSM in the Indian leather industry successfully and effectively.

There is no independent barrier (Sector I). Autonomous barriers are weak drivers and weak dependents, with little system impact. The absence of such obstacles in the current study suggests that all the barriers evaluated play a major effect. Inconsistent quality and a lack of motivation laws are dependent obstacles (Sector II). This barrier is a weak driver, but it is extremely dependent on others. Industries are not focused on laws because of a lack of motivation laws, which is why this barrier has a poor drive. This proves that industries place little emphasis on rules and product quality, which should be reorganized and properly enforced.

There are 23 obstacles in the linkage enabler (Sector III). This proves how difficult it is for the Indian leather manufacturing industries to assess and monitor their goods for environmental norms and GSCM deployments. The independent barrier is the problem of supporting the GSCM implementation described in (Sector IV). In our study, there are no variables in this Sector. This

shows that no barrier has a strong driving power and a low dependence on other variables. Decision-makers and practitioners should give priority while addressing these factors to achieve success in GSCM implementation.

15.1. Conclusion

Leather manufacturing, as well as its entire supply chain, has been forced to realize the importance of enhancing the environment by adopting practices that recycle key resources because of increasing pressure from international and national regulations, as well as a scarcity of resources. By examining the barrier categories using ISM, vital barriers that hinder GSCM implementation in the Indian leather industry can be extracted from this study. From Figure 2, all the barriers are interlinked to each other and share greater linkage as most of them fall in the III Sectors. Inconsistent quality and Absence of motivational law fall in the second Sector and show low driving power and high dependence. Both barriers, i.e., Inconsistent quality and the Absence of motivational law have interrelated with all the barriers. This model does not quantify the influence of each barrier, although giving useful insight into how they interact to affect GSCM practices in the Indian leather industry. In future studies, a graphic theoretic and matrix approach might be employed to quantify the effects of each barrier. Furthermore, this model has not been statistically confirmed and is simply reliant on the expert's assessment. As a result, the model and its conclusions may indeed be verified in the future using structural equation modeling (SEM). A comprehensive National Policy on Solid Waste (NPSW) in India is the need of the hour and will surely help major leather industry players actively take part in GSCM practices at the ground level. Inventive from the government and critical assessment of these barriers will confidently boost the morale of the Indian leather industry in the successful implementation of GSCM.

16. Research limitations/implications

The findings of this study are dependent on expert judgments, which might be biased and have an impact on the structural model's outcome. The research's ramifications are intended to assist the field managers of the sector in comprehending the crucial importance of various barriers and in prioritizing or removing those that stand in the way of the actual implementation of GSCM in the Indian leather industry.

17. Originality/value

A First-time attempt is made to understand the very critical and imminent problem for the Indian leather industry, i.e., finding the relationship between internal and external barriers. The ISM method is also applied for the first time for this type of work. This paper paves a way for various researchers to understand the various barriers and their interrelationships. This paper will surely help in removing various barriers against GSCM implementation in the Indian leather industry.

Author details
Manoj Kumar[1]
E-mail: manoj88.iaf@gmail.com
ORCID ID: http://orcid.org/0000-0002-6265-7484
Rao T Joji[2]
[1] School of Bussiness, University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India.
[2] Business School, OP Jindal Global University Jindal Global Business School, Sonipat, Haryana, India.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Citation information
Cite this article as: Study of the interplay among internal and external barriers to GSCM in the Indian leather industry using the total ISM and MICMAC methodology, Manoj Kumar & Rao T Joji, *Cogent Business & Management* (2023), 10: 2234697.

References

Abolfazl Gharaei, S. A., Hoseini Shekarabi, S. A., Karimi, M., Pourjavad, E., & Amjadian, A. (2021). An integrated stochastic EPQ model under quality and green policies: Generalised cross decomposition under the separability approach. *International Journal of Systems Science: Operations & Logistics*, *8*(2), 119–131. https://doi.org/10.1080/23302674.2019.1656296

AlKhidir, T., & Zailani, S. (2009). Going green in supply chain towards environmental sustainability. *Global Journal of Environmental Research*, *3*(3), 246–251.

Beamon, B. M. (1999). Designing the green supply chain. *Logistics Information Management*, *12*(4), 332–342.

Bechtsis, D., Tsolakis, N., Vlachos, D., & Srai, J. S. (2018). Intelligent Autonomous Vehicles in digital supply chains: A framework for integrating innovations towards sustainable value networks. *Journal of Cleaner Production*, *181*, 60–71. https://doi.org/10.1016/j.jclepro.2018.01.173

Björklund, M., Martinsen, U., & Abrahamsson, M. (2012). Performance measurements in the greening of supply chains. Supply chain management. *An International Journal*, *17*(1), 29–39.

Bouzon, M., Govindan, K., & Rodriguez, C. M. T. (2015). Reducing the extraction of minerals: Reverse logistics in the machinery manufacturing industry sector in Brazil using ISM approach. *Resources Policy*, *46*, 27–36. https://doi.org/10.1016/j.resourpol.2015.02.001

Carter, C. R., & Dresner, M. (2001). Purchasing's role in environmental management: Cross-functional development of grounded theory. *The Journal of Supply Chain Management*, *37*(2), 12–27.

Committee, S. (2012). Leather industry is the oldest manufacturing industry in India dating back to 3000 BC (Vackayil, 2011). The tanning of leather then, was done primarily using indigenous techniques such as rubbing fat, smoking, drying, etc and were used for different utili.

Dhillon, M. K., Bentley, Y., & Bukoye, T. (2016). Investigating employee attitudes towards adopting green supply chain practices in Indian SMEs - using qualitative methods: literature review and research methodology. *Proceedings of the 15Th European Conference on Research Methodology for Business and Management Studies (Ecrm2016)*, United kingdom (pp. 367–374).

Faisal, M. N., Banwet, D. K., & Shankar, R. (2007). Supply chain risk management in SMEs: Analyzing the barriers. *International Journal of Management and Enterprise Development*, *4*(5), 588–607.

Gharaei, A. A. (2021). An integrated reliable five-level closed-loop supply chain with multi-stage products under quality control and green policies: Generalised outer approximation with exact penalty. *International Journal of Systems Science: Operations & Logistics*, *449*.

Gharaei, A., Amjadian, A., Amjadian, A., Shavandi, A., Hashemi, A., Taher, M., & Mohamadi, N. (2022). An integrated lot-sizing policy for the inventory management of constrained multi-level supply chains: Null-space method.

Hamner, B. (2006). Effects of green purchasing strategies on supplier behaviour. In *Greening the supply chain* (pp. 25–37). London: Springer London.

Hervani, A. A., Helms, M. M., & Sarkis, J. (2005). Performance measurement for green supply chain management. *Benchmarking: An International Journal*, *12*(4), 330–353.

Hillary, R. (2004). Environmental management systems and the smaller enterprise. *Journal of Cleaner Production*, *12*(6), 561–569.

Lahane, S., & Kant, R. (2021). Evaluation and ranking of solutions to mitigate circular supply chain risks. *Sustainable Production and Consumption*, *27*, 753–773. https://doi.org/10.1016/j.spc.2021.01.034

Lin, C. Y., & Ho, Y. H. (2008). An empirical study on logistics service providers' intention to adopt green innovations. *Journal of Technology Management & Innovation*, *3*(1), 17–26.

Luthra, S., Kumar, V., Kumar, S., & Haleem, A. (2011). Barriers to implement green supply chain management in automobile industry using interpretive structural modeling technique-an Indian perspective. *Journal of Industrial Engineering & Management*, *4*(2), 231–257. https://doi.org/10.3926/jiem.2011.v4n2.p231-257

Lu, L. Y. Y., Wu, C. H., & Kuo, T. C. (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. *International Journal of Production Research*, *45*(18–19), 4317–4331. https://doi.org/10.1080/00207540701472694

Massoud, M. A., Al-Abady, A., Jurdi, M., & Nuwayhid, I. (2010). The challenges of sustainable access to safe drinking water in rural areas of developing countries: Case of Zawtar El-Charkieh, Southern Lebanon. *Journal of Environmental Health*, *72*(10).

Meade, L., Sarkis, J., & Presley, A. (2007). The theory and practice of reverse logistics. *International Journal of Logistics Systems & Management*, *3*(1), 56–84.

Mohanty, R. P., & Prakash, A. (2014). Green supply chain management practices in India: An empirical study. *Production Planning and Control*, *25*(16), 1322–1337. https://doi.org/10.1080/09537287.2013.832822

Moktadir, M. A., Ali, S. M., Rajesh, R., & Paul, S. K. (2018). Modeling the interrelationships among barriers to sustainable supply chain management in leather industry. *Journal of Cleaner Production*, *181*, 631–651. https://doi.org/10.1016/j.jclepro.2018.01.245

Mudgal, R. K., Shankar, R., Talib, P., & Raj, T. (2010). Modeling the barriers of green supply chain practices: An Indian perspective. *International Journal of Logistics Systems & Management*, *7*(1), 81–107.

Muduli, K., Govindan, K., Barve, A., & Geng, Y. (2013). Barriers to green supply chain management in Indian mining industries: A graph theoretic approach. *Journal of Cleaner Production*, *47*, 335–344. https://doi.org/10.1016/j.jclepro.2012.10.030

Ninlawan, C., Seksan, P., Tossapol, K., & Pilada, W. (2010,). The implementation of green supply chain management practices in electronics industry. In *World Congress on Engineering 2012* (Vol. 2182, pp. 1563–1568).

Phatak, S., & Sople, V. (2018). Drivers and barriers of sustainable supply chain: A literature review on Indian perspective. *International Journal of Business Insights and Transformation*, *12*(1), 17–25. https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,sso&db=bth&AN=135869088&site=ehost-live&custid=s1020214

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance?. *International Journal of Operations & Production Management*, *25*(9), 898–916.

Revell, A., & Rutherfoord, R. (2003). UK environmental policy and the small firm: Broadening the focus. *Business Strategy and the Environment*, *12*(1), 26–35.

Sarkar, A., & Mohapatra, P. K. (2006). Evaluation of supplier capability and performance: A method for supply base reduction. *Journal of Purchasing & Supply Management*, *12*(3), 148–163.

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production*, *11*(4), 397–409.

Shao, J., Taisch, M., & Ortega-Mier, M. (2016). A grey-Decision-Making Trial and Evaluation Laboratory (DEMATEL) analysis on the barriers between environmentally friendly products and consumers: Practitioners' viewpoints on the European automobile industry. *Journal of Cleaner Production*, *112*, 3185–3194. https://doi.org/10.1016/j.jclepro.2015.10.113

Theyel, G. (2000). Management practices for environmental innovation and performance. *International Journal of Operations & Production Management*, *20*(2), 249–266.

Walker, H., DiSisto, L., & McBain, D. (2008). Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of Purchasing & Supply Management*, *14*(1), 69–85.

Wolf, C., & Seuring, S. (2010). Environmental impacts as buying criteria for third party logistical services. *International Journal of Physical Distribution & Logistics Management*, *40*(1/2), 84–102.

Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China: Drivers and practices. *Journal of Cleaner Production*, *14*(5), 472–486.

Zhu, Q., Sarkis, J., & Lai, K. H. (2007). Green supply chain management: Pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production*, *15*(11–12), 1041–1052. https://doi.org/10.1016/j.jclepro.2006.05.021

Zhu, Q., Sarkis, J., & Lai, K. H. (2012). Green supply chain management innovation diffusion and its relationship to organizational improvement: An ecological modernization perspective. *Journal of Engineering and Technology Management*, *29*(1), 168–185.