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Drivers to Climate Change Mitigation Strategies in the Cement Industry in India: A Framework based on Interpretive Structural Modeling

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Abstract

Cement manufacturing is recognized as one of the most energy-intensive and high-emission industries worldwide. India ranks as the second-largest producer and consumer of cement globally. Within the country, the cement sector is currently the third-highest in energy consumption and the second-largest contributor to greenhouse gas (GHG) emissions. The ongoing release of GHGs significantly contributes to global warming and severe climate change. As a result, the cement industry faces increasing pressure to curb its emissions. This study aims to investigate the key factors influencing climate change mitigation strategies within India's cement sector. To achieve this, Interpretive Structural Modeling (ISM) has been employed to analyze and structure these drivers. The ISM method is used to establish the interrelationships among the drivers associated with climate mitigation efforts. The findings reveal a total of thirty drivers linked to mitigation practices. The ISM analysis ranks these drivers based on their driving power, showing that those with high driving power but low dependency are foundational and occupy the lowest levels in the ISM hierarchy. These core drivers should be prioritized when designing and implementing climate mitigation strategies within the Indian cement industry.

Keywords: Climate Change, Greenhouse Gas Emissions, Cement, Interpretive Structural Modeling

1. Introduction

The Cement Industry is vital for economic growth and development (Subiyanto, 2020). The worldwide demand for cement is accelerating due to rising population levels, expanding urban development, and ongoing modernization. This upward trend is expected to continue, with a significant increase in global cement demand anticipated in the near future (Balsara et al., 2021). India ranks as the world's second-largest cement producer, following China. In 2020, global cement production reached approximately 4,400 million tonnes (MT), with China accounting for around 2,500 MT (57%) and India contributing about 330 MT (8%). As reported by the Department for Promotion of Industry and Internal Trade (DPIIT), India's total installed cement production capacity for 2020–21 stood at 537 MT, which includes more than 350 mini cement plants with a combined capacity of 11.10 MT. During the same period, actual cement output was recorded at 299.94 MT, showing a 1% decrease compared to 2019–20 (Indian Bureau of Mines, 2021).

However, the current cement industry is highly CO2-emitting (generally ~0.59 tCO2 per ton of cement produced in 2020; IEA 2021) Among industrial sectors, the indicators point to the cement industry as the industry responsible for a significant portion of GHG emissions (Ali et al., 2011) It is the third largest consumer of industrial energy in the world, accounting for 7% of industrial energy consumption (WEO, 2014) and the second largest industrial emitter of CO_2, with approximately 7% of global emissions (Costa & Ribeiro, 2020). Thus cement industry is regarded as one of the most concerning sectors for CO_2 emission quantification and future decarbonization in the context of prevailing climate governance (IPCC, 2014a).

In light of the above, the present study is guided by the following objectives:
• To recognize the key factors that influence climate change mitigation strategies within the cement manufacturing sector.
• To analyze and define the relationships among these individual drivers affecting climate mitigation efforts.

• To highlight the managerial and practical implications derived from the study's findings.

Implementing all mitigation strategy drivers at once to manage, control, and reduce greenhouse gas emissions (GHGEs) in the cement industry is not feasible. Therefore, it is crucial for the industry to pinpoint specific, high-priority drivers that must be effectively managed to achieve meaningful GHGE reductions. The Interpretive Structural Modeling (ISM) approach is applied for this purpose. This research was conducted across ten cement plants in India. The findings are expected to support improved environmental performance by facilitating the practical implementation of key climate change mitigation strategies. The study's insights are based on extensive surveys, site visits, and interviews.

The structure of the paper is as follows: Section 2 reviews relevant literature for the current study. Section 3 outlines the methodology in detail. Section 4 introduces the proposed research framework and its practical application. Section 5 presents the results and analysis. Section 6 discusses the managerial and practical implications of the findings. Finally, Section 7 offers conclusions, outlines limitations, and suggests directions for future research.

2. Literature review

2.1 Business Risk (BR)

2.1.1 Cut in subsidies and increased taxes on fossil fuels (BR1)

The government has altered its policy direction by cutting back on fossil fuel subsidies and introducing increased taxation, thereby moving from a framework that encouraged carbon emissions to one that discourages them through financial penalties (Hossain et al., 2020; Govindan & Hasanagic, 2018; Sa et al., 2017; CDP India, 2015; MoEF&CC, 2015b).

2.1.2 Fluctuating raw material prices (BR2)

Fluctuations in the costs of energy and raw materials can greatly influence operating costs and capital expenditures, which may lead to a decrease in the current value of anticipated profits (Gupta et al., 2021; Gao et al., 2016; Long, 2013; Sullivan, 2010).

2.1.3 Litigation risk because of high emission profile of the company (BR3)

Companies with high carbon emissions could be subject to lawsuits based on claims of negligence, public nuisance, or trespassing (Balsara et al., 2020; Long, 2013; Sullivan, 2010).

2.1.4 Physical threat to assets and supply chain disruption (BR4)

Severe weather conditions can occasionally cause damage to manufacturing facilities, impair infrastructure, and break supply chain continuity (Viswanadham, 2018; Sullivan, 2010; Busch & Hoffmann, 2007).

2.1.5 Technological change and innovation (BR5)

It represents the approaches businesses adopt to reduce their reliance on fossil fuels and achieve significant cuts in greenhouse gas emissions (Benhelal et al., 2021; Miller & Moore, 2020; J. Liu et al., 2018).

2.2 Role of government regulations and policies (GR)

2.2.1 Environmental regulation compliance (GR1)

Adhering to regulations plays a crucial role in advancing vital environmental improvements, especially for companies with higher environmental risks, and fosters the creation of cleaner technologies by driving innovation (Karttunen et al., 2021; Hossain et al., 2020; Habert et al., 2020; Kumar & Dixit, 2018b; Gupta & Barua, 2017; Bossle et al., 2016).

2.2.2 SEBI mandate Business Responsibility Reporting (GR2)

A company's activities related to environmental, social, and governance (ESG) matters are documented in its Business Responsibility Report (BRR). This report is mandatory for the top 500 companies listed on the BSE and NSE based on market capitalization (Agarwal, 2018; SEBI, 2017; SEBI, 2015).

2.2.3 Energy Conservation (EC) Act 2001 and energy auditing by accredited BEE-certified Energy Auditor/Manager (GR3)

The Energy Conservation Act of 2001 aims to enhance energy efficiency, support conservation efforts, and tackle related and emerging challenges (Benhelal et al., 2021; Hossain et al., 2020; MoEF&CC, 2015a; MoEF&CC, 2015b).

2.2.4 PAT Scheme by BEE, internal price on carbon emission (GR4)

Perform Achieve and Trade (PAT) is a market-based mechanism that enhances cost efficiency by verifying excess energy savings in energy-intensive industries, enabling the trading of these savings. This system plays a crucial role in establishing an internal carbon pricing framework, assisting organizations in handling carbon-related risks and opportunities (Bhandari & Shrimali, 2018; BEE, 2017a; BEE, 2017b; CDP India, 2015; MoEF&CC, 2015a; MoEF&CC, 2015b).

2.2.5 High penalty for environmental pollution (GR5)

Impose heavy penalties on industries responsible for environmental pollution (Benhelal et al., 2021; Miller & Moore, 2020; Mathiyazhagan et al., 2014).

2.3 Internal factors (IF)

2.3.1 Top management involvement and commitment to emission reduction (IF1)

Top management in organizations has committed to achieving carbon neutrality or significantly lowering their total greenhouse gas emissions in the long run (Gupta et al., 2021; Govindan & Hasanagic, 2018; Sa et al., 2017; Bossle et al., 2016).

2.3.2 Improving risk management (IF2)

Tackling climate change can be understood as a risk management approach that involves navigating challenges while also uncovering possible opportunities in the face of uncertainty (Viswanadham, 2018; Abadie et al., 2017; IPCC, 2014c).

2.3.3 Cost reduction through material substitution and operational improvement (IF3)

Various operational strategies can lead to cost reductions, including partially replacing fossil fuels with alternative or renewable energy, and substituting clinker with materials such as fly ash or blast furnace slag. Furthermore, enhancing energy efficiency, optimizing resource utilization, and minimizing waste are essential approaches (Panjaitan et al., 2021; Habert et al., 2020; J. Liu et al., 2018b; Kumar & Rahman, 2017; Kajaste & Hurme, 2016a; Salas et al., 2016).

2.3.4 Emission reduction through material substitution and operational improvement (IF4)

Emissions reduction can be accomplished by replacing materials, such as raw materials or clinker, combined with operational improvements like boosting energy efficiency, implementing effective housekeeping, conducting routine maintenance, and ensuring thorough cleaning (Benhelal et al., 2021; Miller & Moore, 2020; Hossain et al., 2020; CSI/ECRA, 2017; Cadez & Czerny, 2016; Salas et al., 2016; Kajaste & Hurme, 2016a; Cao et al., 2016; Gao et al., 2015; Feiz et al., 2015; Morrow et al., 2014).

2.3.5 Environmental Awareness of Employee (IF5)

Employee environmental awareness is crucial for addressing climate change, as it expands their understanding of related issues (Karttunen et al., 2021; Hossain et al., 2020; Bossle et al., 2016; CDP India, 2015).

2.3.6 Corporate social responsibility (CSR) and ethical responsibility (IF6)

Corporate social responsibility and ethical duties compel organizations to reduce greenhouse gas emissions as part of a wider dedication to sustainable development, extending beyond just making profits (Kudtarkar & Shah, 2018; Huszlak, 2017; MoEF&CC, 2015b; IPCC, 2014a; Mathiyazhagan et al., 2014; Long, 2013).

2.4 Market pressure (MP)

2.4.1 Greenmarket competitive pressure (MP1)

There is a growing market demand for low-carbon products, which makes it challenging for companies to differentiate their products from those of their competitors (Govindan & Hasanagic, 2018; CDP India, 2013; Long, 2013).

2.4.2 Demand for low carbon Products (MP2)

Changes in consumer preferences are influenced by increasing environmental consciousness and the adoption of eco-friendly behaviors. More customers are willing to choose low-carbon products, while governments encourage sustainable consumption and lifestyles through education and awareness initiatives (Karttunen et al., 2021; Govindan & Hasanagic, 2018).

2.4.3 Enhanced brand image and corporate reputation/improved public image (MP3)

Companies can turn potential reputational risks into advantages by implementing measures that lower their total emissions (Faisal et al., 2020; IPCC, 2014a; CDP India, 2013; Long, 2013; Sullivan, 2010).

2.4.4 Media and NGOs attention to climate change issue (MP4)

Besides the government, media outlets and environmental non-governmental organizations play significant roles in exerting external pressure (Karttunen et al., 2021; Hossain et al., 2020; Mathiyazhagan et al., 2014; Long, 2013).

2.5 Stakeholder engagement/pressure (SP)

2.5.1 Investor demand (SP1)

Investors are demanding more transparency from businesses as they face financial risks arising not only from the direct effects of climate change but also from indirect factors such as the expenses involved in lowering emissions (Hossain et al., 2020; CDP India, 2015; Long, 2013).

2.5.2 Supplier engagement (SP2)

Since certain organizations do not monitor their suppliers' emissions, suppliers frequently pass on increasing carbon-related expenses to them (Karttunen et al., 2021; Bossle et al., 2016).

2.5.3 Local public or societal pressure for emission reduction (SP3)

Social and community pressures significantly influence climate change mitigation by encouraging organizations to adopt environmentally responsible practices. Studies by Karttunen et al. (2021), Hossain et al. (2020), and Bossle et al. (2016) highlight how societal expectations and community activism drive firms to reduce emissions and improve sustainability performance.

2.5.4 Health issue (SP4)

Unregulated NOx emissions from alternative fuels, combined with dust generated by cement factories, can adversely affect respiratory health. These pollutants might also impair visibility, cause irritation or buildup in the eyes, ears, and nasal passages, and may damage the skin or mucous membranes through chemical or physical means (Benhelal et al., 2021; Miller & Moore, 2020; Habert et al., 2020; Govindan & Hasanagic, 2018; Verma et al., 2018; CPCB, 2016; Diabat et al., 2014).

2.5.5 Demand from customers in environmental protection requirements (SP5)

Consumer interest in environmental conservation is a major factor motivating the creation of sustainable and eco-friendly products (Karttunen et al., 2021; Hossain et al., 2020; Bossle et al., 2016).

2.6 Business opportunity (BO)

2.6.1 Earn through emission reduction certification through carbon reduction projects (BO1)

An internal emission trading system is an efficient method for organizations to offset greenhouse gas emissions within their operations. This approach enables companies to lower emissions by working together with other firms or governmental bodies through trading emission allowances or cooperating on offset initiatives (Bhandari & Shrimali, 2018; BEE, 2017a; Cadez & Czerny, 2016; Kajaste & Hurme, 2016a; IPCC, 2014a).

2.6.2 Generate stream of revenue from low-carbon product (BO2)

The opportunity to generate continuous income by launching innovative low-carbon products (Industry expert's opinion).

2.6.3 New market opportunity (BO3)

Offering unique low-carbon products to the market provides a competitive advantage and creates new business prospects (Karttunen et al., 2021; Mathiyazhagan et al., 2014; Long, 2013; Vickers et al., 2009).

2.6.4 Investment opportunity (BO4)

Investment prospects emerge in developing low-carbon infrastructure and increasing production capacity (Pee et al., 2018; CDP India, 2013; Vickers et al., 2009).

2.6.5 Opportunity to modify product and process (BO5)

Current organizations have the opportunity to modify their operations and products to become more sustainable, resulting in cost reductions, lower emissions, and increased profit margins by improving energy efficiency and conserving resources (Dunuweera & Rajapakse, 2018; Cadez & Czerny, 2016; Long, 2013).

2.7 Research gaps and highlights

Mitigation strategies are crucial for lowering greenhouse gas emissions across industries, thereby enabling the production of low-carbon and sustainable products. Numerous studies have been conducted on climate change mitigation approaches within carbon-intensive sectors (Balsara et al., 2021; Hossain et al., 2020; Balsara et al., 2019; Govindan & Hasanagic, 2018; Abadie et al., 2017; Cadez & Czerny, 2016; Singh et al., 2015; Wahyuni & Ratnatunga, 2015; Tang & Luo, 2014; Hashmi & Al-Habib, 2013; Weinhofer & Busch, 2013; Bocken & Allwood, 2012; Lee, 2012; Botto et al., 2011; Lee, 2011; Muthu et al, 2011; Pasqualino et al., 2011; Weinhofer & Hoffmann, 2010; Jeswani et al., 2008; Jones & Levy, 2007; Kolk & Pinkse, 2005; Kolk & Pinkse, 2004). While the studies referenced above primarily concentrate on lowering the carbon footprint of certain industries or products, only a limited number have explored the factors driving the adoption of mitigation strategies. A few studies have specifically examined the drivers behind implementing carbon management (Liu, 2012; Okereke, 2007), but these studies focus mostly noncarbon intensive industries.

Numerous studies have been conducted on the factors driving the implementation of green supply chain management (GSCM) across various industries (Somsuk & Laosirihongthong, 2017; Dubey et al., 2015; Tachizawa et al., 2015; Mathiyazhagan et al., 2014; Mathiyazhagan & Haq, 2013; Diabat & Govindan, 2011; Walker et al., 2008; Zhu et al., 2007; Zhu & Sarkis, 2006; Zhu et al., 2005; Rao, 2002). These studies, which analyzed responses from various industries categorized into multiple sectors, include only a limited number that focus specifically on emission-intensive sectors or particular emission-intensive industries

Cement production is a sector with significant carbon emissions. While some research has been conducted on cement manufacturing, the majority of these studies focus on developed countries (Cao et al., 2016; Gao et al., 2016; Salas et al., 2016; Feiz et al., 2015; Gao et al., 2015; Ishak & Hashim, 2015; Benhelal et al., 2013; Hasanbeigi et al., 2013; Madlool et al., 2013; Wang et al., 2013; Hasanbeigi et al., 2012; Ke et al., 2012; Ali et al., 2011; Madlool et al., 2011). There are very few studies that are done in India, the second largest producer and consumer of cement (Soni et al., 2017; Kajaste & Hurme, 2016; Morrow et al., 2014; Mandal & Madheswaran, 2011; Dutta & Mukherjee, 2010; Mandal & Madheswaran, 2010; Mandal, 2010; Gielen & Taylor, 2009). Moreover, while previous research on GHGEs and energy use in the cement industry has employed various methods, very few have examined the drivers behind climate change mitigation strategies in this emission-intensive sector. To the best of our knowledge, this study is the first to apply the ISM technique to both identify and evaluate the key common drivers of climate change mitigation in cement manufacturing, as well as to explore the relationships among these drivers. This study uniquely assesses the relative importance of each driver and maps their interconnections within the energy- and emission-intensive cement industry.

3. Solution methodology

In this study, ISM techniques are utilized. The factors identified through ISM analysis are organized into a hierarchical framework that reveals the relationships among them, showing how one factor influences others and its overall impact on the system. Additionally, this method aids in enhancing strategic performance (Kumar & Dixit, 2018).

3.2 Interpretative Structural Modeling (ISM)

Developed by Warfield (1974), ISM is a systemic structural modeling approach commonly used to identify and organize the relationships among various factors. It is an interactive learning technique that arranges a group of distinct, interconnected variables into an integrated systemic model, typically illustrated as a hierarchical diagram (Warfield, 1974, Sage, 1977, Agarwal, Shankar, & Tiwari, 2007). ISM offers a method for individuals to create an objective hierarchy of factors through mathematical reasoning based on the pairwise relationships between them (Song et al., 2017). Therefore, the resulting model depicts the framework of a complex problem, system, or area of study as a thoughtfully organized pattern, incorporating visuals and text that illustrate the hierarchical relationships among the different enabling factors (Nishat et al., 2006). ISM has been used in several studies as shown in Table 1

Table1: Summary on the use of ISM analysis in various studies

12	Authors	Studies
1.	S. Kumar et al., (2021)	To pinpoint the obstacles to adopting Industry 4.0 and circular economy practices within the agricultural supply chain
2.	Xu & Zou, (2020)	Examination of factors and their hierarchical connections affecting the energy performance of buildings
3.	Tan et al., (2019)	Obstacles to the adoption of Building Information Modeling (BIM) in China's prefabricated construction sector
4.	Kumar & Dixit, (2018)	To examine the obstacles impacting the implementation of e-waste management practices
5.	Song et al. (2017)	Examined the vulnerability factors of the urban rail transit system through the application of ISM
6.	Kumar & Rahman (2017)	Examine the factors that facilitate a sustainable supply chain
7.	Patil & Warkhedkar (2016)	Explored knowledge management and its application within India's automobile ancillary industries

The ISM methodology has various steps as follows (Kannan et al., 2009; Kumar & Dixit, 2018)

Step 1: Identify and list the drivers influencing the system being studied.
Step 2: Establish contextual relationships among the identified drivers based on the specific aim of the research.
Step 3: Create a Structural Self-Interaction Matrix (SSIM) to represent the pairwise relationships between the drivers.
Step 4: Develop a reachability matrix from the SSIM and verify it for transitivity, which in ISM means that if driver A is related to B, and B is related to C, then A is also related to C.
Step 5: Partition the reachability matrix into different hierarchical levels.
Step 6: Construct a directed graph from the reachability matrix, eliminating any transitive links.
Step 7: Convert the directed graph into an ISM model by replacing nodes with corresponding driver statements.
Step 8: Review the ISM model for any conceptual inconsistencies and make necessary adjustments.

These steps are illustrated in Figure 1.

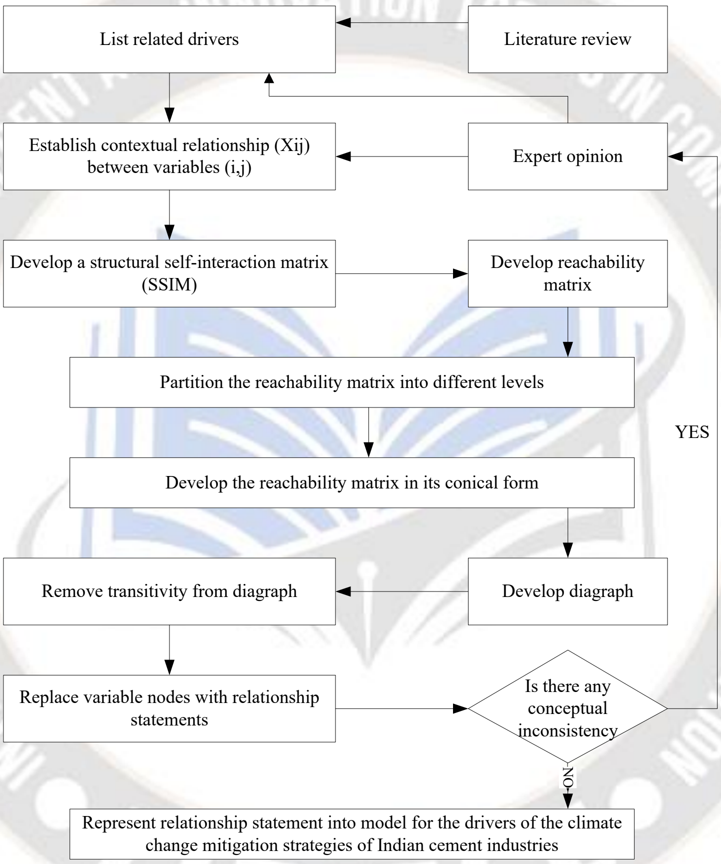

Figure 1: Flow diagram for preparing the ISM model

4. Proposed research framework and its application

The proposed research framework for assessing the drivers of climate change mitigation strategies in Indian cement industries, based on ISM techniques, comprises several phases.
Phase I: Identifying the common drivers of climate change mitigation strategies in Indian cement industries through literature review and consultation with industry experts.
Phase II: Using the ISM technique to analyze the relationships among the identified drivers of climate change mitigation strategies.

Phase I: Involves identifying common drivers of climate change mitigation strategies in the cement industry and collecting relevant data. This phase begins with recognizing the 30 most prevalent drivers of climate change mitigation in cement manufacturing, based on a review of literature and insights from industry experts. The study focuses on ten cement companies in India, where survey questionnaires were personally distributed to officials involved in the manufacturing process over a two-month period from June to July 2019. Respondents were selected using a purposive snowball sampling technique to ensure they possessed the

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necessary knowledge to provide accurate information (Raju & Becker, 2013; Kabra et al., 2015). Mid-level and senior engineers and managers with varied responsibilities were chosen during data collection, as they play a crucial role in the strategic decision-making team (Carter et al., 1998). The chosen ten industry experts possessed significant expertise in their field, each with over 10 years of industrial experience. The questionnaire was designed to gather expert opinions on the cement industry. Prior to collecting data, the purpose and benefits of the study were clearly communicated to each participant.

Phase II: Establishing the interrelationships among the identified common drivers of climate change mitigation strategies in the cement industry using ISM, After listing the drivers to analyze their interactions, it is crucial to determine the contextual relationships among them to develop the Structural Self-Interaction Matrix (SSIM). To identify these relationships, the same industry experts were asked whether variable i influences variable j or vice versa. The standard ISM VAXO scale was applied, where:

- V indicates variable i facilitates variable j;
- A indicates variable j facilitates variable i;
- X means both variables mutually influence each other;
- O signifies no relationship between variables i and j.

Using the experts' feedback, the SSIM was created for the 30 drivers of climate change mitigation strategies in the Indian cement manufacturing sector. The resulting SSIM is presented in Table 2.

Table 02: Structural self-interaction matrix (SSIM)

	BO	BO	BO	BO	BO	SP	SP	SP	SP	SP	MP	MP	MP	MP	IF	IF	IF	IF3	IF2	IF1	GR5	GR4	GR3	GR2	GE1	BR5	BE4	BR3	BR2
BR	V	V	V	O	V	A	A	A	V	V	A	O	A	V	O	V	V	V	V	V	X	V	V	O	V	V	O	A	X
Br	V	V	O	O	V	A	A	A	V	V	A	O	A	V	O	V	O	V	V	V	X	V	V	O	O	V	O	A	
BR 3	V	V	V	O	V	V	X	V	V	V	V	O	V	V	O	V	V	O	V	V	V	V	V	V	V	V	O		
BR	O	O	O	O	O	V	O	V	V	V	V	O	O	O	O	V	O	O	V	V	O	O	O	O	O	V			
BR 5	V	V	V	O	V	A	A	A	O	A	A	V	A	V	O	X	V	V	V	X	A	A	A	A	A				
GR	V	V	V	O	V	A	A	A	O	O	A	V	A	V	V	V	V	V	V	O	A	X	X	A					
GR 2	V	V	V	O	V	A	A	A	V	V	A	V	A	V	X	V	V	O	V	V	X	V	V						
GR	V	V	V	O	V	A	O	A	O	O	A	O	A	V	O	O	V	V	V	O	A	X							
GR 4	V	V	V	V	V	A	A	A	V	V	A	V	A	V	V	V	V	V	V	V	A								
GR	V	V	V	V	V	A	A	A	V	V	A	O	A	V	O	V	V	O	V	V									
IF1	V	V	O	O	V	A	A	A	A	A	A	V	A	O	X	X	V	V	V										
IF2	A	A	O	V	A	A	O	A	A	A	A	X	A	A	X	A	X	V											
IF3	A	A	V	X	A	O	A	O	A	O	O	O	O	A	O	A	X												
IF4	A	A	O	V	X	A	A	A	A	A	A	A	A	A	A	A													
IF5	V	V	A	V	V	A	A	A	X	A	A	V	A	O	X														
IF6	O	O	O	O	O	O	O	A	A	O	O	V	A	O															
MP 1	V	V	X	V	X	A	O	A	V	X	A	X	A																
MP	V	V	V	V	V	X	A	X	V	V	X	V																	
MP 3	A	A	A	O	A	O	O	O	A	A	O																		
MP	V	V	V	O	V	X	A	X	V	V																			
SP 1	V	V	A	O	V	A	A	A	X																				
SP	V	O	A	V	V	A	A	A																					
SP 3	V	V	V	O	V	X	A																						
SP	V	V	O	O	O	V																							
SP 5	V	V	V	O	V																								
BO	A	O	X	V																									
BO 2	A	A	A																										
BO	V	O																											
BO 4	X																												

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The SSIM was converted into a reachability matrix to represent the relationships between variables in binary form. The symbols V, A, X, and O from the SSIM were replaced with binary digits 0 and 1 according to the following rules:

- If the (i, j) position in SSIM is V, then the (i, j) entry in the reachability matrix is 1, and the (j, i) entry is 0;
- If the (i, j) position in SSIM is A, then the (i, j) entry becomes 0, and the (j, i) entry becomes 1;
- If the (i, j) position is X, both (i, j) and (j, i) entries are 1;
- If the (i, j) position is O, both entries are 0.

This resulting matrix is called the initial reachability matrix, presented in Table 3. The final reachability matrix is derived by applying the principle of transitivity, which states that if a relationship exists between element i and j, and between j and k, then it must also exist between i and k. The completed reachability matrix is shown in Table 4.

Table 3: Initial reachability matrix

	B	B	B	B	B	G	G	G	G	G	I	I	I	I	I	I	M	M	M	M	S	S	S	S	S	B	B	B	B	B
B	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	1	0	1	1	1
B	1	1	0	0	1	0	0	1	1	1	1	1	1	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	1
B	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1
B	0	0	0	1	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	1	1	1	0	1	0	0	0	0	0
B	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	1	0	0	0	0	0	0	1	0	1	1	1
G	0	0	0	0	1	1	0	1	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	1	1	1
G	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	1	0	0	0	1	0	1	1	1
G	0	0	0	0	1	1	0	1	1	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1
G	0	0	0	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1
G	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0	0	1	1	0	0	0	1	1	1	1	1
I	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	1	0	0	0	1	0	0	1	1
I	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
I	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
I	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	1	0	0	0	1	1	0	1	1
I	0	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
M	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	1	1	0	0	0	1	1	1	1	1
M	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
M	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
M	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1
S	0	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	1	0	1	0	1	1	0	0	0	1	0	0	1	1
S	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	1	1	0	0	0	1	1	0	0	1
S	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1
S	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	1	1	1	1	0	0	0	1	1
S	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	1	1	1	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	0	0	0	1	1	1	0	1
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	1

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Table 4: Final reachability matrix

	B	B	B	B	B	G	G	G	G	G	I	I	I	I	I	I	M	M	M	M	S	S	S	S	S	B	B	B	B	B	
B	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	23
B	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	23
B	1	1	1	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	29
B	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	28
B	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	16
G	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	20
G	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	23
G	0	0	0	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	19
G	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	20
G	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	23
IF	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	17
IF	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	12
IF	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	1	1	0	0	0	1	1	1	0	1	12
IF	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	9
IF	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	17
IF	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	21
M	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	16
M	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	27
M	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	13
M	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	27
SP	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	16
SP	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	17
SP	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	27
SP	1	1	1	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	29
SP	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	27
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	14
B	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	4
B	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	16
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	1	11
B	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	1	11
	1	11	2	1	22	15	18	15	15	12	2	2	3	3	2	2	29	7	29	7	2	2	7	2	7	29	30	30	26	27	56

The final reachability matrix is partitioned to determine the level of each variable. This partitioning uses reachability and antecedent sets, defined as follows:

- **Reachability set:** Includes the variable itself and all variables it can help to achieve.
- **Antecedent set:** Includes the variable itself and all variables that contribute to achieving it.

Following Warfield's (1974) guidelines, these sets are derived from the final reachability matrix for each driver. The reachability set of a driver comprises itself and any drivers it influences, while the antecedent set includes itself and any drivers that influence it. Once both sets are identified, their intersection is determined. A driver whose reachability set matches the intersection set is assigned Level I, representing the topmost barrier in the ISM model hierarchy. (Kannan & Haq, 2007). Once Level I is identified, the first iteration concludes, and the drivers assigned to Level I are removed from the remaining set of drivers. Subsequent iterations continue in the same manner to determine the levels of the other drivers. According to Table 5, the factors such as cost reduction through material substitution and operational improvements (IF3), emission reduction through similar means (IF4), generating revenue from low-carbon products (BO3), and new market opportunities (BO3) are positioned at Level I in the ISM hierarchical model

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Table 5 Level partition for drivers: Iteration I - VIII

Br.Code	REACHABILITY SET	ANTECEDENT SET	Intersection set	Level
IF3	12,13,14,15,17,19,21,22, 26,27,28,30	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,29,30	12,13,14,15,17,19,21,22, 26,27,28,30	I
IF4	12,13,14,16,17,19, 26,27,28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,29,30	12,13,14,16,17,19, 26,27,28	I
BO2	13,14, 27,28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,29,30	13,14, 27,28	I
BO3	5,11,12,13,14,15,16,17,19,21,22, 26,27,28,29,30	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25,26,27,28,29,30	5,11,12,13,14,15,16,17,19,21,22, 26,27,28,29,30	I
IF2	7,11,12,15,16,17,19, 26	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22, 23,24,25,26,29,30	7, 11,12, 15,16,17,19, 26	II
IF6	5,6,7,8,9,10,11,12, 15,16,17,19,21,22, 26, 29,30	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22, 23,24,25,26,29,30	5,6,7,8,9,10,11,12, 15,16,17,19,21,22, 26, 29,30	II
MP1	5,11,12,15,16,17,19,21,22, 26, 29,30	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22, 23,24,25,26,29,30	5,11,12,15,16,17,19,21,22, 26, 29,30	II
MP3	12,16,17,19,21,22, 26, 29,30	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22, 23,24,25,26,29,30	12,16,17,19,21,22, 26, 29,30	II
BO1	12,15,16,17,19,21,22 ,26, 29,30	1,2,3,4,5,6,7,8,9,10,11,12,15,16,17,18,19,20,21,22, 23,24,25,26,29,30	12,15,16,17,19,21,22 ,26, 29,30	II
BO4	29,30	1,2,3,4,5,6,7,8,9,10,11,15,18,20,21,22,23,24,25,29, 30	29,30	III
BO5	29,30	1,2,3,4,5,6,7,8,9,10,11,15,18,20,21,22,23,24,25,29, 30	29,30	III
BR5	5, 11,15, 21,22	1,2,3,4,5,6,7,8,9,10,11,15, 18,20,21,22,23,24,25	5, 11,15, 21,22	IV
IF1	5,7,11,15, 21,22	1,2,3,4,5,6,7,8,9,10,11,15,18,20,21,22,23,24,25	5,7,11,15, 21,22	IV
IF5	5,7, 11,15, 21,22	1,2,3,4,5,6,7,8,9,10,11,15,18,20,21,22,23,24,25	5,7, 11,15, 21,22	IV
SP1	5, 11,15, 21,22	1,2,3,4,5,6,7,8,9,10,11,15,18,20,21,22,23,24,25	5, 11,15, 21,22	IV
SP2	5,7, 11,15, 21,22	1,2,3,4,5,6,7,8,9,10,11,15, 18,20,21,22,23,24,25	5,7, 11,15, 21,22	IV
GR1	6,7,8,9	1,2,3,4,6,7,8,9,10,18,20, 23,24,25	6,7,8,9	V
GR3	6,8,9	1,2,3,4,6,7,8,9,10,18,20, 23,24,25	6,8,9	V
GR4	6,7,8,9	1,2,3,4,6,7,8,9,10,18,20, 23,24,25	6,7,8,9	V
BR1	1,2,7, 10	1,2,3,4, 7, 10, 18,20, 23,24,25	1,2,7,10	VI
BR2	1,2,7,10	1,2,3,4, 7, 10, 18,20, 23,24,25	1,2,7,10	VI
GR2	1,2,7,10	1,2,3,4,7,10, 18,20,23,24,25	1,2,7,10	VI
GR5	1,2,7,10	1,2,3,4, 7, 10,18,20, 23,24,25	1,2,7,10	VI
MP2	18,20,23,25	3,4,18,20,23,24,25	18,20,23,25	VII
MP4	18,20,23,25	3,4,18,20,23,24,25	18,20,23,25	VII
SP3	18,20,23,25	3,4,18,20,23,24,25	18,20,23,25	VII
SP5	18,20,23,25	3,4,18,20,23,24,25	18,20,23,25	VII
BR3	3,24,	3,24	3,24,	VIII
SP4	3, 24	3,24	3, 24	VIII
BE4	4	4	4	VIII

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The structural model is developed from the final reachability matrix and is illustrated in Figure 2. An arrow from factor i to factor j represents the relationship between barriers i and j. This initial representation is known as a digraph. By eliminating transitive links according to the ISM methodology, the digraph is transformed into the final ISM model, as depicted in Figure 3.

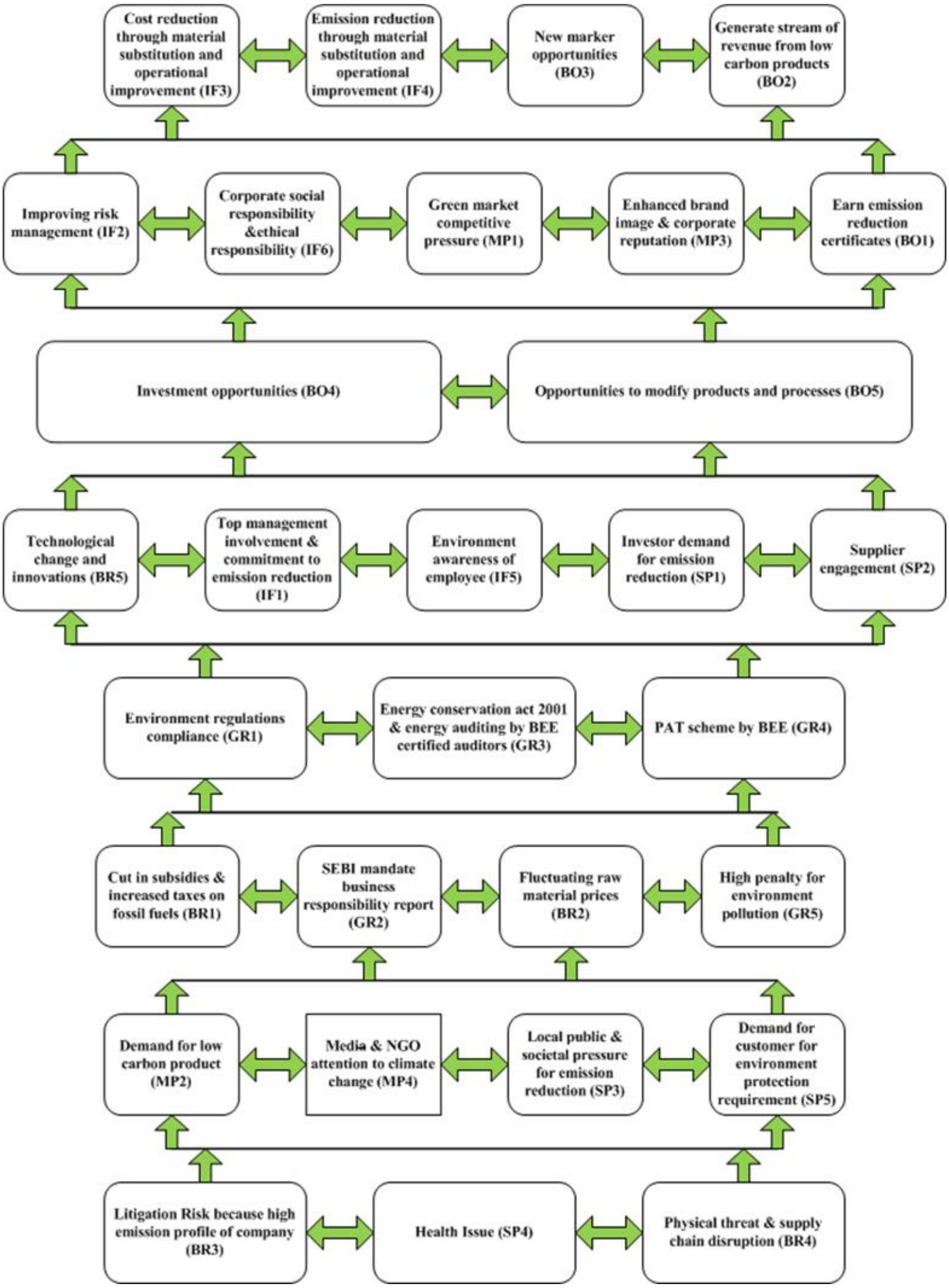

Figure 2: ISM based model for drivers of climate change mitigation strategies of Indian cement manufacturing industries with transitivity.

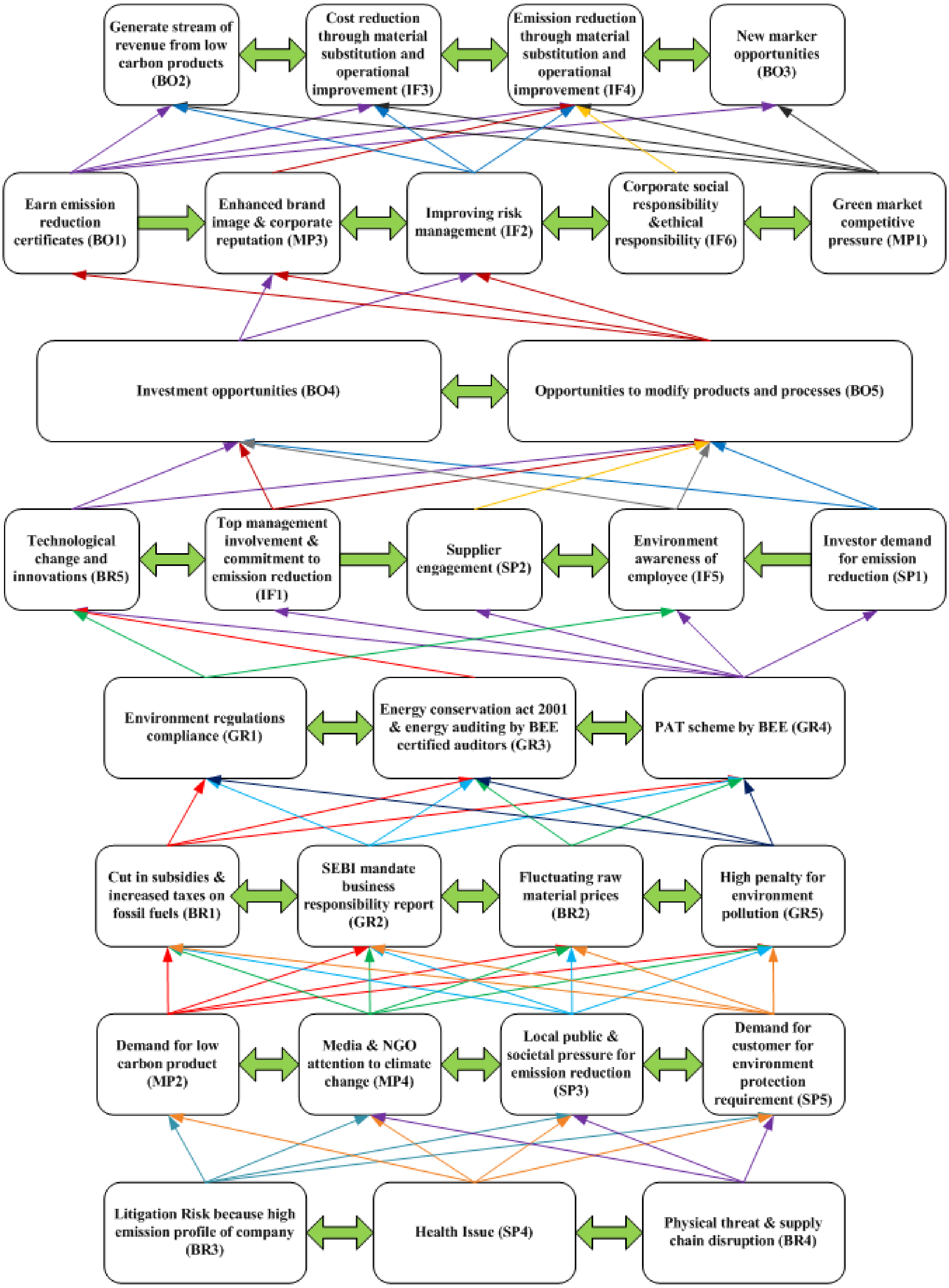

Figure 3: ISM based model for drivers of climate change mitigation strategies of Indian cement manufacturing industries after removing transitivity.

The Cross-impact matrix multiplication applied to classification (MICMAC) principle is based on multiplication properties of matrices (Sharma & Gupta, 1995).The MICMAC analysis aims to evaluate the driving power and dependence power of various drivers to pinpoint the key factors influencing the system. Based on their levels of driving and dependence power, the drivers in this study are grouped into four categories, as shown in Figure 4:

1. **Autonomous drivers:** These have low driving and dependence power, are largely disconnected from the system, and maintain few but potentially strong links. They fall into Quadrant I.

2. **Dependent drivers:** Characterized by weak driving power but strong dependence, these drivers are placed in Quadrant II.

3. **Linkage drivers:** Possessing both strong driving and strong dependence power, these drivers are found in Quadrant III. They tend to be unstable since any action on them impacts others and also causes feedback effects on themselves.

4. **Independent drivers:** These drivers have strong driving power but low dependence and are located in Quadrant IV.

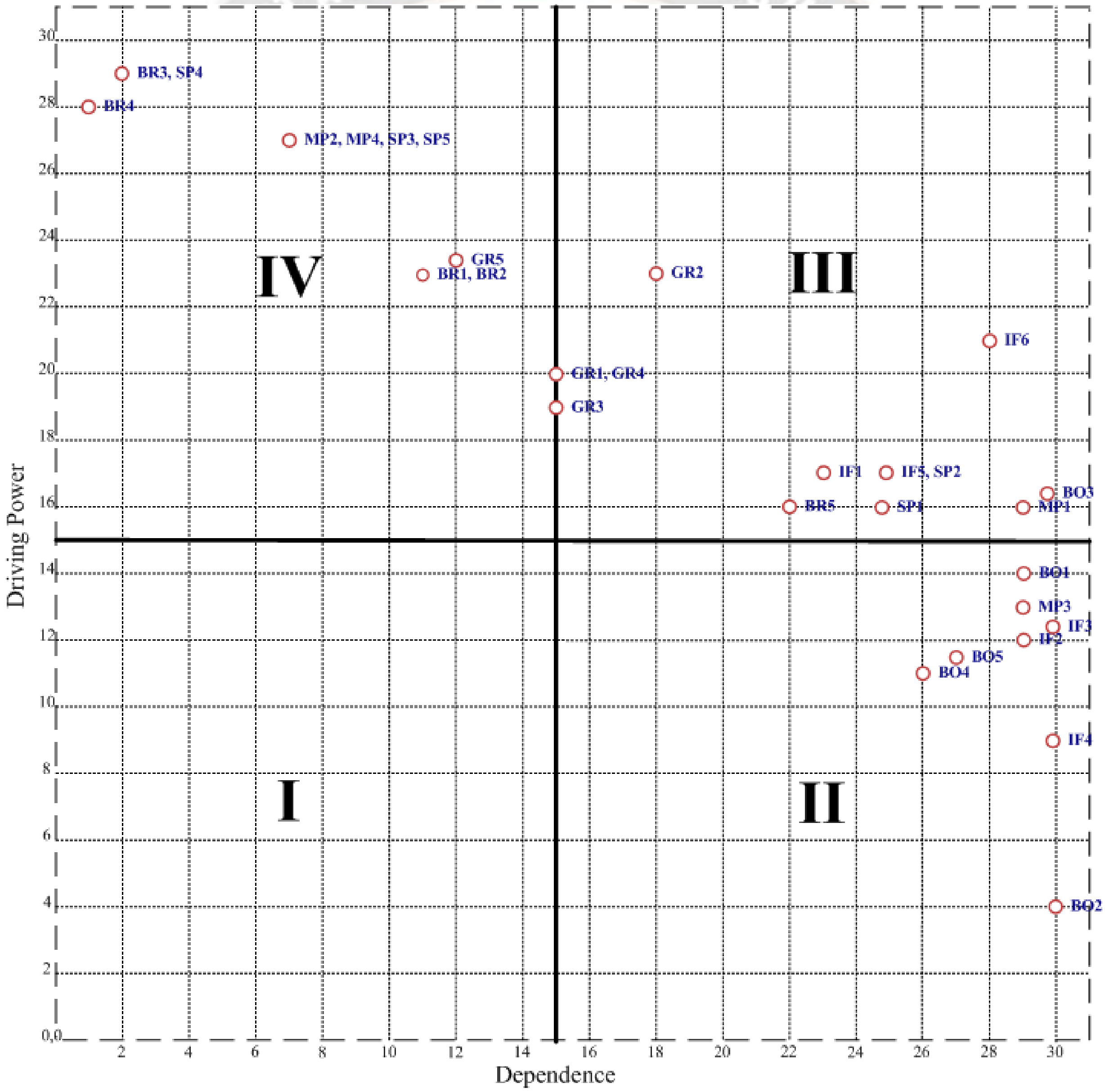

Figure 4: Driving Power and dependence diagram

5. Results and discussions

ISM level basis analysis: Utilizing insights from professionals across ten cement manufacturing companies in India, an SSIM was developed to serve as the foundation for the ISM. The identified drivers are organized across eight hierarchical levels, as illustrated in Figure 3. A structural model was then constructed using ISM, highlighting key elements such as revenue generation from low-carbon products (BO2), as well as cost and emission reductions achieved through material substitution and improvements in operations (IF3, IF4) (Panjaitan et al., 2021; Benhelal et al., 2021; CSI/ECRA, 2017; Salas et al., 2016) and At the highest level, the driver 'new market opportunity (BO3) (Karttunen et al., 2021; Mathiyazhagan et al., 2014) was identified. Compared to other influencing factors, it has a relatively lower impact and provides less motivation for adopting climate change mitigation strategies within the Indian cement sector. Since these top-level drivers are heavily reliant on more fundamental, lower-level factors and contribute minimally to driving change, they require less strategic focus.

In the second iteration level, there were five drivers: Improving risk management (IF2) (Viswanadham, 2018; Busch & Hoffmann, 2007), enhanced brand image and corporate reputation (MP3) (Faisal et al., 2020; IPCC, 2014a), earn through emission reduction certification (BO1) (Kajaste & Hurme, 2016), green market competitive pressure (MP1) (Govindan & Hasanagic, 2018; Sullivan, 2010) and corporate social responsibility and ethical responsibility (IF6) (Kudtarkar & Shah, 2018; Hoffman, 2007). These five drivers offer a moderate level of influence in encouraging the adoption of climate change mitigation strategies within India's cement manufacturing sector, especially when compared to those at the preceding level.

In the third iteration level, Investment opportunities (BO4) (Pee et al., 2018; CDP India, 2013) and opportunities to modify products and processes (BO5) (Cadez & Czerny, 2016) drivers exert more pressure than above two top levels.

Next, fourth level of iteration, again there were five drivers: Technological change and innovation (BR5) (Feiz et al., 2015), investor demand (SP1) (Hossain et al., 2020; Lash & Wellington, 2007), top management involvement and commitment to emission reduction (IF1) (Long, 2013), environmental awareness of employee (IF5) (Karttunen et al., 2021; Govindarajulu & Daily, 2004) and supplier engagement (SP2) (Karttunen et al., 2021; Lash & Wellington, 2007).

Fifth level of iteration, Energy conservation act 2001 and energy auditing (GR3) (MoEF&CC, 2015a), PAT Scheme by BEE (GR4) (BEE, 2017a) and environmental regulation compliance (GR1) (Habert et al., 2020; Zhu et al., 2008) drivers appear. In this level, it is inferred that government regulation and policies for emission reduction and energy conservation are driving the cement organization to mitigate climate change.

SEBI mandate business responsibility reporting (GR2) (SEBI, 2015), cut in subsidies and increased taxes on fossil fuels (BR1) (CDP India, 2015), fluctuating raw material prices (BR2) (Gao et al., 2015) and high penalty for environmental pollution (GR5) (Mathiyazhagan et al., 2014) are four drivers appear in sixth level of iteration are more important than all of the previous iterations.

Again, in the seventh level of iteration four drivers are appear which are demand for low carbon Products (MP2) (CDP India, 2013), media and NGOs attention to climate change issue (MP4) (Kim, 2007), local public or societal pressure for emission reduction (SP3) (Hossain et al., 2020; Lee & Kim, 2009) and demand from customers in environmental protection requirements (SP5) (Wu et al., 2012). In this level, it is inferred that pressure from NGOs, media, local public and customers for emission reduction plays a significant role to opt climate change mitigation strategies among Indian cement industries.

At final level iteration, there are three drivers: Physical threat to assets and supply chain disruption (BR4) (Viswanadham, 2018; Kolk & Pinkse, 2004), litigation risk because high emission profile of the company (BR3) (Balsara et al., 2020, Lash & Wellington, 2007) and health issue (SP4) (Miller & Moore, 2020; World Bank, 2013). These drivers are crucial in facilitating the implementation of climate change mitigation strategies in the Indian cement industry. Positioned at the lowest level, they possess strong driving power and minimal dependence on other factors, thereby influencing all other drivers in the hierarchy.

MICMAC basis analysis: The driver power-dependence diagram (Figure 4) reveals that there are no autonomous drivers present in Quadrant I. Such variables typically exhibit low driving power and low dependence, meaning they have minimal impact on the overall system (Diabat et al., 2014). The lack of autonomous drivers in this analysis suggests that each of the identified drivers plays a role in shaping climate change mitigation strategies within India's cement manufacturing sector, highlighting the need for management to consider all of them carefully.

According to the driver power-dependence diagram, the dependent drivers located in Quadrant II occupy the upper levels of the ISM hierarchy. These drivers exhibit high dependence but limited driving influence, suggesting they should be addressed with lower priority, as their effectiveness relies heavily on resolving the drivers they are linked to. For instance, emission and cost reductions through material substitution and operational enhancements (IF3 and IF4) are strongly influenced by the availability and affordability of alternative materials such as fly ash and granulated blast furnace (Benhelal et al., 2021; CSI/ECRA, 2017, Planning Commission, 2011), improving risk management (IF2) (IPCC, 2014b), generate stream of revenue from low carbon product (BO2), investment opportunity (BO4) (Pee et al., 2018; Vickers et al., 2009), opportunity to modify product and process (BO5) (Dunuweera & Rajapakse, 2018; Jeswani et al., 2008) earn through emission reduction certification (BO1) (Bhandari & Shrimali, 2018b, Okereke, 2007) and enhanced brand image and corporate reputation (MP3) (Faisal et al., 2020; Kolk & Pinkse, 2004). All these dependent drivers depend on other lower level drivers like technological change and innovation (BR5), top management involvement (IF1), investor demand for emission reduction (SP1) etc.

Next, the linkage drivers are placed in quadrant III of driver power and dependence figure having strong drive power as well as strong dependence and are placed in between the surface and bottom layers of ISM model. These linkage drivers are technological change and innovation (BR5) (Benhelal et al., 2021), investor demand (SP1) (Hossain et al., 2020), supplier engagement (SP2) (Long, 2013), green market competitive pressure (MP1) (Govindan & Hasanagic, 2018), new market opportunity (BO3) (Karttunen et al., 2021), top management involvement and commitment (IF1) (Sullivan, 2010), environmental awareness of employee (IF5) (CDP India, 2014) corporate social responsibility (IF6) (IPCC, 2014a), energy conservation act 2001 (GR3) (Planning Commission, 2014), PAT Scheme by BEE (GR4) (MoEF, 2012), environmental regulation compliance (GR1) (CDP India, 2014) and SEBI mandate business responsibility reporting (GR2) (SEBI, 2015). GR3, GR4, and GR1 having the same dependence of 15 and appear on the axis between quadrant III and IV. These linkage drivers are unstable and can change if there are changes in the driving variables hence they can disturb the whole system (Qureshi et al., 2008).

In conclusion, the independent or driving factors found in Quadrant IV are positioned at the foundational levels of the ISM model (Figure 3), characterized by high driving power and minimal dependence on other variables. As such, they can be considered the root causes influencing all other drivers. Examples of these key drivers include the reduction of subsidies and the imposition of higher taxes on fossil fuels (BR1) (MoEF&CC, 2015b), fluctuating raw material prices (BR2) (Okereke, 2007), physical threat to assets and supply chain disruption (BR4) (Viswanadham, 2018b), litigation risk (BR3) (Balsara et al., 2020), high penalty for environmental pollution (GR5) (Mathiyazhagan & Haq, 2013), demand for low carbon Products (MP2) (IEA, 2013), media and NGOs attention (MP4) (Sullivan, 2010), local public or societal pressure (SP3) (Karttunen et al., 2021), demand from customers in environmental protection requirements (SP5) (Mathiyazhagan & Haq, 2013) and health issue (SP4) (Verma et al., 2018), (IL&FS Ecosmart Limited, 2010). Greater managerial focus should be directed toward these independent drivers in Quadrant IV, as they serve as the foundation upon which all other climate change mitigation drivers rely.

6. Managerial and practical implications of research

This study highlights the role of key driving factors in facilitating the adoption of climate change mitigation strategies within the Indian cement industry, while also examining the interconnections among these factors. It identifies thirty specific sub-factors drawn from major cement companies. These elements provide valuable insights for management, enabling more effective implementation of climate strategies. As a result, greenhouse gas emissions (GHGEs) can be reduced alongside the production of low-carbon, cost-effective cement, conservation of natural resources and minerals, and a reduction in industrial waste. Collectively, these efforts contribute to enhancing the overall performance of Indian cement companies, strengthening their global competitiveness, and fostering a sustainable, green business image.

Importantly, each of these drivers holds a distinct level of relevance at different stages of strategy implementation. Therefore, managers should adopt a balanced approach that recognizes the influence of all drivers, ensuring none are overlooked in the implementation process. High-priority drivers contribute significantly to improving tactical and operational outcomes, while those identified by their driving power and dependence support long-term strategic objectives. Strategic improvements can also be achieved by continually enhancing the interconnected driving factors.

The case study employing the ISM methodology offers managers a systematic approach to analyze and prioritize drivers based on their significance, while also identifying the relationships among them to understand how one factor influences others and impacts the overall system. Tools such as the ISM digraph and MICMAC analysis assist managers in strategically distributing resources across these drivers to optimize outcomes within the Indian cement industry.

Ultimately, this study serves as a foundational benchmark for ranking the drivers involved in adopting climate change mitigation strategies. The findings provide valuable guidance for managers in developing effective frameworks and adaptable decision-making processes aimed at implementing low-carbon practices in an environmentally sustainable manner, thereby paving the way toward achieving economic and social sustainability within India's cement manufacturing sector.

7. Conclusions, limitations, and scope of future work

The findings of this research assist in pinpointing and prioritizing key drivers for adopting climate change mitigation strategies in the Indian context, supported by insights from industry experts. Cement industry management can leverage this framework to identify crucial factors that help reduce greenhouse gas emissions, thereby promoting the production of low-carbon cement at an affordable cost and enhancing their green corporate reputation. However, from the industry's perspective, it is challenging to treat all drivers with equal emphasis. Hence, using the ISM approach enables organizations to determine which drivers should be prioritized when implementing climate change mitigation strategies in Indian cement companies.

The study identifies thirty drivers related to climate change mitigation practices. By examining the relationships among these drivers, the framework proves valuable in clarifying how the drivers interact with each other.

The MICMAC analysis ranking of driving factors based on their driving power reveals that litigation risk (BR3), health concerns (SP4), physical threats to assets and supply chain disruptions (BR4), demand for low-carbon products (MP2), attention from media and NGOs (MP4), pressure from local communities or society (SP3), customer demands for environmental protection (SP5), severe penalties for environmental pollution (GR5), reduction of subsidies and increased fossil fuel taxes (BR1), and fluctuating raw material prices (BR2) are the primary independent factors. These factors possess strong driving power but low dependence, placing them at the lower levels of the ISM model. Among these, BR3, SP4, and BR4 stand out as the most influential drivers, holding the highest driving power in the final reachability matrix (Table 13), occupying top positions in the MICMAC analysis (Figure 4), and situated at the bottom in the ISM hierarchy (Figure 3).

Conversely, factors such as generating revenue streams from low-carbon products (BO2), reducing emissions and costs through material substitution and operational improvements (IF4 and IF3), enhancing risk management (IF2), improving brand image and corporate reputation (MP3), earning through emission reduction certifications (BO1), opportunities to modify products and processes (BO5), and investment prospects (BO4) are identified as dependent drivers in the MICMAC analysis. These drivers exhibit weak driving power but strong dependence on others and are located at the upper levels of the ISM model, indicating they are influenced by other factors. It is advisable for Indian cement industries to carefully analyze and acknowledge these dependent drivers, given their reliance on other factors during the implementation of climate change mitigation strategies.

Factors including new market opportunities (BO3), green market competitive pressure (MP1), corporate social responsibility and ethical obligations (IF6), investor demands (SP1), employee environmental awareness (IF5), supplier engagement (SP2), top management commitment (IF1), technological innovation (BR5), SEBI's business responsibility reporting mandate (GR2), the Energy Conservation Act 2001 and energy auditing (GR3), the PAT Scheme by BEE (GR4), and compliance with environmental regulations (GR1) fall within the linkage quadrant. These factors exhibit both high driving power and high dependence, meaning they significantly influence and are simultaneously influenced by other criteria, making them unstable and requiring careful attention. Positioned between independent and dependent drivers in the hierarchy, Indian cement manufacturers should continuously monitor these factors throughout all stages of implementing climate change mitigation strategies.

Although the findings are valuable, this study has certain limitations. The model considers thirty drivers across six categories, based on extensive literature review and expert discussions; however, the scope remains somewhat limited. Future research could explore additional drivers. This study was conducted as a case study involving only ten cement companies, so expanding data collection to include more industries could enhance the findings. Additionally, identifying critical drivers in other emission-intensive sectors for climate strategy implementation could be pursued.

The current research applies the ISM methodology to develop an interrelationship model, which has inherent limitations and heavily depends on expert judgment. Future work could validate the model using structural equation modeling (SEM), with ISM serving as the foundation for model development and SEM used for statistical testing. The proposed ISM framework could also be adapted for other emission- and energy-intensive industries within India or internationally.

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