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Drivers of Climate Change Mitigation Strategies in the Cement Industry: An Empirical Study in India

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Abstract: Production of cement is among the high-emission and most energy-intensive industrial processes worldwide. India ranks as the second-largest consumer and producer of cement globally. Within the country, the cement sector is the second-largest contributor to greenhouse gas (GHG) emissions and the third-highest consumer of energy. These ongoing emissions significantly contribute to severe climate change. As a result, the cement industry faces increasing pressure to lower its GHG output. The purpose of this study is to investigate the major variables affecting climate change mitigation initiatives in the cement industry in India. To achieve this, the Analytical Hierarchy Process (AHP) is employed to identify and rank the main drivers behind these mitigation strategies. A systematic assessment of these factors according to their relative importance is made possible by the AHP technique.The findings of the study identified thirty key factors influencing climate change mitigation strategies and practices. The AHP analysis revealed that the most critical drivers, based on global rankings, include litigation risks, physical threats to infrastructure and supply chains, public health concerns, increasing demand for low-carbon products, customer expectations regarding environmental responsibility, scrutiny from media and societal pressure and non-governmental organizations to reduce emissions.

Keywords: *Climate Change, Greenhouse Gas Emissions, Cement, AHP.*

1. Introduction

The increasing amounts of greenhouse gases (GHGs) in the atmosphere, which cause global warming, show how human activity has a major impact on climate change (Balsara et al., 2021). Between 1951 and 2010, GHG emissions were likely responsible for a global average surface temperature increase ranging from 0.5°C to 1.3°C. Ongoing emissions are expected to intensify warming and impact the Earth's climate system (IPCC, 2014a).

Mitigating climate change and lowering the dangers associated with it require significant and long-term reductions in greenhouse gas emissions (GHGEs) (Balsara et al., 2020; IPCC, 2014b). Global efforts to address climate change have gained momentum through key international agreements such as the The Copenhagen Conference (Bodansky, 2010), the Kyoto Protocol (UNFCCC, 1997), and more recently, the Paris Agreement (UNFCCC, 2015), which emphasizes shared responsibility among nations to combat climate change (Dimitrov, 2016; Rogelj et al., 2016). Beyond international frameworks, increasing pressure from regulatory bodies, consumers, investors, and society at large has intensified the push for reductions in GHGEs (Karttunen et al., 2021; Hossain et al., 2020).

The term "mitigation" refers to "human intervention to reduce the sources or enhance the sinks of GHGs" in the context of climate change. The United Nations Framework Convention on Climate Change's (UNFCCC) goal is furthered via mitigation. "To stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" is the ultimate goal of this convention. In order to support sustainable economic development, such a level should be reached in a time frame that permits ecosystems to naturally

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adjust to climate change. Since mitigation lessens the likelihood of severe events and the anticipated effects of climate change, it is a crucial part of larger climate policy (IPCC, 2014a).

Drivers are factors that can compel companies to engage in climate-related actions, even if such actions were not part of their initial plans (Okereke, 2007). Within the framework of climate policy, these drivers are seen as processes, behaviors, or mechanisms that create favorable conditions or incentives for addressing climate change (Reckien et al., 2015). In industrial settings, a driver is essentially any element that encourages or motivates the implementation of strategies aimed at reducing greenhouse gas emissions.

Among the worldwide energy consumption, industries use around 40% and it contributes around 37% of global GHGEs in most countries, CO_2 emissions (CO_2Es) contribute more than 90% of GHGEs from the industrial sector (Balsara et al., 2021). Reducing greenhouse gas emissions is especially important in highly emission and energy-intensive industries such as aluminium, chemicals and petrochemicals, iron and steel, pulp and paper and cement (Balsara et al., 2019). Globally, these sectors currently contribute about 77% of total direct CO_2Es from industry and in India, they contribute about 56% of industrial energy consumption and 82% of direct CO_2Es (Trudeau et al., 2011).

Over the past hundred years, concrete made with cement has become the most widely produced material globally by volume and is second only to water in terms of overall consumption (Habert et al., 2020). Cement production is also recognized as the most energy-intensive industrial processes (Poudyal & Adhikari, 2021). Among industrial sectors, it is a significant contributor to human-caused carbon dioxide emissions (Miller & Moore, 2020; Feiz et al., 2015). An estimated 5–7% of global anthropogenic CO_2 emissions are thought to be caused by the manufacture of cement (Liu et al., 2018; Kajaste & Hurme, 2016; Ishak & Hashim, 2015).

Given these factors, the following are the study's aims:

- To identify the main variables influencing climate change mitigation tactics in the cement industry.
- To evaluate each identified driver's importance and relative weight in supporting efforts to mitigate climate change.
- To provide actionable insights and recommendations for industry managers and practitioners based on the study's findings.

Implementing all the potential drivers of mitigation strategies at once to control and reduce GHG emissions in the cement industry is not feasible. Hence, it is important for industries to prioritize certain key drivers that must be effectively managed to achieve meaningful emission reductions. This can be done by applying the Analytical Hierarchy Process (AHP) to systematically evaluate and select these critical factors. The present study was conducted across ten cement plants in India, seeking to improve environmental performance through the identification of workable and significant mitigation methods for climate change. A thorough survey, site visits, and discussions with professionals in the field served as the foundation for the conclusions.

The structure of this paper is organized as follows: Section 2 reviews relevant literature related to the study. Section 3 describes the methodology used. The research framework and its practical application are presented in Section 4. Section 5 discusses the results and analysis. Managerial and practical implications are addressed in Section 6. Finally, Section 7 concludes the paper by outlining the study’s limitations and suggesting directions for future research.

2. Literature review

Changes in climate patterns that are either directly or indirectly related to human activity, especially those that affect the composition of the global atmosphere, are defined as climate change under Article 1 of the UNFCCC (IPCC, 2014a). Mandal (2010) employed Data Envelopment Analysis (DEA) to assess energy efficiency in India's cement sector, considering both productive output and emissions. Similarly, Mandal & Madheswaran (2010) analyzed environmental performance using a joint production model that accommodates both desirable and undesirable outputs, utilizing DEA and directional distance functions. Ali et al. (2011) synthesized a broad spectrum of emission sources and mitigation approaches within the cement industry. Madlool et al. (2011) reviewed energy usage patterns and provided an overview of CO_2 reduction strategies, estimating payback periods and costs for energy-saving measures at various stages of production. Mandal & Madheswaran (2011) further explored energy efficiency in Indian cement companies using production theory frameworks. Hasanbeigi et al. (2012) identified emerging technologies in cement and concrete manufacturing, focusing on energy savings, emissions reduction, cost-effectiveness, and market adoption. Ke et al. (2012) used modeling techniques to project energy use and CO_2E trends in China's cement industry through 2030. Benhelal et al. (2013) evaluated global strategies for mitigating greenhouse gas emissions in the sector. In another study, Hasanbeigi et al. (2013) used a conservation supply curve to assess 23 energy efficiency interventions in China's cement sector, quantifying energy and emissions savings. (Madlool et al. (2013) conducted a comprehensive review of CO_2 reduction and energy efficiency technologies. Wang et al. (2013) analyzed emissions trajectories and influencing factors in Chinese cement production. Morrow et al. (2014) projected future demand and assessed potential energy efficiency gains using a bottom-up modeling approach for India's cement sector. Feiz et al. (2015) proposed a framework for identifying and evaluating CO_2E mitigation strategies based on technical and organizational criteria. Gao et al. (2015) conducted a comparative analysis of CO_2E from multiple Chinese cement production lines. Ishak & Hashim (2015) reviewed CO_2E point sources and outlined mitigation strategies for all stages of cement production. Choudhary et al. (2015) and Bi et al. (2015) incorporated carbon metrics into supply chain decision models and innovation risk analysis, respectively. Singh et al. (2015) used cloud technology to manage beef supply chain emissions. Subramaniam et al. (2015) examined how Australian firms integrate carbon risks into enterprise risk frameworks. Talbot & Boiral (2015) analyzed how Canadian firms use impression management to address climate impacts. Wahyuni & Ratnatunga (2015) reviewed carbon strategies in the Australian energy sector. Cao et al. (2016) calculated emission factors based on a wide-ranging dataset of Chinese cement facilities. Gao et al. (2016) examined resource use and environmental impacts using material flow analysis to optimize process efficiency. Kajaste & Hurme (2016) evaluated various cement production alternatives through a climate impact management matrix, focusing on cradle-to-gate emissions. Salas et al. (2016) reviewed the environmental implications of cement production, emphasizing life cycle assessment methods and mitigation alternatives. Cadez & Czerny (2016) outlined mitigation strategies among EU firms. Long & Young (2016) developed a framework on corporate climate mitigation efforts using UK data. Soni et al. (2017) studied energy intensity across five major Indian industries, identifying ways to lower consumption. Mao et al. (2017) assessed how integrating low-carbon strategies influences both environmental and financial performance in Chinese manufacturing sectors. J. Liu et al. (2018) used spatial-temporal analysis to investigate national and regional drivers of energy use and emissions in China's cement industry between 2005 and 2012. Habert et al. (2020) reviewed technologies and strategies expected to significantly reduce emissions in the near and long term. Hossain et al. (2020) examined energy management approaches in Bangladeshi cement plants. Miller and Moore (2020) explored how emissions reductions could align with improvements in local air quality, offering insights into policy feasibility. Benhelal et al. (2021) highlighted obstacles to effective implementation of emission control strategies, proposing actionable solutions. Lastly, Karttunen et al. (2021) investigated the factors influencing environmental innovation adoption among both new and established firms in the cement sector.

Table 1: Drivers of the cement industry's climate change mitigation measures, along with a description.

Sub Criteria	Description	References
BUSINESS RISK		
Cut in subsidies and increased taxes on fossil fuels	The government has shifted its policy approach by reducing fossil fuel subsidies and imposing higher taxes, effectively transitioning from a system that supported	Hossain et al., 2020; Govindan & Hasanagic, 2018; Sa et al., 2017; CDP India, 2015; MoEF&CC, 2015b

	carbon emissions to one that penalizes them	
Fluctuating raw material prices	Variations in energy and raw material prices can significantly impact both operational expenses and capital investment, ultimately reducing the present value of expected profits	Gupta et al., 2021; Gao et al., 2016; Long, 2013; Sullivan, 2010
Litigation risk because of high emission profile of the company	Organizations that produce substantial carbon emissions may face legal actions alleging negligence, public nuisance, or trespass	Balsara et al., 2020; Long, 2013; Sullivan, 2010
Physical threat to assets and supply chain disruption	Extreme weather events can intermittently damage production sites, disrupt infrastructure, and interrupt supply chains	Viswanadham, 2018; Sullivan, 2010; Busch & Hoffmann, 2007
Technological change and innovation	It reflects the strategies companies use to transition away from dependence on fossil fuels and pursue substantial emissions reductions	Benhelal et al., 2021; Miller & Moore, 2020; J. Liu et al., 2018
ROLE OF GOVERNMENT REGULATIONS AND POLICIES		
Environmental regulation compliance	Compliance with regulations is key to promoting essential environmental progress, particularly for businesses with greater environmental exposure, and encourages the development of cleaner technologies through innovation	Karttunen et al., 2021; Hossain et al., 2020; Habert et al., 2020; Kumar & Dixit, 2018b; Gupta & Barua, 2017; Bossle et al., 2016
SEBI mandate Business Responsibility Reporting (BRR)	A business's actions pertaining to environmental, social, and governance (ESG) issues are detailed in its Business Responsibility Report (BRR). For the top 500 businesses listed on the BSE and NSE by market capitalization, it is a required disclosure.	Agarwal, 2018; SEBI, 2017; SEBI, 2015
Energy Conservation (EC) Act 2001 and energy auditing by accredited BEE-certified Energy Auditor/Manager	Promoting energy efficiency, aiding conservation initiatives, and addressing associated and incidental issues are the goals of the Energy Conservation Act of 2001.	Benhelal et al., 2021; Hossain et al., 2020; MoEF&CC, 2015a; MoEF&CC, 2015b
PAT Scheme by BEE, internal price on carbon emission	Perform Achieve and Trade (PAT) is a market-driven approach that improves cost efficiency by certifying surplus energy savings in energy-intensive sectors, allowing these savings to be traded. This mechanism serves as an important strategy to assign an internal carbon price, helping organizations manage carbon-related risks and opportunities	Bhandari & Shrimali, 2018; BEE, 2017a; BEE, 2017b; CDP India, 2015; MoEF&CC, 2015a; MoEF&CC, 2015b
High penalty for environmental pollution	Enforce stringent fines on industries for causing environmental pollution	Benhelal et al., 2021; Miller & Moore, 2020; Mathiyazhagan et al., 2014
INTERNAL FACTORS		
Top management involvement and commitment to	Senior leadership within organizations has pledged to attain carbon neutrality or substantially reduce their overall greenhouse	Gupta et al., 2021; Govindan & Hasanagic, 2018; Sa et al., 2017; Bossle et al., 2016

emission reduction	gas emissions over the long term	
Improving risk management	Addressing climate change can be viewed as a risk management process that presents both challenges and potential opportunities amid uncertainties	Viswanadham, 2018; Abadie et al., 2017; IPCC, 2014c
Cost reduction through material substitution and operational improvement	Cost savings can be achieved through various operational measures, such as replacing a portion of fossil fuels with alternative or renewable energy sources, and substituting clinker with materials like fly ash or blast furnace slag. Additionally, improving energy efficiency, optimizing resource use, and reducing waste are key operational strategies	Panjaitan et al., 2021; Habert et al., 2020; J. Liu et al., 2018b; Kumar & Rahman, 2017; Kajaste & Hurme, 2016a; Salas et al., 2016
Emission reduction through material substitution and operational improvement	Reducing emissions can be achieved by substituting materials, such as replacing raw materials or clinker, along with operational enhancements like improving energy efficiency, maintaining good housekeeping practices, regular maintenance, and 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
Environmental Awareness of Employee	Because it broadens their knowledge of connected topics, employee environmental awareness is essential to mitigating climate change.	Karttunen et al., 2021; Hossain et al., 2020; Bossle et al., 2016; CDP India, 2015
Corporate social responsibility (CSR) and ethical responsibility	CSR and ethical obligations require organizations to lower greenhouse gas emissions as part of their broader commitment to sustainable development, going beyond mere profit generation	Kudtarkar & Shah, 2018; Huszlak, 2017; MoEF&CC, 2015b; IPCC, 2014a; Mathiyazhagan et al., 2014; Long, 2013
MARKET PRESSURE		
Greenmarket competitive pressure	The market is increasingly focused on low-carbon products, creating challenges for companies to distinguish their offerings from those of competitors	Govindan & Hasanagic, 2018; CDP India, 2013; Long, 2013
Demand for low carbon Products	Shifts in consumer demand are driven by rising environmental awareness and the growth of pro-environmental behaviors. Customers are increasingly open to low-carbon products, while governments promote sustainable consumption and lifestyles through education and awareness campaigns	Karttunen et al., 2021; Govindan & Hasanagic, 2018
Enhanced brand image and corporate reputation/improved public image	Businesses can transform reputational risks into opportunities by adopting practices that reduce their overall emissions	Faisal et al., 2020; IPCC, 2014a; CDP India, 2013; Long, 2013; Sullivan, 2010
Media and NGOs attention to climate change issue	In addition to government, media and environmental NGOs are key sources of external pressure	Karttunen et al., 2021; Hossain et al., 2020; Mathiyazhagan et al., 2014; Long, 2013
STAKEHOLDER ENGAGEMENT/PRESSURE		
Investor demand	Investors are increasingly requesting greater transparency from companies, as they encounter financial risks both from the direct	Hossain et al., 2020; CDP India, 2015; Long, 2013

	impacts of climate change and from indirect factors like the costs associated with reducing emissions	
Supplier engagement	Because some organizations do not track their suppliers' emissions, suppliers often transfer rising carbon-related costs to them	Karttunen et al., 2021; Bossle et al., 2016
Local public or societal pressure for emission reduction	Efforts to mitigate climate change are also heavily influenced by social and community demands to reduce emissions.	Karttunen et al., 2021; Hossain et al., 2020; Bossle et al., 2016
Health issue	Uncontrolled NOx emissions from alternative fuels, along with dust produced by cement plants, can negatively impact respiratory health. These pollutants may also reduce visibility, cause irritation or deposits in the eyes, ears, and nasal passages, and potentially harm the skin or mucous membranes through chemical or physical effects	Benhelal et al., 2021; Miller & Moore, 2020; Habert et al., 2020; Govindan & Hasanagic, 2018; Verma et al., 2018; CPCB, 2016; Diabat et al., 2014
Demand from customers in environmental protection requirements.	Customer demand for environmental protection plays a key role in driving the development of sustainable and eco-friendly products	Karttunen et al., 2021; Hossain et al., 2020; Bossle et al., 2016
BUSINESS OPPORTUNITY		
Earn through emission reduction certification (like CER) through carbon reduction projects (CDM/PAT)	One effective way to internally offset greenhouse gas emissions is through an internal emission trading system. This allows companies to reduce emissions by collaborating with other businesses or governments, either by exchanging emission credits or partnering on offset projects	Bhandari & Shrimali, 2018; BEE, 2017a; Cadez & Czerny, 2016; Kajaste & Hurme, 2016a; IPCC, 2014a
Generate stream of revenue from low-carbon product	The potential to create ongoing revenue through the introduction of new low-carbon products	Industry expert’s opinion
New market opportunity	Gaining a competitive edge in the market by offering distinct low-carbon products opens up new business opportunities	Karttunen et al., 2021; Mathiyazhagan et al., 2014; Long, 2013; Vickers et al., 2009
Investment opportunity	Opportunities for investment arise in building low-carbon infrastructure and enhancing productive capacity	Pee et al., 2018; CDP India, 2013; Vickers et al., 2009
Opportunity to modify product and process	Existing organizations have the chance to adapt their processes and offerings toward greater sustainability, which can lead to cost savings, reduced emissions, and improved profit margins through enhanced energy efficiency and resource conservation	Dunuweera & Rajapakse, 2018; Cadez & Czerny, 2016; Long, 2013

2.1. Research gaps and highlights

To reduce GHG emissions in companies and enable the manufacture of sustainable and low-carbon products, mitigation measures are essential. Climate change mitigation strategies in carbon-intensive industries have been the subject of numerous studies. (Karttunen et al., 2021; Habert et al., 2020; Govindan & Hasanagic, 2018; Sa et al., 2017; Singh et al., 2015). While these works primarily focus on reducing carbon footprints in various sectors or products, only a limited number address the motivating factors driving the adoption of such mitigation measures. Some research has explored the drivers of carbon management implementation (Sa et al., 2017; Liu, 2012), though these tend to concentrate on industries with lower carbon intensity.

Likewise, a great deal of study has been done on the factors that influence the adoption of green supply chain management (GSCM) in various industries (Somsuk & Laosirihongthong, 2017; Dubey et al., 2015; Tachizawa et al., 2015). However, these studies often cover a broad range of industries, with relatively few focusing specifically on emission-intensive sectors or particular high-emission industries.

The cement manufacturing sector is recognized as highly carbon-intensive. Although several studies have been conducted concerning cement production, the majority have focused on developed countries (Karttunen et al., 2021; Benhelal et al., 2021; Miller & Moore, 2020; Raffetti et al., 2019; Ramsheva & Remmen, 2018; Georgiopoulou & Lyberatos, 2018; Matar & Elshurafa, 2017; Cao et al., 2016; Ishak & Hashim, 2015). Despite being the world's second-largest producer and consumer of cement, there is a considerable dearth of study on the Indian cement business (Soni et al., 2017; Kajaste & Hurme, 2016; Morrow et al., 2014).

Furthermore, while earlier studies on the energy consumption and greenhouse gas emissions of the cement industry have employed a variety of approaches, very few have focused on determining the primary forces underlying efforts to mitigate climate change in such energy- and emission-intensive sectors. This study offers new insights into how to prioritize actions in the cement manufacturing industry by using the AHP method for the first time to assess and rank the relative importance of common drivers influencing climate change mitigation strategies.

3. Solution methodology

The Analytic Hierarchy Process (AHP) method, which uses expert judgment to rank various elements according to their significance, is used in this study. This strategy gives cement producers the chance to quickly enhance their performance. AHP is well known for being a useful method for setting priorities for many factors (Gandhi et al., 2016; Najmi & Makui, 2010).

3.1 Analytical Hierarchy Process (AHP)

An established and popular instrument for mathematically organized decision-making in a variety of corporate contexts is AHP. As indicated in Table 2, the AHP approach is applied in a variety of fields.

Table 2: Summary of the use of AHP analysis in various areas

S. No.	Authors	Area
1.	Lin & Kou, 2021	Rank the alternatives
2.	Lyu et al., 2020	Risk assessment
3.	Dos Santos et al., 2019	Decision making for sustainable development
4.	Gnanavelbabu & Arunagiri, 2018	Ranking of MUDA
5.	Zyoud & Fuchs-Hanusch, 2017	Bibliometric-based survey
6.	R. P. Singh & Nachtnebel, 2016	Reinforcement of hydropower strategy
7.	Zak & Kruszyński, 2015	Urban Transportation Projects

Researchers and practitioners have not generally embraced other multi-criteria decision-making (MCDM) techniques like ELECTRE and TOPSIS. While the Analytic Network Process (ANP) entails a more intricate process with multiple pairwise comparisons that can be difficult for individuals without experience, the Analytic Hierarchy Process

(AHP) provides a simpler, linear evaluation (Mathiyazhagan et al., 2014).

Developed by Thomas L. Saaty in 1980, AHP is a widely recognized method for addressing MCDM problems that include both quantitative and qualitative criteria. The technique utilizes Saaty's 1-to-9 scale (see Table 3), enabling experts to express their preferences effectively. AHP's primary objective is to assign relative importance weights to various factors and sub-factors. For more in-depth information on AHP, refer to (Saaty, 1980) and Borade et al. (2013).

Table 3: Scores' importance in AHP

Score	Definition
1	Both elements are equally significant
3	One element that is somewhat more significant than another
5	One element is more significant than another
7	One element is far more significant than another
9	One element is more significant than another
2,4,6,8	Intermediate value between two adjacent judgments

(Saaty, 1980)

Three steps are needed for AHP: **Step 1:** involves determining the factors that influence the cement manufacturing industry's climate change mitigation strategies and creating a hierarchy prioritization model.

Step 2: involves creating a questionnaire and using it to gather expert opinions from various cement industries in India.

Step 3: involves normalizing weights for each major factor and sub-factor.

Take a look at the consistency ratio. Inconsistencies in the pairwise evaluations are measured by the CR. The following procedures are used to calculate the consistency ratio:

1. Determine each matrix of order n's relative weights, eigenvector, and λ Max.

2. Use the following formulas to get the consistency index (CI) for any matrix of order n:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \qquad (1)$$

The CR was then computed using the following formulas:

$$CR = \frac{CI}{RI} \qquad (2)$$

The result is regarded as consistent if the CR is less than 0.1 (Govindan et al., 2014; Chan et al., 2006).

Table 4 provides the random consistency index (RI) value based on the value of n.

Table 4: Random consistency index (RI)

Order of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0.00	0.00	0.52	0.89	1.11	1.25	1.32	1.41	1.45	1.49

(Saaty, 1980)

4. Proposed research framework and its application

There are two primary phases to the research framework created to evaluate the driving factors influencing climate change mitigation tactics in the Indian cement sector using AHP.

Phase I: Using input from industry experts and an analysis of the body of existing literature, identify the main driving factors influencing the mitigation of climate change in the cement industries of India.

Phase II: Application of the AHP method to rank and prioritize these identified drivers according to their significance.

Phase I: Data gathering and identification of common drivers of the cement industry's solutions to mitigate climate change.

Based on a review of the literature and discussions with industry experts, phase I started by identifying 30 major factors associated with climate change mitigation methods in the cement sector, as shown in Table 1. Over the course of two months, from June to July 2019, survey questionnaires were individually delivered to officials involved in the manufacturing process of ten cement businesses in India. Purposive snowball sampling was used to select respondents in order to guarantee that they could supply accurate and pertinent information (Kabra et al., 2015; Raju & Becker, 2013). Given their crucial role in strategic decision-making, middle and senior level engineers and managers with a range of responsibilities were specifically addressed (Carter et al., 1998). Each of these professionals has worked in the industry for more than ten years, giving them substantial industrial experience. Table 5 provides information about the jobs, departments, experience, and plant capacity of the respondents.

Table 5: Position and department of the respondent, experience, and production capacity of the corresponding plant

Respondent	Respondent's Position, Department	Production capacity of Respective industry in million tonnes per annum (MTPA)	Respondents' Experience in years
1	Ex-Whole time director	N.A.	35
2	Process & Production Head	7 (Two unit)	26
3	Sr. Manager Project	3	25
4	Sr. Manager, Production	2.72 (Two Unit)	24
5	Sr. GM, Mechanical	3	23
6	DGM, Grinding	5 (Four Units)	21
7	DGM, Process	9 (Four Units)	17
8	Sr. Engineer, Production	10 (Four Units)	14
9	Sr. Engineer, Mechanical	3	13
10	Sr. Engineer, process	13 (6 units)	12

The purpose of the questionnaire was to collect professional viewpoints on the cement sector. Each participant received a thorough explanation of the study's goals and advantages prior to data collection. Then, using the language scale shown in Table 3, experts were asked to assess the common drivers of climate change mitigation efforts in the cement industry.

Business Risk (BR), Government Regulations and Policies (GR), Internal Factors (IF), Market Pressure (MP), Stakeholder Pressure (SP), and Business Opportunities (BO) were the six primary categories into which the 30 drivers that were found were then divided. The significant linkages between the various drivers of mitigation strategies served as the basis for this classification.

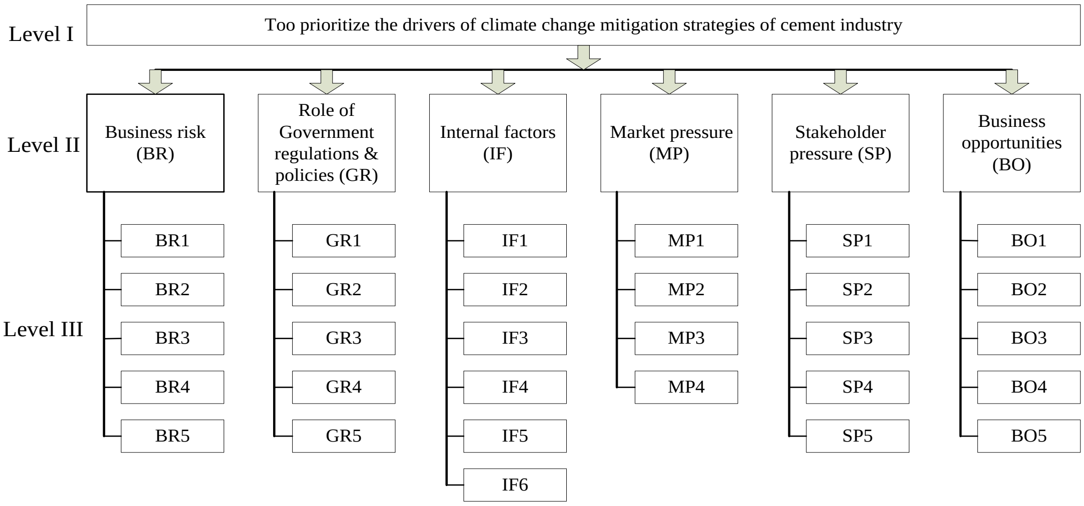

Figure 1: The common drivers of the cement industries' climate change mitigation measures in India are arranged hierarchically

Phase II: Applying the AHP technique to assess the relative importance of the common drivers of climate change mitigation solutions in the cement sector.

The detected drivers are ranked according to their relative importance using the AHP technique. As shown in Figure 1, a hierarchical decision structure with three levels is developed to solve the issue: the overall goal (Level I), important factors (Level II), and sub-factors (Level III).

Using Saaty's scale, each expert offers pairwise comparison matrices for the primary factors and their corresponding sub-factors. The geometric mean method is used to aggregate the opinions of several experts and determine the final factor rankings (Mangla et al., 2016). The key factors' pairwise comparison matrix is shown in Table 6, and the associated ranks and computed weights for these factors are shown in Table 7.

Table 6: Evaluation matrix for the primary group factors, pairwise

	BR	GR	IF	MP	SP	BO
BR	1	5.2811	7.68586	4.32761	2.25869	6.85042
GR	0.1893545	1	4.12892	0.3316	0.2419	2.25869
IF	0.1301091	0.24219	1	0.20246	0.16252	0.51459
MP	0.2310744	3.01568	4.93925	1	0.48836	4.15565
SP	0.4427345	4.13394	6.15309	2.04767	1	5.05059
BO	0.1459765	0.44273	1.94329	0.24064	0.198	1

Additionally, the calculated Eigen values and Eigen vectors are less than 0.10 and are as follows: Consistency index, C.I. = 0.09661, Consistency ratio, C.R. = 0.07791, and Eigen value (maximum), λ_{max} = 6.48303.

Table 7: The primary elements' proportionate rankings and respective importance weights

Main factors	Ranks	Relative importance weights

Business Risk (BR)	1	0.42244
Stakeholder pressure (SP)	2	0.24562
Market pressure (MP)	3	0.15955
Role of government regulations and policies (GR)	4	0.08821
Business opportunities (BO)	5	0.05004
Internal factors (IF)	6	0.03414

The proportionate ranks and relative relevance weights for each sub-factor are also shown in Table 8. As shown in Table 8, the relative importance weights of the sub-factors are multiplied by the importance weights of the main factors that they are related with to get their global weights and overall ranks. The reliability of the judgments is ensured by the consistency ratio (C.R.) for all major components and sub-factors being below the permissible threshold of 0.10.

Table 8: Ranking of the key factors and supporting factors of Indian cement industries' climate change mitigation plans

Main Factor	Relative Weights	Sub-factors	Relative Weights	Relative Rank	CI	CR	Global Weights	Global rank
BR	0.42244	BR1	0.09081	3	0.1066	0.09603	0.03836	8
		BR2	0.06464	4			0.02731	10
		BR3	0.52231	1			0.22064	1
		BR4	0.27809	2			0.11748	2
		BR5	0.04414	5			0.01865	13
GR	0.08821	GR1	0.15	3	0.09463	0.08525	0.01323	17
		GR2	0.37771	1			0.03332	9
		GR3	0.11952	4			0.01054	20
		GR4	0.06999	5			0.00617	24
		GR5	0.28278	2			0.02494	11
IF	0.03414	IF1	0.36448	1	0.12022	0.09695	0.01244	18
		IF2	0.13224	3			0.00451	25
		IF3	0.05928	5			0.00202	29
		IF4	0.04313	6			0.00147	30
		IF5	0.29565	2			0.01009	21
		IF6	0.10523	4			0.00359	27
MP	0.15955	MP1	0.09455	3	0.08637	0.09704	0.01509	14
		MP2	0.48653	1			0.07763	4
		MP3	0.0592	4			0.00945	22
		MP4	0.35972	2			0.05739	6

SP	0.24562	SP1	0.06104	4	0.10351	0.09325	0.01499	15
		SP2	0.04705	5			0.01156	19
		SP3	0.18988	3			0.04664	7
		SP4	0.45733	1			0.11233	3
		SP5	0.2447	2			0.0601	5
BO	0.05004	BO1	0.16282	3	0.0879	0.07919	0.00815	23
		BO2	0.08575	4			0.00429	26
		BO3	0.06446	5			0.00323	28
		BO4	0.39048	1			0.01954	12
		BO5	0.29649	2			0.01484	16

6. Implications of research on management and practice

The adoption of climate change mitigation techniques within the Indian cement industry is facilitated by several important drivers, which are highlighted in this study and prioritized appropriately. It identifies six primary factors and thirty related sub-factors relevant to large cement companies. These drivers serve as valuable tools for management to effectively implement climate strategies, helping to reduce greenhouse gas emissions while producing low-carbon, cost-effective cement, conserving natural resources, and minimizing waste. Additionally, embracing these strategies can enhance overall organizational performance, improve global market competitiveness, and foster a reputation as a sustainable, environmentally responsible business.

It is important to recognize that each driver holds a distinct level of significance during different phases of climate strategy implementation. Therefore, managers should approach these drivers holistically, ensuring no critical factor is overlooked during the execution process. The highest priority drivers are essential for improving tactical and operational success.

Managers can model and rank drivers according to their relative relevance in a methodical way by using the AHP method in this case study. When it comes to assigning weights and rankings to factors and sub-factors, AHP is renowned for its reliability.

Ultimately, this research serves as a foundational study in ranking drivers for adopting climate mitigation strategies. The findings provide valuable guidance for managers in designing effective frameworks and adaptable decision-making processes to promote low-carbon practices in an environmentally sustainable manner. This approach supports the broader goals of economic and social sustainability within India’s cement manufacturing sector.

7. Conclusions, restrictions, and future work scope

With the help of industry experts' insights, the study's findings help identify the major factors influencing the adoption of climate change mitigation solutions in the Indian context. Managers in the cement sector can use this study methodology to identify the key elements that lower greenhouse gas emissions. This will allow them to concentrate their efforts on these drivers, improving their company's green image and producing low-carbon cement at a reasonable cost. Treating every driver as equally significant, however, is difficult from an industry standpoint. Therefore, while putting climate change mitigation policies into action, it is crucial for enterprises to determine which elements require more attention. The AHP technique makes this work possible.

Notwithstanding the insightful information provided, this study has certain drawbacks. Developed through a thorough literature analysis and expert contacts, the model takes into account thirty drivers divided into six groups; nonetheless, these components might not be all-inclusive. The list of pertinent drivers may be expanded in future studies. Only ten cement businesses provided data for this study, indicating that data collection from a wider range of organizations could improve the validity of subsequent analyses. Another area of study is determining the key factors that influence the implementation of climate strategies in other carbon-intensive industries.

Despite its effectiveness, the AHP approach used in this study has inherent limitations because it mostly relies on the expert panel's opinions. Validating the results with methods like structural equation modeling (SEM) may be part of future research. Furthermore, the suggested AHP framework may be modified and used in other energy-intensive and emission-intensive industries in India or abroad.

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