Examining Sustainability Issues in Small-Scale Interlocking Cement Tile Manufacturing Firms: A Case Study using Integrated MCDM techniques

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Received: 14.04.2024 Revised : 13.05.2024 Accepted: 17.05.2024

ABSTRACT
This study examines the sustainability practices of small-scale Interlocking cement tile manufacturing firms in Karnataka, India. The purpose is to shed light on the economic, environmental, and social challenges and opportunities that shape sustainability in these small-scale industries. The research employs a robust framework that blends the Triple Bottom Line (TBL) approach with Multi-Criteria Decision-Making (MCDM) techniques. The methodology encompasses the development of a specialized survey instrument and the execution of comprehensive surveys across 70 distinct firms, further enhanced by the application of an integrated SWARA-TOPSIS MCDM approach. The findings underscore the key sustainability priorities for these small-scale firms. On the economic front, the top priorities are strategic alliances, cost optimization, and market expansion. The most pressing environmental concerns are raw material sourcing, carbon emissions reduction, and environmental compliance. In the social domain, the firms must focus on mental health support, diversity and inclusion, child/forced labour prevention, employee well-being, and safety protocols. The study's limitations provide opportunities for future research, advocating for broader industrial assessments and longitudinal impact studies. The practical implications include strategic recommendations for supply chain managers to drive sustainable growth, focusing on strategic alliances, cost optimization, responsible resource sourcing, employee well-being, and stakeholder engagement. Ultimately, this research contributes substantially to the scholarly dialogue on sustainable manufacturing, offering valuable insights and guidance for small-scale Interlocking cement tile firms in India. The study's originality lies in its integrated TBL-MCDM approach, which facilitates a nuanced understanding of the multidimensional sustainability challenges these micro-industries face.

Keywords: Small-scale Interlocking cement tile manufacturing firms, Triple Bottom Line (TBL) Approach, SWARA-TOPSIS MCDM, Sustainability Priorities

INTRODUCTION

Sustainability has emerged as a paramount concern in contemporary society, driven by the predicted global population growth and the strain on natural resources. The United Nations has projected the world population to reach eight billion by 2030, underscoring the pressing need for sustainable practices across various sectors (Correia, 2019). The urgency of this issue arises from the rapid growth in human consumption, the intensifying depletion of natural resources, and the resulting environmental devastation. The notion of sustainability has evolved beyond a philosophical concept and has become an essential requirement for the preservation and welfare of humanity (Correia, 2019). The research topic can be traced back to the 1970s when the United Nations Human Environment Conference recognized the urgent need to address environmental consciousness and its extensive consequences. These challenges are inherently interconnected with the overexploitation of resources, posing a threat to biodiversity and negatively impacting human well-being and quality of life (Correia, 2019). Various interpretations of sustainability have arisen, frequently mirroring the speaker's viewpoint. Environmentalists place significant emphasis on preserving and safeguarding the natural environment, whereas economists tend to perceive sustainability in terms of sustained economic growth. According to the World Commission on Environment and Development, sustainable development may be defined as the attainment of current societal requirements while ensuring that the capacity of future generations to fulfill their own needs remains intact (Harlem, 1987). The comprehensive understanding of sustainability encompasses the intricate relationship among economic well-being, environmental conservation, and social fairness, as encapsulated in the triple bottom line framework (Elkington, 1998). Elkington's seminal contribution in 1997 created the triple bottom line, which incorporates the dimensions of people, planet, and profit, as a strategy framework for promoting sustainability (Svensson, 2015; Chabowski, 2011). The comprehensive approach emphasizes that achieving genuine sustainability necessitates the integration of environmental preservation, social equity, and economic feasibility.

In recent years, the pursuit of sustainable development has become increasingly vital, particularly within the industrial sector where environmental degradation and resource depletion pose significant challenges (Bhakar et al., 2018; Kaur, 2017; Zhu & Sarkis, 2004; Veleva & Ellenbecker, 2001; Hartini et al., 2020; Gereffi& Lee, 2016; Blome et al., 2014). Among the various industries contributing to these concerns, India's Interlocking cement tile sector stands out due to its resource-intensive operations and environmental impact. The problem at hand revolves around the challenges faced by small and medium-sized enterprises (SMEs) within India's Interlocking cement tile sector in aligning their operations with sustainability principles. Globalization requires supply chain management to address factors other than economic issues strictly, such as fair working conditions and production characterized by environmental responsibility (Carter & Liane Easton, 2011). Companies of all sizes and across a wide variety of sectors are becoming increasingly concerned with managing their supply chains in a sustainable manner (Seuring& Müller, 2008b). Sustainable supply chain development is discussed by many, but not for SMEs. Few studies have analyzed how to create a sustainable cement supply chain on account of the uniqueness of the product (Seuring& Müller, 2008a). This study evaluates supply chain sustainability to fill a research gap through the examination of SME supply chain sustainability issues. The sustainable development of Small and Medium Enterprises (SMEs) within the cement industry is a pressing concern that requires careful consideration of economic, environmental, and social factors (Refer Table 1 for detailed notations and references). The study underscores the unique potential of supply chain managers to act as catalysts for positive change, wielding influence through supplier development, mode and carrier selection, vehicle routing, site selection, and packaging choices. The SWARA-TOPSIS approach is employed in this study to assess and prioritize 11 economic, 9 environmental, and 14 social sustainability factors, drawing insights from both literature and expert opinions (Refer Table 1 for detailed notations and references). The findings of this comprehensive analysis shed light on critical challenges faced by SMEs in the cement industry, unveiling the specific obstacles that demand immediate attention for sustainable growth. The study highlights that society and businesses are embracing "sustainability," with climate change, renewable energy, and environmental concerns becoming increasingly crucial (Carter & Liane Easton, 2011; Seuring& Müller, 2008b). Managers must address these environmental and social issues, which are the by-product of their operations, as customers, government agencies, non-governmental organizations, and employees are prompting businesses to take action (Seuring& Müller, 2008a). The subsequent sections delve into the specific findings of the SWARA-TOPSIS approach, providing a nuanced understanding of the prioritized factors and offering insights that can guide targeted interventions for the sustainable development of SMEs in the cement industry. The prioritized difficulties can guide sustainable supply chain growth milestones, and case implementation is shown using Indian cement companies.

The SWARA-TOPSIS analysis reveals that the top economic sustainability factors for SMEs in the cement industry are Economic Performance (EP), Market Presence (MP), Making Healthy Operation Profit (MHOP), and Lowering Costs (LC) (Bhakar et al., 2018; Kaur, 2017; Zhu & Sarkis, 2004; Veleva & Ellenbecker, 2001; Hartini et al., 2020; Leszczynska, 2018; Gereffi& Lee, 2016; Blome et al., 2014). These findings underscore the critical importance of financial viability and competitiveness for SMEs in the cement industry to achieve sustainable development. On the environmental front, the study identifies key factors such as Waste Management (WM), Energy Efficiency (EE), Water Conservation (WC), and Greenhouse Gas Emissions (GGE) as top priorities (Seuring& Müller, 2008a; Carter & Liane Easton, 2011). These findings highlight the need for SMEs to address their environmental footprint through efficient resource utilization, waste reduction, and emissions control. The social sustainability factors that emerge as most crucial include Occupational Health and Safety (OHS), Employee Welfare (EW), Community Engagement (CE), and Stakeholder Engagement (SE) (Seuring& Müller, 2008b; Carter & Liane Easton, 2011). These findings underscore the importance of prioritizing the well-being of workers, fostering positive relationships with local communities, and engaging with a broader range of stakeholders. By integrating the Triple Bottom Line (TBL) approach, which emphasizes the interconnectedness of environmental, social, and economic considerations, this study provides a

comprehensive framework for addressing the sustainability challenges faced by SMEs in the cement industry (Seuring& Müller, 2008a; Carter & Liane Easton, 2011). The prioritized factors identified through the SWARA-WASPAS analysis can serve as a roadmap for targeted interventions and strategic decision-making to drive sustainable development within this sector. The case implementation using Indian cement companies further illustrates the practical application of the study's findings, offering insights that can be leveraged by SMEs in the cement industry to enhance their sustainability performance and contribute to the broader goal of sustainable development (Seuring& Müller, 2008b; Carter & Liane Easton, 2011).
However, these small-scale manufacturing firms often face unique challenges in adopting and implementing sustainable practices. The key research questions addressed in this study are: 1) How do economic constraints, environmental challenges, and social differences impact the adoption and effectiveness of sustainability practices in these small-scale firms? 2) How can MCDM techniques be used to weight and rank sustainability indicators? 3) What strategies can be proposed to enhance the economic, environmental, and social sustainability of these firms? By addressing these research questions, this study seeks to uncover the challenges and opportunities for fostering sustainability in the SMEs Interlocking cement tile manufacturing sector, ultimately contributing to the academic discourse and providing practical insights for sustainable transformations in this industry.

LITERATURE REVIEW

Sustainability is generally defined as using resources to meet the needs of the present without compromising the ability of future generations to meet their own needs (Pazienza et al., 2022). The Triple Bottom Line (TBL) approach considers a broad range of indicators and criteria for measuring organizational success, encompassing not only environmental factors but also social and economic aspects. As the Interlocking cement tile manufacturing industry is large, it is expected from every stakeholder in the supply chain to remain competitive. To remain competitive and capture significant market share, it is desired that firms reduce cost and improve the quality of products along with efficiency improvement of their supply chain (Goel, 2010). The pursuit of sustainability has started to reshape the competitive landscape, driving organizations and supply chains to re-evaluate their processes, technologies, and products. To overcome the barriers to sustainable supply chain management (SSCM) in a given organization, it is imperative to identify strategies and practices that can enable the successful implementation of SSCM and provide a framework that allows proactive decision-making to assess performance and future problems, determine significant risks, and implement strategies to address the risks (Mudgal et al., 2010). According to the findings, the category of barriers with the greatest importance is the economic and financial barrier, followed by the technological, regulatory and institutional, and organizational categories (Gonçalves et al., 2024). The cement industry holds a significant position in the worldwide building sector, but it encounters complex sustainability issues shaped by economic and environmental factors. Karttunen et al. (2021) researched the complex dynamics between drivers and constraints to environmental innovation in this industry. One of the main factors driving environmental innovation is the presence of cost-efficiency incentives that are specifically designed to cater to clients who are sensitive to pricing. In order to meet the demands of cost-conscious consumers who prioritize competitive pricing and standardized products, established enterprises focus their efforts on adopting environmental process advances. Nevertheless, the endeavor to achieve sustainability is not without obstacles. The research emphasizes that economic viability and limitations associated with manufacturing infrastructure serve as significant obstacles in the pursuit of environmental product developments.
In contrast, emerging participants in the cement sector employ a unique strategy that is guided by internal principles and has a purpose focused on the development of ecologically sustainable goods. These organizations utilize their strategic vision to lead the development of environmentally friendly product innovations that are customized to cater to specialized markets and unique use cases. This strategy situates new participants as agents that promote enhanced environmental performance within the industry. Karttunen et al. (2021) emphasize the critical need for policy interventions to effectively address and bring about substantial transformations in the face of sustainability concerns. The authors propose adopting novel policies to foster client demand for emerging market participants and established industry players. By implementing strategies that provide incentives and support for the adoption of environmental technologies within the sector, these policies have the potential to expedite the shift towards reduced emissions in cement manufacturing. The process of integrating sustainable practices inside small and medium-sized enterprises (SMEs) is not devoid of obstacles, which encompass a lack of understanding regarding the tangible advantages linked to sustainability, resource constraints, insufficient technical expertise, and employee resistance (Malesios et al., 2018; Cao et al., 2017;

Juodagalvienė et al., 2017; Haider et al., 2018). However, it is critical to acknowledge that these challenges are frequently accompanied by an abundance of opportunities for SMEs to embrace and advance sustainable practices actively. Governmental entities worldwide offer diverse financial incentives, the inclusion of sustainability consultants equips SMEs with the essential knowledge and capabilities, and internet resources provide substantial insights and information regarding sustainable practices (Malesios et al., 2018; Cao et al., 2017; Juodagalvienė et al., 2017). By adopting sustainable practices, SMEs can enhance their reputation, reduce their environmental footprint, and improve their cost-efficiency, transforming challenges into opportunities that generate substantial and significant contributions to sustainability. The Interlocking cement tile manufacturing industry is a crucial component of the construction sector, contributing significantly to the development of buildings, infrastructure, and urban landscapes. However, the resource-intensive nature of this industry and its environmental impact have made it a prime focus for sustainability initiatives (Correia, 2019). Within the Interlocking cement tile manufacturing industry, small and medium-sized enterprises (SMEs) play a vital role, particularly in developing economies like India. These small-scalefirms face unique challenges in adopting and implementing sustainable practices due to various economic, environmental, and social constraints (Malesios et al., 2018; Cao et al., 2017; Juodagalvienė et al., 2017; Haider et al., 2018). The existing literature has explored the barriers and drivers of sustainability in the cement industry from multiple perspectives. Karttunen et al. (2021) examined the complex dynamics between drivers and constraints to environmental innovation in the cement industry, highlighting the importance of cost-efficiency incentives and the role of emerging market participants in promoting sustainable product innovations. The study by Gonçalves et al. (2024) identified the key categories of barriers to sustainable supply chain management (SSCM) in the cement industry, with economic and financial barriers being the most significant, followed by technological, regulatory, and organizational constraints. These findings underscore the multifaceted nature of sustainability challenges faced by firms in this sector. To effectively address these challenges, researchers have emphasized the critical need for policy interventions that can foster client demand for sustainable products, provide incentives for the adoption of environmental technologies, and support the shift towards reduced emissions in cement manufacturing (Karttunen et al., 2021). While the existing literature has provided valuable insights into the sustainability issues in the cement industry, the focus has primarily been on large-scale enterprises. The unique challenges and opportunities faced by SMEs in this sector have received relatively less attention (Malesios et al., 2018; Cao et al., 2017; Juodagalvienė et al., 2017; Haider et al., 2018). This study aims to address this gap by examining the sustainability issues faced by SMEs in the Interlocking cement tile manufacturing sector in Karnataka, India, using an integrated framework of the Triple Bottom Line (TBL) approach and Multi-Criteria Decision-Making (MCDM) techniques. By exploring the economic, environmental, and social factors that impact the sustainability of these small-scalefirms, the research seeks to uncover the specific challenges and opportunities for enhancing their overall sustainability performance.

METHODOLOGY

The case study focuses on Indian interlock cement tile SMEs, examining challenges related to sustainable growth within the industry. Table 1 lists 11 economic, 9 environmental, and 14 social sustainability factors, prioritized according to previous research and insights from industry professionals. In order to evaluate the difficulties, the study assessed the problem's significance and applicability and appraised different solutions by applying SWARA and TOPSIS methods.

Table 1: Factors for Analysis (Source: Table created by authors)

Economic Factors	Notations	Reference
Economic Growth	E1	(Bhakar, 2018; Kaur, 2017; Zhu & Sarkis, 2004; Veleva & Ellenbecker, 2001)
Market Share	E2	(Hartini et al., 2020; Kaur, 2017)
Profitability	E3	(Kaur, 2017)
Cost Optimization	E4	(Leszczynska, 2018; Gereffi and Lee, 2016; Blome, Paulraj, and Schuetz, 2014)
Maintenance Cost Savings	E5	(Bhakar, 2018)
Energy and Electricity Cost Reduction	E6	(Bhakar, 2018; Moon et al., 2013; Madlool et al., 2011)
Labor Cost Management	E7	(Bhakar, 2018; Winroth et al., 2016; Azapagic, 2004; Krajnc et al., 2003)

Economic Risk Mitigation	E8	(Sharma et al., 2020; Bhakar, 2018; Kaur, 2017)
Transportation Cost Reduction	E9	(Kayikci, 2018; Kaur, 2017)
Raw Material Availability	E10	(Erdogan & Tosun, 2021; Susan Helper and Evan Soltas, 2021; Aday & Aday, 2020; Cai & Luo, 2020; Chaib, 2020; Guan et al., 2020)
Raw Material Price Volatility	E11	(Kaur, 2017)
Environmental Factors		
Dust Pollution from Raw Materials	EV1	(Manisalidis et al., 2020; Manhart et al., 2019)
Effluent and Waste Discharge	EV2	(Sharma et al., 2020; Ni and Sun, 2018; Kaur, 2017; Tidy, Wang, and Hall, 2016; Lintukangas, Hallikas, and Kähkönen, 2015; Merminod and Paché, 2011)
High Energy Consumption	EV3	(Sharma et al., 2020; Gaur et al., 2020; Kaur, 2017)
Resilience to Environmental Uncertainties	EV4	(Sharma et al., 2020)
Water Usage	EV5	(Xiang et al., 2021; Niinimäki et al., 2020; Kaur, 2017)
Transportation of Raw Materials	EV6	(Kaur, 2017)
Greenhouse Gas Emissions	EV7	(Rahman et al., 2022; Rehman et al., 2021; Kaur, 2017)
Air Pollution	EV8	(Kaur, 2017)
Raw Material Procurement	EV9	(Manhart et al., 2019)(Manisalidis et al., 2020)
Social Factors		
Health and Safety Practices for Workers	S1	(Ahmadi et al., 2017; Amindoust et al., 2012; Aydin Keskin et al., 2010; Azadnia et al., 2014; Kaur, 2017; Ziout et al., 2013)(Sharma et al., 2020)
Diversity and Equal Opportunity	S2	(Kaur, 2017; Kumar & Anbanandam, 2019)
Forced/Compulsory Labor Rights	S3	(Kaur, 2017)
Employment Practices	S4	(Sweeney, 2009; Winroth et al., 2016), Heller and Keoleian (2000), Li et al. (2012), Singh et al. (2007
Employee Satisfaction	S5	(Sweeney, 2009; Winroth et al., 2016), Heller and Keoleian (2000), Li et al. (2012), Singh et al. (2007
Employee Productivity	S6	(Sweeney, 2009)
Employee Retention	S7	(Agarwal et al., 2022; Azapagic, 2004; Cooper et al., 2018; Sweeney, 2009; Veleva & Ellenbecker, 2001), GRI Guidelines (2011 - 2015)
Labor/Management Relations	S8	Heller and Keoleian (2000), Li et al. (2012), Singh et al. (2007
Legal Compliance	S9	Ashby, Leat, and Hudson-Smith (2012); Harms, Hansen, and Schaltegger (2013); Yawar and Seuring (2017)(Sharma et al., 2020)
Labor Laws and Social Standards Compliance	S10	Ashby, Leat, and Hudson-Smith (2012); Harms, Hansen, and Schaltegger (2013); Yawar and Seuring (2017)(Sharma et al., 2020)
Accident Prevention and Lost Work Days	S11	(Bhakar, 2018)
Child Labor Practices	S12	(Kaur, 2017)
Anti-Corruption Measures	S13	(Joung et al., 2013; Kaur, 2017; Kumar & Anbanandam, 2019)
Community Support	S14	(Bhakar, 2018)

Based on extensive experience in the cement block manufacturing industry, 10 Decision Makers (DM) were chosen. These individuals hold positions such as Owner, Partner, Manager, or Supervisor.

Stepwise Weight Assessment Ratio Analysis (SWARA) method

In 2010, SWARA was developed by Kersuliene, Zavadskas, and Turskis. This method employs decision-makers and weighting techniques. The SWARA-TOPSIS approach combines subjective expert opinions with objective data derived from literature, resulting in a comprehensive analysis that balances theoretical foundations with practical expert knowledge. The methodical, step-by-step nature of SWARA allows for the systematic breakdown of complex issues into more manageable components. The second phase, TOPSIS, introduces weighted criteria aggregation, which considers the varying importance of different factors. This enables a more nuanced prioritization and accurately reflects the challenges faced by SMEs in the cement industry.

The process begins by determining the comparative significance of each attribute. Next, the alternatives for each characteristic are ranked, and the importance of each quality is evaluated. The subsequent method then establishes the final ranking and priority of the qualities based on two principles:

1) The attributes can compensate for one another;

2) The attributes are independent of each other.

In the SWARA approach, decision-makers' perspectives are considered to determine the relative importance (Sj) of the jth attribute.

Step 1: Initial Attribute Prioritization

Initially, decision-makers rank the attributes based on their relative significance, beginning with the most crucial and ending with the least important (See Table II for comprehensive notations and references).

Table 2: Relative Average Importance by 10 Decision Makers (Source: Table created by authors)

Criteria's	**E7**	**E4**	**E2**	**E5**	**E3**	**E10**	**E8**	**E6**	**E1**	**E9**	**E11**			
Merged Relative Importance Score (Ordered)	4.96	4.84	4.73	4.63	4.60	4.60	4.58	4.47	4.22	4.21	4.08			
Criteria's	**EV4**	**EV6**	**EV3**	**EV5**	**EV8**	**EV1**	**EV2**	**EV7**	**EV9**					
Merged Relative Importance Score (Ordered)	4.66	4.51	4.11	2.53	2.15	2.01	1.56	1.49	1.23					
Criteria's	**S1**	**S2**	**S7**	**S9**	**S14**	**S6**	**S4**	**S5**	**S10**	**S13**	**S8**	**S12**	**S3**	**S11**
Merged Relative Importance Score (Ordered)	4.81	4.81	4.80	4.58	4.51	4.41	4.38	4.36	4.35	4.18	4.14	4.10	4.06	4.02

Step 2: The Coefficient (k)

Beginning with the second criterion, each subsequent criterion j is assigned values based on its relationship to the preceding (j-1) criterion. This relationship is expressed as a ratio, which indicates the Relative Significance of the Mean Value.

$$kj = \begin{cases} 1 j = 1 \\ Sj + 1 J > 1 \end{cases} \quad \text{.............(1)}$$

Step 3: The Initial Weight

In this step recalculated weight qj is determined using:

$$qj = \begin{cases} 1 j = 1 \\ q\,(j-1)/_{ki} \;\; j > 1 \end{cases} \quad \text{………………(2)}$$

At this point, the previously mentioned approach is used to determine the initial weight of an attribute for each decision maker.

Step 4: The Relative Weight

In this stage, the relative weights of the assessment criteria are calculated using:

$$wj = \frac{qj}{\sum_{k=1}^{n} qk} \quad \text{…………… (3)}$$

Where:

wj = Relative weight of the j criterion.

n = Criteria number.

(Refer Table 3, 4 & 5 for detailed notations and references).

Table 3: Relative Weights of Economic Indicators (Source: Table created by authors)

Criteria's	E7	E4	E2	E5	E3	E10	E8	E6	E1	E9	E11
Merged Relative Importance Score (Ordered)	4.96	4.84	4.73	4.63	4.60	4.60	4.58	4.47	4.22	4.21	4.08
Comparative Importance		0.12	0.12	0.09	0.03	0.00	0.02	0.11	0.25	0.00	0.13
Coefficient Value	1.00	1.12	1.12	1.09	1.03	1.00	1.02	1.11	1.25	1.00	1.13
Corrected Weight Value	1.00	0.89	0.80	0.73	0.71	0.71	0.69	0.62	0.50	0.50	0.44
Final Weight Value	0.13	0.12	0.11	0.10	0.09	0.09	0.09	0.08	0.07	0.07	0.06

Table 4: Relative Weights of Environmental Indicators (Source: Table created by authors)

Criteria's	EV4	EV6	EV3	EV5	EV8	EV1	EV2	EV7	EV9
Merged Relative Importance Score (Ordered)	4.66	4.51	4.11	2.53	2.15	2.01	1.56	1.49	1.23
Comparative Importance		0.16	0.40	1.58	0.38	0.14	0.45	0.07	0.26
Coefficient Value	1.00	1.16	1.40	2.58	1.38	1.14	1.45	1.07	1.26
Corrected Weight Value	1.00	0.87	0.62	0.24	0.17	0.15	0.11	0.10	0.08
Final Weight Value	0.30	0.26	0.19	0.07	0.05	0.05	0.03	0.03	0.02

Table 5: Relative Weights of Social Indicators (Source: Table created by authors)

Criteria's	S1	S2	S7	S9	S14	S6	S4	S5	S10	S13	S8	S12	S3	S11
Merged Relative Importance Score (Ordered)	4.81	4.81	4.80	4.58	4.51	4.41	4.38	4.36	4.35	4.18	4.14	4.10	4.06	4.02
Comparative Importance		0.00	0.01	0.22	0.07	0.10	0.03	0.02	0.01	0.17	0.04	0.04	0.04	0.04
Coefficient	1.00	1.00	1.01	1.22	1.07	1.10	1.03	1.02	1.01	1.17	1.04	1.04	1.04	1.04

Value														
Corrected Weight Value	1.00	1.00	0.99	0.81	0.76	0.69	0.67	0.66	0.65	0.56	0.53	0.51	0.49	0.48
Final Weight Value	0.10	0.10	0.10	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.05

The Order of Preference by Similarity to Ideal Solution (TOPSIS) method

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method that was initially developed by Hwang and Yoon in 1981 (Hwang & Yoon, 1981) and further developed by Yoon in 1987 (Yoon, 1987) and Hwang, Lai, and Liu in 1993 (Hwang et al., 1993). This method is recommended by researchers and users in various scientific fields (Qangormeh& Roshan, 2015; Azmi et al., 2011). The TOPSIS method is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution (PIS) and the longest geometric distance from the negative ideal solution (NIS) (Assari et al., 2012). Options are ranked based on their similarity to an ideal solution, with the option closer to the ideal solution receiving a higher rank. This decision analysis method has a solid mathematical foundation and understanding and compliance with its assumptions are crucial for the accuracy of the results (Wang & Elhag, 2006; Wang & Chang, 2007; Chen et al., 2011). It is suggested that this method be used only when there is an adequate number of criteria for deciding on a subject (Greene et al., 2011).

StepOne:Anevaluationmatrixiscreated.Itconsistsofmalternativesandncriteria.Therefore, we have a$(x_{ij})_{m\ xn}$matrix.

Step Two: The matrix $(x_{ij})_{mxn}$is then normalized to form the matrix $(r_{ij})_{mxn}$,using the normalization method in Equation(1) Huang, Keisler, and Linkov (2011).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,2,\ldots,m, j = 1,2,\ldots,n \qquad (1)$$

Table 6: Normalization matrix of Economic Indicators (Source: Table created by authors)

Weights from SWARA Method	0.066	0.105	0.093	0.118	0.096	0.082	0.132	0.091	0.065	0.093	0.058
Normalization Matrix	**Criteria**										
Economic Alternatives	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**E11**
Cost Optimization	0.47	0.44	0.36	0.35	0.42	0.42	0.44	0.36	0.35	0.42	0.42
Market Expansion	0.38	0.44	0.45	0.35	0.34	0.34	0.44	0.45	0.35	0.34	0.34
Lean Manufacturing	0.47	0.35	0.45	0.44	0.42	0.42	0.35	0.45	0.44	0.42	0.42
Supply Chain Optimization	0.38	0.44	0.36	0.44	0.42	0.42	0.44	0.36	0.44	0.42	0.42
Customer Relationship Management	0.38	0.35	0.45	0.44	0.42	0.42	0.35	0.45	0.44	0.42	0.42
Strategic Alliances	0.19	0.26	0.27	0.18	0.25	0.25	0.26	0.27	0.26	0.25	0.25
Product Diversification	0.28	0.35	0.27	0.35	0.34	0.34	0.35	0.27	0.35	0.34	0.34

Table 7: Normalization matrix of Environmental Indicators (Source: Table created by authors)

Weights from SWARA Method	0.046	0.032	0.186	0.300	0.072	0.260	0.029	0.052	0.023
Normalization Matrix	**Criteria**								
Environmental Alternatives	**EV1**	**EV2**	**EV3**	**EV4**	**EV5**	**EV6**	**EV7**	**EV8**	**EV9**
Energy Efficiency	0.53	0.46	0.43	0.48	0.50	0.48	0.48	0.50	0.48
Raw Material Sourcing	0.21	0.28	0.32	0.29	0.30	0.29	0.29	0.30	0.29
Environmental Compliance	0.21	0.28	0.22	0.29	0.30	0.29	0.29	0.30	0.29
Waste Reduction	0.53	0.46	0.43	0.48	0.40	0.48	0.48	0.40	0.48
Carbon Emissions	0.42	0.46	0.43	0.38	0.50	0.38	0.38	0.40	0.38

Reduction									
Water Conservation	0.42	0.46	0.54	0.48	0.40	0.48	0.48	0.50	0.48

Table 8: Normalization matrix of Social Indicators (Source: Table created by authors)

Weights from SWARA Method	0.102	0.102	0.050	0.068	0.067	0.071	0.101	0.055	0.083	0.066	0.049	0.052	0.057	0.078
Normalization Matrix	Criterias													
Social Alternatives	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**
Work-Life Balance Initiatives	0.37	0.29	0.36	0.22	0.30	0.35	0.30	0.30	0.29	0.30	0.29	0.29	0.30	0.29
Community Involvement	0.30	0.36	0.21	0.37	0.30	0.28	0.30	0.30	0.29	0.30	0.29	0.29	0.30	0.29
Ethical Sourcing	0.22	0.22	0.28	0.22	0.22	0.28	0.22	0.22	0.29	0.22	0.29	0.29	0.22	0.29
Mental Health Support	0.37	0.29	0.36	0.37	0.37	0.35	0.37	0.37	0.36	0.37	0.36	0.36	0.37	0.36
Diversity and Inclusion	0.30	0.36	0.36	0.37	0.37	0.35	0.37	0.37	0.36	0.37	0.36	0.36	0.37	0.36
Child Labor and Forced Labor Prevention	0.30	0.29	0.28	0.29	0.30	0.28	0.30	0.30	0.29	0.30	0.29	0.29	0.30	0.29
Employee Well-Being	0.37	0.36	0.36	0.37	0.37	0.35	0.37	0.37	0.36	0.37	0.36	0.36	0.37	0.36
Safety Protocols	0.37	0.36	0.36	0.37	0.37	0.35	0.37	0.37	0.36	0.37	0.36	0.36	0.37	0.36
Employee Training and Development	0.22	0.22	0.28	0.22	0.22	0.28	0.22	0.22	0.29	0.22	0.29	0.29	0.22	0.29
Community Engagement	0.30	0.36	0.28	0.29	0.30	0.28	0.30	0.30	0.29	0.30	0.29	0.29	0.30	0.29

Step Three: Weighting coefficients are calculated. The weighting matrix of the decision is calculated by Equation (2).

$$T = (t_{ij})_{m\times n} = (w_j r_{ij})_{m\times n}, i = 1,2,\ldots,m \quad w_j = \frac{W_j}{\sum_{j=1}^{n} W_j}, j = 1,2,\ldots,n \quad \sum_{j=1}^{n} w_j = 1 \tag{2}$$

and Wj is the original weight given to the indicator vj, j = 1, 2,……., n.
Step Four: Calculate the worst Aw and best Ab alternative.

$$A_w = \{\langle \max(t_{ij}|i = 1,2,...,m|j \in J_-\rangle, \langle \min(t_{ij}|i = 1,2,...,m|j \in J_+\rangle\} \equiv \{t_{wj}|i = 1,2,...,n\} \tag{3}$$

$$A_b = \{\langle \min(t_{ij}|i = 1,2,...,m|j \in J_-\rangle, \langle \max(t_{ij}|i = 1,2,...,m|j \in J_+\rangle\} \equiv \left\{t_{bj}|j = 1,2,...,n\right\} \tag{4}$$

where J+ = {j = 1, 2, ..., n|j } is associated with the criteria having a positive impact, and J− = {j = 1, 2, , n|j } is associated with the criteria having a negative impact.

Table 9: Ideal best and ideal worst value of Economic Indicators (Source: Table created by authors)

V+	0.03	0.05	0.03	0.02	0.04	0.02	0.03	0.04	0.03	0.02	0.02
V-	0.01	0.03	0.04	0.05	0.02	0.03	0.06	0.02	0.02	0.04	0.01

Table 10: Ideal best and ideal worst value of Environmental Indicators (Source: Table created by authors)

V+	0.02	0.01	0.10	0.09	0.04	0.07	0.01	0.03	0.01
V-	0.01	0.01	0.04	0.14	0.02	0.12	0.01	0.02	0.01

Table 11: Ideal best and ideal worst value of Social Indicators (Source: Table created by authors)

V+	0.04	0.04	0.02	0.03	0.02	0.02	0.04	0.02	0.03	0.02	0.02	0.02	0.02	0.03
V-	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02

Step Five: Determine each alternative distance to the best and the worst alternative. The distance between the target alternative i and the worst condition Aw is calculated by

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}, i = 1, 2, \ldots, n \quad (5)$$

and the distance between the alternative i and the best condition Ab is calculated by

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2}, i = 1, 2, \ldots, m \quad (6)$$

Step Six: Similarity to the worst condition is calculated by

$$s_{iw} = \frac{d_{iw}}{(d_{iw} + d_{ib})}, 0 \leq s_{iw} \leq 1, i = 1 = 1, 2, \ldots, m \quad (7)$$

S_{iw} = 1, if and only if the alternative solution has the best condition
S_{iw} = 0, if and only if the alternative solution has the worst condition
Step Seven: Alternatives are evaluated and ranked as S_{iw}(i = 1, 2, ..., m)

Conclusion and managerial implication

The findings of this study highlight the key sustainability challenges facing small-scale interlocking cement tile firms. The analysis using SWARA and TOPSIS techniques identified the most critical factors that need to be addressed for these SMEs to achieve greater sustainability. The top economic priorities are strategic alliances, cost optimization, and market expansion. On the environmental front, the most pressing concerns are raw material sourcing, carbon emissions reduction, and environmental compliance. In the social domain, the firms must focus on mental health support, diversity and inclusion, child/forced labor prevention, employee well-being, and safety protocols. To drive sustainable growth, supply chain managers at small-scale interlocking cement tile firms must prioritize these critical factors. Some key actions they can take include: Developing strategic alliances with larger industry players, suppliers, and distributors to gain economies of scale and access new markets. Implementing cost optimization measures such as lean manufacturing, supply chain optimization, and product diversification to improve profitability. Ensuring responsible raw material sourcing and investing in technologies/processes to reduce carbon emissions and improve environmental compliance. Enhancing employee well-being through mental health support, diversity initiatives, and robust safety protocols. This will improve worker productivity and retention. Engaging with local communities, NGOs, and government agencies to address social issues like child labor and promote ethical business practices. By proactively addressing these multidimensional sustainability challenges, small-scale interlocking cement tile firms can strengthen their competitive position, mitigate risks, and contribute to the broader goal of sustainable development. This will require the concerted efforts of all stakeholders - customers, suppliers, employees, and regulators - to create an enabling ecosystem for these SMEs to thrive.

Table 12: Performance score and Ranking of Economic Alternatives
(Source: Table created by authors)

Economic Alternatives	Si+	Si-	Pi	Rank
Strategic Alliances	0.04	0.05	0.55	1
Cost Optimization	0.04	0.04	0.48	2
Market Expansion	0.04	0.03	0.46	3
Lean Manufacturing	0.04	0.04	0.45	4
Product Diversification	0.04	0.03	0.45	5
Customer Relationship Management	0.04	0.03	0.43	6
Supply Chain Optimization	0.05	0.03	0.42	7

Table 13: Performance score and Ranking of Environmental Alternatives
(Source: Table created by authors)

Environmental Alternatives	Si+	Si-	Pi	Rank
Raw Material Sourcing	0.05	0.08	0.63	1
Carbon Emissions Reduction	0.04	0.06	0.57	2
Environmental Compliance	0.06	0.08	0.54	3
Water Conservation	0.08	0.06	0.45	4

Energy Efficiency	0.08	0.05	0.37	5
Waste Reduction	0.08	0.04	0.36	6

Table 14: Performance score and Ranking of Social Alternatives
(Source: Table created by authors)

Social Alternatives	Si+	Si-	Pi	Rank
Mental Health Support	0.10	0.07	0.40	1
Diversity and Inclusion	0.10	0.07	0.40	1
Child Labor and Forced Labor Prevention	0.10	0.07	0.40	1
Employee Well-Being	0.10	0.07	0.40	1
Safety Protocols	0.10	0.07	0.40	1
Community Engagement	0.10	0.06	0.39	6
Community Involvement	0.10	0.06	0.39	7
Ethical Sourcing	0.09	0.06	0.39	8
Work-Life Balance Initiatives	0.09	0.06	0.39	9
Employee Training and Development	0.09	0.06	0.39	9

Small-scale interlocking cement tile firms can use the findings of this study to prioritize their resource management strategies. For instance, they can implement efficient raw material sourcing practices to address shortages and reduce dependency on limited resources; this could involve exploring alternative materials, optimizing production processes to minimize waste, and investing in recycling and reuse initiatives. The findings can inform these SMEs' long-term planning and decision-making processes. The results can be used to assess their current sustainability performance, identify areas for improvement, and set goals for future sustainability initiatives. This may involve developing sustainability action plans, establishing performance metrics, and monitoring progress over time to ensure continuous improvement and long-term sustainability. By addressing the environmental and social concerns highlighted in the findings, small-scale interlocking cement tile firms can differentiate themselves in the market and enhance their brand reputation. They can leverage sustainability as a competitive advantage by communicating their commitment to environmental stewardship, social responsibility, and ethical business practices to customers, investors, and other stakeholders. This can lead to increased market share, customer loyalty, and long-term business success. The findings have the potential to shape these SMEs' advocacy endeavors aimed at promoting supportive policies and regulations within the interlocking cement tile production sector. Leveraging these insights, small-scale firms can actively engage with policymakers, industry associations, and other stakeholders to advocate for incentives, subsidies, or regulatory adjustments that incentivize sustainable practices. This collaborative effort aims to foster a favorable policy environment conducive to sustainable development goals, facilitating industry-wide transformation. The top economic priorities for small-scale interlocking cement tile firms are strategic alliances, cost optimization, and market expansion. On the environmental front, the most pressing concerns are raw material sourcing, carbon emissions reduction, and environmental compliance. In the social domain, the firms must focus on mental health support, diversity and inclusion, child/forced labor prevention, employee well-being, and safety protocols.

The current article has a few limitations that provide opportunities for future research. Firstly, the data and conclusions are specific to the example studied and may differ when extended to other industries or regions. Future studies could explore the applicability of the findings in other small-scale manufacturing sectors or conduct comparative analyses across various contexts. Additionally, the use of SWARA and TOPSIS MCDM techniques may influence the findings, and future research could employ alternative MCDM methods to validate and potentially expand the understanding of sustainability issues in this industry. The case-based approach also limits the generalizability of the results, and expanding the scope to include a larger sample size or conducting multi-case analyses could enhance the robustness and transferability of the findings. Finally, the study relied primarily on literature review and expert opinions, and incorporating additional data collection methods, such as surveys and interviews, could provide a more comprehensive understanding of sustainability challenges and priorities from various stakeholder perspectives. Addressing these limitations in future research can further strengthen the insights on sustainability issues faced by small-scale interlocking cement tile manufacturing firms and support the development of effective sustainability practices and policies within the industry.

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