Understanding Multidimensional Barriers to Sustainable Development Goals in Vietnam's Construction Industry: Insights from a Rough Set Theory Approach

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Abstract: This study presents a groundbreaking application of Rough Set Theory (RST) to systematically identify and analyze the multidimensional barriers to achieving sustainable development goals (SDGs) within Vietnam's construction industry. The construction sector in Vietnam, a rapidly growing economy, faces numerous challenges that hinder the adoption of sustainable practices. Recognizing the complexity and imprecision inherent in the data surrounding these challenges, this research leverages RST to provide a robust framework for classification and analysis. RST is particularly well-suited for handling uncertain and vague information, making it a great tool for analyzing the complex barriers to sustainability. Through this innovative approach, the study categorizes various development states and identifies critical barriers- both core and non-core - that impede progress toward sustainability. Key obstacles highlighted include financial constraints, technological limitations, and significant gaps in stakeholder awareness. These barriers collectively pose substantial challenges to the implementation of sustainable practices within the construction industry, thereby stalling the sector's alignment with broader sustainability goals. Employing the LEM2 algorithm, the research formulates evidence-based decision rules that offer actionable strategies tailored to the unique challenges of each identified development state. This algorithm facilitates the extraction of meaningful patterns from the data, allowing for the development of targeted interventions that address specific barriers. By focusing on the unique characteristics of Vietnam's construction sector, the study provides insights that are both contextually relevant and practically applicable. The findings of this research underscore the potential of RST to enhance data-driven decision-making processes. Policymakers and industry stakeholders are empowered to craft targeted interventions that not only address systemic inefficiencies but also promote collaboration and innovation within the sector. This data-centric approach is crucial for aligning Vietnam's construction industry with global sustainability objectives, ensuring comprehensive progress across environmental, social, and economic dimensions. This study provides a comprehensive framework for identifying and addressing the challenges to sustainable development in Vietnam's construction industry. It enhances understanding of the intricate factors influencing sustainability and offers strategic insights for effective policy development and implementation. Beyond Vietnam, the findings serve as an adaptable model for other regions grappling with similar sustainability challenges, offering valuable guidance for global efforts toward more sustainable construction practices. In conclusion, through the application of RST, this study not only identifies key obstacles but also proposes practical solutions that can drive the construction industry in Vietnam and beyond toward a more sustainable future. The findings provide valuable insights for a range of stakeholders, including government policymakers and industry professionals, encouraging a collaborative approach to integrating sustainable practices. More than just an analysis of challenges, this research serves as a call to action, urging all involved in the construction sector to acknowledge these barriers and actively engage in overcoming them. By adopting such an approach, Vietnam's construction industry can improve operational efficiency while also making a meaningful contribution to broader sustainability objectives, striking a necessary balance between economic progress and environmental responsibility.

Keywords: Construction Industry, LEM2 Algorithm, Multidimensional Barriers, Rough Set Theory (RST), Sustainable Development

Introduction

The Sustainable Development Goals (SDGs) have emerged as a cornerstone of global development, shaping the strategies of industries and businesses worldwide. Defined in the CIB Agenda 21 for Sustainable Construction, sustainable development is described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". His principle is particularly critical for the construction sector, whose activities significantly impact the environment, society, and economy (Du Plessis, 2019).

The construction industry serves a pivotal role in shaping the built environment, encompassing buildings, infrastructure, and engineering works. As an integral part of human habitation, this built environment profoundly influences living conditions, societal well-being, and sustainable development (Nguyen, 2014). However, achieving sustainability in the construction sector is a multifaceted challenge, especially in developing countries like Vietnam. The country's rapidly expanding construction industry contends with resource limitations, regulatory obstacles, and inconsistent stakeholder commitment.

In recent years, Vietnam has witnessed significant growth in its construction sector. Notably, in 2013, Vietnam's construction industry recorded the third-highest growth rate in Asia, driven by strong private-sector contributions. Between 2000 and 2009, the industry achieved an average annual growth rate of 9.6%. However, this momentum faltered between 2010 and 2013 due to a real estate crisis, reducing annual growth to 4.6%. Despite these fluctuations, the private sector consistently accounted for over 80% of the total construction output between 2011 and 2014 (Nguyen, 2015). In 2019, the urbanization rate increased to 39.2%**,** reflecting a rise of 0.8% from the previous year (Van Tam et al., 2021). By 2030, the workforce in the construction sector is expected to reach 12–13 million people, while employment in the building materials sector is projected to grow to nearly 3 million workers (Phong, 2020). These developments underscore the sector's importance in Vietnam's economic and social progress.

While Vietnam's government has made strides to align national policies with the United Nations' SDG framework, these efforts have not translated effectively into practical adoption within the construction industry. The sector continues to struggle with multidimensional barriers, such as high financial costs, technological constraints, and a lack of coordinated stakeholder engagement. Addressing these obstacles requires an innovative and data-driven approach to uncover underlying systemic inefficiencies and develop actionable solutions.

This study pioneers the application of Rough Set Theory (RST) to analyze these barriers, providing a novel framework for identifying and addressing the complex, interdependent challenges that impede SDG adoption. By utilizing RST, this research aims to enhance the precision of data analysis, uncover critical decision-making patterns, and support evidence-based strategies for sustainable development in Vietnam's construction sector. Through this approach, the study seeks to empower policymakers, industry stakeholders, and researchers with actionable insights to advance sustainable practices, contributing to Vietnam's alignment with global sustainability objectives.

Literature review

Barriers to Sustainable Development Goals (SDGs)

The adoption of Sustainable Development Goals (SDGs) in the construction industry is impeded by various multidimensional barriers that require systematic identification and analysis to enable effective interventions. This study applies Rough Set Theory (RST) to enhance the precision of barrier identification and support evidence-based decision-making in Vietnam's construction sector. The methodology is driven by data collected through a structured questionnaire, designed to quantify these barriers and provide actionable insights.

Economically, high initial investment costs and limited access to funding remain critical obstacles. Abu Bakar et al. identified financial constraints, such as elevated upfront expenses, as major barriers to SDG adoption (Abu Bakar et al., 2018). Similarly, Aghimien et al emphasized financial constraints as one of the significant challenges in implementing SDGs (Aghimien et al., 2018). The high cost of transferring techniques is also considered a barrier in the research conducted by Pleasa Serin Abraham and Haripriya Gundimeda (Gundimeda and Abraham, 2018). Le Khanh Linh also pointed out that the 20-30% increase in investment costs is a barrier to implementing sustainable development goals in Vietnam (Linh, 2023).

Policy and regulatory barriers also reduce the effectiveness of SDG deployment, as noted in the study by Hwang & Tan in 2012 (Hwang and Tan, 2012). Furthermore, inadequate awareness of sustainable development and resistance to change within an organizational culture are crucial factors hindering progress. These cultural and organizational challenges further compound the difficulty of implementing sustainability practices. Poor government support for sustainable construction has been identified as a barrier to implementing SDGs in the research by Chigozie Osuizugbo (Chigozie Osuizugbo et al., 2020).

Technical barriers are another key obstacle, with companies lacking advanced technologies and the supporting infrastructure required for SDG adoption. This issue has been explored in the studies of De-Graft. Opoku (De Graft et al., 2018). Karji and Tafazzoli's research also aligns with De-Graft (Karji and Tafazzoli, 2020).

Inefficient coordination among stakeholders further exacerbates these challenges, as highlighted by Susanti, who also identified technical limitations as a significant impediment to SDG implementation (Susanti et al., 2019). Technological difficulties were also identified by Simion and colleagues as a highly significant barrier (Simion et al., 2019). Additionally, Munyasya emphasized the lack of cooperation and networking as a significant hindrance (Munyasya and Chileshe, 2018).

Beyond the aforementioned barriers, the scarcity of green materials and the lack of information about them are also seen as significant challenges hindering the adoption of SDGs in Vietnamese construction companies. Mohsin's study identified unreliable sustainable material suppliers and maintenance procedures as the third major material barrier (Mohsin et al., 2021). Tathagat identified the difficulty and complexity of making required materials available for green buildings as a key barrier to material adoption (Tathagat and Dod, 2015). Ha Chin Yee, in the study titled *The Barriers of Implementing Green Building in Penang Construction Industry*, also highlighted numerous obstacles to adopting green materials in sustainable construction (Ha Chin Yee., et al 2020).

By synthesizing insights from the above studies, this research identifies key dimensions—economic, policy, technological, material, and stakeholder barriers—for inclusion in a structured questionnaire. The data collected through this instrument forms the basis data for applying RST, allowing for the classification of core and non-core barriers and the generation of actionable decision rules. This integration aligns with the objective of pioneering RST in analyzing multidimensional barriers, enhancing data accuracy, and supporting evidence-based decision-making to achieve sustainable development in Vietnam’s construction industry.

Rough Set Theory Application

Rough set theory is a mathematical approach introduced by Zdzisław Pawlak in the early 1980s for dealing with vagueness and uncertainty in data analysis (Zdzisław Pawlak, 1982). The philosophy of rough sets is founded on the assumption that every object in the universe of discourse is associated with some information (data, knowledge) (Skowron and Dutta 2018). It is widely used in artificial intelligence, data mining, and decision-making processes. Rough set theory has found many interesting applications. The rough set concept can be of some importance, primarily in some branches of artificial intelligence, such as inductive reasoning, automatic classification, pattern recognition, and learning algorithms (Zdzisaw Pawlak, 1982). Rough Set Theory offers a robust approach to managing imprecise, ambiguous, and incomplete data. It is particularly effective in data mining, where extracting meaningful insights from large datasets is crucial (Muriana and Ogba 2024).

Rough Set Theory (RST) has been widely applied across various fields, offering powerful tools for data analysis, decision-making, and knowledge extraction. Researchers worldwide have explored its potential, achieving significant insights and advancements.

Similarly, Xia Lou and his research team employed RST to analyze the traffic accidents and propose preventive measures through a structured decision-making framework (Luo et al., 2009). Similarly, Yonglan Jiao and Bingzhen Sun employed RST to analyze railway traffic safety factors, rank accident severity, and propose preventive measures through a structured decision-making framework (Jiao and Sun 2008).

In construction project management, Bingsheng Liu and colleagues utilized RST to identify five critical owner characteristics influencing project delivery system (PDS) decision-making. Their work provided actionable insights for selecting optimal PDSs in Chinese construction projects (Liu et al., 2015). Additionally, Chi Mint Tam and his team applied RST to identify critical safety measures in Hong Kong's construction industry, emphasizing the role of safety orientation programs and award campaigns in reducing workplace accidents (Tam et al., 2007).

RST's utility extends to engineering and medical fields. Chen et al**.** used RST to determine six core factors influencing engineering consulting employees’ willingness to expatriate, providing key insights for workforce management (Chen et al., 2014). Earlier, Roman Słowiński demonstrated RST's applicability in medical diagnosis and engineering control, underlining its versatility and practical significance (Słowiński and Stefanowski 1989).

In infrastructure management, Attoh-Okine utilized RST to support decision-making in pavement rehabilitation and maintenance, streamlining processes and optimizing resource allocation (Okine, 1997). Similarly, Choi et al integrated RST with case-based reasoning to develop a Conceptual Cost-Prediction Model for public road planning, enhancing accuracy in budget estimations (Choi et al., 2014).

The logistics sector has also benefited significantly from RST applications. Bin Shuai**,** Yu Wang, and Jing Li applied RST to improve decision-making in city logistics layout planning (Shuai Bin et al., 2007). Additionally, Wenli Shi utilized RST to refine decision-making processes in logistics management (Wenli and Tianbao, 2010). Weng Xiao Xiong and the research team demonstrated RST's utility in estimating multidimensional states in urban traffic systems, providing innovative approaches to optimize urban traffic flow (Weng Xiao Xiong et al., 2007).

These diverse applications highlight RST's adaptability and potential to address complex problems across disciplines, from transportation safety and project management to logistics and medical diagnostics. By transforming raw data into actionable insights, RST continues to empower researchers and practitioners in decision-making and strategic planning.

Rough set theory principle

The notion of a set is not only basic for the whole of mathematics but it also plays an important role in natural language (Zdzisław Pawlak, 1982). Rough set theory is still another approach to vagueness. Similarly to fuzzy set theory, it is not an alternative to classical set theory but it is embedded in it (Zdzisław Pawlak, 1982). Rough set theory can be viewed as a specific implementation of Frege's idea of vagueness, i.e., imprecision in this approach is expressed by a boundary region of a set, and not by a partial membership, like in fuzzy set theory. In Rough Set Theory, given a universe U and an equivalence relation R, the lower approximation of a set X contains objects certainly belonging to X, the upper approximation contains objects possibly belonging to X, and the boundary region consists of objects that cannot be definitively classified as X or not-X.

Information system

An information system is a data table, whose columns are labeled by attributes, rows are labeled by objects of interest, and entries of the table are attribute values (Pawlak, 2001). In the information system, we have S = (U, Q, V, p). Where U is a finite set of objects, Q is a finite set of attribute, V= $\bigcup_{q\in Q}$ V_q and V_q is the domain of attribute q and ; $p: U \times Q \to V$ is a total function such that p (x, a) ∈ V_q. for every q ∈ Q, x ∈ U, called information function. Any pair (q,v), q ∈ Q, v ∈ V_q is called descriptor in S (Słowiński and Stefanowski 1989).

Indiscernibility relation

Let S = (U, Q, V, p) be an information system and let P $\subseteq$ Q; x,y ∈ U. We say that x and y are indiscernible by the set of attributes P in S (denotation $x \hat{P} y$) if $p\ (x,q) = p\ (y,q)$ for every q ∈ P. Equivalence classes of relations $\hat{P}$ are called P-elementary sets in S. Q-elementary sets are called atoms in S (Słowiński and Stefanowski 1989).

Approximation of sets in an information system

The family of all equivalence classes of relation $\hat{P}$ on U is denoted by P*. Des $_p$ (X) denotes the description of the equivalence class (P-elementary set) X∈P* (Słowiński and Stefanowski 1989).

$$Des_p(X) = \{(q,v)|p(x,q) = v, \text{ for every } x \in X, q \in P\} \quad (1)$$

To evaluate how well the set {Des_p(X)|X∈P*} describes the object of the set Y $\subseteq$ U, Pawlak has introduced the following concepts.

$\underline{P}Y = \bigcup_{X \in P^* and X \subseteq Y}$ - P- lower approximately (P-positive region) of Y in S – set $\underline{P}Y$ is the set of all objects of U which can certainly be classified as belonging to Y, using the set of attributes P;

$\overline{P}Y = \bigcup_{X \in P^* and X \cap Y \neq \emptyset}$ - P- upper approximation of Y in S-set $\overline{P}Y$ is the set of all objects of U which can possibly be classified as belonging to Y, using the set of attributes P;

$Bn_p(Y) = \overline{P}Y - \underline{P}Y$ - P- boundary of Y in S. It is also called the P-doubtful region of Y, since it is not possible to determine whether an object in $Bn_p(Y)$ belongs to Y solely on the basis of the description of the P- elementary sets.

Definition of Accuracy of approximation

For every subset $Y \subseteq U$, we can define the accuracy of approximation of Y by P in S, denote as $\mu_p(Y)$ as follows (Słowiński and Stefanowski 1989):

$$\mu_p(Y) = \frac{card(\underline{P}Y)}{card(\overline{P}Y)} \qquad (2)$$

Properties:

- $0 \leq \mu_p(Y) \leq 1$
- $\mu_p(Y) = 1$ if set Y is P - definable in S.

Rough classification

Let S be an information system, P⊆Q, and let $X=\{X_1,X_2,\ldots,X_n\}$be a classification of U, $X_i \cap X_j=\emptyset$ for every i, j, $i \neq j$ and $\bigcup_{i=1}^{n} X_i = U$ (Słowiński and Stefanowski 1989).

X_i is called the classes of X, if every class of X is P-definable then classification X is called P-definable.

The P-lower and P-upper approximations of a classification X in S are represented by the sets: $\underline{P}X = \{\underline{P}X_1, \underline{P}X_2, \ldots, \underline{P}X_n\}$ and $\overline{P}Y = \{\overline{P}X_1, \overline{P}X_2, \ldots, \overline{P}X_n\}$ respectively.

The quality of approximation of X with respect to the attributes P, denoted as γP(X) is defined by the coefficient.

$$\gamma_p(X) = \frac{\sum_{i=1}^{n} card(\underline{P}X_i)}{card(U)} \qquad (3)$$

This coefficient measures the quality of classification X by evaluating the proportion of objects in U that are correctly classified with respect to P. In other words, it reflects the ratio of all P-correctly classified objects to the total number of objects in the system the coefficient.

Reduction of attributes

A set of attributes R⊆Q is said to depend on another set of attributes P⊆Q within S (denoted as P→R) if and only $\hat{P}$ if ⊆R (Stefanowski, 1989).

To determine a reduce, one can utilize the quality of classification $\gamma_p(X)$, A reduction in S is the smallest subset of attributes that ensures the same classification quality as the complete set of attributes. It is also referred to as a minimal set of attributes.

Note that an information system can possess multiple reduces or minimal sets. The core is defined as the intersection of all reduces or minimal sets. The core represents the most critical attributes essential for classification within the system.

Decision tables

In a decision table, presented as columns, belong to either of two categories: attributes and decisions. Usually, a decision table has only one decision. Rows, like in information tables, are labeled by case names (Grzymala-Busse, 2005). Then the system will be called a decision table and will be denoted by S = (U, C, D) ,where C and D are disjoint sets of condition and decision attributes, respectively (Pawlak, 2002).

Decision rules (LEM2*)*

An idea of blocks of attribute-value pairs is used in the rule induction algorithm LEM2 (Learning from Examples Module, version 2), another component of LERS. The option LEM2 of LERS is most frequently used since—in most cases—it gives better results. LEM2 explores the search space of attribute-value pairs (Grzymala-Busse, 2009). Its input data file is a lower or upper approximation of a concept (for definitions of lower and upper approximations of a concept see, e.g., (Grzymala-Busse, 1997)), so its input data file is always consistent. In general, LEM2 computes a local covering and then converts it into a rule set (Grzymala-Busse, 2009).

Methodology research

The research methodology is divided into four steps, namely: questionnaire development, data collection, reliable data evaluation, and finally, the application of the LEM2 algorithm to identify patterns and rules. These steps are illustrated in Figure 1.

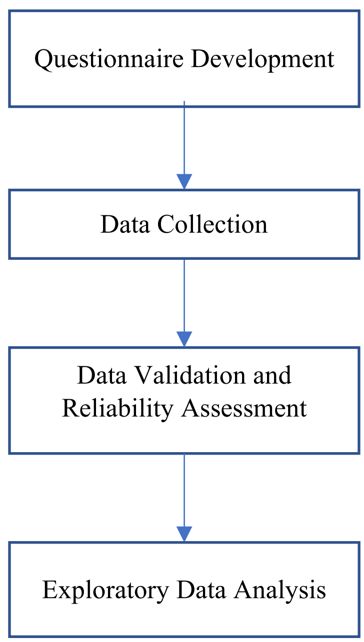


Figure 1. Research Workflow

Questionnaire development

The development of the survey questionnaire was meticulously guided by the foundational principles outlined in Hamed Taherdoost's seminal work (Taherdoost, 2022). Taherdoost’s framework provided a comprehensive roadmap, ensuring the questionnaire's design was both robust and tailored to the research objectives.

The questionnaire was meticulously designed with insights from individuals recognized as experts in Vietnam's construction industry to ensure the credibility and relevance of their contributions to the research. The criteria for identifying and evaluating these experts were grounded in the framework proposed by Poleacovschi and Javernick-Will (Poleacovschi and Javernick-Will, 2017). According to Poleacovschi's study, expert qualifications encompass a distinguished reputation within the construction sector, advanced academic credentials, significant professional achievements, and recognition by peers. These criteria were rigorously applied to select participants whose insights would provide a comprehensive understanding of the industry's dynamics. By leveraging the expertise of such qualified individuals, the questionnaire was enriched with perspectives that align closely with the realities of the construction field in Vietnam, thereby enhancing the depth and validity of the research findings.

The second principle guiding the questionnaire design involved an extensive review of the existing literature and the synthesis of survey questions from credible sources. This comprehensive approach ensured that the questionnaire was firmly rooted in established research while addressing the specific objectives of the study. A total of 44 questions were carefully formulated, reflecting key themes and insights derived from the reviewed studies. Each question was crafted to capture relevant data, aligning with best practices in survey development to ensure clarity, reliability, and validity. This methodical process not only reinforced the theoretical foundation of the questionnaire but also ensured its alignment with the nuanced requirements of the research.

Data collection

Data collection was carried out through a structured survey in Vietnam, utilizing a questionnaire comprising 44 questions designed as attributes and one question serving as the decision attribute. The survey targeted professionals actively engaged in various sectors of Vietnam's construction industry, ensuring the data reflected diverse perspectives and experiences. A total of 260 participants responded to the survey, representing 260 distinct data points. These participants were categorized into seven key groups of barriers: government, finance, training, technology, partnership, materials, and management**.** An additional group focused specifically on evaluating the adoption of Sustainable Development Goals (SDGs) within the industry. The demographic and professional biographies of the respondents are presented in Figure 2, providing a comprehensive overview of the survey population. This systematic approach ensured the data collected was both representative and relevant, forming a robust foundation for analyzing the barriers to SDG adoption in Vietnam's construction sector.

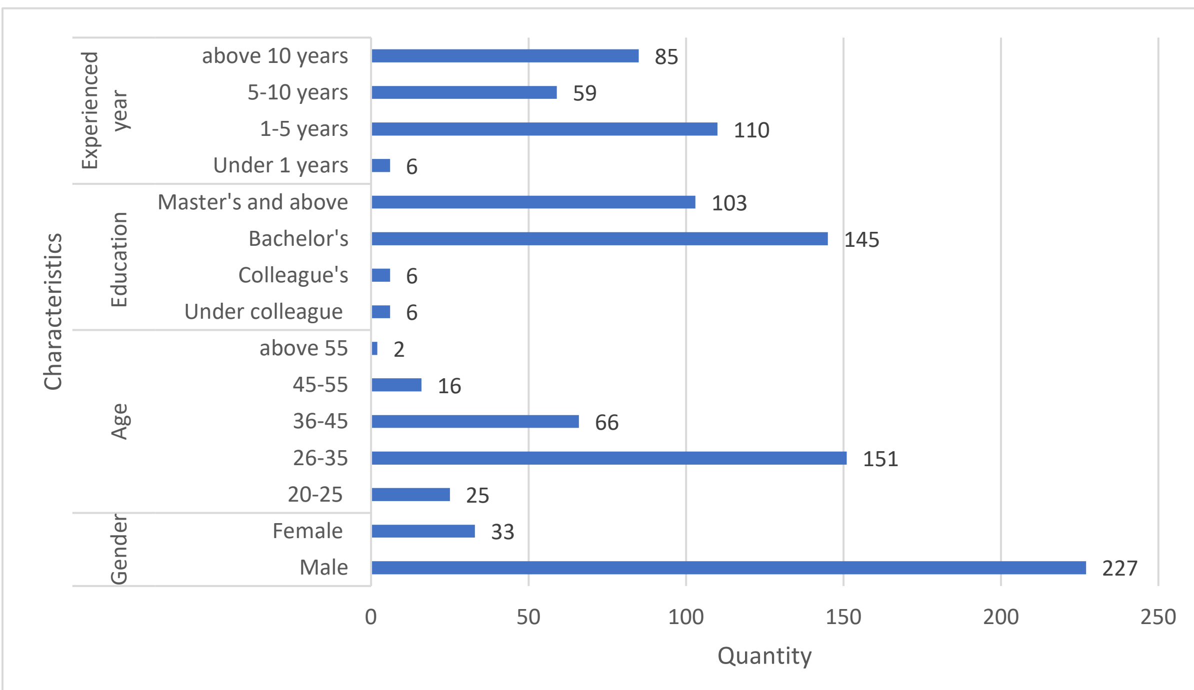


Figure 2. Biography of the respondent

Data Validation and Reliability Assessment

To assess the quality of data for research purposes, the Cronbach's alpha coefficient is employed to evaluate the reliability of the data. According to some researchers on data reliability such as the research of Keith S. Taber (Taber, 2018); Dejan Dragan and Darja Topolšek (Topolšek and Dragan, 2014) and Mustafa Emre Civelek (Civelek, 2018) suggested Cronbach's alpha coefficient should be greater than 0.7.

The average statistical result reflects the range of variable values through the smallest value/largest value. At the same time, to reflect the degree of data dispersion around the average value, the standard deviation is used. When the standard deviation is greater than 1, it indicates that the data fluctuates significantly, and the responses of respondents for that variable differ greatly. Conversely, if the standard deviation is less than 1, the data exhibit moderate variability, with respondents' answers being less divergent.

Exploratory Data Analysis

After confirming the reliability of the data, the LEM 2 algorithm was used to uncover hidden patterns within the dataset. These patterns were analyzed to identify and extract the underlying rules embedded in the data. This process enables a deeper understanding of the relationships and dependencies among the variables, providing critical insights into the factors influencing the study's outcomes.

Results

Cronbach's alpha result

To ensure the reliability of the dataset for applying Rough Set Theory (RST)**,** Cronbach's Alpha was used to evaluate the consistency of survey constructs. All constructs achieved values above 0.7, indicating high internal reliability. The results show strong reliability ($\alpha > 0.82$). These findings confirm that the data is robust for RST analysis. The results are shown in Table 1.

Table 1: Cronbach's Alpha results

Barrier	Cronbach's Alpha
Government Barrier	0.825
Finance Barrier	0.822
Training Barrier	0.825
Technology Barrier	0.826
Stakeholder Barrier	0.838
Material Barrier	0.841
Management Barrier	0.846
Implementation	0.829

This reliability supports the precise classification of barriers and the generation of actionable decision rules through RST. By leveraging reliable data, the study systematically identifies multidimensional barriers and enhances evidence-based decision-making to advance sustainable development in Vietnam's construction industry.

The standard deviation result

To assess the dispersion of respondent perceptions across identified barriers, standard deviation (SD) values were analyzed for each item. This analysis provides insight into the degree of agreement or variability among construction professionals regarding sustainable development challenges in Vietnam.

Government Barriers revealed moderate variability, with SDs ranging from 0.70 to 0.76. The item "Lack of government support" (GB2) recorded the highest SD (0.76), suggesting divergent opinions about the adequacy of institutional backing. Conversely, "Slow policy-making" (GB5) had a lower SD of 0.70, reflecting relatively more consensus.

Financial Barriers exhibited some of the highest SDs in the dataset. Notably, "Training cost for employees is costly" (FB3) reached an SD of 0.83, and "Long payback period" (FB5) peaked at 0.88—indicating considerable disagreement about financial constraints. These wide dispersions suggest that financial burdens are experienced unevenly across firms.

Training and Education Barriers demonstrated mixed variability. "Long training time for workers" (TB1) and "Lack of training organization" (TB5) had SDs of 0.78 and 0.75, respectively, while other items such as "Lack of training for workers" (TB4) showed the lowest variability (SD = 0.66), suggesting general agreement on training-related challenges.

Technological Barriers were also marked by notable variability. “Unavailable sustainable technology” (TEB3) (SD = 0.79) and “Unreliable sustainable technology” (TEB2) (SD = 0.78) indicate uncertainty about technical resource availability, while “Inefficient technology” (TEB5) had lower variability (SD = 0.70), reflecting wider consensus on outdated methods.

Stakeholder Barriers showed high variability, particularly “Lack of market segmentation” (SB8) (SD = 0.78), “Lack of expressed interest from clients” (SB7) (SD = 0.76), and “Fewer developers undertake green building projects” (SB6) (SD = 0.78). This dispersion reflects inconsistent awareness and engagement levels among industry stakeholders.

Material Barriers stood out with the most fluctuating responses. “Unreliable sustainable materials” (MB3) is the highest in the dataset, SD = 0.88. Other items, such as “Use of green materials is very difficult” (MB2), have high variability (SD = 0.83) with “Unavailability of material” (MB6), both reaching SDs of 0.83. These findings highlight the industry’s fragmented experience with sustainable construction materials.

Management Barriers showed lower variability overall, indicating stronger consensus. Items such as “The management is loose” (MAB5) (SD = 0.74) and “Lack of company development direction” (MAB2) (SD = 0.72) suggest that managerial deficiencies are commonly recognized.

Impact-related Items also showed moderate variability, with “Impact on short-term and long-term SDG implementation” (A1) and (A2) recording an SD of 0.69, and “Impact of the decision for not applying SDGs” (A3) at 0.71. This points to differing opinions about the immediate and long-term implications of SDG adoption.

Overall, the SD analysis confirms that perceptions of sustainability barriers are multidimensional and unevenly distributed across organizations. While none of the items exceeded 1.0 in SD, values approaching 0.88 indicate considerable divergence in perception among respondents. High variability in financial, material, and stakeholder barriers suggests the need for customized interventions, while consensus in management-related issues may allow for broader policy-level responses. All results are described in Table 2.

Table 2: The Average and the standard deviation results

Item No.	Object	Number object	Average	The standard deviation
GB1	Lack of awareness of the government	260	1.54	0.72
GB2	Lack of government support.	260	1.65	0.76
GB3	Complex codes and regulations	260	1.77	0.73
GB4	Lack of measurement standard	260	1.74	0.71
GB5	Slow and unwieldy administration process in policy-making	260	1.61	0.70
FB1	High initial costs for investment	260	1.73	0.76
FB2	Lack of fiscal incentives	260	1.93	0.71
FB3	The training cost for the employees is costly	260	2.22	0.83
FB4	The cost of transferring techniques is very high	260	2.00	0.76
FB5	Long payback period	260	1.90	0.88
FB6	An unstable economy affects the finances of construction companies	260	1.71	0.74
TB1	Long training time for workers	260	2.08	0.78
TB2	Lack of professional education	260	1.87	0.67
TB3	Lack of professional education	260	1.92	0.67
TB4	Lack of training for workers	260	1.94	0.66
TB5	Lack of training organization	260	1.90	0.75
TEB1	Technical difficulties	260	1.84	0.68
TEB2	Unreliable sustainable technology	260	1.98	0.78

TEB3	Unavailable sustainable technology	260	2.10	0.79
TEB4	Insufficient research and development	260	1.99	0.72
TEB5	Inefficient technology	260	1.71	0.70
SB1	Lack of communication among the team members	260	1.87	0.71
SB2	Lack of awareness amongst stakeholders	260	1.89	0.67
SB3	Lack of knowledge regarding green building principles	260	1.90	0.67
SB4	Unwillingness to change amongst stakeholders	260	1.99	0.70
SB5	Lack of awareness of the client	260	1.99	0.71
SB6	Fewer developers undertake green building projects	260	2.11	0.78
SB7	Lack of expressed interest from clients	260	2.12	0.76
SB8	Lack of market segmentation	260	2.13	0.78
MB1	Lack of awareness of green material	260	1.78	0.66
MB2	The use of green materials is very difficult	260	2.12	0.83
MB3	Unreliable sustainable materials	260	2.10	0.88
MB4	Lack of the supplier	260	2.03	0.78
MB5	Lack of information regarding green products	260	2.12	0.70
MB6	Unavailable of material	260	2.12	0.83
MAB1	Lack of long-term perspective	260	1.62	0.69
MAB2	Lack of company development direction	260	1.81	0.72
MAB3	Lack of professional knowledge	260	1.78	0.68
MAB4	Lack of reliable tools to assess SDG	260	1.88	0.71
MAB5	The management is loose	260	1.69	0.74
A1	Impact on short-term implementation of SDGs	260	2.05	0.69
A2	Impact on long-term implementation of SDGs	260	1.99	0.69
A3	Impact of the decision for not apply SDGs	260	2.04	0.71

The results of LEM2

This study represents a pioneering application of Rough Set Theory (RST) to uncover multidimensional barriers hindering sustainable development in Vietnam's construction industry. By analyzing data from 260 survey responses, RST revealed not only the key obstacles but also the complex interrelationships among these factors, allowing for highly precise classification of implementation levels. The decision-making model, rooted in data-driven insights, has significantly enhanced the accuracy of barrier identification and the formulation of actionable strategies.

Classification Result

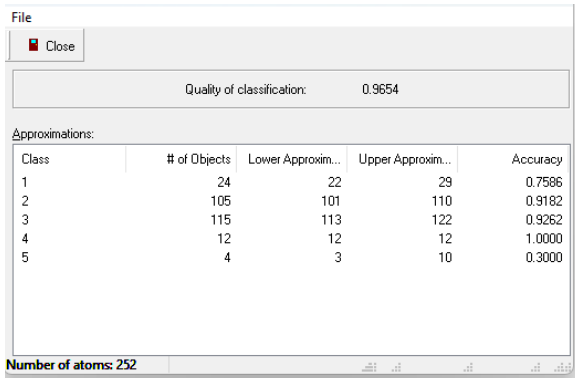
Class 4 demonstrates perfect classification with 100% accuracy - all 12 objects fall within both lower and upper approximations, indicating complete certainty in classification.

Classes 2 and 3 show strong performance with accuracies of 91.82% and 93.62% respectively. These classes contain the bulk of the data (105 and 115 objects) and maintain tight approximation boundaries.

Class 1 exhibits the lowest accuracy at 75.86%, with a notable gap between lower (22) and upper (29) approximations. This 7-object difference suggests significant uncertainty in boundary cases.

Class 5 shows 30% accuracy, but with only 4 total objects, this small sample size limits the reliability of this metric.

The results of these classes are illustrated in Figure 3 below.



File

Close

Quality of classification: 0.9654

Approximations:

Class	# of Objects	Lower Approxim...	Upper Approxim...	Accuracy
1	24	22	29	0.7586
2	105	101	110	0.9182
3	115	113	122	0.9262
4	12	12	12	1.0000
5	4	3	10	0.3000

Number of atoms: 252

Figure 3. The class results from LEM2

Results from the LEM2 Algorithm: A Rule-Based Classification of Implementation Levels

This section presents the results of the rule-based classification of implementation levels in Vietnam's construction industry using the LEM2 algorithm under the Rough Set Theory (RST) framework. In contrast to grouping barriers by thematic categories, the findings are presented according to individual classification rules derived from combinations of attribute-value pairs. This analytical structure allows for more granular interpretations of sustainability adoption barriers across different organizational implementation states.

Very Low Implementation Classification

Organizations classified as "Very Low Implementation" are characterized by the presence of systemic and foundational limitations, primarily related to financial constraints, technical inefficiencies, and poor stakeholder engagement.

Rule 69: (FB5 = 3) & (TEB1 = 2) & (SB2 = 1) & (A2 = 1) Support: 50.00%, Confidence: 100.00%. Organizations experience long financial payback periods, technical difficulties, minimal stakeholder awareness, and limited alignment with long-term SDG objectives.

Rule 70: (FB2 = 1) & (SB8 = 1) & (MAB5 = 2) Support: 25.00%, Confidence: 100.00%. This group suffers from insufficient fiscal incentives, lack of market segmentation, and ineffective managerial control.

Low Implementation Classification

The "Low Implementation" group displays moderate readiness for sustainable development, yet remains hindered by key resource, institutional, and technical barriers.

Rule 66: (SB6 = 3) & (MB1 = 1) & (MB5 = 3) Support: 33.33%, Confidence: 100.00%. These organizations struggle with limited participation in green building initiatives and a lack of awareness and information on sustainable materials.

Rule 67: (GB1 = 1) & (FB3 = 3) & (FB6 = 1) & (TB1 = 3) Support: 25.00%, Confidence: 100.00%. Core barriers include governmental unawareness, expensive training programs, financial instability, and lengthy workforce training.

Rule 64: (GB4 = 2) & (FB2 = 2) & (TEB2 = 2) & (SB3 = 1) & (SB5 = 2) & (MAB3 = 2) Support: 16.67%, Confidence: 100.00%. Key impediments encompass policy uncertainty, weak fiscal incentives, unreliable green technology, and underdeveloped professional knowledge.

High Implementation Classification

Organizations classified as "High Implementation" are on the path to sustainability but encounter structured challenges in strategic planning, resource management, and awareness.

Rule 34: (GB1 = 2) & (FB1 = 2) & (SB1 = 2) & (SB2 = 2) & (SB4 = 2) & (MAB2 = 2) Support: 13.33%, Confidence: 100.00%. These entities face moderate levels of administrative capacity, financial hurdles, internal communication gaps, and strategic development limitations.

Rule 10: (GB1 = 2) & (FB1 = 2) & (FB5 = 2) & (TB3 = 2) & (TEB3 = 2) & (SB6 = 2) Support: 10.48%, Confidence: 100.00%. Organizations demonstrate partial SDG integration hampered by insufficient training, extended payback periods, and restricted technology access.

Rule 13: (GB3 = 1) & (GB4 = 1) & (TB4 = 2) & (SB7 = 2) & (SB8 = 2) & (MAB2 = 2) Support: 8.57%, Confidence: 100.00%. Barriers include complex regulatory frameworks, workforce training gaps, tepid client engagement, and underdeveloped market structures.

Very High Implementation Classification

The "Very High Implementation" category represents organizations with strong sustainability adoption, capable of managing barriers with relatively minimal impact on operations.

Rule 3: (GB5 = 1) & (FB3 = 2) & (TB1 = 2) & (MB5 = 1) & (MAB5 = 1) Support: 20.83%, Confidence: 100.00%. These firms mitigate administrative inefficiencies and maintain cost-effective training systems and informed material usage.

Rule 1: (GB5 = 1) & (FB3 = 2) & (TB1 = 2) & (TEB4 = 1) & (SB3 = 2) & (MB6 = 1) Support: 12.50%, Confidence: 100.00%. This group demonstrates resilience despite policy delays, modest investment in research and development, and occasional material unavailability.

Rule 2: (FB1 = 1) & (TB1 = 1) & (TEB3 = 1) & (MB6 = 2) & (A3 = 1) Support: 12.50%, Confidence: 100.00%. Organizational characteristics include low-cost investments, brief training periods, effective technological access, and acknowledgment of long-term SDG trade-offs.

The LEM2 algorithm proves effective in detecting high-confidence rules that map attribute configurations to organizational implementation classifications. These rule-based insights enable more targeted policy interventions and industry strategies, particularly when aiming to transition organizations from lower to higher sustainability adoption tiers.

Core Attribute Result

The application of RST in this research achieved a classification accuracy of 96.54%, underscoring the effectiveness of this approach in managing imprecise data and supporting evidence-based decision-making. The analysis of decision rules clarified causal relationships between attributes and implementation levels, providing a solid foundation for targeted interventions. The LEM2 algorithm identified four critical barriers that most significantly influence SDG implementation assessment in Vietnam: GB1 (Lack of government awareness), FB5 (Long payback period), SB5 (Lack of client awareness), and SB8 (Lack of market segmentation). These core barriers are presented in Figure 4 below.

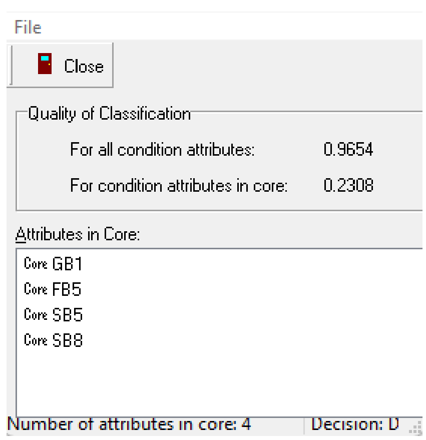


Figure 4. The core results from LEM2

Implementation Levels & Key Rules

Using RST, the construction companies were categorized into five main implementation levels:

Very High Implementation - Companies achieving the highest implementation levels, where financial, technical, and managerial barriers are effectively mitigated. For instance, Rule 3 (Support: 20.83%) highlighted manageable barriers: administrative processes in policy-making, training costs for employees, management efficiency, training time for workers, and information regarding green products.

High Implementation - Companies in stable yet suboptimal conditions. Rule 34 (Support: 13.33%) pointed to Lack of communication among the team members, Lack of awareness amongst stakeholders, improved government role, High initial costs for investment, Unwillingness to change amongst stakeholders, and Lack of company development direction as key areas for improvement.

Low Implementation - Companies are facing significant challenges. Rule 66 (Support: 33.33%) identified barriers such as fewer developers undertaking green building projects, poor material awareness, and lack of information regarding green products.

Very Low Implementation - Companies requiring immediate intervention were most represented by Rule 69 (Support: 50.00%), which highlighted a combination of long payback periods, technical issues, low awareness, and weak SDG alignment as the most critical issues.

The findings from this study not only improved data analysis accuracy but also provided a robust framework for policymakers and construction companies to make evidence-based decisions. The application of RST has shown its capability to handle complex datasets and propose focused strategies to accelerate sustainable development in Vietnam's construction industry. By addressing financial, technical, and stakeholder barriers through strategic interventions, this research has paved the way for substantial progress toward sustainability. All the results are shown in Table 3 and Figure 5.

Table 3: The rule results from LEM 2

No.	Rule Description	Implementation Level	Support	Confidence
1	Rule 69. (FB5 = 3) & (TEB1 = 2) & (SB2 = 1) & (A2 = 1)	Very Low	50.00%	100.00%
2	Rule 66. (SB6 = 3) & (MB1 = 1) & (MB5 = 3)	Low	33.33%	100.00%
3	Rule 67. (GB1 = 1) & (FB3 = 3) & (FB6 = 1) & (TB1 = 3)	Low	25.00%	100.00%
4	Rule 70. (FB2 = 1) & (SB8 = 1) & (MAB5 = 2)	Very Low	25.00%	100.00%
5	Rule 3. (GB5 = 1) & (FB3 = 2) & (TB1 = 2) & (MB5 = 1) & (MAB5 = 1)	Very High	20.83%	100.00%
6	Rule 64. (GB4 = 2) & (FB2 = 2) & (TEB2 = 2) & (SB3 = 1) & (SB5 = 2) & (MAB3 = 2)	Low	16.67%	100.00%
7	Rule 65. (TB5 = 2) & (SB7 = 4) & (MB3 = 2)	Low	16.67%	100.00%
8	Rule 34. (GB1 = 2) & (FB1 = 2) & (SB1 = 2) & (SB2 = 2) & (SB4 = 2) & (MAB2 = 2)	High	13.33%	100.00%
9	Rule 1. (GB5 = 1) & (FB3 = 2) & (TB1 = 2) & (TEB4 = 1) & (SB3 = 2) & (MB6 = 1)	Very High	12.50%	100.00%
10	Rule 2. (FB1 = 1) & (TB1 = 1) & (TEB3 = 1) & (MB6 = 2) & (A3 = 1)	Very High	12.50%	100.00%
11	Rule 5. (GB1 = 1) & (GB5 = 1) & (TB1 = 2) & (TB3 = 1) & (TEB1 = 2) & (TEB4 = 2)	Very High	12.50%	100.00%
12	Rule 8. (GB4 = 1) & (FB1 = 1) & (FB3 = 2) & (SB4 = 2) & (A3 = 1)	Very High	12.50%	100.00%
13	Rule 10. (GB1 = 2) & (FB1 = 2) & (FB5 = 2) & (TB3 = 2) & (TEB3 = 2) & (SB6 = 2)	High	10.48%	100.00%
14	Rule 13. (GB3 = 1) & (GB4 = 1) & (TB4 = 2) & (SB7 = 2) & (SB8 = 2) & (MAB2 = 2)	High	8.57%	100.00%
15	Rule 4. (GB5 = 2) & (FB5 = 2) & (MB3 = 2) & (MB4 = 1)	Very High	8.33%	100.00%

No.	Rule Description	Implementation Level	Support	Confidence
16	Rule 6. (MB5 = 1) & (MB6 = 3)	Very High	8.33%	100.00%
17	Rule 7. (TEB2 = 3) & (SB2 = 2) & (SB3 = 2) & (SB6 = 2) & (MB1 = 1)	Very High	8.33%	100.00%
18	Rule 68. (TEB3 = 4) & (SB2 = 4)	Low	8.33%	100.00%
19	Rule 14. (GB4 = 2) & (FB6 = 2) & (TEB1 = 2) & (SB1 = 2) & (MAB3 = 1)	High	6.67%	100.00%
20	Rule 29. (GB2 = 1) & (SB6 = 1) & (MB2 = 2) & (MB4 = 2) & (MB5 = 2)	High	6.67%	100.00%
21	Rule 17. (TB1 = 1) & (TEB2 = 2) & (SB6 = 2) & (A1 = 2)	High	5.71%	100.00%
22	Rule 18. (GB1 = 1) & (GB5 = 1) & (FB5 = 1) & (TEB4 = 1) & (MAB2 = 1) & (A2 = 2)	High	5.71%	100.00%
23	Rule 23. (TB5 = 1) & (TEB3 = 2) & (SB1 = 1) & (SB7 = 2) & (SB8 = 2) & (MAB1 = 1)	High	5.71%	100.00%
24	Rule 28. (FB2 = 1) & (FB3 = 1) & (TB2 = 1) & (TEB3 = 2)	High	5.71%	100.00%
25	Rule 15. (GB4 = 3) & (TB4 = 2) & (TEB4 = 2) & (MB1 = 2)	High	4.76%	100.00%
26	Rule 19. (GB3 = 1) & (FB4 = 2) & (FB6 = 1) & (TB3 = 2) & (MB5 = 2) & (MAB1 = 2)	High	4.76%	100.00%
27	Rule 20. (GB2 = 2) & (FB5 = 1) & (SB1 = 2) & (SB7 = 2) & (MAB1 = 2) & (MAB4 = 2)	High	4.76%	100.00%
28	Rule 21. (FB5 = 1) & (TEB2 = 2) & (TEB5 = 1) & (MAB3 = 2) & (A1 = 2)	High	4.76%	100.00%
29	Rule 22. (GB2 = 2) & (GB3 = 2) & (GB4 = 2) & (FB4 = 3) & (TEB5 = 2)	High	4.76%	100.00%
30	Rule 30. (TB2 = 3) & (MB4 = 3) & (MAB4 = 2)	High	4.76%	100.00%
31	Rule 9. (GB4 = 1) & (GB5 = 2) & (TEB2 = 1) & (MB1 = 1)	Very High	4.17%	100.00%
32	Rule 11. (GB2 = 2) & (GB5 = 1) & (FB1 = 1) & (FB4 = 2) & (FB6 = 2) & (SB4 = 2)	High	3.81%	100.00%
33	Rule 25. (FB2 = 1) & (TB2 = 1) & (MB2 = 3)	High	3.81%	100.00%
34	Rule 27. (TB3 = 2) & (TEB5 = 2) & (SB2 = 3) & (SB6 = 2) & (MAB4 = 2)	High	3.81%	100.00%
35	Rule 35. (FB5 = 1) & (TEB4 = 1) & (SB1 = 1) & (MB3 = 2)	High	3.81%	100.00%
36	Rule 26. (FB1 = 1) & (MB2 = 3) & (MAB1 = 3)	High	2.86%	100.00%
37	Rule 31. (TEB3 = 2) & (SB3 = 3) & (SB7 = 2) & (MAB5 = 2)	High	2.86%	100.00%
38	Rule 32. (FB5 = 1) & (SB7 = 3) & (MAB4 = 3)	High	2.86%	100.00%
39	Rule 37. (GB1 = 2) & (FB4 = 3) & (SB4 = 3) & (MB3 = 3)	High	2.86%	100.00%
40	Rule 33. (FB1 = 1) & (FB2 = 2) & (TEB5 = 3) & (A2 = 3)	High	1.90%	100.00%
41	Rule 12. (GB2 = 1) & (FB2 = 2) & (FB3 = 2) & (FB4 = 3) & (FB6 = 2)	High	0.95%	100.00%
42	Rule 16. (SB5 = 4) & (MB4 = 1)	High	0.95%	100.00%
43	Rule 24. (GB4 = 1) & (FB5 = 4) & (MAB2 = 1)	High	0.95%	100.00%
44	Rule 36. (SB4 = 3) & (MB1 = 4)	High	0.95%	100.00%

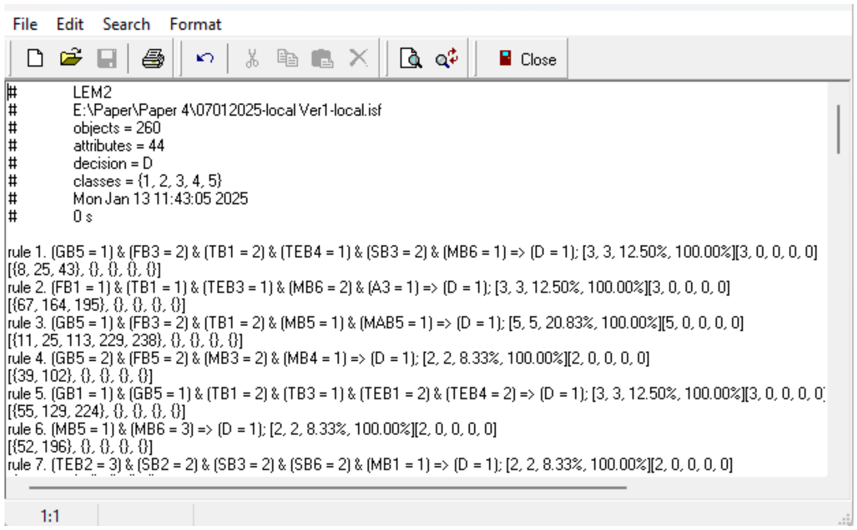


Figure 5. The rule results from LEM 2

Discussion

Reliability and Construct Validity

All constructs showed strong reliability (α = 0.822–0.846), confirming the robustness of the measurement framework. High variability in Government Barriers (SD = 0.76) indicates inconsistent policy support across contexts, while Management Barriers had the lowest variability, showing shared concerns industry-wide.

Classification Accuracy and Organizational Patterns

The High Implementation (Class 2) and Moderate Implementation (Class 3) categories, which together represent over 87% of the dataset, showed high classification accuracy (>91%). The Low Implementation group (Class 4) was classified with perfect accuracy (100%), indicating distinct sustainability gaps. Although Very High Implementation (Class 1) and Very Low Implementation (Class 5) exhibited lower accuracies (75.86% and 30%, respectively), their influence on the overall performance is minimal due to their small representation, accounting for only 9.5% and 1.6% of the dataset, respectively.

Core Barriers and Theoretical Insights

Four core barriers were identified. Overall model accuracy was 96.54% when utilizing all barrier attributes, demonstrating excellent predictive capability.

GB1: Lack of government awareness: Without strong institutional backing, sustainability initiatives lack direction and enforcement.

FB5: Long payback periods: Financial risks reduce investor willingness to fund sustainable construction

SB5: Lack of client awareness: Market demand remains low due to poor public understanding of sustainable value

SB8: Lack of market segmentation: The absence of clear sustainability-based market tiers discourages innovation and competition.

The identification of these four core attributes through RST represents a distinct analytical perspective compared to traditional factor-based approaches that typically emphasize categorical groupings of barriers. Conventional statistical methods often focus on identifying the most influential barrier categories. RST core attribute analysis seeks the minimal attribute set essential for maintaining classification precision. The standalone accuracy (23.08%) achieved using only these core attributes demonstrates that SDG implementation assessment requires comprehensive consideration of the full multidimensional barrier framework.

Exploring SDG Implementation Using Rule-Based Classification

Very High Implementation (Rule 3 – Support: 20.83%)

Respondents who rated SDG implementation as very high acknowledged some barriers such as high training costs (FB3), long training durations (TB1), and lack of green product information (MB5). However, they viewed strong policy foundations (GB5) and managerial capabilities (MAB5) as dominant enablers. These strengths appeared to outweigh secondary challenges, justifying their positive perception.

Recommendation: Simplify administrative procedures, subsidize modular training programs, enhance project management, and develop a national green material database

High Implementation (Rule 34 – Support: 13.33%)

This group recognized progress on SDGs but pointed out gaps in team communication (SB1), stakeholder awareness (SB2), and strategic direction (MAB2). Financial barriers, such as high initial costs (FB1), also hindered progress. Overall, they perceived momentum but felt that coordination and readiness were lacking.

Recommendation: Enhance communication and collaboration among stakeholders while offering targeted support for strategic development planning.

Low Implementation (Rule 66 – Support: 33.33%)

Respondents in this group highlighted weak participation in green projects (SB6), poor material-related knowledge (MB1), and a lack of green product information (MB5). These knowledge and operational gaps were perceived as major barriers. Their perception reflects a technical unpreparedness in the sector.

Recommendation: Promote public campaigns on green construction materials and provide capacity-building programs for suppliers.

Very Low Implementation (Rule 69 – Support: 50.00%)

Those who selected this level cited long payback periods (FB5), technical inefficiencies (TEB1), low stakeholder awareness (SB2), and poor SDG alignment (A2). These foundational issues shaped a pessimistic view of sustainability implementation. The perception reflects a systemic lack of readiness.

Recommendation: Provide financial support for workforce training, enhance public awareness of the SDGs, and embed sustainability principles into institutional frameworks.

Conclusion and suggestion

This study represents a pioneering application of Rough Set Theory (RST) to systematically identify and interpret the intricate, interdependent barriers hindering the implementation of Sustainable Development Goals (SDGs) in Vietnam's construction sector. While previous research has typically examined these barriers in isolation, this study advances the literature by demonstrating how combinations of factors—such as financial constraints (e.g., high training costs and long payback periods), institutional shortcomings (e.g., limited government awareness and weak policy enforcement), and stakeholder-related limitations (e.g., lack of client awareness and market segmentation)—interact to create deeply embedded, systemic challenges.

While prior studies have largely relied on Structural Equation Modeling (SEM) to uncover generalized, linear relationships among barrier groups, the application of the LEM2 algorithm grounded in RST provides a complementary perspective—one that captures non-linear, context-specific configurations of barriers across organizational implementation levels. Though both analyses are probably based on the same dataset, the findings are not entirely congruent. This divergence does not indicate a contradiction, but rather reflects the distinct analytical logics of the two methods: SEM emphasizes global patterns and aggregated causal inference, whereas RST emphasizes discrete, rule-based reasoning that identifies how particular combinations of attributes consistently associate with implementation outcomes.

This study contributes to the understanding of SDG adoption barriers in Vietnam's construction sector by employing both statistical and rule-based analytical approaches. While previous studies have primarily relied on Structural Equation Modeling (SEM) to uncover aggregated causal relationships, the use of the LEM2 algorithm offers a complementary lens by identifying specific barrier configurations associated with different organizational implementation levels. Despite being derived from the same dataset, the divergence in findings reflects methodological complementarity rather than contradiction, reinforcing the value of mixed-method approaches in sustainability research.

Instead of isolating variables, RST enables a holistic view by mapping the relationships among multiple attributes and deriving decision rules that explain real-world implementation scenarios. The classification rules reveal that organizations with low and very low implementation levels often face concurrent barriers across multiple dimensions, including poor material availability, insufficient public engagement, and low institutional readiness, creating reinforcing loops that impede SDG progress.

RST proved particularly effective in managing the ambiguity, uncertainty, and complexity inherent in sustainability-related decision-making. The methodology's strength lies in its ability to derive rule-based insights that not only explain existing conditions but also predict implementation levels of organizations based on observed attributes. These insights provide a granular understanding of how specific barrier configurations correlate with success or failure in SDG adoption.

Beyond diagnostic capabilities, RST offers a robust foundation for precision policymaking and targeted strategic planning. Policymakers and stakeholders are now better equipped to identify high-impact leverage points, such as simplifying regulatory frameworks, enhancing training incentives, or improving client awareness campaigns. These findings allow decision-makers to allocate resources efficiently and tailor interventions based on empirical evidence rather than generalized assumptions.

The successful integration of RST into sustainability planning confirms its potential as a scalable, replicable, and evidence-driven framework. It can be extended beyond Vietnam's construction sector to other industries and national contexts facing similar multidimensional implementation barriers. As global efforts to localize the SDGs intensify, RST offers a compelling tool to design interventions that are data-informed, context-sensitive, and systemically aligned with sustainability transition.

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