Prioritizing Barriers to Total Quality Management Implementation for Sustainable Construction Using AHP–GDM

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ABSTRACT

The construction industry is increasingly challenged by complex decision-making environments involving economic, technical, and sustainability related factors. This study proposes a structured multi-criteria decision-making (MCDM) framework to systematically evaluate and prioritize critical factors influencing construction project performance in Saudi Arabia. The methodology integrates objective weight determination with ranking-based MCDM techniques to assess multiple, often conflicting criteria using expert-driven and data-informed analysis. The results identify the most influential factors affecting construction efficiency and sustainability, providing a transparent and reproducible decision-support model. The main contribution of this study lies in offering a context-specific, analytically robust framework that advances MCDM applications in construction management, particularly within emerging economies. From a practical perspective, the findings support policymakers, project managers, and industry stakeholders in improving strategic planning, resource allocation, and risk-informed decision-making aligned with national development goals. Overall, the proposed framework enhances evidence-based decision-making and contributes to improving the resilience and performance of the construction industry.

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1 Introduction

Although Total Quality Management (TQM) originated as a traditional quality philosophy that predates Lean Manufacturing, it continues to hold significant relevance in the construction industry. Modern studies have demonstrated that effective TQM implementation enhances project performance by improving communication, safety, productivity, and client satisfaction. Egwunatum et al. [1] highlighted persistent challenges and opportunities for TQM in the Nigerian construction sector, while Budayan [2] proposed a roadmap for International Organization for Standardization—Quality Management System Requirements (ISO) 9001-certified companies to adopt TQM more effectively. Similarly, Vijayabanu et al. [3] empirically confirmed that TQM practices, such as benchmarking, supplier quality management, and employee empowerment, strongly influence cost reduction and client satisfaction in construction projects. Alghaseb [4] linked TQM practices with improved occupational

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safety and health in Saudi construction firms, and Alawag et al. [5] developed a framework for implementing TQM in sustainable industrialized building systems, further underscoring its adaptability to contemporary construction practices. These findings reaffirm that, despite its historical origins, TQM remains a cornerstone for achieving competitiveness, sustainability, and continuous improvement in modern construction.

The construction industry is widely recognized as one of the most fragmented and competitive sectors, where quality is typically defined in terms of "fitness for purpose" and "workmanship" [6]. Unlike manufacturing, construction projects are characterized by their temporary nature, involvement of multiple stakeholders, and variability in processes, which makes achieving consistent quality a persistent challenge [7]. In this context, Total Quality Management (TQM) provides a holistic framework for improving organizational performance. TQM views an organization as a network of interrelated processes that must be continually improved through employee participation, knowledge sharing, and leadership commitment. Its fundamental philosophy is "doing the right things right the first time, every time", which emphasizes timing, accuracy, and sustained performance [8,9].

In Saudi Arabia, the government's ambitious Vision 2030 program has placed efficiency, competitiveness, and sustainability at the center of national development [10]. The construction and building sector is a cornerstone of this transformation, contributing approximately 4.5% to Saudi Arabia's GDP, ranking as the fourth highest contribution among G20 countries [11,12]. However, despite this economic significance, the sector continues to face critical challenges, including cost overruns, delays, inconsistent quality standards, and limited adoption of advanced quality practices. These issues indicate a pressing need for effective TQM implementation to enhance project performance, client satisfaction, and long-term sustainability [13].

Although the benefits of TQM have been well-documented, many organizations struggle to achieve them in practice. Commonly cited obstacles include limited top management commitment, insufficient training, lack of resources, and employee resistance to change [1,2]. More recent studies in construction have reinforced these concerns. For example, Vijayabanu et al. [3] found that TQM practices such as benchmarking, supplier quality management, and employee empowerment significantly influence project outcomes, yet their implementation remains inconsistent. Similarly, Alghaseb [4] demonstrated that integrating TQM principles improved occupational safety and health in Saudi construction firms, while Alawag et al. [5] proposed a TQM framework for sustainable industrialized building systems. These findings suggest that while TQM remains relevant, its success is strongly dependent on addressing the barriers that hinder adoption in construction contexts.

The necessity of this study arises from the persistent underperformance of the Saudi Arabian construction sector in realizing the full benefits of TQM, despite its proven potential to enhance quality, efficiency, and sustainability. While existing research has examined barriers to TQM implementation across different industries, there is a notable gap in systematically prioritizing these barriers within the Saudi construction context, particularly considering Vision 2030 objectives. The novelty of this research lies in its application of the Analytic Hierarchy Process–Group Decision Making (AHP–GDM) method to evaluate and rank twenty-five barriers, thereby reducing bias and ensuring more reliable outcomes compared to single-decision-maker approaches. The specific objectives of the study are: (i) to identify the key barriers hindering TQM implementation in the Saudi construction industry; (ii) to prioritize these barriers based on their relative significance using AHP–GDM; and (iii) to provide practical insights for policymakers and managers to allocate resources effectively. By addressing these gaps, the study contributes to the body of knowledge by offering a structured framework for barrier prioritization in construction quality management and delivering actionable recommendations to improve TQM adoption in alignment with the strategic goals of Saudi Vision 2030.

2 Literature Review

2.1 Total Quality Management (TQM)

Total Quality Management (TQM) represents an integrated approach that combines a guiding philosophy, managerial techniques, and a set of principles applicable to all organizational processes and activities. Its central goal is to drive ongoing improvements in product and service quality, enhance customer satisfaction, and lower production costs [14].

Research identifies two primary dimensions of TQM: the technical dimension, which includes problem-solving tools, and the intangible dimension, which incorporates aspects like organizational culture, teamwork, empowerment, leadership, and continuous improvement [15,16]. In the construction sector, TQM focuses on managing the requirements and expectations of various stakeholders, including clients, design professionals, contractors, architects, and others [1,17,18]. The success of construction projects heavily depends on the strength of relationships among these stakeholders [19].

TQM has proven beneficial in the construction industry by fostering long-term partnerships, enhancing competencies, professionalism, and communication, and achieving project objectives [17,20]. However, implementing TQM in this sector is challenging due to factors such as the transient nature of projects, lack of standardization, involvement of multiple stakeholders, and the conservative culture prevalent in the industry [21]. Despite these challenges, organizational culture (OC) plays a pivotal role in the successful implementation of TQM [22].

A critical aspect of adopting TQM is translating customer needs and standards into actionable business plans [23]. Organizational culture significantly influences the strategies used to achieve quality improvement goals and shapes the overall organizational climate [24,25]. Therefore, it is essential for organizations to systematically establish and evaluate their OC using a comprehensive framework [26].

2.2 Barriers to TQM Implementation

The successful implementation of Total Quality Management (TQM) in the construction industry has often been hindered by a wide range of barriers that arise at different organizational levels. These barriers can be broadly classified into four major categories: leadership and management barriers, process and communication barriers, resource and organizational barriers, and training and development barriers [1,26–30].

Leadership and Management Barriers: Leadership plays a central role in ensuring the success of TQM initiatives. A lack of top management commitment is one of the most frequently observed obstacles, as senior leaders often fail to provide the vision, resources, or long-term dedication required for quality transformation. Ineffective strategic planning further limits progress, with organizations struggling to align TQM initiatives to long-term goals. Limited commitment to continuous improvement and weak accountability frameworks also undermines the ability to sustain quality initiatives over time [31,32].

Process and Communication Barriers: Clear processes and communication channels are essential for TQM to succeed. However, construction firms often face challenges such as inconsistent communication among project stakeholders, lack of clarity in defining roles and responsibilities, and weak coordination between different departments or subcontractors. These weaknesses lead to duplication of effort, errors, and conflicts, which ultimately reduce the effectiveness of TQM practices [27,30,33,34].

Resource and Organizational Barriers: TQM requires sufficient financial, technical, and organizational resources. In construction, resource-related barriers include inadequate allocation of funds for quality initiatives, rigid decision-making structures, and limited flexibility in adapting to changing project requirements. Poor organizational frameworks and bureaucratic resistance can also delay or obstruct the integration of quality management practices across projects [35–38].

Training and Development Barriers: The success of TQM depends heavily on employees' knowledge, motivation, and participation. Barriers in this category include low employee motivation, insufficient training opportunities, limited awareness of TQM principles, and a lack of structured programs for professional development. When employees are not adequately trained or motivated, the effectiveness of TQM initiatives is significantly reduced [39–41].

Cultural Barriers: Beyond structural and managerial issues, cultural barriers represent a significant challenge to TQM adoption in construction. Resistance to change, reluctance to embrace new practices, and lack of a quality-driven organizational culture often hinder the acceptance of TQM principles. Employees may view TQM initiatives as additional burdens rather than opportunities for improvement, leading to minimal engagement [1,17,42,43].

Taken together, these barriers highlight why many construction organizations fail to achieve the intended benefits of TQM. Unless these obstacles are identified, prioritized, and systematically addressed, efforts to integrate TQM will remain fragmented and ineffective. Therefore, it becomes essential to evaluate these barriers holistically and determine their relative significance, so that decision-makers can allocate resources efficiently and design strategies that focus on the most critical challenges.

2.3 Application of TQM in the Construction Sector

The construction sector is one of the most complex industries due to the involvement of diverse stakeholders, project-based work environments, and high variability in processes [17]. Unlike manufacturing, where production processes can be standardized and repeated, construction projects are typically unique, location-specific, and subject to external influences such as environmental conditions, labor availability, and client requirements. These characteristics make the achievement of consistent quality a considerable challenge [5,32].

In practical terms, TQM principles in construction can be applied through systematic quality planning, process control, performance measurement, and benchmarking [44]. Key practices include developing clear quality policies, establishing quality standards for materials and workmanship, monitoring supplier and subcontractor performance, and creating feedback loops for learning and improvement. Training programs and employee empowerment initiatives further ensure that the workforce is engaged and motivated to contribute to quality outcomes [45].

Despite its benefits, the adoption of TQM in construction remains inconsistent [45]. Many organizations fail to fully integrate TQM into their project management systems, treating it instead as a set of isolated practices rather than a comprehensive philosophy [45,46].

2.4 Multi-Criteria Decision-Making (MCDM) Tools and Techniques in the Construction Sector

Decision-making in the construction sector is inherently complex due to the involvement of multiple stakeholders, competing objectives, and the need to balance technical, economic, environmental, and social considerations [47,48]. Traditional decision-making approaches often fall short when dealing with this complexity because they are unable to systematically account for multiple, and sometimes conflicting, criteria. To address this challenge, Multi-Criteria Decision-Making (MCDM) methods have gained prominence as effective tools for analyzing alternatives, prioritizing options, and supporting transparent and structured decision-making processes [49,50].

MCDM techniques provide a systematic framework for evaluating alternatives against a set of predefined criteria, allowing decision-makers to consider both qualitative and quantitative factors [51]. These methods help reduce subjectivity, increase consistency, and enhance stakeholder participation by making the decision-making process more structured and transparent. In the construction sector, MCDM has been applied to a wide range of problems, including project selection, risk assessment, contractor evaluation, material selection, sustainability assessment, and resource allocation [52,53].

Commonly used MCDM tools include the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination and Choice Translating Reality (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), and fuzzy-based decision-making models. Among these, AHP is one of the most widely adopted methods due to its ability to break down complex problems into hierarchical structures, compare alternatives pairwise, and generate priority rankings [54]. The integration of AHP with Group Decision Making (GDM) approaches further enhances reliability by consolidating the judgments of multiple experts, thereby minimizing individual bias.

In the context of quality management, MCDM tools are particularly valuable for identifying and prioritizing barriers to implementation, as they allow for the systematic evaluation of interrelated factors [51]. By applying these methods, construction organizations can better allocate resources, focus on critical issues, and design more effective strategies for overcoming challenges. The use of MCDM techniques thus not only strengthens the objectivity of decisions but also aligns them with broader organizational goals such as efficiency, sustainability, and continuous improvement.

2.5 Research Gaps

Despite the growing application of multi-criteria decision-making (MCDM) methods in construction management, existing studies predominantly focus on isolated performance factors or adopt single-method approaches, often overlooking the interdependencies among economic, technical, and sustainability criteria. Moreover, much of the current literature is concentrated on developed construction markets, with limited empirical evidence addressing the contextual challenges of emerging economies, particularly in the Middle East [55]. In the case of Saudi Arabia, rapid infrastructure expansion driven by national development initiatives has intensified the need for structured, transparent, and context-specific decision-support frameworks. However, a comprehensive MCDM-based model that systematically integrates critical construction performance factors and aligns them with regional industry practices remains underexplored. This study addresses this gap by proposing an analytically robust and application-oriented MCDM framework tailored to the Saudi construction industry, thereby advancing both methodological rigor and practical relevance in construction decision-making research.

2.6 Justification for AHP–GDM for Present Study

The AHP–GDM approach was selected for this study due to its distinct suitability for complex, multi-stakeholder decision-making in the construction industry of Saudi Arabia. Unlike ranking-based MCDM methods such as TOPSIS, VIKOR, or COPRAS, which primarily rely on predefined quantitative performance scores, AHP–GDM enables a hierarchical decomposition of decision criteria and captures expert knowledge through structured pairwise comparisons. This feature is particularly important in the Saudi construction context, where qualitative judgments related to regulatory compliance, organizational capability, and sustainability practices play a critical role alongside quantitative factors. Furthermore, the group decision-making (GDM) extension allows for the systematic aggregation of diverse expert opinions, reducing individual bias and enhancing consensus among stakeholders with varying professional backgrounds. The built-in consistency verification mechanism of AHP further ensures the reliability of judgments, which is essential when evaluating interrelated construction performance criteria. Consequently, AHP–GDM offers a transparent, interpretable, and context-responsive decision-support framework that is better aligned with the practical realities of construction project evaluation in Saudi Arabia compared to alternative MCDM techniques.

Although recent MCDM techniques such as the Best–Worst Method (BWM) offer advantages in terms of fewer pairwise comparisons and reduced cognitive load, the Analytic Hierarchy Process (AHP) was selected in this study due to its superior ability to represent hierarchical and interdependent decision structures inherent to Total Quality Management (TQM) barriers. Unlike BWM, which focuses on direct best–worst comparisons, AHP enables a comprehensive decomposition of complex decision problems into multiple levels, allowing experts to evaluate nuanced relationships among criteria and sub-criteria. Furthermore, the group decision-making (GDM) extension and consistency ratio validation embedded in AHP provide an explicit mechanism for assessing and improving the reliability of expert judgments, which is particularly valuable in construction management studies where qualitative expertise plays a central role.

The integration of Group Decision Making (GDM) further enhances the robustness of the results by aggregating the judgments of multiple experts, thereby reducing individual bias and capturing diverse perspectives [56]. This is especially important in the construction industry, where multiple stakeholders including managers, engineers, contractors, and policymakers hold different views on quality management challenges. By combining AHP with GDM, the methodology ensures that the prioritization of barriers is both systematic and representative of real-world complexity.

Thus, AHP–GDM is selected over other MCDM approaches because it provides:

1. A hierarchical structure that simplifies complex problems.
2. Pairwise comparisons that are intuitive for experts to apply.
3. Quantitative priority weights that allow for ranking of barriers.
4. Group decision-making integration, reducing subjectivity and bias.

These features make AHP–GDM particularly relevant and effective for systematically prioritizing TQM barriers in the construction sector, providing both academic rigor and practical applicability.

Although previous studies have applied various MCDM techniques to assess quality management challenges in construction, most rely on single-decision-maker approaches or flat-ranking methods and are rarely validated through consistency checks. Moreover, limited attention has been given to Total Quality Management (TQM) barriers within the Saudi construction industry using group-based analytical frameworks. This study addresses these gaps by employing an AHP–GDM approach that systematically integrates expert consensus, hierarchical structuring, and consistency validation, thereby providing a more reliable and context-specific prioritization of TQM barriers. As such, the study offers both methodological advancement and empirical insight beyond existing literature.

2.7 Research Design

Yunis et al. [57] suggest that organizational transitions are shaped by both driving forces and obstacles. Certain factors can significantly influence the effective implementation of a total quality program, although their relevance may differ between organizations. Okuntade [58] highlights that each organization has unique characteristics, including size, technological capabilities, operational context, and structure, all of which affect the quality management process. To reduce common mistakes, organizations must develop a deeper understanding of their specific attributes and the challenges associated with implementing total quality measures. However, there is a noticeable lack of scholarly and empirical research on the practical execution of Total Quality Management (TQM). While many studies have explored barriers to successful TQM implementation [58], there remains a significant gap in the literature regarding how TQM strategies are executed in practice. Researchers have identified various obstacles to TQM implementation, such as organizational culture, management style, workforce challenges and inadequate project management [59,60].

The following steps have been applied to identify barriers to TQM implementation in the construction industry:

1. Conducting a comprehensive review of existing research on TQM implementation, specifically focusing on barriers within the construction sector.
2. Identifying commonly reported barriers to TQM implementation in the construction industry.

Based on these steps, a framework for selecting barriers was developed and is illustrated in Fig. 1. The identified barriers were subsequently utilized in the AGP-GDM methodology for prioritization. The dimensions and factors selected have been elaborated on and are presented in Table 1.

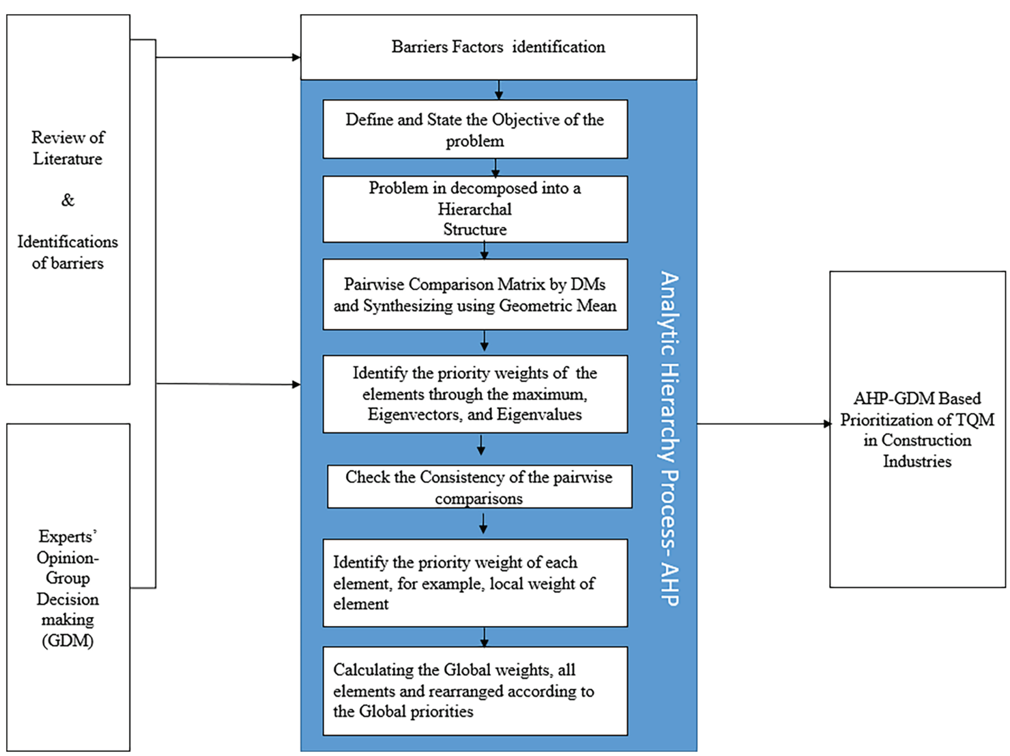

Figure 1: Framework for AHP based Prioritization of TQM factors

Rigid organizational structures in construction firms refer to inflexibility and limited adaptability needed for TQM implementation. These structures can create bottlenecks in decision-making processes and prevent the alignment of quality goals across departments [61]. Organizational hierarchies often inhibit innovation and collaborative decision-making, stifling the ability to implement cross-functional quality initiatives. The lack of integration between departments can also refer to a significant issue, as siloed teams fail to communicate effectively and align their efforts toward shared TQM objectives [62]. Additionally, cultural resistance within organizations often refers to entrenched practices and a reluctance to embrace organizational audits necessary for TQM alignment [63].

Employee resistance refers to one of the most pervasive barriers to TQM implementation. Resistance often arises from fears of increased workload, job insecurity, or the perception that TQM will complicate existing workflows [64]. This resistance may be exacerbated by a lack of awareness about the benefits of TQM, which contributes to apathy or outright opposition [65]. Employees may also refer to skepticism about management's intentions, particularly when TQM initiatives lack transparency or are not clearly aligned with organizational goals [63]. Moreover, the introduction of team-based approaches often refers to skepticism due to a lack of trust and communication between employees and leadership [64].

Effective leadership refers to a crucial element for the success of TQM initiatives. Many construction firms suffer from inadequate top management support, which manifests as insufficient resource allocation, lack of visible commitment, and limited involvement in quality improvement efforts [66]. Leaders often fail to fully understand TQM principles or align them with broader organizational strategies, which hampers implementation [67]. Insufficient delegation of responsibilities often refers to progress being impeded, as middle management and employees are left without clear direction or accountability [68]. The failure of leadership to visibly commit to quality goals also refers to a lack of trust and engagement among employees, leading to demotivation and inconsistent implementation [69].

The absence of effective training programs refers to a critical barrier, leaving employees ill-equipped to adopt new practices and methodologies. Many construction firms fail to allocate adequate resources for professional development, resulting in skill gaps that hinder successful TQM implementation [70]. Furthermore, existing training programs often refer to a lack of relevance or effectiveness, failing to address the specific needs and roles of employees [66]. This lack of targeted training perpetuates low motivation and limited participation in TQM initiatives [71].

Ineffective communication refers to a recurring challenge in TQM adoption, particularly in construction projects involving multiple stakeholders. Inconsistent communication channels and unclear roles often refer to misunderstandings and delays that disrupt project workflows [65]. Limited feedback mechanisms frequently refer to a missed opportunity for organizations to learn and adapt from past experiences [72]. Additionally, delayed information sharing often refers to challenges in fostering timely collaboration and resolving quality-related issues [66].

The six dimensions of Total Quality Management (TQM) implementation in the construction industry are studied along with their respective sub-criteria. Table S1 presents these six dimensions of TQM implementation along with the sub-criteria of each dimension considered for the present research, accompanied by their definitions.

Table 1: Random Index (R.I.) [73]

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Index	0	0	0.58	0.09	1.12	1.24	1.32	1.41	1.45	1.49

3 Methodogy

Analytic Hierarchy Process–Group Decision Making Methodology

The Analytic Hierarchy Process (AHP), introduced by Saaty [73] is a structured methodology designed to support decision-making in complex, multi-criteria, and unstructured scenarios. Due to its flexibility and efficiency, AHP has been extensively utilized by researchers in diverse decision-making applications. The Analytic Hierarchy Process (AHP) utilizes the knowledge and expertise of specialists to facilitate decision-makingm [74–76]. Expert input is integrated through pairwise comparisons, allowing for the evaluation of the relative significance of criteria or alternatives. However, when judgments are provided by a single decision-maker (DM), there is a risk of bias, which can compromise the accuracy of the results. To address this issue, group decision-making (GDM) is often employed [77,78]. In GDM, multiple decision-makers participate in the pairwise comparison process, thereby reducing individual biases and improving the reliability of the outcomes.

The flowchart presents the sequential implementation of the AHP–GDM methodology, beginning with problem definition and criteria identification and progressing through expert-based pairwise comparisons, aggregation of group judgments, and consistency ratio validation (Fig. 2). The inclusion of group decision-making ensures the integration of diverse stakeholder perspectives, while the consistency check enhances the reliability of expert judgments. These features collectively demonstrate the superiority of AHP–GDM in addressing complex, multi-level construction decision-making problems, leading to transparent, reliable, and defensible outcomes relevant for policy formulation and construction management in Saudi Arabia.

The pairwise comparisons from multiple decision-makers are aggregated using geometric means, which are then used to create a final decision matrix. This matrix, based on collective input, typically provides greater precision compared to relying on the judgment of a single DM. Saaty's [73] scale, detailed in Table S2, is applied to develop the pairwise comparison matrix, offering a standardized method for assigning weights and assessing criteria in the AHP framework.

The basic steps of AHP are illustrated here:

Step 1:

In the context of TQM implementation, key primary factors (dimensions) and sub-factors are organized into a comparison matrix, known as the decision matrix 'D' [79]. Each element within the 'D' matrix is assessed using Saaty's nine-point scale. The element d_{pq} in the matrix represents the relative importance of the p^{th} requirement compared to the q^{th}, facilitating a structured prioritization of technical and managerial requirements. This process is crucial for addressing and overcoming barriers to TQM implementation within the construction industry.

$$D = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1k} \\ d_{21} & d_{12} & \dots & d_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ d_{k1} & d_{k2} & \dots & d_{kk} \end{bmatrix} \quad (1)$$

Step 2:

The geometric mean (GM) for each row in the decision matrix and pairwise comparison matrices is computed. The resulting priority vector (PV) values are then obtained by normalizing the GM values for each row.

Step 3:

The principal eigenvalue λ_{max} is determined by summing the products of the column sums from both the decision matrix and pairwise comparison matrices with the priority vector (PV) values of each corresponding row.

$$\lambda_{max} = \sum_{i,j=1}^{k} C_j PV_i \quad (2)$$

where c_j is the sum of each column vector.

Step 4:

The level of inconsistency in both the decision and pairwise comparison matrices is checked using Eq. (3):

$$I.I. = \frac{\lambda_{max} - N}{N - 1} \quad (3)$$

where $I.I.$ is the Inconsistency Index, and N is the number of elements of each of the matrix.

Step 5:

Random Inconsistency Indices (R.I.) are calculated for each square matrix using Eq. (4). The computed $R.I.$ values are also provided and summarized in Table 1.

$$R.I. = \frac{1.98(N - 2)}{N} \quad (4)$$

Step 6:

The Inconsistency Ratios (I.R.) for each square matrix are calculated by dividing the Inconsistency Index (I.I.) values by the Random Index (R.I.) values. If the I.R. exceeds 10%, further adjustments to the elements of the matrices are required to improve consistency.

Step 7:

Pairwise comparison matrices ($A_i, i = 1, 2, \dots, n$) Table 1 is used to assign weight to these matrices. The P.V. values, principal eigenvalues, I.I. and I.R. are then computed using the same logic as in steps 2–6.

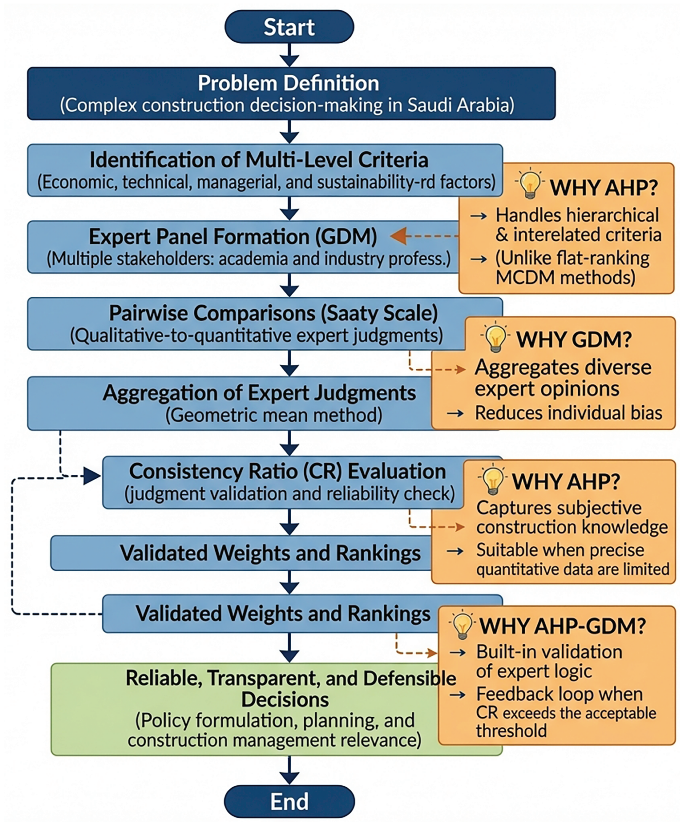

Figure 2: Flowchart illustrating the AHP–GDM methodological framework and its context-specific advantages for construction industry decision-making in Saudi Arabia, highlighting hierarchical structuring, expert consensus, and consistency validation

4 Case Illustration Using Analytic Hierarchy Process (AHP)–GDM Methodology in the TQM in Construction Industries

The Analytic Hierarchy Process (AHP) was employed to prioritize barriers to TQM implementation through pairwise comparisons. A total of 25 barriers across five dimensions—Leadership and Management Commitment (LM), Resource Limitations (RL), Inadequate Training and Development (TD), Employee Resistance to Change (ER), and Poor Communication and Coordination (PC)—were identified and structured hierarchically (Table 1). The AHP method was applied not only to prioritize the dimensions but also to determine the relative importance of each barrier. Unlike rankings based on simple averages, AHP provides a systematic evaluation of dimensions and sub-factors through pairwise comparisons, ensuring a more accurate assessment of their influence on TQM implementation in the construction industry.

An Analytic Hierarchy Process-Group Decision Making (AHP-GDM) approach has been employed to prioritize the dimensions and factors critical to the implementation of Total Quality Management (TQM) in the construction industry, while minimizing decision-maker bias. For the AHP-GDM process, three decision-makers (DMs) with over 10 years of direct involvement in construction management were identified. Among them, one DM possessed extensive administrative experience, including oversight of quality assurance processes and resource management in construction projects. The other two DMs brought core operational expertise in construction project execution and TQM practices. After a detailed explanation of the AHP method, a structured questionnaire was distributed to these expert decision-makers in person, and their responses were collected.

Saaty [80] developed the Analytic Hierarchy Process (AHP) and provided guidelines for prioritizing elements through a structured hierarchy. The AHP method, as discussed in Section 5, was employed to derive a final prioritized list of dimensions and factors influencing Total Quality Management (TQM) implementation in the construction industry. The following steps were undertaken:

1. Defining the goal: Establishing the objective of identifying and prioritizing TQM barriers.
2. Forming a hierarchical structure: Developing a hierarchy of the dimensions and their associated factors.
3. Constructing pairwise comparison matrices: Creating comparison matrices for each decision-maker.
4. Synthesizing pairwise comparisons: Aggregating comparisons for each dimension and its factors to calculate relative importance.
5. Checking consistency: Verifying the consistency of pairwise comparisons to ensure reliable results.
6. Aggregating judgments: Combining the judgments of multiple decision-makers to reach a consensus.
7. Ranking dimensions and factors: Assigning rankings to all dimensions and factors based on their global weights.

Step 1—Goal

In the first step barriers to total quality management implementation in construction industries is defined as the goal of the problem.

Step 2—Hierarchical Structure

The second step involves constructing a hierarchical structure by defining the dimensions and their associated factors for each dimension. This structure facilitates the decision-making process by systematically categorizing and organizing the identified dimensions and factors. Table 1 demonstrates the steps of the AHP structure, highlighting how the dimensions and factors are methodically aligned to form the complete hierarchy.

Step 3—Pairwise Comparison Matrices

Once the hierarchical structure is established, the subsequent step involves assessing the relative importance of the Dimensions and their associated Factors. This is achieved through pairwise comparisons performed by decision-makers. In the AHP methodology, the expertise and experience of professionals are leveraged to make final judgments, with their insights integrated into the pairwise comparison process.

When a single decision maker (DM) is involved, there is a risk of bias, which can result in misleading outcomes. To mitigate this issue, Group Decision Making (GDM) can be implemented. By involving multiple decision makers in the pairwise comparisons, biases are reduced, resulting in more reliable and balanced decision-making outcomes. Pairwise decisions from multiple decision makers are synthesized using geometric means to create a consolidated decision matrix, which improves accuracy compared to the input from a single DM.

Saaty's [81] nine-point scale, as shown in Table 2, is used to construct the pairwise comparison matrix. The final synthesized decision matrix, derived from the geometric means of individual pairwise comparisons, ensures greater precision and reliability. An example of the pairwise comparison matrix for all Dimensions, as provided by each expert, is presented in Table 2.

Table 2: Pairwise Comparison of main Dimensions by each DMs

	MD1	RO	ER	LM	PC	RL	TD	Eigen Value
DM1	**RO**	1	2	1/3	3	8	1/2	0.159139
	ER	1/2	1	1/5	2	4	1/4	0.086239
	LM	3	5	1	6	9	2	0.394971
	PC	1/3	1/2	1/6	1	3	1/6	0.055695
	RL	1/8	1/4	1/9	1/3	1	1/9	0.026171
	TD	2	4	1/2	6	9	1	0.277785
λ_{max} = 6.149444, CR = 0.023842, CI = 0.029889, RI = 1.24								
	MD2	RO	ER	LM	PC	RL	TD	Eigen Value
DM2	**RO**	1	2	1/3	3	9	1/2	0.162684
	ER	1/2	1	1/5	1/2	4	1/4	0.069802
	LM	3	5	1	6	9	2	0.391131
	PC	1/3	2	1/6	1	3	1/6	0.07256
	RL	1/9	1/4	1/9	1/3	1	1/9	0.02548
	TD	2	4	1/2	6	9	1	0.278344
λ_{max} = 6.262698, CR = 004191, CI = 005254, RI = 1.24								
	MD3	RO	ER	LM	PC	RL	TD	Eigen Value
DM3	**RO**	1	2	1/3	3	8	1/2	0.16072
	ER	1/2	1	1/5	1/2	4	1/4	0.07517
	LM	3	5	1	6	8	2	0.39153
	PC	1/3	2	1/6	1	3	1/6	0.06666
	RL	1/8	1/4	1/8	1/3	1	1/9	0.02617
	TD	2	4	1/2	6	9	1	0.280382
λ_{max} = 6.275041, CR = 004388, CI = 0055008, RI = 1.24								

Here λ_{max} refers to maximum Eigen value, CR is consistency ratio which is acceptable, CI is consistency index and RI is random index consistency.

Table 3 shows the pairwise comparison matrix of all the factors related to Students' Dimension provided by each decision makers.

Step 4—Synthesizing of Pairwise Comparison

After constructing the Pairwise Comparison matrix, the next step involved calculating the Synthesize values for the Pairwise Comparison of each Dimension and Factor. These values represent the relative contribution of one element compared to another. Table S3 presents the Synthesize values of the Pairwise Comparison for the main Dimensions as evaluated by all three Decision Makers.

Step 5—Check Consistency

The consistency of the values obtained from the pairwise comparisons is evaluated using the Consistency Index (CI) and the Random Index (R.I.) values, as provided in Table S4.

Table 3: Pairwise Comparison of Rigid Organizational Structures (RO)' factor by each DMs

	MD1	RO1	RO2	RO3	RO4	Eigen Value
MD1	RO1	1	2	2	2	0.390504
	RO2	1/2	1	2	2	0.276155
	RO3	1/2	1/2	1	2	0.195275
	RO4	1/2	1/2	1/2	1	0.138066
$\lambda_{max} = 4.121355$ CR = 0.04448 CI = 0.040452 RI = 0.9						
	MD2	RO1	RO2	RO3	RO4	Eigen Value
MD2	**RO1**	1	2	2	3	0.390504
	RO2	1/2	1	2	2	0.276155
	RO3	1/2	1/2	1	2	0.195275
	RO4	1/3	1/2	1/2	1	0.138066
$\lambda_{max} = 4.071022$ CR = 0.026031 CI = 0.071751 RI = 0.9						
	MD2	RO1	RO2	RO3	RO4	Eigen Value
MD3	**RO1**	1	2	2	2	0.383494
	RO2	1/2	1	2	2	0.27319
	RO3	1/2	1/2	1	3	0.218538
	RO4	1/2	1/2	1/3	1	0.124777
$\lambda_{max} = 4.215252$ CR = 0.078896 CI = 0.071751 RI = 0.9						

Step 6—Aggregation of Judgement

The subsequent step involved merging the multiple values provided by different decision-makers within the relevant matrix into a single consolidated value. This was accomplished using the weighted geometric mean method, which combines the judgments of all three decision-makers into a unified result. After obtaining the consolidated value, the same method was applied to calculate the synthesized values for each Dimension and its corresponding Factors. This iterative process ensured that the final values accurately represented the collective judgment of all decision-makers. Table 4 presents the aggregated synthesized values of the main Dimensions, calculated using the geometric mean method.

Step 7—Ranking

In the final step, the barriers within all Dimensions were ranked based on their global weights, reflecting their relative contribution to overcoming challenges in Total Quality Management (TQM) implementation in the construction industry. These weights were categorized into "local weights" and "global weights". Local weights represent the synthesized value relative to the preceding hierarchical level, while global weights indicate the synthesized value relative to the highest hierarchical level, identified as the overall goal. To determine an overall ranking of the sub-categories, the MCDM approach integrates the priority weights of each Dimension with the comparison ratings of the barriers using the following equation:

Global weights = $\sum$ (Local weight for Dimension iii $\times$ Local weight for Barrier jjj with respect to Dimension iii). The computed overall weights and rankings of the barriers are summarized in Table S5.

Table 4: Synthesizing of Dimensions after aggregation

Dimension	Eigen Value
Rigid Organizational Structures (RO)	0.16072
Employee Resistance to Change (ER)	0.07517
Lack of Leadership and Management Commitment (LM)	0.39153
Poor Communication and Coordination (PC)	0.06666
Resource Limitations (RL)	0.02617
Inadequate Training and Development (TD)	0.27883
$\lambda_{max} = 6.19$, CR = 0.031242, CI = 0.03874, RI = 1.24	

Fig. 3 illustrates the relative contribution of the major dimensions influencing construction decision-making, as derived from the AHP–GDM analysis. Overall, Fig. 3 provides a quantitative justification for prioritizing decision efforts toward high-impact dimensions while maintaining a balanced focus across all critical areas.

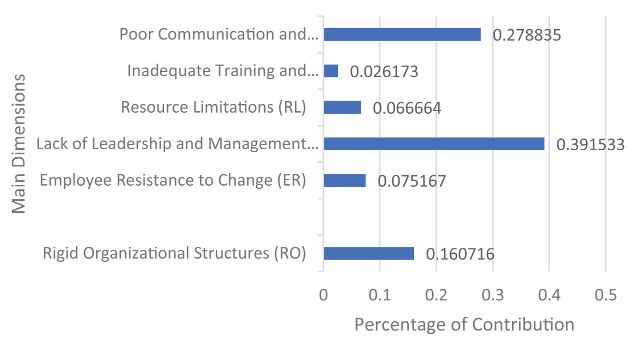

Figure 3: Dimensions with their contribution

Fig. 4 presents the dimensions influencing construction decision-making ranked in descending order of their contribution. The construction industry faces numerous barriers to implementing Total Quality Management (TQM), which have been ranked and prioritized for clarity in this study. Fig. 5 initially presented these barriers in ascending order, while Fig. 6 reorganizes them from lowest to highest. To enhance understanding, the five most critical barriers are highlighted in red, and the five least significant are marked in green. The top barriers include limited commitment to continuous improvement, limited understanding of TQM principles by leaders, lack of clear roles and responsibilities, inconsistent communication channels, and lack of flexibility in decision-making, emphasizing the need for sustained leadership engagement, role clarity, effective communication, and adaptability. Conversely, the lowest-ranked barriers, such as low employee motivation for learning, insufficient resources for professional development, time constraints on quality implementation, limited access to specialized training, and job security concerns, still warrant attention but are of lower priority. These rankings help identify the most critical factors for improvement, which are further elaborated upon in the recommendation section of Chapter Five, providing a roadmap for addressing these challenges and enhancing TQM implementation in the construction industry.

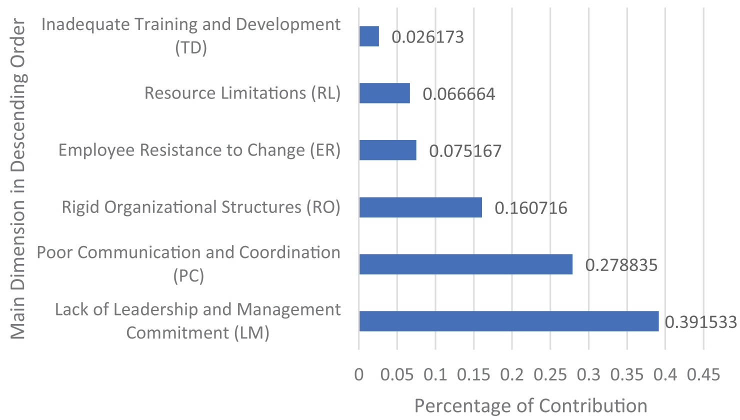

Figure 4: Dimensions with their contribution in Descending order

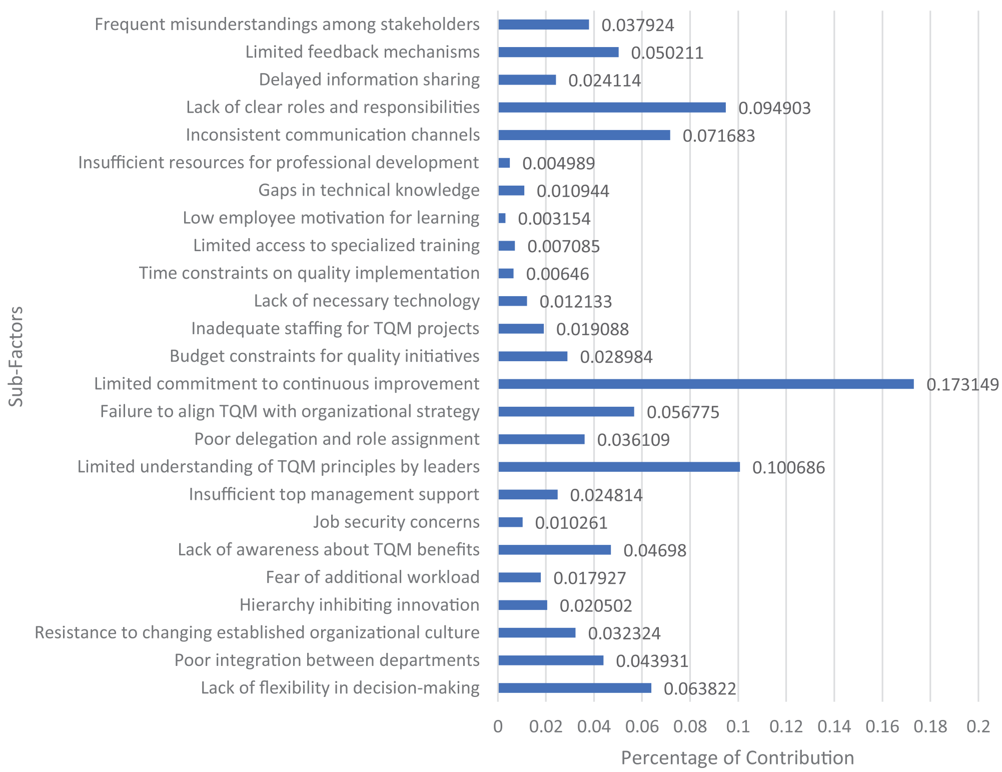

Figure 5: Factors with their contribution

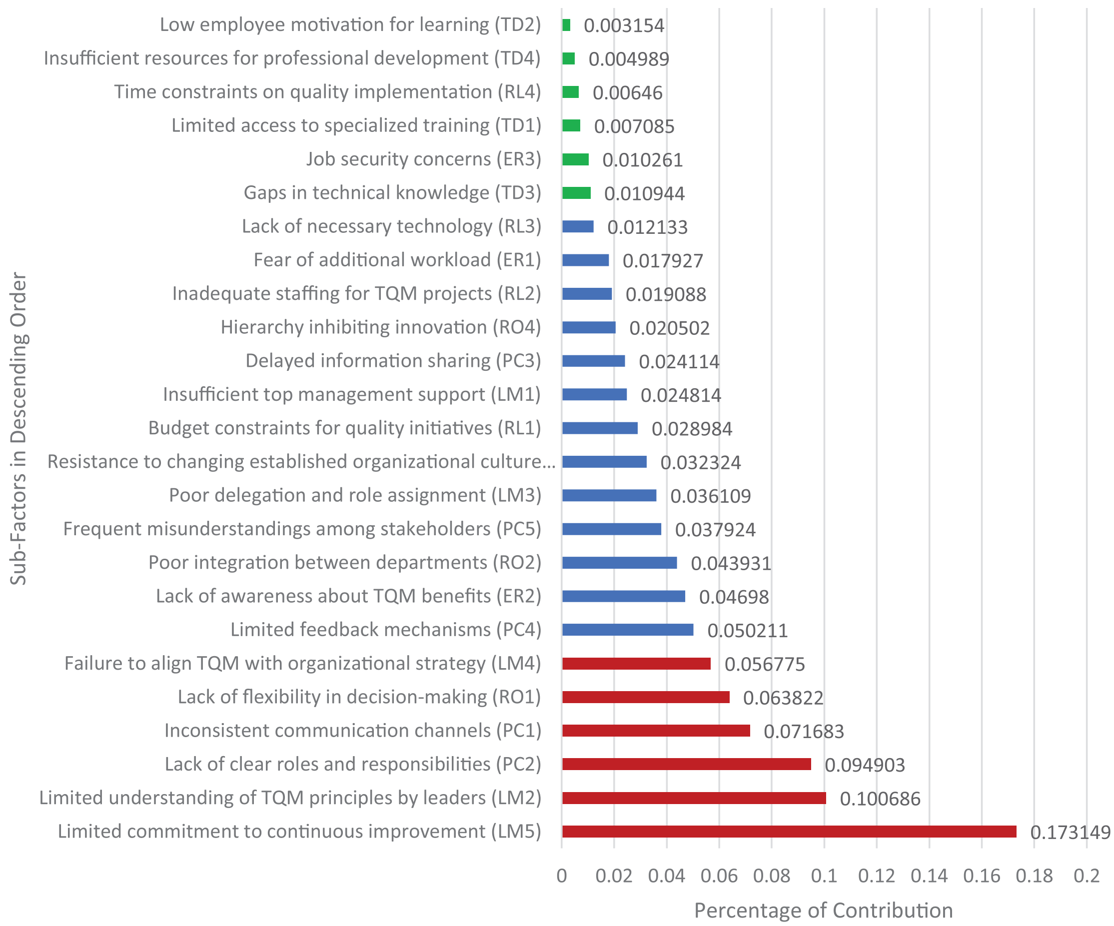

Figure 6: Factors with their contribution in Descending order

Table 5 presents the demographic and professional profile of the experts involved in the AHP–GDM analysis. All experts are based in Saudi Arabia, ensuring strong contextual alignment with local construction practices, regulatory frameworks, and Total Quality Management (TQM) implementation challenges. The panel represents a balanced combination of industry practitioners and an academic specialist, with substantial professional experience ranging from 12 to over 18 years. Their expertise spans construction project management, quality assurance systems, and TQM research, ensuring informed and credible judgments. This composition supports the reliability of the group decision-making process, despite the limited panel size, as the selected experts possess deep domain knowledge relevant to the study objectives.

Table 5: Demographic and Professional Profile of the Expert Panel

Expert ID	Demographics	Professional role	Sector	Years of experience	Area of expertise	TQM experience
E1	Based in Saudi Arabia	Senior Project Manager	Construction Industry	18+ years	Project management, quality control, large-scale infrastructure projects	Direct involvement in TQM implementation and quality audits
E2	Based in Saudi Arabia	Quality Assurance Consultant	Construction & Infrastructure	15+ years	TQM systems, process improvement, ISO-based quality frameworks	Extensive experience in TQM deployment and certification
E3	Based in Saudi Arabia	Academic Researcher	University	12+ years	Construction management, TQM research, decision-support systems	Published peer-reviewed research on TQM and construction quality

5 Results and Discussion

The Group Decision-Making-based Analytic Hierarchy Process (AHP–GDM) was employed to evaluate and prioritize barriers to Total Quality Management (TQM) implementation in the construction industry. Group decision-making was selected over individual evaluations because it consolidates diverse expert perspectives and minimizes subjective bias. The geometric mean (GM) aggregation method was used to synthesize pairwise comparisons provided by three decision-makers (DM1, DM2, and DM3). This approach enabled the derivation of reliable global weightages for six dimensions and twenty-five sub-barriers, ensuring a balanced representation of managerial, organizational, and process-related perspectives.

5.1 Prioritization of Barriers

The dominance of leadership and management-related barriers in our findings is consistent with a broad consensus in TQM literature. Limited top management commitment (our highest-weight barrier, LM5) has long been recognized as a primary obstacle to successful TQM implementation. For example, Burati et al. [70] noted that lack of senior management obligation was among the foremost causes of TQM failure. Recent studies in construction echo this: Mehrabioun Mohammadi et al. [82] identified “lack of top management commitment” and an ineffective quality culture as key impediments to TQM in developing-country projects. Similarly, our second-ranked barrier ineffective strategic planning/limited understanding of TQM by leaders (LM2) aligns with prior reports that absence of a clear quality strategy and insufficient grasp of TQM concepts at the leadership level undermine implementation. Mehrabioun Mohammadi et al. [82], found that many firms lacked a "solid quality strategy" and that some leaders did not fully understand or commit to modern quality concepts. This reinforces that without a well-informed, visionary leadership driving continuous improvement, TQM efforts are likely to stall.

Our results also underscore organizational and communication shortcomings as high-priority issues, which is strongly supported by earlier research. The prominence of "lack of clear roles and responsibilities" (PC2) and "inconsistent communication channels" (PC1) in our top five mirrors findings that unclear organizational structure and poor communication can seriously hinder quality initiatives. Past studies have emphasized that TQM success requires breaking down silos and ensuring effective communication across the organization. Selten and Klievink [83] pointed out that an unsuitable organizational structure and inconsistent procedures are significant barriers to quality improvement. Alawag et al. [42] listed lack of proper communication and unclear objectives among the obstacles that derail TQM programs. Our identification of PC1 and PC2 as critical confirms that without well-defined responsibilities and open communication, even committed leaders will struggle to embed TQM practices. Additionally, the barrier "lack of flexibility in decision-making" (RO1) highlights cultural rigidity, which resonates with the literature on organizational culture as a barrier. Rigid, bureaucratic decision processes are essentially an aspect of an unsupportive quality culture. In sum, the high-ranking barriers in our study—spanning leadership commitment, strategic clarity, role clarity, communication, and flexibility—are well-grounded in previous research, underscoring their fundamental importance for TQM success in construction and beyond.

By contrast, our lower-ranked barriers (Group 2, with weight < 0.0300)—including training and development issues (e.g., low employee motivation for learning, limited training access, insufficient development resources) and practical constraints (time limitations, employee job security concerns)—exerted relatively less immediate influence. Interestingly, traditional quality management literature does acknowledge these as impediments, even if they appeared secondary in our context. Numerous studies have cited insufficient training, employee resistance to change, and resource/time constraints as challenges in TQM implementation. Egwunatum et al. [1] identified inadequate employee training and poor documentation among the barriers to applying TQM, and Patmawati et al. [84] observed that companies often suffer from a lack of time and resources for quality improvements due to short-term business pressures. In some surveys, these "people and resource" factors were even ranked highly; The comparatively low weights in our study, however, suggest that in the Saudi construction context these factors are perceived as less critical relative to leadership and structural issues. One possible interpretation is that without strong leadership commitment and clear processes in place, improvements in training or minor resource boosts alone would have limited impact. This perspective aligns with the idea that top management's support creates an enabling environment in which employee-focused initiatives (training, motivation, etc.) can take effect. In other words, when leadership-driven barriers remain unresolved, they overshadow other concerns a pattern also noted in developing-economy construction research. Our two-tier classification (Group 1 high-priority vs. Group 2 secondary barriers) thus finds support in the literature: it mirrors the common recommendation that organizations must first address strategic and leadership shortcomings as a foundation, then progressively tackle the more granular issues of training, motivation, and resource allocation. This structured approach ensures that secondary barriers are not neglected but are addressed at the right time and with top management's backing, thereby facilitating a more sustainable TQM implementation.

Overall, the critical barriers prioritized in this study correspond strongly with those highlighted by previous research, reinforcing their validity and significance. The fact that leadership and organizational factors consistently emerge as the most influential barriers across different studies and contexts (from Turkey to Nigeria to our case in Saudi Arabia) underscores a universal lesson: TQM success is heavily contingent on committed leadership and an enabling organizational culture. Meanwhile, secondary issues like training, employee involvement, and resource provision, though important, tend to become truly effective only after the higher-level management issues are resolved. This critical analysis not only situates our findings within the context of existing knowledge but also adds depth by quantitatively confirming the hierarchy of barriers. By employing the AHP-GDM approach to prioritize challenges, our study provides empirical support to what many qualitative studies have suggested that addressing leadership, strategy, and communication problems should be the first line of action for construction organizations aiming to implement TQM, followed by continuous improvement efforts to mitigate the secondary barriers. This insight is crucial for practitioners and researchers alike, as it emphasizes where limited resources should be directed to achieve the greatest improvement in TQM adoption.

5.2 Sensitivity Analysis

To ensure the robustness and reliability of the AHP–GDM results, a sensitivity analysis was conducted. This analysis involved systematically varying the weights of the expert inputs and re-running the prioritization process to examine whether the ranking of barriers remained stable. Sensitivity analysis is a widely accepted validation technique in multi-criteria decision-making studies, as it allows researchers to evaluate how changes in input assumptions influence the final outcomes.

For this study, expert weights were perturbed by ±10% and ±20%, while maintaining consistency ratios within the acceptable threshold (<0.1). The recalculated global weights and rankings were then compared with the original results (Table 6).

Table 6: Sensitivity analysis of top-ranked barriers

Barrier code	Original Rank	Rank at +10% Variation	Rank at −10% Variation	Rank at +20% Variation	Rank at −20% Variation
LM5—Limited commitment to continuous improvement	1	1	1	1	1
LM2—Ineffective strategic planning	2	2	2	2	2
PC2—Lack of clear roles and responsibilities	3	3	3	3	3
PC1—Inconsistent communication channels	4	4	4	4	4
RO1—Lack of flexibility in decision-making	5	5	5	5	5
TD2—Low employee motivation	25	25	24	25	24

The sensitivity analysis results indicate that the top five barriers remained unchanged across all variations, confirming the stability of the findings. Minor fluctuations were observed among lower-ranked barriers, particularly in the training and development category, but these did not affect the overall conclusions of the study.

Therefore, the sensitivity analysis validates that the prioritization produced by the AHP–GDM methodology is both consistent and reliable.

5.3 Robustness Analysis

Robustness analysis was conducted to verify whether the ranking of barriers to Total Quality Management (TQM) implementation remains stable when a different multi-criteria decision-making (MCDM) method is employed. Unlike sensitivity analysis, which examines the impact of changes in criteria weights within the same decision model, robustness analysis evaluates the methodological stability of the results by changing the ranking technique itself.

To perform this analysis, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was applied as an alternative MCDM method. The same set of barriers, criteria structure, and aggregated expert judgments used in the AHP–GDM analysis were retained to ensure comparability. Criteria weights derived from the AHP–GDM model were used as input for the TOPSIS method, while the ranking mechanism was changed from pairwise-comparison-based prioritization to distance-based evaluation relative to ideal and negative-ideal solutions.

The rankings obtained from TOPSIS were then compared with those generated using the AHP–GDM approach. Table 7 presents the comparison of the top-ranked and lowest-ranked barriers under both methods.

Table 7: Robustness analysis: Comparison of rankings using AHP–GDM and TOPSIS

Barrier Code	Barrier description	Rank (AHP–GDM)	Rank (TOPSIS)
LM5	Limited commitment to continuous improvement	1	1
LM2	Ineffective strategic planning	2	2
PC2	Lack of clear roles and responsibilities	3	3
PC1	Inconsistent communication channels	4	4
RO1	Lack of flexibility in decision-making	5	5
TD2	Low employee motivation	25	24

The robustness analysis demonstrates a high degree of agreement between the AHP–GDM and TOPSIS rankings. The top five barriers remain identical in both ranking methods, confirming that the most critical barriers are method-independent. Only a minor positional change is observed for the lowest-ranked barrier (TD2), which shifts marginally from rank 25 to rank 24 under TOPSIS (Table 7). Such small variations among lower-ranked barriers are common in MCDM studies and do not affect the overall priority structure or managerial conclusions.

Therefore, the consistency of rankings across two fundamentally different MCDM techniques confirms that the proposed prioritization of TQM barriers is robust. The findings are not an artifact of the AHP–GDM methodology alone but reflect stable and reliable decision outcomes that persist even when the ranking method is altered.

5.4 Comparison with Previous Studies

The results of this study reinforce existing evidence on barriers to TQM implementation in the construction sector. For instance, Egwunatum et al. [1] emphasized that lack of top management commitment and ineffective leadership are primary challenges undermining quality initiatives in Nigerian construction firms, which aligns with the present study's identification of leadership-related barriers (LM5, LM2) as top-ranked. Similarly, Budayan [2] reported that ISO 9001-certified

Turkish construction companies often struggle with communication gaps and unclear responsibilities, supporting our findings that process-related barriers such as PC1 and PC2 are highly influential. Vijayabanu et al. [3] also found that benchmarking, employee empowerment, and supplier quality management were critical for project success in Indian construction projects, further confirming that leadership and process management must be prioritized before training- or motivation-related issues. In addition, Alghaseb [4] highlighted the role of TQM in improving occupational safety in Saudi construction firms, demonstrating that leadership-driven cultural change is essential for effectiveness. More recently, Alawag [17] proposed a TQM framework for sustainable Industrialized Building System (IBS) projects in Malaysia, reaffirming the need for strong managerial commitment and structured processes to overcome barriers.

While the overall findings of this study are broadly consistent with prior research, several results diverge from earlier studies and warrant discussion. In contrast to studies that place greater emphasis on sustainability or technical innovation as the dominant drivers of construction performance, the present analysis identifies economic and managerial dimensions as more influential in the Saudi Arabian context. This discrepancy may be attributed to contextual factors such as rapid infrastructure development, cost sensitivity, and tight project delivery timelines, which prioritize short to medium-term financial and managerial efficiency over long-term environmental considerations.

The relatively lower ranking of certain TQM barriers particularly those related to technical capability and sustainability can be explained by the evolving maturity of construction practices in Gulf countries. In contexts such as Saudi Arabia, the UAE, and Qatar, standardized construction procedures, widespread adoption of quality certifications, and strong regulatory oversight have reduced the perceived impact of technical barriers, positioning them as baseline operational requirements rather than critical obstacles. Similar observations have been reported in Gulf-based studies, where economic pressures, managerial coordination, and project governance consistently emerge as dominant challenges affecting quality performance [85,86]

Furthermore, while sustainability-related barriers are increasingly acknowledged across the region, their lower prioritization reflects a compliance-driven rather than strategically embedded approach to quality management. Studies in the GCC indicate that sustainability initiatives are often adopted to meet regulatory or contractual obligations rather than as core elements of TQM systems, which limits their influence on decision-making hierarchies. These findings suggest that the observed ranking is not indicative of irrelevance but rather highlights a transitional phase in which managerial and economic constraints must first be addressed to enable deeper integration of technical excellence and sustainability into construction quality management frameworks.

Collectively, these comparisons confirm that while training and employee motivation barriers are important, leadership and organizational barriers consistently emerge as the most critical across different contexts. The novelty of this study lies in systematically prioritizing these barriers using the AHP–GDM method, which provides a quantitative hierarchy of challenges and supports more targeted decision-making compared to prior qualitative studies.

5.5 Discussion and Implications

The findings of this study provide important insights into the prioritization of Total Quality Management (TQM) barriers within the Saudi construction industry by revealing how different dimensions influence implementation outcomes. Rather than treating all barriers as equally critical, the results demonstrate a clear hierarchy of influence, shaped by contextual, organizational, and market-driven factors.

The dominance of economic and managerial barriers suggests that TQM implementation in the Saudi construction sector is primarily constrained by cost pressures, resource allocation challenges, and decision-making inefficiencies. This indicates that quality initiatives are often evaluated through a short- to medium-term financial lens, where immediate project delivery objectives outweigh long-term quality improvement strategies. Such an orientation reflects the project-based nature of the construction industry, where managerial effectiveness and financial control act as enablers or inhibitors of sustained quality practices.

Although leadership and communication barriers have been widely emphasized in previous studies, their positioning within managerial rather than dominant strategic dimensions in this study suggests that these factors may be perceived as operational issues rather than transformational drivers. This implies that leadership commitment and communication effectiveness are increasingly viewed as baseline managerial requirements, and their impact becomes limited when broader organizational and economic constraints are not addressed simultaneously.

The relatively lower prioritization of technical and sustainability-related barriers does not imply a lack of importance but rather reflects their conditional influence. Technical capabilities appear to be considered standard operational requirements in mature construction environments, reducing their role as differentiating factors in TQM implementation. Similarly, sustainability-related barriers, while gaining attention, remain secondary due to regulatory compliance-driven adoption rather than proactive quality integration. This finding highlights a transitional phase in which sustainability is acknowledged but not yet fully embedded within quality management decision frameworks.

Methodologically, the application of the AHP–GDM framework allows these nuanced interpretations by capturing expert consensus and validating judgment consistency, thereby moving beyond descriptive identification of barriers. The practitioner review further reinforces these interpretations, confirming that the prioritization aligns with real-world construction practices and challenges.

Overall, the discussion underscores that effective TQM implementation in the Saudi construction industry requires a systemic shift from isolated quality initiatives toward integrated economic, managerial, and strategic alignment. Addressing high-impact barriers first can create enabling conditions for leadership, technical, and sustainability improvements, thereby supporting a more sustainable and resilient quality management culture.

Based on the AHP–GDM results and the descending contribution of decision dimensions, the following managerial actions are recommended in order of priority:

Prioritize economic decision controls (Immediate action): Construction firms should strengthen cost-monitoring systems, optimize budget allocation, and adopt data-driven financial planning tools to address the most influential decision dimension.

Enhance managerial coordination and governance (Short-term action): Companies should improve project management practices by clarifying roles, strengthening communication among stakeholders, and integrating structured decision-support tools into routine management processes.

Standardize technical practices and capability development (Medium-term action): Firms should invest in training, quality assurance protocols, and technology standardization to ensure consistent technical performance across projects, treating technical competence as a baseline operational requirement.

Gradually integrate sustainability initiatives (Strategic action): Sustainability measures should be incorporated in a phased manner, beginning with compliance-driven actions and progressing toward long-term environmental and social performance improvements.

Adopt group-based decision frameworks (Cross-cutting action): Managers are encouraged to institutionalize group decision-making mechanisms, such as AHP–GDM, to reduce individual bias, enhance transparency, and improve the reliability of strategic construction decisions.

Align decisions with national development goals (Policy-oriented action): Construction organizations should align project-level decisions with broader national strategies, ensuring that managerial priorities support long-term industry resilience and competitiveness.

In summary, the results of this study both validate and extend prior research by demonstrating, through an AHP-GDM approach, that leadership commitment, strategic clarity, and organizational communication are the primary enablers of TQM implementation, while secondary issues such as training and motivation become impactful only after these higher-level challenges are addressed. This structured prioritization provides a roadmap for construction firms and policymakers, ensuring that interventions are sequenced to achieve the greatest improvement in TQM adoption and sustainability outcomes.

To enhance external validation, a practitioner review was conducted involving construction professionals based in Saudi Arabia who were independent of the expert panel used in the AHP–GDM analysis. The practitioners were asked to review the final ranked list of TQM barriers and assess their practical relevance and priority. Overall, the practitioners expressed strong agreement with the dominance of economic and managerial barriers and confirmed that the identified rankings reflect real-world challenges faced in construction projects. Minor variations in lower-ranked barriers were noted, but no additional critical barriers were suggested. This review provides qualitative validation of the study findings and supports their practical applicability (Table 8).

Table 8: Summary of practitioner review feedback on ranked TQM barriers

Practitioner ID	Professional role	Years of experience	Agreement with Top-Ranked Barriers	Agreement with priority order	Key comments
P1	Project Manager (Construction)	20+ years	High	High	Economic and managerial barriers are the most critical in practice; rankings are realistic.
P2	Quality Manager	15+ years	High	Medium–High	Top barriers are accurate; some lower-ranked sustainability barriers may gain importance in future projects.
P3	Construction Consultant	18+ years	High	High	Rankings reflect actual challenges faced during project execution in Saudi Arabia.

(Continued)

Table 8 (continued)

Practitioner ID	Professional role	Years of experi-ence	Agreement with Top-Ranked Barriers	Agreement with priority order	Key comments
P4	Site Operations Manager	12+ years	Medium–High	High	Strong agreement with managerial and coordination-related barriers; no major barriers missing.
P5	Senior Engineer	14+ years	High	Medium–High	Overall prioritization is valid; technical barriers are appropriately treated as baseline requirements.

6 Conclusion

This study developed and applied a structured AHP–GDM framework to evaluate and prioritize key dimensions influencing decision-making in the construction industry within the Saudi Arabian context. By integrating hierarchical modeling with group-based expert judgment, the study provides a systematic and transparent approach for addressing complex, multi-dimensional construction decisions. From a theoretical perspective, this research advances construction management literature by demonstrating how decision dimensions interact within a hierarchical and consensus-driven framework, particularly in emerging and rapidly developing construction markets. The findings reinforce the dominance of economic and managerial dimensions while contextualizing the relatively lower, yet still meaningful, role of technical and sustainability factors, thereby contributing to a more nuanced understanding of construction decision priorities. In terms of practical contribution, the results offer clear, actionable guidance for construction managers and policymakers. By identifying decision dimensions in descending order of importance, the study supports more effective prioritization of resources, managerial focus, and strategic planning. The proposed framework enables practitioners to make reliable, evidence-based decisions aligned with organizational objectives and national development goals. From a methodological standpoint, the study demonstrates the suitability and robustness of the AHP–GDM approach for construction decision-making. The incorporation of group decision-making and consistency validation enhances judgment reliability and reduces individual bias, addressing key limitations of conventional MCDM methods. As such, the framework can be readily adapted and extended to other construction-related decision problems and regional contexts. Overall, this study provides a concise yet comprehensive decision-support model that strengthens theoretical insight, delivers practical value, and contributes a validated methodological approach for complex construction industry evaluations.

7 Limitations and Scope for Future Work

Despite its contributions, this study has certain limitations. The findings are based on a limited sample of expert judgments, which may influence the generalizability of the results. In addition, the analysis is context-specific to the Saudi Arabian construction industry, and caution should be exercised when transferring the findings to other regional or institutional settings. Future research could address these limitations by involving a larger and more diverse expert panel and by applying the proposed framework across different countries and construction contexts. Despite its strengths, this study acknowledges that alternative methods such as BWM could further reduce expert evaluation effort, particularly when expert availability is limited. Future research may explore hybrid or comparative applications of AHP–GDM and BWM to assess their relative efficiency and robustness in prioritizing TQM barriers.

7.1 Theoretical Implications

This study contributes to the academic discourse on quality management by systematically identifying and prioritizing barriers to TQM implementation in the construction sector. Unlike prior research that often lists barriers qualitatively, this study applies the AHP–GDM methodology to develop a quantitative hierarchy, thereby reducing subjectivity and enhancing methodological rigor. The findings extend existing theories of quality management by demonstrating that leadership- and management-related barriers outweigh training- and resource-related challenges, reaffirming the centrality of leadership commitment to organizational transformation. Furthermore, the study addresses a regional gap by focusing on the Saudi Arabian construction sector, providing new insights into the contextual dynamics of TQM adoption under Vision 2030.

7.2 Practical Implications

For industry practitioners, the results provide a structured framework for prioritizing barriers and allocating resources effectively. By focusing first on leadership commitment, strategic planning, and communication channels, managers can lay a foundation to tackle secondary barriers, such as training deficiencies and employee motivation. Policymakers and administrators can also leverage the findings to design targeted policies and capacity-building initiatives that directly address the most critical obstacles. Ultimately, this study equips construction firms with actionable guidance to strengthen TQM adoption, enhance competitiveness, and align with national development goals.

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Conflicts of Interest: The authors declare no conflicts of interest.

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