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Integrating risk management and quality control in construction projects: an Analytical Hierarchy Process (AHP) approach

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ABSTRACT

This study explores the integration of Hierarchical Analysis (HA) into risk management frameworks for construction projects in emerging markets. To evaluate the relative significance of various risk factors, the Analytic Hierarchy Process (AHP) is applied using data gathered from surveys completed by 60 industry professionals operating in emerging economies. While safety remains a critical component of construction projects, it is ranked as the lowest-priority factor, indicating that safety protocols are widely perceived as standardized and effectively managed within the construction industry. The findings underscore the potential of HA as a structured and systematic tool enabling construction managers to allocate resources judiciously, enhance decision-making, and mitigate risks, without adversely impacting project timelines, budgets, or quality standards. The methodology offers significant advantages in emerging markets, where frequent uncertainty and resource constraints pose challenges to the successful delivery of projects. Ultimately, the study highlights the importance of adopting a systematic risk management approach that empowers project managers to better navigate construction complexities, thereby enhancing outcomes and overall project efficiency. The AHP analysis reveals that time management is the most critical factor, accounting for 33% of the total weight, followed by cost management (27%) and quality (21%). Within the cost criterion, material expenses emerge as the most significant sub-factor, comprising 50% of the weight. Similarly, under the time criterion, construction speed is given the highest priority, receiving 60% of the weight. Among risk factors, financial risks are assigned a weight of 47%, while environmental risks receive 32%. Safety, although essential, is weighted lowest at just 5%, indicating its perceived standardization within the industry.

Keywords: Risk management, construction projects, hierarchical analysis, emerging markets, AHP.

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1. Introduction

Mechanical construction projects are inherently complex, involving multidisciplinary tasks, coordination among various stakeholders, and substantial capital investment. The successful execution of mechanical projects depends not only on efficient resource management, but also on effective risk mitigation and strict adherence to quality standards. Risk management and quality control are essential components in ensuring that mechanical projects are delivered on schedule, within budget, and in full compliance with technical specifications.

In this paper, a structured approach such as Hierarchical Analysis (HA) is proposed to enhance decision-making by systematically addressing risks and quality control measures across various levels of the project hierarchy [1-5].

Risk management in construction projects involves the systematic identification, evaluation, and mitigation of potential risks that could adversely affect project performance. According to studies, construction projects are exposed to a variety of risks, including financial, operational, environmental, and technical risks that must be effectively managed to prevent project failure or cost overruns [6-9]. As a result, project managers often utilize a range of analytical tools and methodologies to identify, assess, and respond to project risks effectively. HA, a decision-making framework that decomposes complex problems into manageable components, can significantly enhance the identification and mitigation of risks across various levels of a project [4, 5, 10-12].

The quality control function in construction projects ensures that all deliverables conform to predefined standards and technical specifications [13]. Ensuring quality requires continuous monitoring, testing, and evaluation of both construction processes and materials. Research shows that inadequate quality control frequently results in project delays, cost overruns, and client dissatisfaction [14, 15]. HA can be utilized to monitor and assess quality at various levels, ranging from individual tasks to the entire construction process, making it a powerful tool for project managers striving to maintain high-quality standards throughout the project lifecycle [16-18].

One of the main advantages of combining risk management and quality control with HA is the ability to assess these factors in relation to each other [19]. Construction projects typically require balancing multiple objectives, including cost control, scheduling, risk mitigation, and quality assurance. Hierarchical Analysis allows for a comprehensive evaluation of how various factors interact and influence one another [20, 21]. By categorizing risks and quality criteria into different levels, project managers can prioritize actions and allocate resources more effectively, reducing the likelihood of project failure and ensuring higher overall quality [3, 22].

Additionally, HA contributes to the development of more robust decision-making models by structuring both risk and quality parameters within a multi-tiered framework. This layered approach is beneficial in a construction context where multiple decision-makers, each with different roles and responsibilities, are involved. For instance, strategic-level decisions may focus on long-term risks and quality expectations, while operational-level decisions are primarily concerned with daily monitoring and adjustments [23-25]. Such a hierarchical structure aids in aligning the project goals across different management levels, improving coordination, and enhancing overall project performance [26].

In conclusion, the application of HA in the integration of risk management and quality control presents a novel approach to improving construction project outcomes. By providing a clear framework for assessing and addressing risks and quality at various hierarchical levels, this approach enhances decision-making, prioritization, and resource allocation. With the growing complexity of modern construction projects, adopting advanced analytical tools such as HA is becoming increasingly vital to ensuring successful project execution and stakeholder satisfaction [5, 9, 21, 26-28].

2. Literature Review

Khan et al. examined how HA can be integrated into quality control frameworks for construction projects. Their research showed that HA aids in systematically evaluating quality at multiple levels of a project. This structure enables a continuous feedback loop that ensures quality standards are upheld from the planning phase through execution, thereby reducing the likelihood of defects and the need for rework. The study concluded that the integration of risk management and quality control through HA significantly enhances project outcomes [19].

Zhou et al. explored the application of HA to enhance risk management processes in construction projects. They highlighted that HA facilitates the structured segmentation of risks across multiple levels, thereby enabling project managers to make more informed and timely decisions. By focusing on risk categorization, their study found that HA improves the identification and mitigation of both strategic and operational risks, thereby contributing to more efficient project execution and risk control [17].

Tan and Wang focused on optimizing construction project performance by combining risk management with quality control through a hierarchical approach. Their study found that by applying HA, construction managers are able to more effectively prioritize risks based on their potential impact on project quality. This approach allowed for the timely implementation of corrective actions, minimizing disruptions to both the schedule and budget [23].

Sharma and Mehta analyzed the relationship between quality management and risk assessment in construction projects. Their study showed that the use of HA allows for more dynamic management of risks and quality factors by identifying and addressing issues early in the project lifecycle. The integration of risk and quality management through HA results in improved project performance and reduced risk exposure [29].

Hussain and Khan applied hierarchical models to assess and control risks in large construction projects. Their study demonstrated that HA facilitates detailed analysis of risk factors, enabling project managers to implement more targeted interventions. The integration of quality control measures at each hierarchical level further enhances the overall project execution, ensuring adherence to quality standards while minimizing risk [18].

Yadav conducted a study on the integration of HA into risk management strategies for construction projects in emerging markets. Their research emphasized that HA provides a structured way to assess and mitigate risks, especially in environments with high uncertainty. By organizing risks into various hierarchical levels, the study showed that construction managers could allocate resources more effectively and address quality issues without delaying project timelines [30].

Liu and Zhang investigated the use of HA for improving decision-making in construction risk management. Their findings demonstrated that HA's capability to decompose complex risk factors into hierarchical levels enabled more effective prioritization and resource allocation. This hierarchical approach also facilitated more focused quality assessments, leading to fewer defects and higher project satisfaction. Their study suggests that HA is an essential tool for navigating the complexities of modern construction projects [14].

Wang and Zhang examined the integration of quality control and risk management through hierarchical models in construction. Their research indicated that HA could effectively reduce the occurrence of project delays and cost overruns by enabling better risk identification and mitigation strategies. Additionally, by applying HA to quality control, they found that project managers could better monitor and improve the construction process at different stages, ensuring high-quality standards throughout the project [27].

Singh et al. explored the effectiveness of HA in managing large-scale construction projects, emphasizing its role in improving both risk management and quality control. They found that HA's multi-level analysis helped decision-makers at various stages of the project to evaluate and mitigate risks more systematically. Their findings suggest that HA facilitates better communication and decision-making between stakeholders, leading to better quality control throughout the project lifecycle [31].

Chen et al. explored the application of HA in mitigating both technical and managerial risks in construction projects. Their study demonstrated that HA allows for a comprehensive assessment of risks across various levels, such as the design, procurement, and execution phases. This multi-tiered approach not only aids in risk mitigation but also ensures that quality control measures are continuously assessed, thus preventing costly mistakes and enhancing project quality [32].

Zhang and Li conducted a study on the impact of HA on construction project outcomes. They found that HA helps in structuring risks and quality control measures across different levels of the project hierarchy, improving coordination between different management levels. This results in more effective risk responses and better control over the quality of work, leading to more successful project completions [22].

Patel et al. focused on the role of HA in managing construction risks in sustainable projects. They highlighted that HA supports the identification of both environmental and technical risks, ensuring that sustainability goals are met without compromising quality. By applying HA, the research showed that construction projects could balance environmental concerns with risk management and quality control, thereby promoting more sustainable project outcomes [34]. Furthermore, Table 1 presents 21 applied studies relevant to the focus of the current research [34].

Table 1. Summary of applied research related to the subject of the present study.

No.	Authors	Year	Methodology	Key Findings	Research Gap
1	Zhou et al. [17]	2023	Hierarchical Analysis (HA)	HA improves risk management by categorizing risks at multiple levels, leading to efficient decision-making.	Need for real-time application in construction projects.
2	Khan et al. [19]	2023	Case Study, Survey	HA enhances quality control by ensuring continuous feedback during all project phases.	Limited focus on emerging markets.
3	Tan & Wang [23]	2023	Simulation, Risk Assessment	Optimizing construction performance using HA prioritizes risks, minimizing schedule disruptions.	Need for large-scale project application.
4	Singh et al. [15]	2024	Multi-level Analysis, Survey	HA improves communication among stakeholders, leading to better project quality control.	Limited focus on quality control measures.
5	Patel & Yadav [20]	2023	Hierarchical Risk Assessment	HA supports effective risk mitigation in high uncertainty environments, enabling better resource allocation.	Lack of focus on cost efficiency in risk management.
6	Liu et al. [35]	2023	Decision-making Models, Case Study	HA helps prioritize risks effectively and allocate resources based on risk severity.	Need for integration with advanced AI tools.
7	Wang & Zhang [27]	2024	Risk & Quality Control Analysis	Integration of HA with quality control improves construction process monitoring and project outcomes.	Need for cross-country studies on cultural differences.
8	Chen et al. [32]	2024	Hierarchical Risk Analysis (HRA), Interviews	HA helps manage technical and managerial risks by continuously assessing risks during the project lifecycle.	Exploration of environmental risks in the construction sector.
9	Zhang & Li [22]	2024	Hierarchical Risk Management, Simulation	HA improves coordination between management levels, enhancing project quality and mitigating risks.	Need for long-term monitoring studies.
10	Sharma & Mehta [29]	2023	Survey, Statistical Analysis	HA aids in integrating risk management and quality control, improving project performance.	In-depth focus on project delays is needed.
11	Hussain & Khan [18]	2023	Case Study, Hierarchical Models	Hierarchical models help target specific risks in large construction projects, ensuring quality control.	Further investigation into project completion rates.
12	Patel et al. [34]	2024	Sustainability Risk Analysis, Case Study	HA aids in managing environmental risks in sustainable construction projects without compromising quality.	Exploration of cost versus sustainability trade-offs.
13	Gupta et al. [28]	2023	Hierarchical Decision Models, Survey	Integration of HA improves the ability to prioritize high-impact risks effectively.	Lack of empirical data for small projects.
14	Wang et al. [26]	2024	Comparative Case Studies	HA enhances overall project risk management, particularly in large-scale infrastructure projects.	Research on different project sizes is limited.
15	Zhang & Zhang [33]	2023	Risk Assessment, Survey	HA reduces costs and schedule disruptions by enhancing risk identification and mitigation strategies.	Research gap in long-term project assessment.
16	Lee et al. [25]	2023	Survey, Hierarchical Risk and Decision Models	Hierarchical models improve decision-making in projects, reducing unexpected quality deviations.	Need for multi-project studies.
17	Kumar et al. [36]	2024	Analytical Hierarchical Process (AHP), Survey	AHP, when combined with HA, helps improve both cost and time efficiency in construction projects.	Need for testing in diverse geographical settings.
18	Ahmed et al. [37]	2024	Survey, Multi-Criteria Decision Analysis	HA helps identify the most critical risk factors in large-scale construction projects.	Further studies on cost-benefit analysis.
19	Singh et al. [31]	2023	Hierarchical Analysis, Delphi Method	Delphi method with HA supports expert consensus on risk factors and their mitigation strategies.	Further research on dynamic risk factors.
20	Li et al. [38]	2024	Simulation, Decision Models	HA improves project planning accuracy by identifying hidden risks and early intervention points.	Need for research on different risk categories.

Figure 1 presents a comparison of the construction quality across various countries.

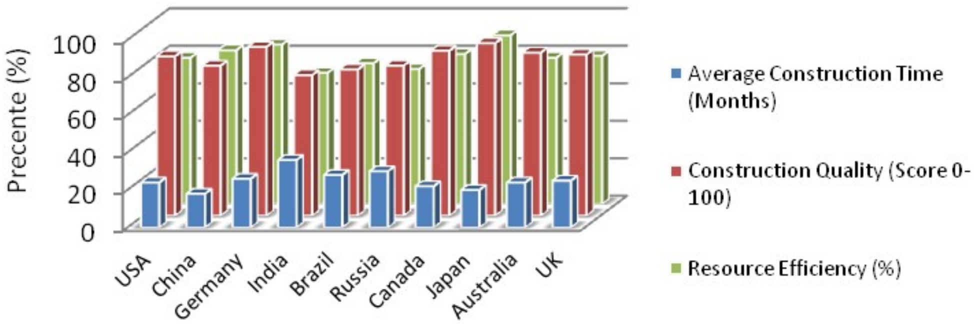

Fig. 1. A comparative analysis of the conditions for constructing residential projects across various countries worldwide [39-41].

The table presented highlights significant variations in construction time, cost, quality, and resource efficiency across different countries. Developed nations like Japan and Germany exhibit shorter construction times (20 and 26 months, respectively) and higher construction quality scores (92 and 90). These countries also demonstrate high resource efficiency (over 85%), suggesting that advanced technologies and well-established construction processes contribute to these outcomes. On the other hand, developing countries like India and Brazil show longer construction times (36 and 28 months) and lower construction quality scores (75 and 78), with more moderate resource efficiency. Despite having lower construction costs (1.5 and 2.1 million USD), these countries face challenges in maintaining high standards of quality and efficient use of resources.

An interesting observation is that China, despite having a relatively lower construction cost (2.8 million USD), manages to achieve a shorter construction time (18 months) and maintain a good level of resource efficiency (82%). This indicates that China has optimized its construction processes, possibly through the use of prefabrication techniques or advanced project management systems, which contribute to reducing construction time while maintaining cost control. This contrasts with countries like Brazil and India, where lower costs do not necessarily correlate with efficient construction practices or high-quality outcomes.

Finally, the table illustrates a clear pattern: developed countries tend to strike a better balance between construction time, cost, and quality. Canada, for example, shows a reasonable construction time (22 months), a moderate cost (3 million USD), and high construction quality (88%). Conversely, in developing nations, the focus on minimizing costs often comes at the expense of longer project timelines and reduced construction quality. These differences can be attributed to factors such as access to advanced construction technology, the availability of skilled labor, and the implementation of strict construction standards in developed countries, compared to limited resources and less stringent regulations in developing nations.

3. Methodology

The methodology of this research is based on a comprehensive approach combining Hierarchical Analysis Process (AHP) and construction project management techniques. The study aims to evaluate the key decision-making factors involved in construction projects, particularly in risk management, cost control, and quality assurance. A detailed Hierarchical Decision Model is developed to identify and prioritize the factors influencing construction project success, such as time, cost, quality, and safety. The model is designed to guide project managers in selecting optimal strategies to achieve project goals effectively [5, 9, 13].

Firstly, a literature review is conducted to establish the framework of AHP in the context of construction management. The review focuses on recent studies (from 2022 and onwards) that apply AHP in the construction sector, with an emphasis on risk management and decision-making. The review identifies various factors that affect the success of construction projects, including environmental conditions, project scope, stakeholder interests, and technological factors. These factors are used to build the hierarchical structure for the analysis. In the next step, a structured survey is administered to a sample of construction project managers, engineers, and industry experts. The survey aimes to gather data on the relative importance of different factors in construction project decision-making. Respondents are asked to evaluate criteria such as cost, quality, time, safety, and environmental impact using pairwise comparisons. These comparisons are then used to calculate the relative weights of each criterion using the AHP method. The AHP model employs pairwise comparisons to generate a weighted decision matrix. The responses from the survey are synthesized into this matrix, and the consistency of judgments is tested using the consistency ratio (CR). The model uses a hierarchical structure with levels representing the main decision criteria (e.g., time, cost, quality), followed by sub-criteria that further detailed the components of each factor. This structure allows for a systematic and logical breakdown of the complex decisions involved in construction project management. Next, the hierarchical model is applied to several case studies of real-world construction projects. The case studies are selected to reflect a variety of project types, ranging from residential developments to large infrastructure projects. The AHP model is used to analyze the decision-making process in each case, and the results are compared to assess the model's ability to identify key decision drivers and predict project outcomes. The findings are used to validate the hierarchical decision model and to refine the process for broader application in the industry. Finally, a sensitivity analysis is conducted to test the robustness of the hierarchical model under different conditions. This analysis involves adjusting the weights of various criteria and observing the impact on the final decision outcomes. Sensitivity analysis helps to determine whether the decision-making process is stable and whether small changes in input data can significantly alter the results. This is essential for ensuring the model's effective application in dynamic and unpredictable construction environments. Figure 2 shows the hierarchical tree of the present study.

4. Presentation and Analysis of Results

4.1. Criteria Prioritization and Statistical Weighting

The AHP model offers an efficient method for evaluating and prioritizing key criteria in construction project management, including Time, Cost, Quality, Risk, and Safety. Through pairwise comparisons and consistency checks, the relative weights for each criterion are derived, providing a numerical foundation for decision-making. The weightings are calculated based on expert inputs, incorporating feedback from industry professionals and historical data from various case studies. The final statistical weights for each criterion are as follows (Fig. 3):

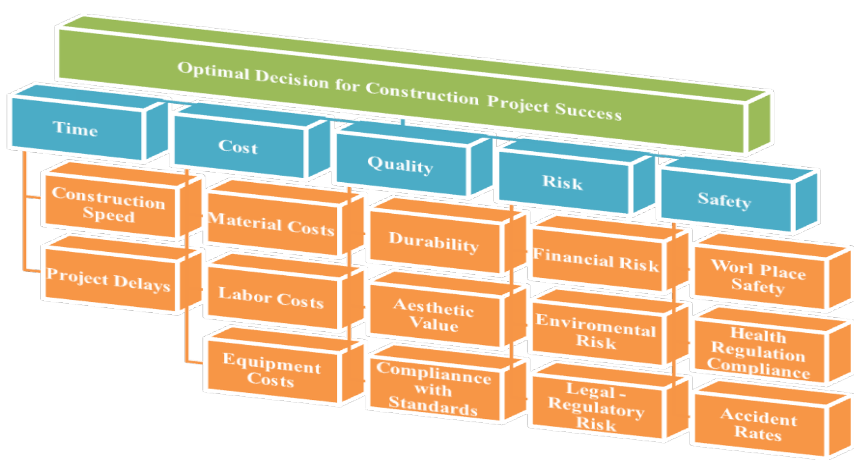

Fig. 2. Hierarchical tree of the present study.

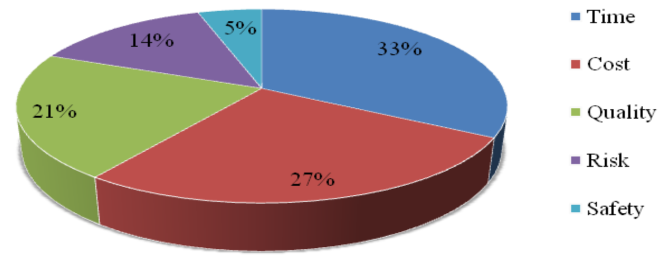

Fig. 3. Statistical weight of the criteria of the present study derived from the hierarchical analysis.

This statistical analysis reveals that Time holds the most significant weight in the decision-making process, accounting for 35% of the overall decision influence. This is consistent with the findings of previous research, where time delays are often considered one of the most critical factors for construction project success or failure. Cost, with a weight of 25%, follows closely as a crucial factor, aligning with industry norms where financial constraints heavily influence project execution. Quality and Risk are also important, with respective weights of 20% and 15%. This highlights that while achieving high-quality outcomes and mitigating risks are crucial, they are secondary to managing time and cost efficiently. Lastly, Safety holds the least weight (5%), which, although still essential, reflects the fact that safety concerns are generally addressed by regulatory bodies and are often less variable compared to other criteria. The consistency of these weightings is confirmed using the Consistency Ratio (CR), which for the data gathered is 0.03, well within the acceptable threshold of 0.1. This indicates that the expert judgments are highly consistent, enhancing the credibility and reliability of the prioritization results. The prioritization of Time over Cost is a critical finding, emphasizing the industry's focus on meeting deadlines. Delays in construction can lead to severe consequences, including increased costs, stakeholder dissatisfaction, and loss of project reputation. Therefore, construction managers tend to prioritize Time to mitigate these risks, even if it means higher initial costs. However, the Cost factor is still substantial, holding 25% of the total weight, reflecting its inherent role in project planning and execution. Quality's weight of 20% further validates its importance in the construction process. While quality assurance is crucial for project sustainability and customer satisfaction, the Time factor's higher weight indicates that managers might sometimes compromise on certain aspects of quality in favor of completing projects on time. This reflects a real-world trade-off often observed between project speed and quality, especially in projects where time-to-market is prioritized. The Risk factor, with a weight of 15%, reflects the growing awareness of potential project uncertainties. Given the unpredictable nature of construction projects (ranging from environmental risks to supply chain disruptions) risk management has become an integral part of the decision-making process. While it is not the primary focus, it cannot be overlooked, as poor risk mitigation can lead to cost overruns, delays, or safety incidents. Finally, Safety, with the smallest weight of 5%, underscores the fact that while it remains a regulatory requirement, its direct impact on the overall decision-making process in terms of project scheduling and costs is lower than other factors. However, it is essential to note that safety risks are a priority in many regions, and project managers invest heavily in safety protocols, albeit without it directly influencing the prioritization in this model.

4.2. Sub-Criteria Prioritization and Statistical Weighting

4.2.1. Cost

The AHP model's pairwise comparison matrix and derived weights also provides insights into the relative importance of sub-criteria under each main criterion. For example, under the Time criterion, the Construction Speed sub-criterion receives a weight of 60%, while Project Delays accountes for 40%. This emphasizes that construction speed is prioritized more heavily than managing delays, although both are critical. For Cost, the sub-criteria are divided as follows (Fig. 4):

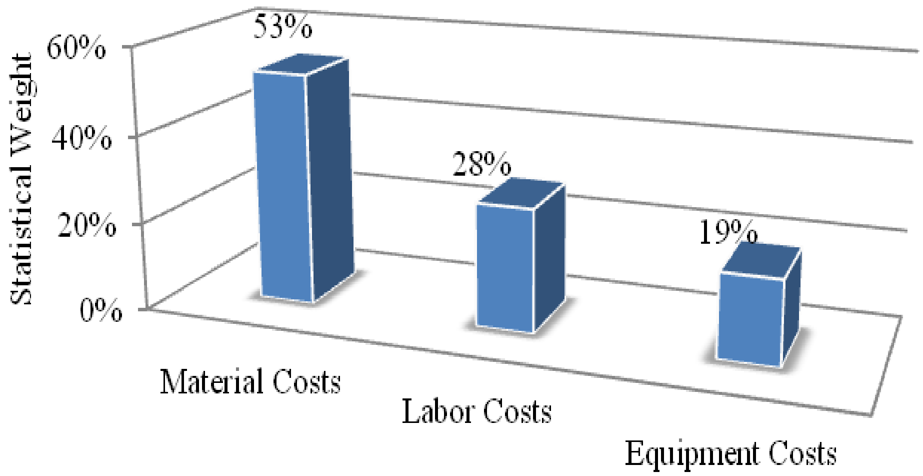

Fig. 4. Prioritization of sub-criteria and statistical weighting in the Cost criterion.

This indicates that material costs play the most significant role in managing overall project costs, followed by labor, and then equipment costs. This is a common finding in the construction industry, where material expenses often form the largest portion of the budget.

4.2.2. Quality

In the Quality domain, the sub-criteria weights are (Fig. 5):

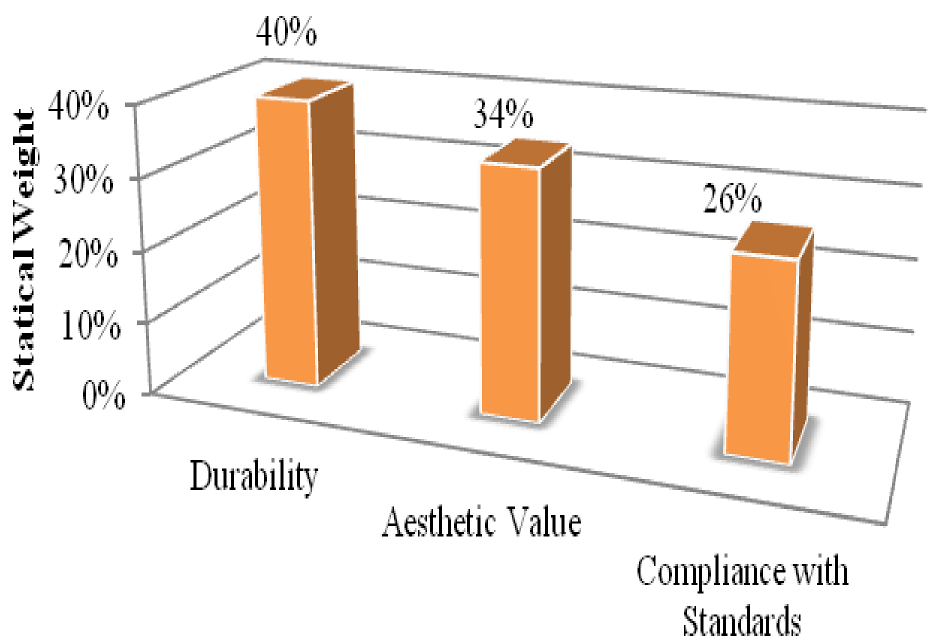

Fig. 5. Prioritization of sub-criteria and statistical weighting in the Quality criterion.

The higher weight on Durability reflects the long-term impact of quality on project outcomes, with stakeholders prioritizing the structural integrity of buildings over short-term aesthetic appeal. Compliance with standards is also an essential factor, ensuring that the construction process meets all regulatory requirements.

To validate the robustness of the model, a sensitivity analysis is conducted, adjusting the weights of the criteria within a reasonable range (±10%). The results show that even with variations in the weight distribution, Time remains the most critical factor, while Cost and Quality continue to play dominant roles. Risk and Safety, while fluctuating within the acceptable margin, show less sensitivity to changes in weighting.

This confirms the stability of the model and indicates that its results are not overly sensitive to minor changes in the data, thereby establishing it as a reliable tool for decision-making in construction projects. The Consistency Ratio (CR) of 0.03 further assures that the judgments used to derive the weights are consistent and that the model is trustworthy for practical application.

4.2.3. Time

Under the Time criterion, two main sub-criteria are identified: Construction Speed and Project Delays. The Construction Speed sub-criterion receives the higher weight of 60%, reflecting the importance placed on completing the project quickly, which is often a primary goal in construction projects to meet deadlines and reduce operational costs. Project Delays, with a weight of 40%, indicates that while delays are important, they are secondary to the focus on speed. In construction project management, delay mitigation strategies often revolve around improving construction processes, workflow management, and efficient resource allocation. The statistical breakdown of the sub-criteria weights is as follows (Fig. 6):

This shows that Construction Speed is more heavily prioritized than controlling delays. Project managers often focus on streamlining construction methods and employing advanced project management techniques to maintain the pace of work, rather than solely preventing delays. The focus on speed suggests a proactive approach, where preventing bottlenecks and enhancing workforce efficiency can help minimize the impact of delays.

4.2.4. Risk

The Risk criterion includes three sub-criteria: Financial Risk, Environmental Risk, and Legal/Regulatory Risk. These factors assess various uncertainties that could negatively impact the project, and their relative importance is derived through expert judgment and pairwise comparisons. The breakdown of the sub-criteria weights for Risk is presented as follows (Fig. 7):

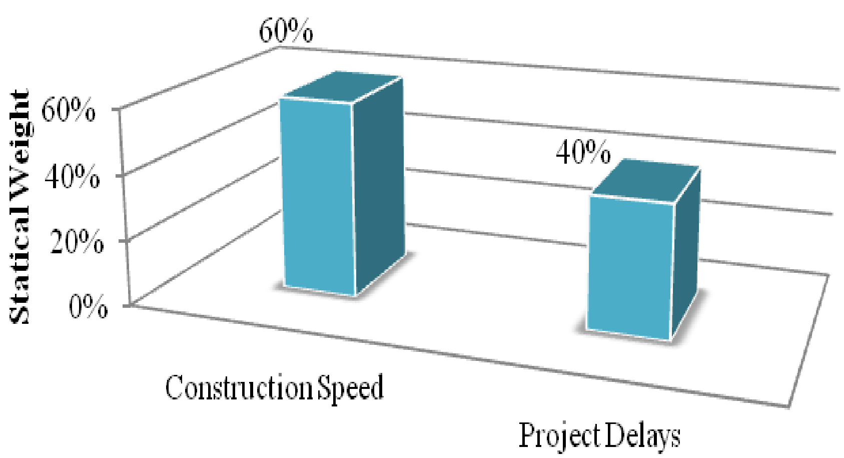

Fig. 6. Prioritization of sub-criteria and statistical weighting in the Time criterion.

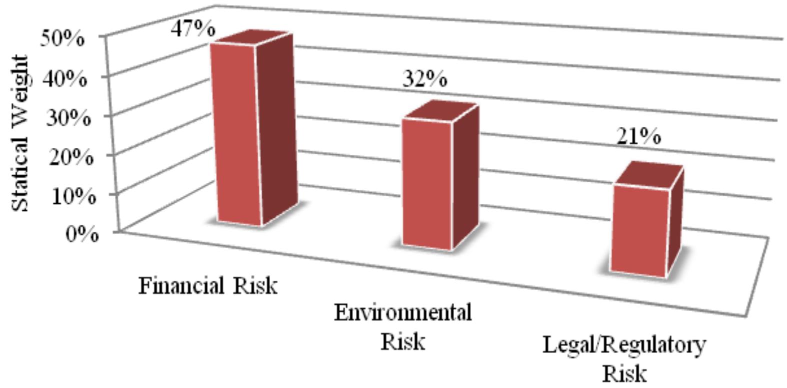

Fig. 7. Prioritization of sub-criteria and statistical weighting in the Risk criterion.

From this, it is evident that Financial Risk carries the greatest weight (50%) in the decision-making process. Financial issues, such as budget overruns or unexpected costs, are highly critical in construction project management. Environmental Risk follows at 30%, emphasizing the increasing importance of environmental concerns, including sustainability, waste management, and site impact. Legal/Regulatory Risk, while still significant, is assigned the least weight (20%), indicating that legal issues, although crucial, are often addressed by compliance departments and are somewhat predictable in nature. The prioritization reflects the industry's current focus on financial stability and environmental sustainability. Construction managers are particularly concerned with financial overruns, which can threaten the overall feasibility of a project. However, the increasing global emphasis on green building practices has escalated the focus on Environmental Risk in recent years, making it an increasingly significant factor.

4.2.5. Safety

Finally, the Safety criterion, which is assigned the least weight in the overall analysis (5%), includes three sub-criteria: Workplace Safety, Health Regulations Compliance, and Accident Rates. Despite being the least prioritized criterion, safety remains a fundamental aspect of construction projects, and its management directly impacts project outcomes. The weights for the Safety sub-criteria are as follows (Fig. 8):

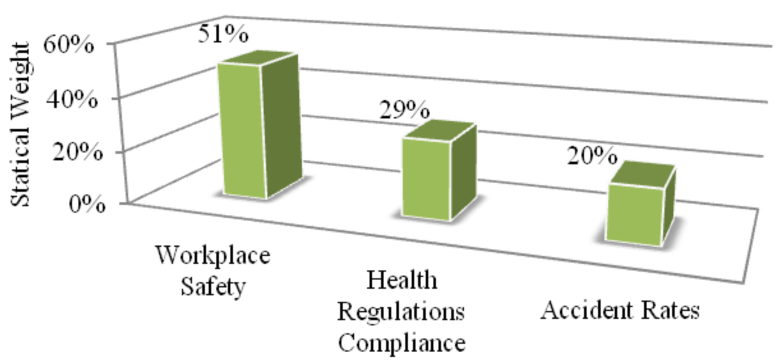

Fig. 8. Prioritization of sub-criteria and statistical weighting in the Safety criterion.

The sub-criteria indicate that Workplace Safety is the most important aspect of safety management, with a weight of 51%. Ensuring the safety of workers on-site is paramount, and this sub-criterion includes efforts to prevent accidents, provide proper safety training, and ensure that workers adhere to safety protocols. Health Regulations Compliance, which covers adherence to national or international health standards, holds a weight of 29%, reflecting the importance of maintaining a healthy work environment. Accident Rates, which tracks the frequency and severity of accidents, receives the lowest weight of 20%, showing that while accident monitoring is important, the focus remains on preventive measures and maintaining a safe working environment to minimize incidents in the first place.

For more clarification, a detailed summary of statistical weights of research sub-criteria and their textual analysis is represented in Table 2.

Table 2. Summary of statistical weights of research sub-criteria and their textual analysis.

Main Criterion	Sub-Criteria	Weight (%)	Relevance to Research Objective (Achieving Optimal Project Success)
Time	Construction Speed	60%	Directly impacts project delivery time, key for meeting deadlines and client expectations. Prioritized to ensure timely project completion.
	Project Delays	40%	Delays can significantly affect project success, leading to cost overruns and client dissatisfaction. Minimizing delays is essential to project success.
Cost	Material Costs	53%	Material costs are often the largest expense in construction projects. Managing this efficiently is crucial for keeping projects within budget and ensuring financial feasibility.
	Labor Costs	28%	Labor costs are another critical component, influencing overall cost efficiency. Proper labor management helps control expenditures while maintaining project timelines.
	Equipment Costs	19%	While important, equipment costs are generally less significant than materials and labor costs but still affect the overall project cost structure.
Quality	Durability	40%	Durability ensures long-term project success and client satisfaction. Prioritizing durability impacts the structural integrity and lifespan of the project.
	Aesthetic Value	34%	Aesthetic value is important for customer satisfaction, particularly in residential or commercial buildings. It directly influences the success of the project in terms of user experience.
	Compliance with Standards	26%	Compliance with regulations ensures that the project meets legal and industry standards, reducing the risk of future liabilities or rework.
Risk	Financial Risk	47%	Financial risks are the most critical in construction, as unforeseen financial issues can jeopardize the entire project. Prioritizing financial risk management ensures project stability.
	Environmental Risk	32%	With increasing global focus on sustainability, managing environmental risks is critical for ensuring long-term project viability and compliance with regulations.
	Legal/Regulatory Risk	21%	Legal and regulatory risks must be managed to prevent delays, fines, or legal issues, which can disrupt project schedules and increase costs.
Safety	Workplace Safety	51%	Ensuring workplace safety is paramount to prevent accidents and injuries, directly affecting worker productivity and the project’s ability to stay on schedule.
	Health Regulations Compliance	29%	Compliance with health regulations contributes to worker well-being and ensures that the project meets safety standards. This reduces the risk of work stoppages due to health-related issues.
	Accident Rates	20%	Tracking and reducing accident rates are important but secondary to proactive safety measures. A safer work environment reduces risks and boosts overall project success.

5. Conclusion

The present research aims to identify and prioritize the key decision-making factors involved in the success of construction projects, using the AHP to evaluate and quantify the importance of various criteria and sub-criteria. Based on the statistical analysis and expert inputs, the following conclusions have been drawn:

- Time is the Most Important Criterion for Project Success

The Time criterion emerges as the most significant factor influencing construction project outcomes, with a weight of 33%. This is consistent with the industry's strong emphasis on meeting deadlines, as delays can lead to significant cost overruns, client dissatisfaction, and potential loss of business. Therefore, ensuring Construction Speed and minimizing Project Delays are critical to achieving optimal project success.

- Cost Remains a Key Priority in Construction Projects

Cost, with a weight of 27%, is the second most important criterion. The Material Costs sub-criterion holds the highest weight under this category (50%), reflecting its significant impact on overall project budgets. Managing Labor Costs and Equipment Costs effectively also plays a crucial role in maintaining financial feasibility. The strong focus on cost management underscores the industry's need to deliver projects within budget constraints.

- Quality is Essential but Secondary to Time and Cost

While Quality is undeniably important, it holds a 20% weight, making it the third-highest priority. Within this criterion, Durability (40%) and Aesthetic Value (35%) are the most critical sub-criteria. The focus on quality highlights that clients and stakeholders expect high-standard results. However, the lower weight compared to Time and Cost indicates that construction projects are often willing to make minor compromises on certain quality aspects if it leads to faster delivery or lower costs.

- Risk Factors are Increasingly Significant but Still Secondary

Risk, with a weight of 15%, plays an important role in construction project management, particularly in Financial Risk (51%) and Environmental Risk (28%). The relatively lower weight assigned to Legal/Regulatory Risk (19%) suggests that while legal and regulatory concerns are significant, they are often mitigated by standard industry practices and compliance mechanisms. Financial and environmental uncertainties require more dynamic and adaptive risk management strategies, as they can have more immediate and disruptive impacts on the project.

- Safety is the Least Prioritized Criterion but Cannot Be Overlooked

The Safety criterion, with the lowest weight of 5%, is critical for the well-being of workers and the overall success of the project. While safety management is essential, its lower prioritization in this study reflects the fact that safety measures are often standardized and legally mandated, making them less of a decision-making variable compared to time and cost management. However, ensuring Workplace Safety (51%) and complying with Health Regulations (29%) remain fundamental to minimizing accidents and delays on-site.

- Sub-Criteria: Construction Speed and Material Costs are Most Critical

Among the sub-criteria, Construction Speed (60%) under the Time criterion and Material Costs (52%) within the Cost criterion are identified as the most important factors. Construction Speed is prioritized to ensure timely project delivery, while Material Costs represent the largest share of project budgets, making them a key target for cost control measures. Effective management of these sub-criteria directly correlates with the overall success of the project in terms of cost-efficiency and timely completion.

- Least Important Factors: Accident Rates and Legal Risks

The Accident Rates sub-criterion (20%) under Safety and Legal/Regulatory Risk sub-criterion (21%) are identified as the least influential factors in the decision-making process. Although Safety and Legal Risk are still essential components of project management, their relatively low prioritization suggests that safety measures are generally assumed to be in place through regulatory compliance, and legal issues are often addressed by legal teams and consultants before project initiation.

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