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Identification and Ranking of Factors Affecting the Delay Risk of High-Rise Construction Projects Using AHP and VIKOR Methods

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Abstract: Construction projects, especially those for commercial purposes, require thorough planning and control to ensure success within predetermined budgets and timelines. This research, conducted in Mashhad, Iran, employs the analytic hierarchy process (AHP) and VIKOR methods to identify and rank factors influencing delays in high-rise projects. The study, based on a sample of 40 projects, emphasizes the comprehensive nature of our research method. The scale for features in project selection includes societal importance (with different applications including cultural hubs, affordable housing initiatives, and urban renewal for social equity), size (less and more than 20 units in residential projects), and diversity (mixed-use development, inclusive infrastructure, and cultural and recreational spaces), contributing to a comprehensive analysis of construction delays. Expert project managers and engineers provided insights through two questionnaires, and their responses underwent thorough analysis. Our findings not only underscore the significance of factors contributing to project success but also rank their impact on the likelihood of delays. The study reveals that the negative effects of these factors on cost, time, and project quality vary. Time emerges as the most influential parameter, with approximately six times more impact on cost and nine times more on quality. Contractor financial weakness, delays in allocating financial and credit resources, insufficient project resource allocation, contractor technical and executive weakness, and a lack of proper implementation and project control are identified as the most important factors contributing to delays.

Keywords: project delay; time management; quality management; analytical hierarchy process (AHP); VIKOR

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1. Introduction

Efforts to mitigate project delays within the construction industry have gained significance due to their widespread negative impact on project success and the stakeholders involved [1,2]. Escalating construction costs, primarily stemming from challenges in adhering to project schedules and frequent modifications during development, exacerbate financial crises. Factors contributing to project elongation and the failure to meet desired standards result in increased implementation costs, heightened losses from missed opportunities, diminished project value, compromised quality of execution, delayed project delivery, and deviations from the prescribed schedule.

Project delays manifest in various forms, including compensable and irreparable, critical and non-critical, and authorized and unauthorized categories. Rarely do projects unfold seamlessly from inception to completion. One benchmark for "project success" is achieving timely completion, adherence to budget constraints, and delivering high-quality outcomes. Project execution is frequently marred by delays at various stages, exerting a detrimental influence on overall success. Irreversible costs associated with delays include expenses linked to delayed product delivery, escalating resource and raw material costs due to inflation, increased labor expenses, permit renewal fees, and contractual commitments with workers and contractors. Additionally, elevated interest rates accrue on bank resources, attributable to late delivery and the buyer's inability to capitalize on the final product.

Our study focuses on high-rise projects in Mashhad, Iran, utilizing the analytic hierarchy process (AHP) and VIKOR methods to identify and rank factors influencing delays. The literature review provides a concise overview of the existing research landscape, which highlights the pervasive nature of project delays across diverse global contexts.

Literature Review

Tariq and Gardezi [3] conducted a global investigation into the concealed relationships between delays and conflicts, identifying key causes such as owner's financial difficulties, scheduling and planning problems, material issues, variations in orders, and communication problems. Viles et al. [4] identified construction changes, poor project management, construction mistakes, economic factors, and conflicts as major contributors to delays. Rezaee et al. [5] attributed delays in Iranian construction projects to inaccurate estimates, insufficient equipment, miscalculated timeframes, and inadequacies in the legal framework. Zidane and Andersen [6] explored delay factors in Norwegian construction projects, highlighting issues like poor planning, scheduling challenges, slow decision processes, administrative difficulties, and inadequate communication.

Agyekum-Mensah and Knight (2017) [7] scrutinized 32 causes of delay in the post-recession UK construction industry, citing, for example, inadequate project planning, suboptimal commercial decisions, design flaws, scope creep, unclear project specifications, financial problems, inexperience, incompetence, and inappropriate risk management. Akogbe et al. (2013) conducted a comprehensive study on the factors influencing the delay of construction projects in Benin. Their findings highlighted several issues contributing to project delays, including financial challenges faced by contractors, owners, and subcontractors; inadequate performance of subcontractors; delays in contractor material procurement; insufficient project planning and scheduling; slow inspection of completed work by consultants; and shortages in equipment [8]. Examining Supreme Court rulings in Taiwan, Huang et al. (2013) identified key factors behind construction project delays. These included changes in orders, alterations in project scope, adverse weather conditions, and delays in the handover of construction sites, all contributing to scheduling setbacks in construction-related legal cases [9]. Kazaz et al. (2012) surveyed 71 Turkish construction firms to determine the impact of 34 factors on project duration. Their results highlighted design changes, delayed payments, cash flow issues, labor productivity challenges, and contractor financial difficulties as the most significant contributors to project delays [10].

Mahdi and Soliman's (2021) study focused on delay factors in Arabic countries, revealing that poor subcontractor performance, inefficiencies in contractor staff, inadequate planning and scheduling, subpar project management by contractors, and delays in client decision making were frequent causes of project delays [11]. Firmpong et al. (2003) conducted a survey in Ghana involving employers, consultants, and contractors, identifying monthly payment issues, weaknesses in contractor management, challenges in raw material supply, poor technical performance, and frequent initial price increases as significant reasons for project delays [12]. Duy Long et al. (2004) highlighted land and building-related issues, inappropriate techniques and tools, and the importance of geographical variables as the most significant causes of project delays, emphasizing the need to consider the opinions of both social and technical stakeholders during project implementation [13]. Manavazhi et al. (2007) investigated 22 highway projects in Nepal, identifying organizational weaknesses, negligence by raw material suppliers, government laws and regulations, and delays in the transportation system as major causes of project delays [14]. Odeh and Battaineh (2002) conducted a thorough investigation into the causes of delays in Jordanian construction projects. Recent research underscores that the most significant contributors to delays include employer interventions, inadequate contractor experience, incompetence of designers and contractors, changes in management, poor forecasts, financial and payment difficulties, an ineffective labor force, delays in decision making, and planning challenges [15].

In a study by Assaf et al. (2006) in Saudi Arabia, the causes of project delays were examined across three key groups: employers, contractors, and consultants. Contractors identified delays in employer payments, sluggish consultant review and approval of design documents, errors and defects in design documents, delays in equipment supply, consultants' inflexibility, and delayed decisions by the employer as factors contributing to project delays [16]. Tumi et al. (2009) identified the main causes of construction delays in Libya, citing inadequate planning, ineffective communication, design errors, material and equipment shortages, late decisions, and liquidity issues as significant factors influencing the project timeline [17]. Abu Hammad (2008) delved into the reasons for project delays in Jordan, pinpointing the contractor's inability to cover project costs, employer interventions and modifications, poor contractor management, a scarcity of skilled labor, and a lack of specialists as the most crucial factors. The author concludes that these issues primarily result from employer negligence, exacerbated in a secondary stage by contractor negligence, as conventional bidding systems and contracts have been recognized as significant contributors to the aforementioned issues [18].

Fugar and Agyakwah-Baah (2010) conducted a study in Ghana to identify the causes of project delays, highlighting factors such as insufficient project funding, delays in periodic work payments, poor procurement, inadequate material supply, inflation, sanctions, and contractor financial problems. The employer is acknowledged as a significant influencer in this context [19]. Gameson (2008) conducted various surveys in Egypt, based on different criteria, to identify factors influencing project delays. The criteria included project groups involved, project subject, and type of industry. The three most critical factors identified were the employer's intervention, lack of proper financing by the employer, and contractor liquidity issues [20]. Hajivand et al. emphasized the political and social tensions and problems arising from project inefficiency [21]. Nouri and Faraji highlighted the repercussions of delays, including capital stagnation, delayed return on investment, increased project costs, reduced purchasing power due to inflation, resource wastage, loss of profits, additional costs, and dissatisfaction among stakeholders [22].

Nourinia and Mokhtari's case study on the Urumia Lake Intermediate Bridge revealed various disadvantages associated with project delays, including increased overall project costs, capital stagnation, delayed return, reduced quality, communication breakdowns, and customer dissatisfaction [23]. Najafi and Rashidi used a fuzzy multi-criteria decision-making method to prioritize the causes of cost, time, and quality delays [24]. Nouraie and Shayanfar considered cost, time, and quality among the most important factors in determining the priorities of construction projects [25]. Rahimian et al. emphasized the significance of time, cost, and quality as primary criteria for evaluating project success [26]. Jamshidi et al. recommended evaluating and controlling the three factors of time, cost, and quality when managing a project [27]. According to Kheiroddin and Asgari, each project operates within a system with three constraints: cost, time, and quality, with changes in one constraint affecting the others due to their interdependence [28].

Shakeri et al. [29] conducted a study investigating the causes of delays in construction projects, focusing on a non-financing approach. The factors considered included non-timely payment of principal and adjustments, changes in the project area, employer interventions, poor management, and insufficient contractor experience. Eshtehardian [30] explored delays in urban development projects, emphasizing the need to transition from traditional to modern management, particularly regarding the adoption of project management systems in large cities. The study emphasized categories such as cost, quality, purpose, risk, communication, and human resources in the project management system, promoting sustainable urban development.

Construction projects, whether in developed or developing countries, face a myriad of challenges that significantly impact their performance. The multifaceted dimensions of these challenges contribute to delays and hinder the successful execution of projects [31,32]. In the context of the research conducted in Mashhad, Iran, several key problems affecting project performance were identified. One prominent issue is the financial weakness of contractors, which can lead to delays in project timelines. Delays in allocating financial and credit resources further exacerbate the problem, hindering the smooth progress of construction projects. The study also underscores the importance of proper project resource allocation, emphasizing that insufficient allocation can contribute to delays and hinder overall project success. Technical and executive weaknesses on the part of contractors pose additional challenges to project performance. The lack of expertise and competence in handling complex construction tasks can lead to setbacks and delays. Moreover, the study highlights the critical role of implementation and project control, identifying a lack thereof as a significant factor contributing to delays in construction projects [33].

In both developed and developing countries, these challenges persist and vary in intensity, impacting projects across different scales and types. This research, based on a sample of 40 projects, provides valuable insights into the factors influencing delays in high-rise construction projects, emphasizing the need for comprehensive planning and control to address these multifaceted issues and ensure the successful execution of construction projects globally.

In the vibrant city of Mashhad, numerous projects are grappling with time delays, as vividly outlined in Table 1. This comprehensive data, sourced from the municipality of the Mashhad City Council in Iran [34], sheds light on the critical factors contributing to project delays. The findings underscore that the primary challenges leading to these delays result in increased project costs, a notable reduction in overall project effectiveness, a significant decline in the quality of work, the necessity for additional budget allocation, expenses incurred for compensating delays, the potential for customer dissatisfaction, delayed utilization of project-generated income, and the crucial aspect of a timely return on the investment [35–38]. These factors collectively highlight the complex dynamics influencing project timelines and underscore the need for strategic interventions to enhance project management and mitigate the impacts of these delays.

The study conducted in Mashhad, Iran, fills a crucial gap in the comprehension and management of delays in high-rise construction projects, specifically those designed for commercial purposes. Employing a fusion of the analytic hierarchy process (AHP) and VIKOR methods, this research identifies and prioritizes factors influencing delays in such projects. The study takes a comprehensive approach, considering societal importance, project size, and diversity, thereby contributing to a nuanced understanding of construction delays. The involvement of expert project managers and engineers is pivotal, as they contributed insights through two questionnaires, and their responses underwent meticulous analysis. Notably, this research introduces, for the first time in the management of high-rise construction projects, a combined method that progresses from conceptual modeling to a quantitative approach for delay control. Another innovative aspect is the case study's connection to urban development traits, approached through an inventive method.

The utilization of AHP and VIKOR methods in this research imparts distinct benefits and added value, setting it apart from other studies in the field. AHP, a multi-criteria decision-making tool, provides a systematic and structured approach to identify and rank factors influencing delays in high-rise construction projects. Its proficiency in handling complex decision-making processes and capturing the relative importance of various criteria contributes to a more comprehensive understanding of the issue. Additionally, the incorporation of the VIKOR method enhances the study by offering a compromise solution in multi-criteria decision-making situations. VIKOR facilitates the identification of a compromise ranking that considers both the maximum group utility and the minimum individual regret, adding sophistication to the analysis. The combined use of AHP and VIKOR not only improves the accuracy of factor identification and ranking but also establishes a more robust foundation for decision making in the context of construction project delays. This methodological choice distinguishes the current research, providing value by offering a more nuanced and holistic perspective compared to studies relying on less sophisticated decision-making approaches [39–42].

Table 1. The project delays and their causes in regards to civil projects of Mashhad City [34].

Project Description	Start Date	End Date	Operation Date	Delay Duration	Reasons
Multi-Level Parking and Subsurface Terminal (Azadi)	07/06/2019	31/10/2020	03/21/2021	135 days	Additional budget allocation required
Phase 3 Front of Ferdowsi Mausoleum	01/12/2018	03/26/2020	04/20/2021	117 days	Timely return on investment
Taksirani Sports Complex	06/21/2017	04/01/2020	06/19/2021	81 days	
Innovation Factory Operation	11/23/2019	08/11/2020	10/18/2020	67 days	Increased project costs
Implementation of Railway Route Deviation Line	09/26/2020	11/26/2020	97% progress	65 days	Significant decline in quality
Rehabilitation Camp for Open Addicts	04/24/2019	10/15/2019	12/18/2019	63 days	Additional budget allocation required
Start of Drilling Operations for Metro Line 4	02/15/2019	11/30/2019	Not Started	61 days	Delayed project income utilization
Construction of Waste Disposal Center	10/08/2019	12/10/2020	01/24/2021	44 days	Costs for compensating delays
Access to Shahid Kaveh Metro Station	02/28/2019	10/30/2019	12/12/2019	43 days	Customer dissatisfaction potential
Kooh Park Project	11/22/2019	03/15/2019	04/26/2019	43 days	Reduced overall project effectiveness
Women's Garden, Vakilabad	09/07/2018	12/29/2019	85% Progress	32 days	Additional budget allocation required
Surface Water Collection Channels	05/15/2019	12/30/2019	30% Progress	31 days	Increased project costs
Widening the Route to Shohada Bazaar, Shushtar	07/23/2019	12/15/2019	01/24/2020	29 days	Costs for compensating delays
Access to Saadi Metro Station	03/03/2019	11/30/2019	12/27/2019	27 days	Additional budget allocation required
Access Route to Kuhan Dezh	04/19/2019	06/09/2019	09/29/2019	24 days	Customer dissatisfaction potential
Al-Zahra (SA) Boulevard	09/10/2019	12/25/2019	01/15/2020	20 days	Delayed project income utilization
Majd Smart Parking	06/21/2017	09/15/2019	09/27/2019	13 days	Costs for compensating delays
Construction of Bicycle Path	07/01/2019	01/20/2020	71% Progress	11 days	Reduced overall project effectiveness

This study aims to explore factors contributing to construction project delays and assess their impact on key project objectives, namely time, cost, and quality. The research aims to fill the existing gap in understanding the nuanced factors contributing to delays in high-rise construction projects, providing valuable insights for the development of targeted strategies and best practices in project management.

The study seeks to achieve the following objectives:

- Identification of the most crucial factors influencing delays in high-rise construction projects.

- Determination of factors contributing to delays in both the primary and ancillary aspects of high-rise construction.
- Understanding the factors affecting delays in the realm of natural factors and external issues beyond those specific to high-rise construction.
- Conducting comparisons of identified factors through pairwise assessments and determining preferences using the AHP method.
- Evaluating the impact of each identified factor on project cost, time, and quality using the VIKOR method.

Through these objectives, the study provides a comprehensive understanding of the factors influencing delays in high-rise construction projects and offers a systematic approach to project management for improved outcomes.

2. Materials and Methods

This section offers as explanation of the methodology of the research, followed by an examination of data collection and analysis methods based on the type of research method employed, and finally, investigates the theoretical underpinnings of the method. The research roadmap of the present study is displayed in Figure 1.

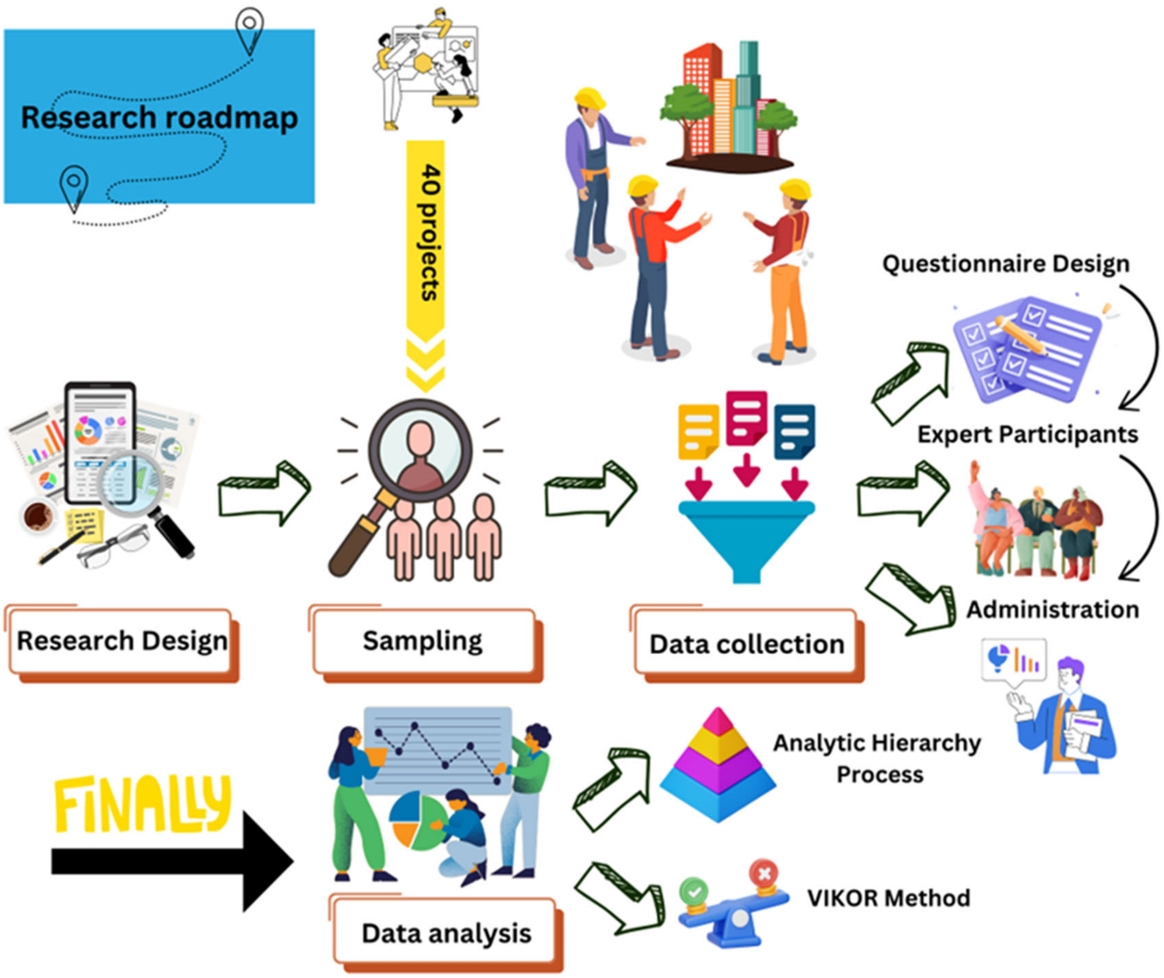


Figure 1. Research road map of this study.

This study employs a descriptive survey methodology to systematically investigate the factors contributing to delays in high-rise construction projects in Mashhad, Iran. To ensure a comprehensive understanding of the key variables, a combination of quantitative and qualitative data collection methods has been utilized. In the sampling phase, a representative sample of 40 high-rise construction projects is selected from a pool of 45, determined using Cochran's formula to achieve statistical significance. The chosen projects are those designated for general commercial utilization in Mashhad. The data collection process involves the development of two distinct questionnaires designed to gather insights from expert project managers and engineers actively involved in high-rise construction projects. These questionnaires aim to elicit responses regarding various factors contributing to delays in construction projects. Expert participants have been selected based on their extensive experience and expertise in managing or overseeing high-rise construction projects in Mashhad. The inclusion criteria prioritize professionals with a proven track record in successful project delivery. The administration of questionnaires has been carried out electronically to ensure efficient data collection. Participants receive clear instructions for completing the surveys, and measures have been implemented to maintain the confidentiality and anonymity of responses, fostering open and honest feedback. For data analysis, the study leverages the analytic hierarchy process (AHP) to prioritize factors contributing to delays. A pairwise comparison matrix is constructed, and expert judgments on the relative importance of each factor is utilized to derive a priority scale. Additionally, the VIKOR method has been employed for multi-criteria decision-making analysis, offering a comprehensive evaluation of project delays based on multiple criteria. The results obtained from the AHP and VIKOR methods are integrated to establish a robust understanding of the factors influencing delays in high-rise construction projects in Mashhad. Sensitivity analyses have been conducted to assess the stability of the results, ensuring the reliability and validity of the findings.

2.1. Data Collection Method

As part of the data collection process, a review of available documents regarding construction projects; and interviews with relevant experts, managers, and specialists were conducted. For the purpose of determining the importance of the identified delays, related to each other due to their multiplicity, a questionnaire is used to collect data, which was then analyzed statistically. We identified the statistical population using the snowball sampling method, which allowed us to communicate directly with individuals and to interview them directly regarding the research topic [43].

The statistical scope of this research encompasses high-rise construction projects in process within the city of Mashhad, predominantly with commercial applications (commercial, commercial-administrative, commercial-residential, commercial-welfare, and cultural buildings) across 13 municipal districts. Approximately 65% of these projects are now completed, and 35% are in progress. Due to the lack of cooperation from the municipal authorities of Mashhad in providing accurate statistics on the total number of high-rise construction projects, the statistical community was identified through the snowball sampling method, as a last resort.

It is important to emphasize that the scope of this study focuses on buildings with more than 20 units, specifically those that have achieved a completion rate of at least 70%. To ensure a representative sample, these buildings have been strategically chosen from various regions within Mashhad City. The geographical distribution of Mashhad City, along with its distinct zones, is visually illustrated in Figure 2. This careful selection process and the consideration of diverse locations enhance the study's ability to capture a comprehensive understanding of the factors influencing larger residential structures across the city. The map serves as a valuable reference, providing a geographical context for the subsequent analyses and findings presented in this research.

The snowball sampling method offers several advantages, making it a valuable technique in research design. One key benefit is its practicality in situations where the population of interest is challenging to access or define. This method is particularly useful when studying elusive or hidden populations in which traditional sampling methods may prove ineffective. Additionally, snowball sampling is cost-effective and time-efficient, as it relies on initial participants to refer and recruit subsequent participants. This creates a network effect, facilitating the identification of individuals who share specific characteristics or experiences. Moreover, the method is adaptable to qualitative research, enabling the exploration of diverse perspectives within a given social context. Despite its limitations, such as potential bias and lack of representativeness, the advantages of snowball sampling make it a valuable tool, especially in studies where alternative sampling approaches are impractical [44].

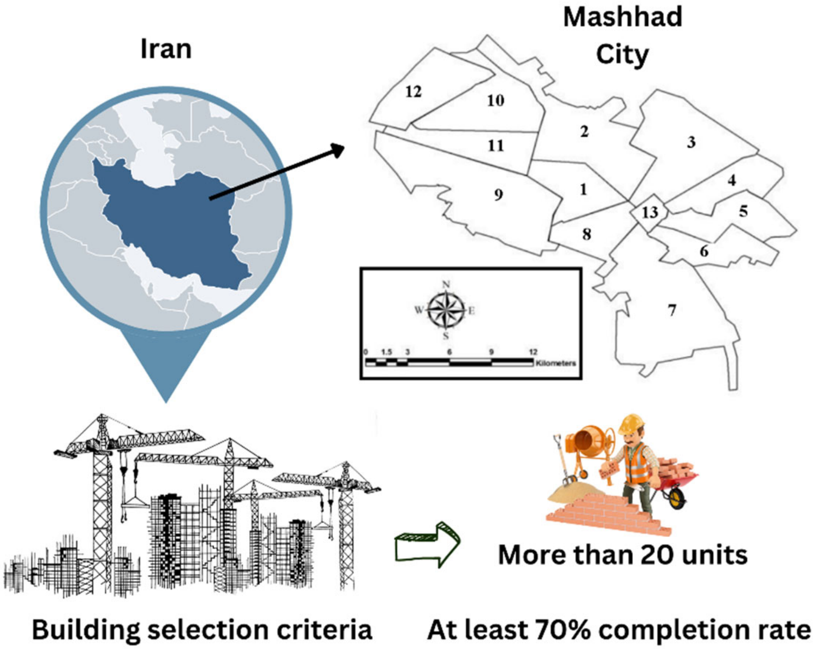


Figure 2. The map of the case study used in the present research.

2.2. Questionnaire

The utilization of questionnaires in this study is driven by the expansive statistical population under investigation, facilitating the systematic examination of the sample. Two distinct questionnaires have been meticulously developed to yield optimal results in ranking the factors influencing project delays and determining their impact on cost, time, and quality. For each project within the sample volume, both questionnaires are administered through interviews with knowledgeable managers or engineers. Questionnaire No. 1 utilizes the analytic hierarchy process (AHP) method to rank identified factors affecting project delays, while Questionnaire No. 2 is constructed using the VIKOR method to assess the impact of these factors on cost, time, and quality.

Validity and Reliability of the Questionnaire

In assessing the validity of the questionnaires employed in this study, formal validity procedures were applied, aligning with the nature and methodology of their usage. Pre-distribution questionnaires were shared with the tutor, several experienced professors, and engineers within the statistical sample to evaluate the number of questions, their relevance to the study's ultimate goal, and their clarity and comprehensibility.

To ensure the reliability of the initial questionnaires, the Cronbach's alpha test, as per Equation (1), is employed. This test, chosen for its ability to estimate test reliability with a single assessment, is conducted in light of the nature of the questions posed [45].

$$\alpha = \left(\frac{k}{k-1}\right)[1 - \frac{\sum_{i=1}^{k} S_i^2}{S^2}] \quad (1)$$

where the number of items is represented by k, S^2 represents the variance of the sum of each respondent's scores, and S_i^2 represents the variance of the scores for item i. In the reliability coefficient, the value ranges from zero to one, which indicates unreliability when it is zero, and complete reliability when it is one [46].

It is acceptable for measuring instruments to produce similar results under the same conditions, if the reliability coefficient is greater than 0.7. Table 2 indicates that the obtained alpha coefficient in all sections of the questionnaire is greater than 0.7. The internal consistency of the questionnaire is acceptable, and the items are relevant to the purpose of the study (variables related to the research hypotheses).

Table 2. Coefficients obtained from Cronbach's alpha method and the internal consistency of the questionnaire.

Row	Heading of Questions	Alpha Coefficient	Internal Compatibility
1	Sub-criteria of employer-related factors	0.822	Appropriate
2	Sub-criteria of factors associated with consultants and supervisors	0.713	Acceptable
3	Sub-criteria of factors related to contractors and builders	0.861	Appropriate
4	Sub-criteria of other related technical and executive factors of the project	0.754	Acceptable
5	Sub-criteria of natural factors; internal and external problems of the project	0.775	Acceptable
6	The main criteria affecting project delays	0.742	Acceptable

2.3. Statistical Population and Sample Size

The statistical population in this study includes high-rise construction projects with general commercial use under construction in 13 districts in Mashhad, where it is assumed that three to four projects with the above characteristics have been identified in each district. A sample size of 40 projects has been calculated, using Cochran's formula, for this study's statistical population, which includes 45 high-level commercial projects. Each project manager or engineer is well versed in the main project elements, including the employers, consultants, supervisors, and contractors involved in the project. In addition, the workshop supervisor and project managers have been selected to complete the questionnaire. Additionally, the statistical population consists of 45 high-level commercial projects in Mashhad, with 40 of those projects being sampled.

2.4. Research Criteria and Sub-Criteria

In this study, five main criteria were analyzed, which were grouped according to the main factors influencing project delays. These criteria include: (1) employer-related factors; (2) consultant and supervisor-related factors; (3) contractor and builder-related factors; (4) other technical and executive factors associated with the project; and (5) natural factors, both internal and external. The sub-criteria are the most important element of this study, since they form the basis for characterizing factors affecting project delays, examining their impact on cost, time, and quality. A list of the criteria and sub-criteria, along with their specific symbols (these letters are used to simplify the explanations in the future), which can be arranged hierarchically, are presented in Table 3.

The participant characteristics, as illustrated in Figure 3, highlight distinctions based on gender, age, work experience, academic qualifications, and job positions. Analysis of the provided scheme indicates that the majority of experts involved in this study were male individuals holding bachelor's and master's degrees. Furthermore, these participants typically possessed 11–15 years of work experience, served in the capacity of contractor staff, and fell within the age bracket of 36–40.

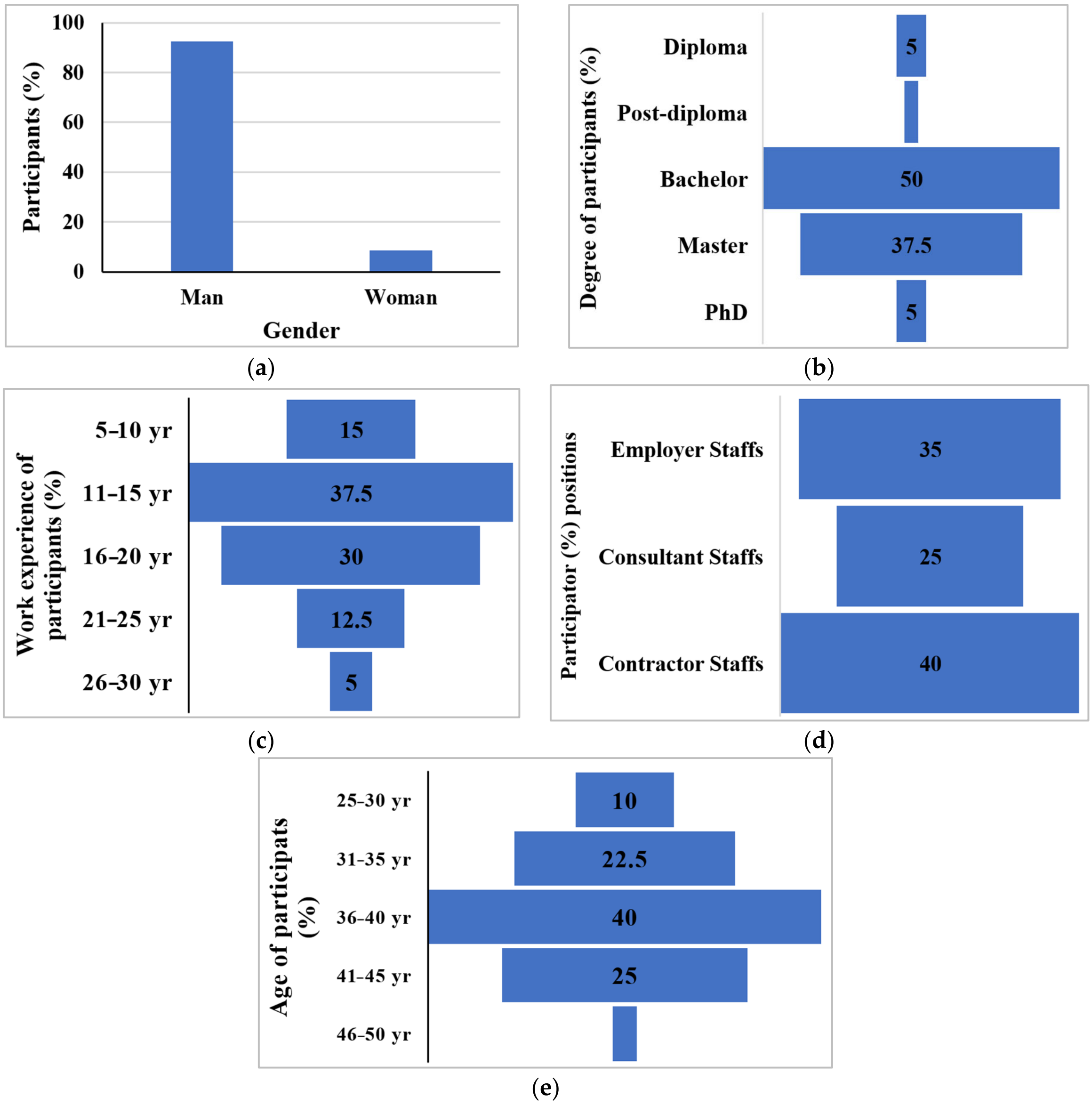


Figure 3. The specification and frequency of participants as per (**a**) gender, (**b**) degree, (**c**) work experience, (**d**) position, and (**e**) age.

Table 3. Grouping the factors affecting project delays.

Factors Associated with Employer (K)	K1: Delay of the employer in the allocation of financial and credit resources.
	K2: Delay of the employer in issuing approvals and licenses (delivery of land, resolution of disputes, supply of materials, etc.).
	K3: Change in management workshop conditions by the employer.
	K4: Lack of attention to the expert opinions of the consultant by the employer.
	K5: Changes in the needs of the employer due to adjustments in the project.
Factors Associated with Consultants and Supervisors (M)	M1: Delay in approvals by the consultant (notification of plans, minutes, status statements, etc.)
	M2: Map changes, revisions and weaknesses in maps and studies by the consultant.
	M3: Lack of technical ability of supervisors and incorrect and inaccurate monitoring.

Table 3. *Cont.*

Factors Related to Contractors and Builders (P)	P1: Technical and executive weakness of contractors.
	P2: Weakness in quality control provided by contractors.
	P3: Financial weakness of contractors.
	P4: Frequent managerial and executive changes by contractors.
	P5: Non-compliance with safety and HSE issues by contractors.
Technical and Executive Factors of the Project (F)	F1: Issues, ambiguities, and problems with the project contract.
	F2: Improper management of project changes and lack of cooperation of stakeholders in their implementation.
	F3: Insufficient allocation of resources for the project (manpower, machinery, etc.).
	F4: Failure to use appropriate project implementation and control methods.
	F5: Lack of effective coordination and information between project elements.
Natural Factors; Internal and External Problems of the Project (T)	T1: Natural disasters (floods, earthquakes, etc.).
	T2: Unsuitable environmental conditions (heat, cold, pollutants, etc.).
	T3: Social, political, economic problems (strikes, sanctions, inflation, etc.).
	T4: Lack of key project resources (cement, reinforcement, machinery, etc.).

2.5. Method of Data Analysis

As part of this study, multi-criteria decision making is employed, based on AHP, to prioritize the identified criteria. The data has been analyzed using ExpertChoice software version 11. The VIKOR method is used to rank the factors affecting project delays, and the impact on cost, time, and quality is determined.

2.5.1. Analytic Hierarchy Process (AHP)

Using AHP, complex problems can be solved by employing a powerful and simple multi-criteria decision-making technique. As a result of the AHP method, the judgment of the decision makers is consistent; pairwise comparisons are performed to determine the best option and solution; criteria and non-criteria can both be considered in evaluating selecitons; and pairs can be used to determine the best options [47].

The hierarchical structure method is used for weighing the factors influencing project delays in this study, after identifying and preparing the criteria for ranking them. Upon completing this step, the factors affecting delays in each group were compared in pairs, along with the main factors, and matrices of pairwise comparisons were developed. As part of pairwise comparisons, we use a time range of 1 to 9 h to determine their importance and preference (Table 4).

Table 4. Saaty's suggested values for creating a pairwise comparison matrix [48].

Significance	The Importance of One Criterion over Another
1	Equal importance
2	Between the same importance to a little more importance
3	A little more important
4	Between a little more importance to strong importance
5	Strong importance
6	Between strong to very strong importance
7	Very strong importance
8	Between very strong to quite important
9	Quite important

2.5.2. The VIKOR Method

The following method refers to the elaboration of agreement between issues requiring multicriteria decision making and the evaluation of these agreements. If a decision maker is unable to identify and express the advantages of an option or issue at the time of its initiation and design, this method can be considered an effective and accurate decision-making tool. In this study, the research is evaluated using the VIKOR method options to rank the most important criteria and sub-criteria, and then the options are prioritized.

The combination of AHP and VIKOR methods provides a robust understanding of the factors influencing delays in high-rise projects due to their complementary strengths [47]. AHP is a structured decision-making technique that allows for the prioritization and evaluation of factors by establishing their relative importance through pairwise comparisons. By employing AHP, the researcher can systematically analyze and quantify the significance of various factors contributing to delays in high-rise projects. This method helps in creating a hierarchical structure of factors and determining the weights associated with each, offering a clear framework for decision making [49]. On the other hand, VIKOR is a multi-criteria decision-making method designed for solving compromise problems. It considers both the best and worst performance of the alternatives, providing a compromise solution that balances conflicting criteria. VIKOR is particularly useful when dealing with complex situations in which there might be conflicting objectives or trade-offs between different factors influencing delays [50]. By integrating AHP and VIKOR, the analysis becomes more comprehensive. AHP assists in identifying the most critical factors and assigning weights to them, while VIKOR helps in handling the inherent uncertainties and compromises in real-world scenarios. The combination allows for a more robust and nuanced understanding of the factors affecting delays in high-rise projects, considering both the aspects of both importance and compromise. It enhances the decision-making process by offering a more holistic perspective, making the analysis more reliable and insightful for project management and planning [51].

3. Results and Discussion

In this section, we analyze the data extracted from the questionnaires using the methods previously introduced. First, we attempted to evaluate and rank the research criteria and sub-criteria using AHP, assigning weights to each of them. In order to evaluate and rank the research options, the VIKOR method is used. It takes into account the weights assigned to the sub-criteria in the previous step, as well as the factors influencing the delays.

The primary hypothesis of this research revolves around financial factors and their substantial impacts on project delays. As anticipated, key factors such as contractor financial weaknesses and delays by the client in allocating financial and credit resources secured the first and second positions in the ranking. Furthermore, inadequate allocation of resources, machinery, and human workforce, positioned at third place, supports the subsequent hypothesis. Additionally, the hypothesis positing that a shortage of key project resources contributes to delays is validated; however, the final results indicate that insufficient allocation of resources has a twofold impact compared to the scarcity of key resources, placing it in the eleventh position. This suggests that even in the presence of resource constraints, if the allocation is conducted accurately and precisely, project delays can be significantly reduced. The hypothesis addressing force majeure events and weather conditions, relegated to the bottom rankings within the sub-criteria, underscores their minimal impact on delays in civil engineering projects from the perspective of stakeholders. By examining key priority indices, it is evident that factors associated with contractors and builders play an essential role in the occurrence of delays in civil engineering projects, claiming the top rank in that category. Strategies for mitigating delays arising from contractor and builder shortcomings include robust oversight of construction operations and timely inspection and control services provided by consultants and regulatory bodies. In the following section, different methods for achieving results will be analyzed.

3.1. Formation of a Hierarchical Structure of the Research Problem

The AHP hierarchical process begins with the creation of a hierarchical tree or structure. Prior to developing this structure, the research criteria and sub-criteria need to be defined. This study's main criteria include five groups of factors related to employers, consultants and supervisors, contractors and builders, technical and executive factors of the project, natural factors, and internal and external problems. The indicators are comprised of several sub-criteria. A total of 22 sub-criteria were introduced in this study, and these are listed in Table 3. The study also considered three options for cost, time, and quality. In order to identify the best factors and the best option, based on preference as compared to other factors and options, the impact of factors influencing delays should be analyzed and examined. Figure 4 depicts the research's hierarchical structure, based on the three options considered (cost, time, and quality).

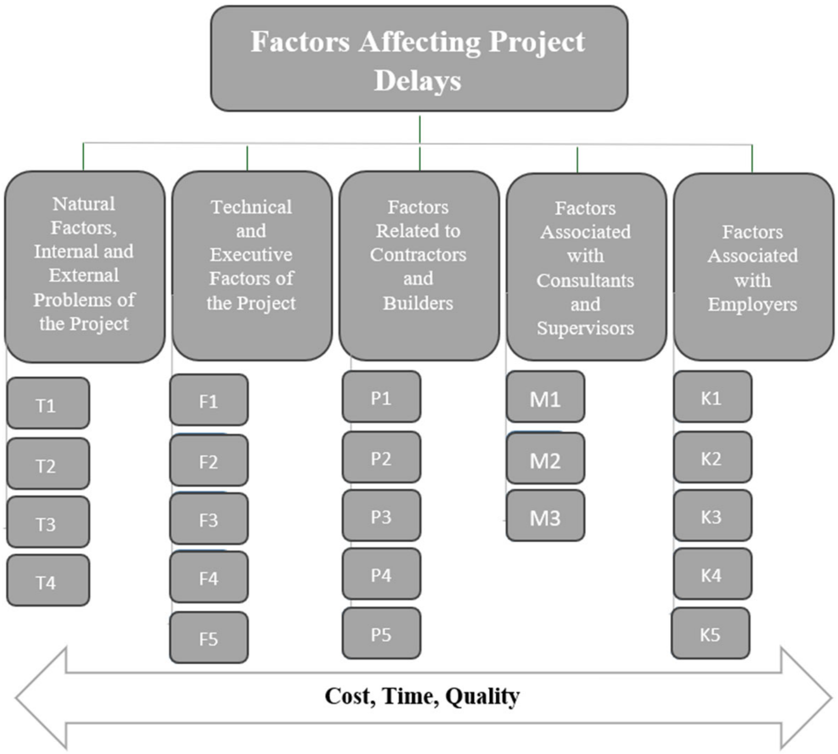


Figure 4. Hierarchical design of factors affecting project delays.

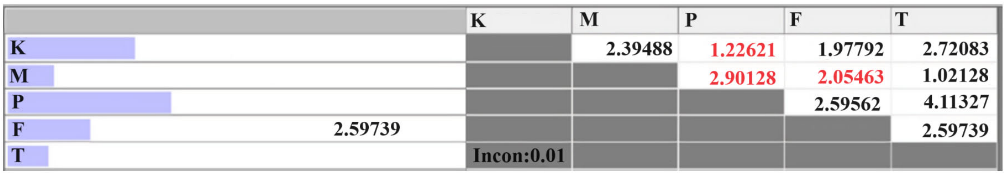
3.2. Analysis of Research Criteria Based on AHP

Using the AHP method and ExpertChoice software, this section analyzes and evaluates the research criteria.

3.2.1. Calculation of Relative Weight of Main Research Criteria

The weight of the research criteria should be calculated after determining the hierarchical structure. First, questionnaires are developed and distributed among experts so that the main criteria can be compared. Following completion of the questionnaires, the information obtained from them is entered into ExpertChoice software, which evaluates the main research criteria and calculates their weight. Generally, we provide the questionnaires if the pairwise comparison matrix incompatibility is acceptable for the main criteria (less than 0.1 percent). Otherwise, the questionnaires are returned to the experts for review. A pairwise comparison matrix has been obtained from respondents, and a degree of noncompliance has been entered into ExpertChoice, as shown in Figure 5.

As shown in Figure 5, the inconsistency rate in this matrix is less than 0.1% (less than 0.01%), which is acceptable. Figure 6 also shows the weight and rank calculated from the pairwise comparison matrix calculations for the main criteria.



		K	M	P	F	T
K			2.39488	1.22621	1.97792	2.72083
M				2.90128	2.05463	1.02128
P					2.59562	4.11327
F	2.59739					2.59739
T		Incon:0.01				

Figure 5. Comparison matrix of data obtained from respondents and the degree of noncompliance entered into ExpertChoice.

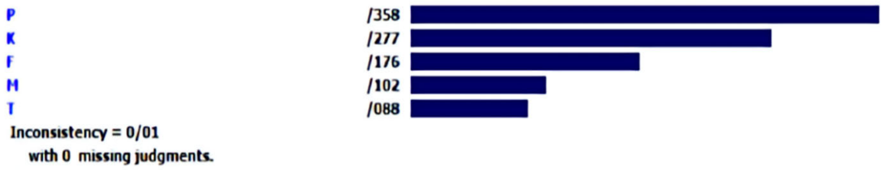


Figure 6. The weight and rank derived from the pairwise comparison matrix calculations for the main criteria.

Referring to Table 5, the criteria associated with the contractors and builders emerge as the most crucial indicators in terms of preference, commanding approximately 36% of the total weight. Following closely behind are internal and external problems, holding around 36% of the weight and indicating significant importance. In contrast, natural factors account for approximately 9% of the total weight, representing the least importance among the criteria. Contractors and builders are identified as the primary contributors to project delays based on their substantial weight in the analysis. Employer-related factors hold the second position, roughly 28% less important than criteria related to contractors, showcasing their notable influence on project timelines. Technical and executive project-related factors secure the third spot, prioritized at about 18%. Notably, these technical and executive factors play a more crucial role compared to that of consultants and supervisors, who are preferred with a 10% weight. This weighted analysis provides a nuanced understanding of the hierarchy of influences, offering valuable insights for effective project management strategies.

Table 5. Preference regarding the main criteria.

Rank	Criteria	Symbol	Weight Value
1	P	criteria related to contractors and builders	0.358
2	K	criteria related to employers	0.277
3	F	criteria related to technical and executive factors of the project	0.176
4	M	criteria related to consultants and supervisors	0.102
5	T	criteria related to natural factors; internal and external problems of the project	0.088

3.2.2. Calculation of the Relative Weight of the Research Criteria and Ranking of the Sub-Criteria

In the preceding section, the determination of the main criteria weights was elucidated through the utilization of a pairwise comparison questionnaire and ExpertChoice software. Expanding on this, the evaluation of the sub-criteria relative weights has been undertaken employing a similar pairwise comparison methodology. Following the establishment of a pairwise comparison matrix for the sub-criteria, the collected data from the statistical population, along with expert surveys, were incorporated into the ExpertChoice program. Subsequently, the results are presented, contingent upon the acceptability of the degree of incompatibility indicated by the pairwise comparison questionnaire for the sub-criteria. Upon computing the relative weights of both the main criteria and the sub-criteria, the final weight of each research sub-criterion is determined. To ascertain the combined weight of each research sub-criterion, the relative weight of the individual sub-criterion is multiplied by the relative weight of the corresponding main criteria. The culmination of this process yields the total (final) weight of the research sub-criteria. Figure 7 visually represents the combined weight of all research sub-criteria, offering insight into their hierarchical ranking based on the calculated weight. This tableau not only presents the combined weight of the research sub-criteria but also delineates their preferences or importance in the overall research framework, thus providing a profound and comprehensive analysis of the results.

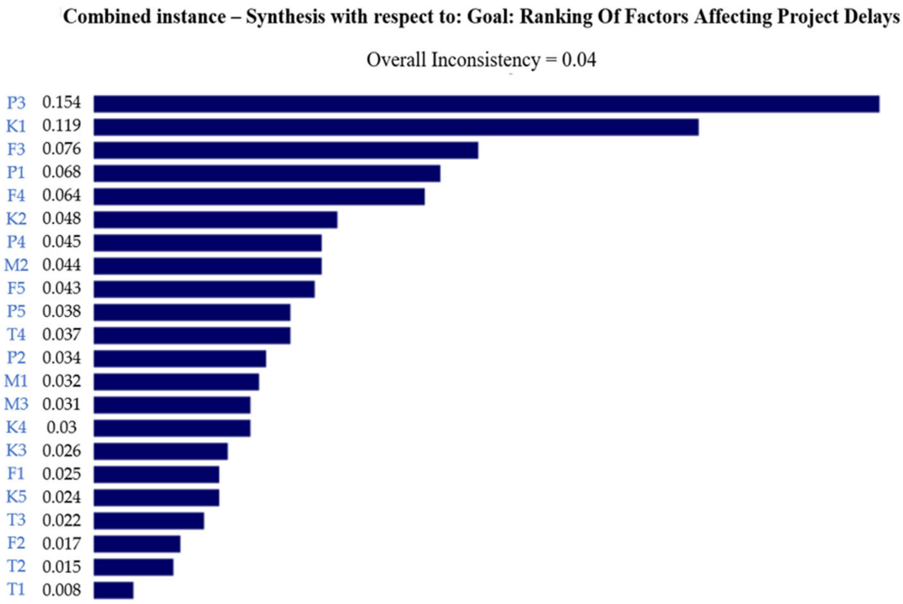


Figure 7. The combined weight of all research sub-criteria and their rankings.

The contractors' financial weakness sub-criterion (P3) exhibits the highest weight among the research sub-criteria, as shown in Table 6.

Table 6. Percentage of preference of all sub-criteria over the others.

Rank	Symbol	Weight Value
1	P3	0.154
2	K1	0.119
3	F3	0.076
4	P1	0.068
5	F4	0.064
6	K2	0.048
7	P4	0.045
8	M2	0.044
9	F5	0.043
10	P5	0.038
11	T4	0.037
12	P2	0.034
13	M1	0.032
14	M3	0.031
15	K4	0.03
16	K3	0.026
17	F1	0.025
18	K5	0.024
19	T3	0.022
20	F2	0.017
21	T2	0.015
22	T1	0.008

3.3. Analysis of Research Options Using the VIKOR Method

For this research section, the VIKOR method has been utilized to evaluate and prioritize the available options (1. cost, 2. time, and 3. quality).

3.3.1. Creation of the Problem Decision Matrix

The VIKOR method begins with creating a decision matrix for the problem. To form the decision matrix, the criteria, criteria type, the weight of criteria and their options, and the status of each option in each criterion must all be present. As previously stated, the criteria and options were developed using research literature and expert opinions. In the previous step, the weight of the research criteria was determined using the AHP hierarchical analysis method. The respondents used the VIKOR questionnaire to determine the status of each option in each of the research criteria. After forming the problem decision matrix, the normalized standard decision matrix should be obtained. The Euclidean measurement method was used in this study to achieve this goal. One advantage of this measurement method is that the indicator direction does not change after the matrix is normalized. The standard normalized decision matrix is shown in Table 7.

Table 7. The standard normalized decision matrix.

Sub-Criteria	Criterion Type	Criterion Weight	Cost	Time	Quality
K1	Positive	0.1190	0.5929	0.6616	0.4591
K2	Positive	0.0480	0.5390	0.7292	0.4215
K3	Positive	0.0260	0.5776	0.6215	0.5293
K4	Positive	0.0300	0.5585	0.5474	0.6232
K5	Positive	0.0240	0.6210	0.6228	0.4759
M1	Positive	0.0320	0.5669	0.6899	0.4502
M2	Positive	0.0440	0.5984	0.6280	0.4975
M3	Positive	0.0310	0.5541	0.5824	0.5948
P1	Positive	0.0680	0.5790	0.5807	0.5723
P2	Positive	0.0340	0.5561	0.5108	0.6557
P3	Positive	0.1540	0.5354	0.6546	0.5336
P4	Positive	0.0450	0.5393	0.6468	0.5393
P5	Positive	0.0380	0.6527	0.5723	0.4964
F1	Positive	0.0250	0.5731	0.6388	0.5134
F2	Positive	0.0170	0.5977	0.6200	0.5084
F3	Positive	0.0760	0.5773	0.6917	0.4339
F4	Positive	0.0640	0.5698	0.6623	0.4865
F5	Positive	0.0430	0.5837	0.6696	0.4592
T1	Positive	0.0080	0.6031	0.6301	0.4891
T2	Positive	0.0150	0.5400	0.6347	0.5528
T3	Positive	0.0220	0.6093	0.6346	0.4755
T4	Positive	0.0370	0.5486	0.6668	0.5045

3.3.2. Determination of the Ideal Positive and Negative Answers

At this point, the ideal positive and negative solutions must be identified. Each index's ideal positive and negative value is determined based on its type among the values of the problem decision table for each index based on the stated relationships. Table 8 shows the ideal positive and negative responses.

Table 8. Ideal responses for various sub-criteria.

Sub-Criteria	Ideal Positive Answer	Ideal Negative Answer
K1	0.6616	0.4591
K2	0.7292	0.4215
K3	0.6215	0.5293
K4	0.6232	0.5474

Table 8. *Cont.*

Sub-Criteria	Ideal Positive Answer	Ideal Negative Answer
K5	0.6228	0.4759
M1	0.6899	0.4502
M2	0.6280	0.4975
M3	0.5948	0.5541
P1	0.5807	0.5723
P2	0.6557	0.5108
P3	0.6546	0.5336
P4	0.6468	0.5393
P5	0.6527	0.4964
F1	0.6388	0.5134
F2	0.6200	0.5084
F3	0.6917	0.4339
F4	0.6623	0.4865
F5	0.6696	0.4592
T1	0.6301	0.4891
T2	0.6347	0.5400
T3	0.6346	0.4755
T4	0.6668	0.5045

3.3.3. Calculation of Utility Index (S), Dissatisfaction Index (R), and VIKOR Index (Q)

The usefulness index, dissatisfaction index, and VIKOR index for each of the research options should be calculated using the relationships expressed in the previous sections. Tables 9 and 10 show each option's calculated utility, dissatisfaction, and VIKOR indices.

Table 9. R, S, and Q values.

Options	Utility Index (Si)	Dissatisfaction Index (Ri)	VIKOR Index (Qi)
Cost	0.5443	0.1516	0.6679
Time	0.0964	0.0340	0.1102
Quality	0.9029	0.1540	0.9926

Table 10. VIKOR index calculation parameters.

V	0.5
S+	0.0964
S-	0.9029
R+	0.0340
R-	0.1540

3.3.4. Evaluation and Ranking of Options

In this section, we employ a mathematical approach to rigorously evaluate and rank various research options. Three key indices—utility index, dissatisfaction index, and VIKOR index values—are utilized for this quantitative assessment. The utility index measures the overall desirability of each option, with higher values indicating greater preference. Conversely, the dissatisfaction index assesses the extent of displeasure associated with each option, with lower values signaling more favorable outcomes. The VIKOR index represents a compromise solution, in which the option with the lowest Qi value is considered to be the optimal choice. The evaluation process involves calculating these indices for each research option and subsequently ranking them based on their performance. The utility index is determined as the reciprocal of the dissatisfaction index, providing a clear quantitative representation of the desirability of each option. The VIKOR index considers the distance between each option and the ideal solution, accounting for both utility and dissatisfaction. The option with the lowest Qi value is considered to be the most favorable choice. The outcomes of this quantitative analysis, along with the rankings based on utility, dissatisfaction, and VIKOR indices, are presented in Table 11. This table serves as a valuable reference, offering a clear and concise overview of the performance of each option across these mathematical metrics. This mathematical approach not only provides a quantitative basis for option assessment but also facilitates a deeper understanding of their relative merits, aiding stakeholders in making well-informed decisions grounded in rigorous quantitative analysis [39–41].

Table 11. Ranking of options based on utility, dissatisfaction, and Vikor indicators.

Options	Ranking Based on Utility Index (Si)	Ranking Based on Dissatisfaction Index (Ri)	Ranking Based on VIKOR Index (Qi)
Cost	2	2	2
Time	1	1	1
Quality	3	3	3

The VIKOR method for evaluating and ranking options meets the following conditions: 1. In terms of the VIKOR index, the option with the first ranking has an acceptable advantage over the option with the second ranking. 2. There should be an acceptable consistency in decision making; the time option is also in place, based on S and R values. The options can be ranked by examining the status of each option based on the VIKOR index (Qi) and the conditions stated. Table 12 indicates the ranking of options, based on the VIKOR index.

Table 12. Ranking based on the VIKOR index (Qi).

Ranking	Ranking Based on VIKOR Index (Qi)
1	Time
2	Cost
3	Quality

According to Table 12, time has been the priority in implementing construction projects within the statistical population and when evaluating the research results. It can be seen that the identified factors affecting project delays have the greatest impact on the timing of high-rise construction projects. In terms of cost and quality, commercial-use projects are superior. Due to the delays in which the main factors were identified and ranked in this study, increasing the time for the project is more important than the other two criteria, cost and quality, from the perspective of project managers and the project's managerial and executive factors.

In the conclusive outcomes of this research, numerical values offer a nuanced perspective on the differential impact of factors influencing project delays. The time parameter, with a notable index of 0.1102, emerges as the most influential indicator, surpassing both cost and quality considerations. This index signifies a substantial sensitivity, with time exerting approximately six times more impact on cost and an even more significant nine times greater impact on project quality. Following closely behind these parameters is the cost parameter, characterized by an index of 0.6679, positioning it as the second most impactful factor. It wields an approximately 5.1 times greater influence on project quality, underscoring its significance in the project management context. In contrast, the quality parameter, with an index of 0.9926, represents the least preferred factor among the options, highlighting its relatively lower impact on the overall project dynamics. Tumi et al. (2009), Ndekugri et al. (2008), and Assaf et al. (2006) concur with the findings of this research, collectively identifying financial factors and liquidity issues as among the most key contributors to project delays, ranking them in the first and second positions. These factors include challenges such as deficiencies in monthly payments, delays in disbursements by the client, and financial difficulties faced by contractors. Previous research has consistently highlighted the significance of these financial aspects in impeding project progress. It is noteworthy that the consensus among these studies underscores the critical role of financial stability and effective cash flow management in ensuring the timely and smooth execution of projects. This alignment across multiple research works not only strengthens the validity of the identified factors but also emphasizes the importance of addressing financial considerations comprehensively within the project management framework [16,17,20].

These numerical values align with established project management theories, providing empirical evidence for the critical role of time and cost considerations in project success. The prominence of the time parameter, in particular, reinforces the time–cost–quality trade-off concept, emphasizing the delicate balance that project managers must maintain to achieve successful project outcomes. Moreover, the identified factors contributing to delays, such as financial weaknesses, resource allocation delays, and technical shortcomings, resonate with theories such as the resource-based view and agency theory in the project management literature. These values not only deepen our empirical understanding of project delays but also provide a quantitative foundation for aligning with theoretical frameworks, enhancing the overall applicability and robustness of project management strategies.

Recognizing the dynamic nature of project execution and the potential for unforeseen challenges to disrupt financial plans, it is advisable to enhance the contractual framework. To address this, the paper recommends the inclusion of specific contract clauses that anticipate and rectify potential financial discrepancies that may arise during the course of the project. This strategic approach aligns with the need for adaptability in project management, ensuring the contract remains robust and responsive to unforeseen financial challenges, ultimately contributing to the overall success of the contractual agreement [52] and can be extended and improved by the use of SWOT analysis [53].

4. Implications, Limitations, and Future Research

In examining the details of high-rise construction projects, this study employed a robust analytical framework, employing the described methods to identify and rank factors influencing project delays. The exploration of these factors not only contributes to the theoretical understanding of project delays but also holds practical implications for stakeholders involved in construction endeavors.

4.1. Theoretical Implications

The theoretical implications of this study lie in the comprehensive identification and ranking of factors influencing delays in high-rise construction projects, particularly those with commercial applications in Mashhad, Iran. The utilization of the analytic hierarchy process (AHP) and VIKOR methods contributes to the theoretical foundation by offering a structured approach to understanding the multifaceted dimensions of project delays. This study advances the theoretical discourse by emphasizing the critical interplay of factors affecting project success, providing a nuanced understanding of their impact on cost, time, and quality.

4.2. Practical Implications

Addressing the practical implications of our findings, it is evident that the lack of funding poses a significant challenge for contractors during project implementation. To mitigate this issue, it is recommended that a robust mechanism be established to ensure the timely payment of contractors' claims. Employers should be attentive regarding the liquidity constraints and delays in payment, addressing these concerns at the contract signing stage. Furthermore, adequate resource allocation and timely implementation and control methods are vital for successful project execution. Employers and project managers, equipped with sufficient credit, should carefully select and appoint contractors based on criteria including quality, technical proficiency, experience, and financial stability. This study underscores the importance of a thorough construction method and a realistic, error-free plan developed in collaboration with experienced executives and technical experts.

4.3. Research Limitations and Future Research Directions

While this study offers valuable insights, it is important to acknowledge its limitations. The statistical population is confined to high-rise construction projects with a commercial focus in Mashhad, Iran, and the snowball sampling method was employed due to restrictions in obtaining information from the Mashhad Municipality Organization.

For future research, emphasizing on sustainable construction can be considered [54–56]. Extending the identified factors to other construction categories, such as road construction projects, and comparing the results is recommended. Additionally, exploring alternative techniques, like the analytic network process (ANP), for ranking factors influencing delays in high-rise projects in Mashhad could provide a richer understanding. ANP, with its focus on examining the effect of parameters on each other, presents an alternative perspective to those of traditional hierarchical analysis methods. Moreover, employing tools such as a dimmer rating technique can further examine the impact of identified influential factors on time, cost, and quality alternatives within a broader system. These recommendations pave the way for future research to expand and refine our understanding of project delays, offering opportunities for interdisciplinary exploration and the application of diverse analytical approaches.

5. Conclusions

The study's discoveries highlight that the adverse impacts of factors influencing project delays on cost, time, and project quality are not uniform. Certain factors exert considerably more pronounced effects on prolonging project execution time. The time parameter emerges as the most influential, with an approximately sixfold impact on cost and ninefold effect on quality. Following time, the cost parameter, with an index of 0.6679, stands as the second most impactful, affecting quality at a rate of roughly 1.5 times that of other factors. Among these parameters, quality ranks the lowest in preference, with an index of 0.9926. Key factors contributing to delays include contractor financial instability, delays in financial and credit resource allocation, insufficient allocation of project resources, contractor technical and managerial deficiencies, and lapses in proper implementation and project control. The initial two factors are financially driven, while the latter three arise from suboptimal work performance. Additionally, this study emphasizes that factors linked to contractors and builders play a fundamental role in instigating delays in construction projects.

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