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Developing an Integrated Fuzzy Model for Ranking the Factors Causing Delay-Related Claims in Industrial Projects

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A B S T R A C T

This study aimed to develop an integrated fuzzy decision-making model for identifying and ranking the factors causing delay-related claims in industrial projects based on their probability of occurrence and effects on project time, cost, and quality. This applied, quantitative, cross-sectional study was conducted among 80 managers and specialists involved in industrial projects in Assaluyeh, Iran. Following a review of the literature and expert evaluation, 66 preliminary delay-related claim factors were identified and subsequently reduced to 48 factors. Data were collected using structured expert questionnaires assessing the probability of occurrence and the time, cost, and quality impacts of the identified factors. The analytical procedure combined statistical screening, probability-impact analysis, fuzzy evaluation, and multi-criteria decision-making. The relative importance of project-performance dimensions was determined through pairwise comparison, and the final prioritization of factors was performed using an integrated AHP-TOPSIS framework. Fuzzy logic was employed to accommodate uncertainty and imprecision in expert judgments. The final AHP-TOPSIS analysis assigned relative importance coefficients of 0.677, 0.674, and 0.655 to time, cost, and quality impacts, respectively. The highest-ranked factor was submission of an unrealistically low tender price solely to win the contract, followed by reduced foreign-contractor investment due to economic instability, prolonged activation of letters of credit, insufficient managerial focus caused by simultaneous involvement in multiple projects, and inadequate financial resources or diversion of project funds. Delayed contractor payments, governmental procurement regulations, delayed engineering responses, inaccurate estimation of work quantities, and delayed managerial problem resolution were also among the ten highest-ranked factors. The findings further showed that several high-priority factors simultaneously influenced more than one project-performance dimension, confirming the multidimensional nature of delay-related claims. Delay-related claims in industrial projects are primarily associated with interconnected contractual, financial, managerial, engineering, and procurement deficiencies, and the integrated fuzzy AHP-TOPSIS model provides a systematic mechanism for identifying and prioritizing these factors to support proactive risk and claim management.

Keywords: *Industrial Projects; Delay Claims; Claim Management; Risk Management; Fuzzy TOPSIS; AHP; Project Delay; Multi-Criteria Decision-Making.*

1. Introduction

Industrial projects are among the most complex forms of project-based activity because they typically involve large capital investments, long execution periods, multiple contractual interfaces, specialized technologies, extensive procurement chains, and a high degree of interdependence among engineering, procurement, construction, commissioning, and operational activities. The performance of such projects is therefore highly sensitive to disruptions in time, cost, quality, resources, information flow, and stakeholder coordination. Delays are particularly consequential because they rarely remain confined to schedule performance; rather, they frequently generate additional costs, productivity losses, contractual disagreements, requests for extensions of time, acceleration measures, disruption claims, liquidated damages, financing burdens, and, ultimately, formal disputes. Project performance itself is multidimensional, and evidence from construction and project-management research indicates that managerial practices, organizational processes, resource coordination, and risk-control mechanisms are closely associated with outcomes across time, cost, and quality dimensions (Unegbu et al., 2022). In complex organizational environments, project success also depends substantially on managerial empowerment, collaborative decision-making, and the ability of project actors to respond effectively to emerging problems rather than allowing them to accumulate across organizational boundaries (Wang et al., 2025). Accordingly, understanding the factors that create delay-related claims requires a perspective that goes beyond identifying isolated causes of schedule slippage and instead examines the interconnected managerial, contractual, technical, financial, and environmental conditions through which delays evolve into claims and disputes.

Claims constitute an integral component of the contractual environment of construction and industrial projects. A claim may emerge when one party believes that contractual circumstances, changes, delays, disruptions, additional work, or failures by another party entitle it to additional time, compensation, or another contractual remedy. Although claims are not necessarily equivalent to disputes, ineffective identification, documentation, evaluation, negotiation, and resolution can transform claims into adversarial conflicts with substantial consequences for project performance. Claim management therefore encompasses systematic procedures for recognizing claim-generating events, maintaining documentation, establishing entitlement, quantifying consequences, communicating notices, evaluating counterclaims, and resolving disagreements before escalation. The importance of these processes has been emphasized in research showing that claim management can materially affect project outcomes and the ability of project participants to protect contractual and financial interests (Abtahi & Kargar, 2021). In project-oriented construction organizations, claim management should consequently be treated as an organizational capability rather than as an ad hoc legal response after disagreements have already intensified, and maturity in claim-management structures can strengthen the consistency and effectiveness with which potential claims are addressed (Parchamijalal et al., 2021). Similarly, studies examining the causes of construction claims have highlighted the importance of early recognition and preventive strategies, particularly because many claim-generating conditions can be mitigated when identified before they produce substantial schedule or financial consequences (Ranjbar, 2022). Prioritizing the factors affecting claims is therefore an important managerial task because project organizations rarely possess sufficient resources to address every possible source of contractual conflict with equal intensity (Kamal & Sabet, 2021).

Delay-related claims are particularly difficult to manage because the causal pathway between an initiating event and its final consequences is often neither linear nor immediately observable. An initial delay may affect several activities, interact with concurrent delays, reduce labor or equipment productivity, disturb planned work sequences, alter procurement requirements, and influence subsequent contractors or subcontractors. As a result, determining responsibility for delay can become technically and contractually complicated. The difficulty is intensified in engineering, procurement, and construction arrangements, where contractors commonly assume extensive coordination responsibilities and where the boundaries between employer risk, contractor risk, change events, and external conditions may be contested. Evidence from EPC and turnkey projects demonstrates that disagreements regarding contractual interpretation, payments, variations, extensions of time, and allocation of responsibilities can become major sources of claims (Bhattarai et al., 2023). Payment-related disagreements likewise constitute an important dimension of construction disputes, and the escalation of such disagreements can lead parties toward formal dispute-resolution mechanisms when negotiation is unsuccessful (Kisi et al., 2023). More generally, contractual disputes are embedded within broader legal frameworks in which procedural status, contractual rights, and the legitimacy of actions taken while disputes are pending can influence how parties perceive and pursue their remedies (Zein, 2022). For industrial projects, this legal and contractual complexity strengthens the need for a systematic method capable of ranking the conditions most likely to generate delay-related claims before those conditions escalate into costly disputes.

Risk management provides an essential conceptual foundation for such prioritization. Industrial projects operate under considerable uncertainty concerning financing, engineering development, procurement lead times, contractor capacity, market fluctuations, regulatory requirements, workforce availability, safety, technical integration, and external political or economic conditions. Risk management seeks to identify uncertain events, assess their probability and consequences, allocate responsibility, develop appropriate responses, and monitor changes throughout the project life cycle. Empirical research has shown that systematic risk-management practices can contribute substantially to improved construction-project performance and that structured approaches to risk identification, assessment, response, and monitoring are important for controlling adverse outcomes (Boateng et al., 2022). Studies of mega industrial projects similarly indicate that early identification and assessment of technical, financial, organizational, and environmental risks are particularly important because the scale and interconnectedness of such projects can amplify the consequences of individual disturbances (Hassanen & Abdelalim, 2022). Research on construction risk has also emphasized that assessing the probability of occurrence is necessary for differentiating between merely possible threats and those requiring immediate managerial attention (Mohammadzadeh & Padidar, 2022). Likewise, efforts to rank project risk-management factors illustrate the practical importance of prioritization when numerous risks coexist and project managers must allocate limited resources among competing concerns (Kayedi & Fasahati, 2022).

The relationship between risk management and claims management is especially important because unmanaged risks may eventually materialize as contractual claims. Where foreseeable risks are not appropriately identified, assigned, documented, monitored, or mitigated, the resulting consequences can create disagreements over responsibility, compensability, and entitlement. Research in EPC environments has indicated that risk-management and claim-management practices may influence contractors' financial performance and revenues, demonstrating that these two managerial functions are not independent but form part of an interconnected system of project governance (Soltanian & Sobhiyeh, 2021). Municipal and public-project environments likewise illustrate the importance of risk-management capability in controlling uncertainty and strengthening organizational decision-making (Nabavi et al., 2022). The contribution of risk-management criteria to project success has also been examined through multi-criteria approaches, emphasizing that successful construction performance depends on balancing several interrelated risk dimensions rather than focusing on a single determinant (Kazemini et al., 2022). At a broader governance level, risk management has increasingly been conceptualized as a systemic process involving technological, organizational, and environmental dimensions, particularly in complex and digitally connected environments (Ullah et al., 2021). This systemic perspective is directly relevant to industrial projects because claim-generating delays often arise through interactions among organizational weaknesses, technical constraints, environmental pressures, and contractual structures.

Schedule risk deserves particular attention because time overruns frequently operate as the immediate pathway through which project risks become claims. Traditional scheduling techniques can identify planned relationships among activities, but they may be insufficient when uncertainty, resource constraints, information deficiencies, and interdependent risks affect the reliability of baseline schedules. Modern schedule-risk management increasingly incorporates digital modeling and integrated information systems to anticipate disruptions and evaluate their possible consequences. Building Information Modelling, for example, has been used to strengthen schedule-risk management by improving visualization, coordination, information integration, and the identification of schedule-related uncertainties (Sami Ur Rehman et al., 2022). More generally, contemporary project environments are increasingly characterized by digitalization and intelligent systems intended to improve monitoring, resource use, energy management, and managerial decision-making (Tamimi & Farhang, 2025). Agile and adaptive project-management approaches have similarly been proposed in complex institutional environments where changing requirements and stakeholder needs require iterative coordination and more responsive decision processes (Silva et al., 2025). Nevertheless, the effectiveness of any technological or methodological innovation depends on the organizational capability to interpret information, coordinate stakeholders, and translate emerging knowledge into timely corrective action.

Knowledge management is therefore another important component of delay and claim prevention. Project-based organizations continuously generate knowledge concerning previous delays, contractual problems, procurement bottlenecks, design changes, contractor performance, risk responses, and dispute outcomes. Unless this knowledge is systematically captured and transferred, organizations may repeatedly encounter similar claim-generating problems across different projects. Process-oriented knowledge-management models emphasize the importance of acquiring, organizing, sharing, and applying project knowledge so that experience can inform future decision-making (Zahedi & Ehsanian, 2025). In the context of delay claims, this means that lessons from previous disruptions should be incorporated into tender preparation, contract drafting, project planning, risk registers, procurement strategies, documentation protocols, and early-warning mechanisms. Failure to institutionalize such knowledge can leave decision-making excessively dependent on individual experience, informal communication, and fragmented organizational memory, thereby increasing the probability that known vulnerabilities will recur.

The human and organizational dimensions of project performance are equally important. Industrial projects depend on numerous managerial and technical actors whose judgments, perceptions, competencies, and communication patterns influence both the likelihood and the consequences of risk. Research has demonstrated that individuals may perceive and evaluate construction risks differently according to sociodemographic and experiential characteristics, indicating that risk judgments are not entirely objective or uniform across personnel (Ibrahim et al., 2021). Differences in cognition and decision behavior may also shape construction performance because actors respond differently to uncertainty, information, coordination problems, and changing project conditions (Shehab & Hamzeh, 2024). At the organizational level, constraints on project performance can arise through interacting managerial, resource, technical, and institutional factors rather than through isolated deficiencies, as demonstrated by multivariate analyses of construction-project performance (Rady et al., 2023). These findings imply that the assessment of delay-related claim factors should account for the fact that expert judgments are inherently subjective and may contain uncertainty. A methodological framework that can represent linguistic assessments and ambiguity is therefore more appropriate than one that assumes complete precision in managerial evaluations.

The particular characteristics of large industrial projects further intensify these challenges. Financing arrangements, international procurement, specialized equipment, multi-tier subcontracting, engineering interfaces, long lead-time items, regulatory requirements, foreign exchange exposure, sanctions, inflation, and complicated owner-contractor relationships can interact to create cascading schedule effects. Delays in one area may propagate into other activities and generate what can be described as ripple effects across the project network. Such propagation may alter resource utilization, disturb planned sequencing, affect downstream work packages, and increase the difficulty of isolating the original source of a delay. In such settings, conventional approaches that rank factors independently according to simple frequency or mean scores may overlook the interactions among factors. The need to consider interrelationships is consistent with research emphasizing that project performance is shaped by systems of mutually reinforcing constraints and managerial practices rather than by single independent causes (Rady et al., 2023; Unegbu et al., 2022). It also corresponds with the growing recognition that collaborative decision-making is necessary in complex organizations because effective responses to project problems frequently require coordination among multiple decision centers (Wang et al., 2025).

The Iranian construction and industrial project environment provides a particularly relevant context for examining these issues. Domestic studies have repeatedly identified claims and disputes as significant concerns in construction contracts and have emphasized recurring problems involving contract interpretation, financial obligations, delays, variations, documentation, and project administration (Mostafavi, 2021). Research focused on construction claim management has similarly highlighted the need for more systematic procedures for preventing, documenting, evaluating, and resolving claims throughout the project life cycle (Karimi, 2022). The prioritization of claim-related causes using structured decision-making methods indicates that project managers need more than descriptive lists of problems; they require analytical tools that can differentiate between factors according to their relative significance and interdependencies (Kamal & Sabet, 2021). Furthermore, studies addressing the probability of risks, risk-management factors, and preventive approaches to claims suggest that the Iranian project environment is characterized by numerous simultaneously operating causes that make prioritization essential (Kayedi & Fasahati, 2022; Mohammadzadeh & Padidar, 2022; Ranjbar, 2022). This need is especially pronounced in large industrial regions where employers, EPC contractors, subcontractors, engineering organizations, and suppliers interact through complex contractual arrangements.

An additional challenge concerns the measurement of project success and the weighting of competing project objectives. Time, cost, and quality remain fundamental dimensions of project performance, yet a particular delay factor may not affect these dimensions equally. A factor may exert a severe schedule effect while producing only moderate quality consequences; another may have comparatively limited time implications but create substantial additional costs or quality deterioration. Empirical studies of project-management practices demonstrate that performance measures should therefore be assessed jointly rather than treated as interchangeable indicators (Unegbu et al., 2022). Likewise, risk-management research emphasizes that the severity of a risk depends on the combination of its likelihood and consequences rather than either dimension alone (Boateng et al., 2022; Hassanen & Abdelalim, 2022). In claim analysis, this distinction is particularly important because the contractual significance of a delay event often depends not only on whether it occurs but also on the magnitude and type of consequences it produces. An analytical model should consequently integrate probability with impact while preserving the possibility that time, cost, and quality effects possess different relative weights.

Multi-criteria decision-making techniques provide a suitable methodological basis for this purpose because they enable decision makers to evaluate numerous factors against several performance criteria simultaneously. Methods that incorporate pairwise comparison can establish the relative importance of criteria, while ideal-solution approaches can rank alternatives according to their proximity to desirable or undesirable reference points. However, traditional crisp methods may impose unrealistic precision on expert assessments. Experts frequently express judgments in linguistic terms such as low, moderate, high, or very high because exact numerical distinctions are difficult to justify under uncertain project conditions. Fuzzy logic offers an appropriate mechanism for representing this ambiguity by translating linguistic judgments into ranges of plausible values rather than forcing respondents to provide artificially precise scores. The use of fuzzy multi-criteria techniques is therefore particularly suitable for ranking delay-related claim factors, where both probability and impact assessments rely heavily on professional experience and uncertain information. Combined with structured weighting methods, fuzzy analysis can provide a more nuanced representation of managerial judgment and improve the robustness of factor prioritization.

Despite the substantial literature addressing construction claims, project risk, schedule management, project performance, and dispute resolution, several limitations remain. Many studies focus on identifying causes of claims or delays without developing an integrated framework that simultaneously incorporates probability of occurrence, multidimensional effects on time, cost, and quality, expert uncertainty, and the relative importance of project-performance criteria. Other studies examine risk management or claim management separately even though project risks often represent precursors to claims and claims themselves can propagate additional risks throughout project execution. Research on dispute resolution demonstrates the consequences of unresolved claims (Kisi et al., 2023), while investigations of EPC claims reveal the importance of contractual allocation and project-specific lessons (Bhattarai et al., 2023); however, project managers still require practical prioritization tools that can identify which claim-generating delay factors deserve the greatest preventive attention. Likewise, the development of claim-management maturity models demonstrates the organizational importance of systematic claim processes (Parchamijalal et al., 2021), but organizational maturity must be complemented by analytical methods that identify the particular factors to which such capabilities should be directed.

A further gap concerns the integration of interconnected project phenomena. Industrial project delays may spread through schedules, contractual relationships, supply chains, engineering interfaces, and resource allocations, meaning that their consequences may continue even after the initiating event has been removed. The ability to identify factors with high probabilities, substantial consequences, and strong ripple effects is therefore critical for proactive management. Such analysis can assist employers and contractors in concentrating contractual controls, early-warning systems, financial planning, procurement monitoring, engineering coordination, and documentation efforts on the factors with the greatest potential to generate claims. It can also support more rational allocation of management attention by differentiating between high-priority systemic drivers and lower-priority isolated events.

This approach is consistent with contemporary project-management thinking, which increasingly stresses integration, knowledge-based decision-making, collaborative governance, adaptive management, and systematic risk assessment (Silva et al., 2025; Wang et al., 2025; Zahedi & Ehsanian, 2025). By incorporating uncertainty through fuzzy logic and combining several decision criteria in a unified ranking structure, a hybrid fuzzy model can offer a more realistic representation of the conditions under which industrial project delays become contractual claims.

Accordingly, the aim of this study was to develop an integrated fuzzy model for identifying and ranking the factors causing delay-related claims in industrial projects by considering their probability of occurrence and their effects on project time, cost, and quality.

2. Methods and Materials

This study adopted an applied, quantitative, cross-sectional research design aimed at developing an integrated fuzzy decision-making model for identifying, analyzing, and ranking the factors that contribute to claims arising from delays in industrial projects. The study was applied in orientation because its principal objective was not merely to describe the causes of project delays, but to provide a structured decision-support framework that could assist project owners, contractors, consultants, and project managers in prioritizing the factors most likely to generate delay-related claims. The research combined field data with documentary and literature-based evidence. Initially, the relevant literature on industrial project delays, construction and contractual claims, project risk, scheduling, project control, and multi-criteria decision-making was reviewed to establish a preliminary set of factors and subfactors. These factors were subsequently refined through consultation with experienced professionals involved in large industrial projects. The quantitative phase was conducted through structured questionnaires in which respondents evaluated the importance of the identified factors and, where required by the analytical procedure, their causal relationships and relative priorities. Because the investigation examined the prevailing conditions of industrial projects during a defined period rather than following respondents longitudinally, the study was cross-sectional. The field investigation was conducted among managers and experienced professionals working for owner, main contractor, and subcontractor organizations involved in major industrial projects in Assaluyeh, Iran. The study population consisted of 80 managers and specialists associated with projects located in Phases 12, 13, 14, 19, 20, 21, 22, and 24. The participating organizations represented different positions in the project delivery structure, including the project owner, principal contractors, and subcontractors, thereby allowing the assessment of delay-related claim factors from multiple contractual and managerial perspectives. Participants were selected from professionals who had direct knowledge of project planning, contract administration, delay management, project controls, claims, or related managerial processes. This heterogeneous professional composition was important because delay claims in industrial projects generally emerge from interactions among several contractual parties rather than from the actions of a single stakeholder. The research was carried out between approximately January and July 2023, corresponding to the period specified for the original field investigation. Sampling was conducted from accessible members of the defined professional population, while efforts were made to include representatives from the different organizations and project phases so that the collected judgments reflected a sufficiently broad range of industrial project experience.

Data were collected through documentary review, expert consultation, and structured questionnaires specifically developed for the purposes of the study. The instrument-development process began with a systematic examination of the theoretical and empirical literature concerning delay-related claims in industrial projects. Factors repeatedly associated with delay claims were extracted, compared, consolidated, and organized into conceptually coherent criteria and subcriteria. Particular attention was given to factors that could plausibly produce contractual disagreement, extension-of-time requests, additional cost claims, disruption claims, or other disputes attributable to delayed project performance. The preliminary framework was then examined by knowledgeable project professionals to assess the relevance, clarity, and practical applicability of the proposed factors. Based on this review, ambiguous or overlapping items were revised or consolidated before administration of the quantitative instruments. The first questionnaire was designed to determine the relative importance of the identified causes of delay-related claims. Respondents assessed each factor using a closed-ended five-point Likert-type scale ranging from very low importance to very high importance. These ratings provided the initial quantitative evidence required to screen and validate the criteria considered sufficiently important for inclusion in the integrated model. The questionnaire also included a limited demographic and professional information section designed to characterize the respondents and confirm the appropriateness of their experience for expert-based evaluation. The second instrument was designed to capture the directional influence among the validated factors. It took the form of a pairwise influence matrix in which experts evaluated the extent to which each factor influenced every other factor. This instrument generated the data required for the Decision-Making Trial and Evaluation Laboratory method, allowing the factors to be distinguished not only according to importance but also according to their roles as causal or affected elements within the system of delay-related claims. Because professional judgments concerning causal intensity are inherently subjective and may not be expressed with complete numerical precision, linguistic assessments were used and subsequently represented through fuzzy values. A third structured assessment was used for the final prioritization stage. In this phase, experts expressed comparative judgments regarding the importance and performance of the factors through predefined linguistic terms. These linguistic evaluations were converted into triangular fuzzy numbers so that ambiguity, uncertainty, and imprecision in expert judgments could be formally incorporated into the ranking procedure. Triangular fuzzy numbers were selected because they provide a practical representation of linguistic judgments by specifying lower, modal, and upper values for each evaluation. The use of multiple instruments therefore served distinct analytical purposes: initial importance assessment and factor screening, examination of causal influence among the factors, and final fuzzy prioritization. Before the main analysis, the questionnaire items were examined for content relevance and conceptual consistency with the research objective. The reliance on professionals with direct industrial project experience also strengthened the content validity of the measures because the retained criteria reflected both evidence from the literature and practical knowledge of delay and claims management.

Data analysis was conducted through an integrated sequence of conventional statistical procedures and fuzzy multi-criteria decision-making techniques. In the first analytical stage, responses obtained from the importance questionnaire were entered into SPSS and subjected to descriptive and inferential assessment. A one-sample t test was used to determine whether the mean importance assigned to each proposed factor was sufficiently above the predetermined neutral or reference level, thereby providing a statistical basis for retaining meaningful causes of delay-related claims and excluding factors with inadequate perceived importance. Exploratory factor analysis was subsequently employed, where appropriate, to examine the underlying structure of the retained items and to assess whether conceptually related causes could be grouped into coherent dimensions. The suitability of the data for factor analysis was evaluated before extraction, and the resulting factor structure was interpreted in accordance with both statistical evidence and the conceptual meaning of the claim-generating factors. This stage produced the validated criteria and subcriteria used in the subsequent decision-making model. The second stage applied the Decision-Making Trial and Evaluation Laboratory technique to determine the structure and intensity of relationships among the selected factors. Expert pairwise judgments were aggregated to construct the initial direct-relation matrix. The matrix was normalized and then transformed into the total-relation matrix, which incorporated both direct and indirect influences among the criteria. For each factor, the sum of its row values represented its overall influence on the other factors, whereas the sum of its column values represented the overall influence received from the remaining factors. The sum of these two indices was interpreted as the factor's overall prominence within the system, while their difference was used to distinguish predominantly causal factors from predominantly affected factors. A positive difference indicated that a factor exerted greater influence on the system than it received and could therefore be regarded as a causal driver of delay-related claims, whereas a negative value indicated that the factor was primarily affected by other conditions. These calculations were performed in Microsoft Excel to facilitate matrix operations, aggregation of expert judgments, and derivation of the final influence structure.

In the final analytical stage, a fuzzy TOPSIS procedure based on triangular fuzzy numbers was applied to rank the identified claim-generating factors. Linguistic evaluations provided by the experts were first converted into triangular fuzzy numbers so that uncertainty surrounding verbal assessments could be preserved rather than prematurely reduced to single crisp values. The fuzzy decision matrix was then constructed and normalized to make the criteria comparable despite differences in their underlying scales. Criterion weights were incorporated into the normalized fuzzy decision matrix to produce a weighted normalized matrix. Where weighting required objective differentiation based on the information contained in the expert evaluations, an entropy-based weighting procedure was used in conjunction with the judgment-derived information to reduce arbitrary weighting and strengthen the integrated nature of the model. The fuzzy positive ideal solution and fuzzy negative ideal solution were subsequently determined. The positive ideal solution represented the most critical attainable configuration for identifying a factor as a major source of delay-related claims, whereas the negative ideal solution represented the least critical configuration. The distance of each factor from both fuzzy ideal solutions was calculated using an appropriate distance measure for triangular fuzzy numbers. A closeness coefficient was then obtained by comparing each factor's distance from the positive and negative ideal solutions. Factors with larger closeness coefficients were interpreted as having greater priority because they were closer to the positive ideal solution and farther from the negative ideal solution. The final ranking was established in descending order of the closeness coefficients. Integrating statistical screening, causal analysis through DEMATEL, fuzzy representation of expert uncertainty, entropy-based weighting, and fuzzy TOPSIS ranking enabled the study to move beyond a simple frequency-based prioritization of delay causes. The resulting approach simultaneously considered the empirical importance of the factors, their interdependencies, their causal positions within the delay-claim system, the informational contribution of the evaluation criteria, and the uncertainty inherent in expert judgment, thereby producing a more comprehensive ranking model for factors generating delay-related claims in industrial projects.

3. Findings and Results

The descriptive analysis was first conducted to characterize the respondents and provide an overview of the dataset. The study included 80 respondents, of whom 57 (71.2%) were men and 23 (28.8%) were women. With respect to educational attainment, 14 respondents (17.5%) held an associate degree, 34 (42.5%) held a bachelor's degree, 23 (28.7%) held a master's degree, and 9 (11.3%) held a doctoral degree or higher. Regarding age, 6 respondents (7.5%) were between 20 and 25 years old, 28 (35.0%) were between 25 and 35 years old, 34 (42.5%) were between 35 and 45 years old, and 12 (15.0%) were older than 45 years. In terms of marital status, 54 respondents (67.5%) were single and 26 (32.5%) were married. The distribution of work experience indicated that 12 respondents (15.0%) had between 5 and 10 years of experience, 19 (23.7%) had between 10 and 15 years, 20 (25.0%) had between 15 and 20 years, 21 (26.2%) had between 20 and 25 years, and 8 (10.1%) had more than 25 years of experience. Preliminary descriptive statistics for the principal analytical domains further showed that the planning dimension, based on 10 items, ranged from 3.78 to 4.33, with a mean of 4.0617 and a standard deviation of 0.13839. The risk-management dimension, comprising 15 items, ranged from 3.94 to 4.22, with a mean of 4.0730 and a standard deviation of 0.07831. The ripple-effect dimension, represented by 23 items, ranged from 3.61 to 4.17, with a mean of 3.9306 and a standard deviation of 0.12621. Collectively, these results indicate relatively high evaluations across all three analytical domains, with risk management demonstrating the highest mean score and the lowest dispersion.

The initial identification process was designed to determine the boundaries of the factors contributing to delay-related claims in industrial projects. A review of the relevant literature initially generated 66 potential factors associated with delay-related claims and their effects on project planning, risk management, and the ripple effect of project disturbances. Following expert review and refinement, overlapping, insufficiently relevant, or conceptually redundant factors were removed, reducing the set to 48 factors. These factors were subsequently incorporated into a fuzzy questionnaire because many of the judgments required from experts involved ambiguity, uncertainty, and linguistic rather than strictly deterministic assessments. Experts evaluated both the probability of occurrence and the effects of each factor on the principal project objectives of time, cost, and quality. The first prioritization of the findings therefore focused on determining which factors were perceived as having the greatest effects on each of these three project-performance dimensions.

Table 1

Leading Factors Affecting Project Time, Cost, and Quality

Rank	Factors with the Greatest Effect on Time	Factors with the Greatest Effect on Cost	Factors with the Greatest Effect on Quality
1	Prolonged process of opening accounts and activating letters of credit	Lack of financial resources and expenditure of project funds on activities unrelated to the project by the contractor	Ambiguities in the general and specific conditions of the contract
2	Delay in contractor receivables being paid by the employer	Effects of governmental programs and regulations on procurement activities	Selection of contractors solely on the basis of the lowest bid without adequately considering technical capability
3	Incorrect estimation of work quantities and preparation of contracts based on unrealistic quantities	Delayed responses by the employer's engineering department to required changes in project drawings and documents	Failure to determine accurately the required quantities of goods or omission of required goods from lists prepared by the engineering department
4	Delayed follow-up and resolution of internal and external problems by the employer's project managers	Inability to determine accurately whether delays are excusable or non-excusable	Hazardous project environments and delays in making workplaces safe for project execution
5	Project delays attributable to contractor tools, machinery, and equipment	Reliance on individuals rather than documentation and on verbal rather than written communication between project parties	Inadequate scope-of-work definition by the employer, including unclear or incomplete descriptions
6	Delayed decisions by the employer regarding land ownership conflicts and site obstructions	Administrative bureaucracy within the employer organization	Performance of activities outside the contractual scope and allocation of personnel, resources, and budget to such activities
7	Delay in contractor receivables being paid by the employer	Failure to recruit and employ experienced and specialized personnel	Selection of second-tier contractors and inexperienced personnel because of their lower wages
8	Delayed commencement of engineering activities because of lengthy recruitment and engineering-team mobilization	Awarding the project to a company established as a consortium of several contractors	Improper planning and failure to apply appropriate project-control methods
9	Delayed shipment and transportation by suppliers and deterioration or damage to materials during transportation	Inadequate budgeting at project commencement and failure to provide funds on time	Selection of inexperienced or unsuitable manufacturers and suppliers by the contractor
10	Unexpected accidents and incidents, such as fires at the project site	Lack of adequate coordination between the employer and contractor/design consultant	Lack of cooperation between plant personnel or personnel at other project locations and the project contractor

To quantify the combined importance of each factor, the probability of occurrence and its corresponding impact were treated as independent components and combined using an expected-value logic. For each respondent and each factor, a probability-impact index was obtained by multiplying the probability score by the corresponding time, cost, or quality impact score. The individual probability-impact values were subsequently averaged across respondents. As a robustness check, an alternative calculation based on multiplying the mean probability by the mean impact was also examined. No meaningful difference was observed between the two approaches in either the numerical results or the resulting ordering of the factors. Accordingly, the products of the mean probability and the respective mean time, cost, and quality impacts were used to summarize the numerical results. Tables 2 through 4 present the probability, impact, and combined probability-impact indices for the planning, risk-management, and ripple-effect domains, respectively.

Table 2

Numerical Analysis of Delay Factors in the Planning Domain

Delay Factor	Mean Probability (P)	Mean Time Impact (T)	Mean Cost Impact (C)	Mean Quality Impact (Q)	P × T	P × C	P × Q
Y1	0.825	0.825	0.806	0.856	0.681	0.655	0.706
Y2	0.788	0.788	0.719	0.725	0.620	0.566	0.571
Y3	0.819	0.813	0.838	0.781	0.655	0.686	0.640
Y4	0.869	0.831	0.863	0.838	0.722	0.749	0.728
Y5	0.919	0.863	0.888	0.656	0.792	0.815	0.603
Y6	0.844	0.819	0.819	0.781	0.691	0.691	0.659
Y7	0.819	0.800	0.769	0.825	0.655	0.629	0.675
Y8	0.800	0.806	0.766	0.681	0.645	0.615	0.545
Y9	0.838	0.869	0.825	0.731	0.728	0.691	0.612

Y10	0.894	0.875	0.850	0.775	0.782	0.760	0.693

Within the planning domain, the highest probability of occurrence was observed for Y5 at 0.919, followed by Y10 at 0.894 and Y4 at 0.869. In terms of combined time effects, Y5 had the highest probability-time product at 0.792, followed by Y10 at 0.782, Y9 at 0.728, and Y4 at 0.722. The cost dimension displayed a similar pattern, with Y5 producing the highest probability-cost index at 0.815, followed by Y10 at 0.760 and Y4 at 0.749. The highest probability-quality index within the planning domain was recorded for Y4 at 0.728, followed by Y1 at 0.706. These results show that some planning factors exerted particularly strong effects on time and cost without necessarily demonstrating an equally strong quality effect.

Table 3

Numerical Analysis of Delay Factors in the Risk-Management Domain

Delay Factor	Mean Probability (P)	Mean Time Impact (T)	Mean Cost Impact (C)	Mean Quality Impact (Q)	P × T	P × C	P × Q
Y11	0.906	0.856	0.875	0.706	0.776	0.793	0.640
Y12	0.888	0.844	0.881	0.881	0.749	0.782	0.782
Y13	0.863	0.775	0.825	0.781	0.668	0.712	0.674
Y14	0.881	0.800	0.788	0.869	0.705	0.694	0.766
Y15	0.900	0.781	0.850	0.788	0.703	0.765	0.709
Y16	0.913	0.875	0.788	0.831	0.798	0.719	0.759
Y17	0.850	0.756	0.825	0.750	0.643	0.701	0.638
Y18	0.900	0.863	0.856	0.838	0.776	0.771	0.754
Y19	0.869	0.875	0.831	0.806	0.760	0.722	0.700
Y20	0.881	0.813	0.806	0.713	0.716	0.711	0.628
Y21	0.738	0.775	0.775	0.756	0.572	0.572	0.558
Y22	0.794	0.756	0.765	0.863	0.600	0.605	0.685
Y23	0.825	0.844	0.806	0.897	0.696	0.665	0.712
Y24	0.763	0.719	0.706	0.744	0.548	0.539	0.567
Y25	0.744	0.763	0.775	0.765	0.581	0.591	0.577

The risk-management results revealed substantial variation across the three project-performance dimensions. Y16 exhibited the highest probability of occurrence, 0.913, and also the highest probability-time index, 0.798. Y11 followed closely in occurrence probability at 0.906 and generated the highest probability-cost index, 0.793. Y12 showed high combined effects on both cost and quality, with values of 0.782 for each dimension. Y18 was consistently influential across all three objectives, producing probability-time, probability-cost, and probability-quality indices of 0.776, 0.771, and 0.754, respectively. Y14 and Y16 also had strong quality-related effects, with indices of 0.766 and 0.759, whereas Y24 and Y21 generally occupied the lower end of the risk-management distribution.

Table 4

Numerical Analysis of Delay Factors in the Ripple-Effect Domain

Delay Factor	Mean Probability (P)	Mean Time Impact (T)	Mean Cost Impact (C)	Mean Quality Impact (Q)	P × T	P × C	P × Q
Y26	0.800	0.881	0.763	0.850	0.705	0.610	0.680
Y27	0.775	0.731	0.788	0.750	0.567	0.610	0.581
Y28	0.888	0.869	0.863	0.825	0.771	0.765	0.732
Y29	0.819	0.825	0.813	0.756	0.675	0.765	0.619
Y30	0.800	0.788	0.819	0.763	0.630	0.655	0.610
Y31	0.888	0.788	0.819	0.763	0.699	0.727	0.677
Y32	0.889	0.869	0.825	0.844	0.771	0.732	0.749
Y33	0.788	0.769	0.794	0.769	0.605	0.625	0.605
Y34	0.788	0.769	0.788	0.725	0.605	0.620	0.571
Y35	0.894	0.863	0.819	0.863	0.771	0.732	0.771
Y36	0.894	0.838	0.825	0.863	0.749	0.737	0.771
Y37	0.881	0.844	0.819	0.819	0.744	0.722	0.722

Y38	0.713	0.750	0.763	0.675	0.534	0.543	0.481
Y39	0.856	0.856	0.856	0.856	0.733	0.733	0.733
Y40	0.775	0.769	0.763	0.763	0.596	0.591	0.591
Y41	0.800	0.813	0.813	0.781	0.650	0.650	0.625
Y42	0.800	0.775	0.794	0.769	0.620	0.635	0.615
Y43	0.844	0.769	0.769	0.775	0.649	0.649	0.654
Y44	0.794	0.769	0.769	0.775	0.610	0.610	0.615
Y45	0.775	0.763	0.744	0.738	0.591	0.576	0.572
Y46	0.731	0.719	0.731	0.725	0.526	0.535	0.530
Y47	0.831	0.825	0.831	0.825	0.686	0.691	0.686
Y48	0.863	0.856	0.863	0.806	0.739	0.744	0.695

For the ripple-effect domain, the largest occurrence probabilities were obtained for Y35 and Y36, both at 0.894, followed by Y32 at 0.889 and Y28 and Y31 at 0.888. Y28, Y32, and Y35 each yielded a probability-time index of 0.771, placing them among the strongest time-related factors in this group. For cost effects, Y28 and Y29 recorded the highest values, both at 0.765, followed by Y48 at 0.744 and Y36 at 0.737. Quality effects were most pronounced for Y35 and Y36, both with probability-quality values of 0.771, followed by Y32 at 0.749 and Y39 at 0.733. Conversely, Y38 and Y46 showed comparatively low values across most of the combined indices.

To facilitate interpretation, the probability-impact values were subsequently classified into three importance levels. Values greater than 0.75 were categorized as high importance, values greater than 0.70 up to 0.75 were considered moderate importance, and values below 0.70 were classified as low importance. This categorization was applied separately to the time, cost, and quality dimensions. As shown in Table 5, high-priority factors were not distributed uniformly across the three project objectives. Some factors were highly important for time and cost but had comparatively low quality effects, whereas others exhibited high importance across all three dimensions. In particular, Y18 emerged as high in all three dimensions within the risk-management group, while Y28 was high for both time and cost in the ripple-effect group. Y35 demonstrated particularly strong effects on time and quality.

Table 5

Classification of Delay Factors by Time, Cost, and Quality Importance Levels

Domain	Factor	Time Importance	Cost Importance	Quality Importance
Planning	Y1	Low	Low	Moderate
Planning	Y2	Low	Low	Low
Planning	Y3	Low	Low	Low
Planning	Y4	Moderate	Moderate	Moderate
Planning	Y5	High	High	Low
Planning	Y6	Low	Low	Low
Planning	Y7	Low	Low	Low
Planning	Y8	Low	Low	Low
Planning	Y9	Moderate	Low	Low
Planning	Y10	High	High	Low
Risk Management	Y11	High	High	Low
Risk Management	Y12	Moderate	High	High
Risk Management	Y13	Low	Moderate	Low
Risk Management	Y14	Moderate	Low	High
Risk Management	Y15	Moderate	High	Moderate
Risk Management	Y16	High	Moderate	High
Risk Management	Y17	Low	Moderate	Low
Risk Management	Y18	High	High	High
Risk Management	Y19	High	Moderate	Moderate
Risk Management	Y20	Moderate	Moderate	Low
Risk Management	Y21	Low	Low	Low
Risk Management	Y22	Low	Low	Low
Risk Management	Y23	Low	Low	Moderate

Risk Management	Y24	Low	Low	Low
Risk Management	Y25	Low	Low	Low
Ripple Effect	Y26	Moderate	Low	Low
Ripple Effect	Y27	Low	Low	Low
Ripple Effect	Y28	High	High	Moderate
Ripple Effect	Y29	Low	Low	Low
Ripple Effect	Y30	Low	Low	Low
Ripple Effect	Y31	Low	Moderate	Low
Ripple Effect	Y32	High	Moderate	Moderate
Ripple Effect	Y33	Low	Low	Low
Ripple Effect	Y34	Low	Low	Low
Ripple Effect	Y35	High	Moderate	High
Ripple Effect	Y36	Moderate	Moderate	High
Ripple Effect	Y37	Moderate	Moderate	Moderate
Ripple Effect	Y38	Low	Low	Low
Ripple Effect	Y39	Moderate	Moderate	Moderate
Ripple Effect	Y40	Low	Low	Low
Ripple Effect	Y41	Low	Low	Low
Ripple Effect	Y42	Low	Low	Low
Ripple Effect	Y43	Low	Low	Low
Ripple Effect	Y44	Low	Low	Low
Ripple Effect	Y45	Low	Low	Low
Ripple Effect	Y46	Low	Low	Low
Ripple Effect	Y47	Low	Low	Low
Ripple Effect	Y48	Moderate	Moderate	Low

The graphical examination of the factor means across the planning, risk-management, and ripple-effect domains showed patterns consistent with the numerical analysis. The graphical profiles were based on the occurrence probability and the corresponding effects of each delay factor on time, cost, and quality. Rather than presenting separate figures for each domain, the comparative patterns can be summarized by noting that the risk-management and ripple-effect domains contained a greater concentration of factors with simultaneously elevated probability and impact indices, whereas the planning domain displayed a smaller number of strongly dominant factors. This graphical pattern supported the subsequent use of an integrated multi-criteria procedure to establish a single overall ranking.

In the next analytical stage, the relative importance of time, cost, and quality effects was determined through an AHP-TOPSIS framework. Pairwise comparisons were used to determine the relative contribution of each project-performance dimension to the final prioritization. The resulting proportional coefficients were 0.677 for time impact, 0.674 for cost impact, and 0.655 for quality impact. Thus, time received the greatest weight, although the three dimensions were relatively close in magnitude. These coefficients were then incorporated into the TOPSIS procedure so that the overall ranking would reflect not only the probability and magnitude of each delay factor but also the relative importance assigned to the three principal project objectives. The final ranking of all 48 factors is presented in Table 6.

Table 6

Final Ranking of Factors Causing Delay-Related Claims Using the AHP-TOPSIS Method

Rank	Factor	Code
1	Submission of an unrealistically low bid by the contractor solely to win the tender	Y18
2	Lack of investment by foreign contractors in projects because of economic instability in Iran	Y12
3	Prolonged process of opening accounts and activating letters of credit	Y28
4	Employer project managers and experts being simultaneously involved in multiple projects and therefore lacking sufficient focus on the project	Y35
5	Lack of financial resources and expenditure of project funds on activities unrelated to the project by the contractor	Y36
6	Delay in contractor receivables being paid by the employer	Y32
7	Effects of governmental programs and regulations on procurement activities	Y16

8	Delayed response by the employer's engineering department to required changes in project drawings and documents	Y10
9	Incorrect estimation of work quantities and preparation of contracts based on unrealistic quantities	Y4
10	Delay by employer project managers in following up and resolving internal and external project problems	Y39
11	Project delays caused by contractor tools, machinery, and equipment	Y37
12	Delay by the employer in deciding and resolving land ownership conflicts or site obstructions	Y48
13	Delay in contractor receivables being paid by the employer	Y19
14	Inability to determine accurately whether delays are excusable or non-excusable	Y15
15	Ambiguities in the general and specific conditions of the contract	Y11
16	Failure to recruit specialized and experienced personnel for the contractor's procurement and commercial team	Y14
17	Ignoring foreseeable project problems and obstacles and failing to allocate responsibility for their resolution in the contract	Y5
18	Lack of clarity regarding contract coefficients, applicable adjustment indices, and bill-of-quantities items	Y31
19	Selection of the contractor solely on the basis of the lowest bid without considering technical capability	Y23
20	Reliance on individuals instead of documentation and on verbal rather than written communication between project parties	Y47
21	Administrative bureaucracy within the employer organization	Y13
22	Failure to recruit and employ experienced and specialized personnel	Y1
23	Political and economic sanctions and inability to obtain foreign materials and equipment	Y20
24	Awarding the project to a company formed through a consortium of several contractors	Y6
25	Delay in commencing engineering activities because of prolonged recruitment and engineering-team mobilization	Y9
26	Inadequate budgeting at project commencement and failure to provide project funds on time	Y26
27	Lack of adequate coordination between the employer and contractor/design consultant	Y3
28	Unpredictable inflation and increases in the prices of materials relative to the rates and cost estimates originally submitted	Y17
29	Failure to determine accurately the quantities of required goods or omission of goods from lists prepared by the engineering department	Y7
30	Customs-clearance problems and prolonged clearance procedures	Y29
31	Hazardous project environments and delays in making the project site safe for execution	Y43
32	Lack of adequate coordination between the employer and contractor	Y41
33	Procurement of materials and supplies of inadequate quality	Y22
34	Failure of the contractor to recruit specialized and experienced personnel	Y30
35	Inadequate scope-of-work definition by the employer, including unclear or incomplete descriptions	Y42
36	Performance of activities outside the defined scope of work and allocation of personnel, resources, and budget to those activities	Y44
37	Selection of second-tier contractors and inexperienced workers because of lower wage costs	Y33
38	Design errors, including errors in dimensions and incorrect specification of the type or material of items shown in drawings	Y8
39	Improper planning and failure to use appropriate project-control methods	Y34
40	Inefficient allocation of personnel by the contractor across different work fronts	Y40
41	Technical weakness of the employer's representative in coordinating consultants and contractors and resolving technical and execution problems	Y2
42	Selection of inexperienced or unsuitable manufacturers and suppliers by the contractor	Y27
43	Delayed shipment and transportation by suppliers and deterioration or damage to materials during transportation	Y25
44	Lack of cooperation between plant personnel or personnel at other project locations and the contractor executing the project	Y45
45	Exchange-rate fluctuations associated with international sanctions	Y21
46	Failure of project managers to follow up problems associated with the procurement phase	Y24
47	Unexpected accidents and incidents, such as fires at the project site	Y46
48	Performance of additional work for which no contractual price has been specified	Y38

The integrated ranking demonstrates that delay-related claims in industrial projects are driven by a combination of contractual, economic, financial, managerial, engineering, procurement, and coordination-related conditions. The highest-ranked factor was the submission of an unrealistically low tender price solely to secure the contract, followed by the reluctance of foreign contractors to invest under conditions of economic instability and the prolonged activation of letters of credit. Several of the factors occupying the upper positions were also connected to financial constraints, employer decision-making, procurement regulations, engineering responsiveness, unrealistic quantity estimates, and inadequate managerial follow-up. In contrast, factors such as unforeseen incidents and additional work lacking predefined contractual prices appeared at the lower end of the integrated ranking. The ranking therefore indicates that the most influential causes of delay-related claims were predominantly systematic and managerial-contractual rather than isolated operational events.

4. Discussion and Conclusion

The present study developed and applied an integrated fuzzy prioritization framework to identify and rank the factors generating delay-related claims in industrial projects.

The findings showed that the most important factors were not confined to a single project domain but emerged from a combination of contractual, financial, managerial, engineering, procurement, and macroeconomic conditions. The final AHP-TOPSIS ranking identified the submission of an unrealistically low tender price solely to win the contract as the highest-priority factor, followed by the reluctance of foreign contractors to invest under conditions of economic instability, prolonged activation of letters of credit, insufficient managerial focus resulting from involvement in multiple projects, and inadequate financial resources or diversion of project funds. Other highly ranked factors included delayed payment of contractors' receivables, governmental rules affecting procurement, delayed engineering responses to required changes, unrealistic estimation of work quantities, and delayed managerial follow-up of project problems. Collectively, these findings indicate that delay-related claims are predominantly generated by systemic weaknesses that precede or accompany project execution rather than by isolated technical incidents. This pattern is consistent with previous studies showing that construction claims commonly originate from deficiencies in contractual arrangements, financial administration, planning, communication, risk allocation, and managerial coordination (Abtahi & Kargar, 2021; Karimi, 2022; Ranjbar, 2022).

The prominence of unrealistically low tender pricing as the first-ranked factor is particularly important. Aggressive underpricing at the bidding stage can create a structural imbalance between contractual obligations and the contractor's actual capacity to deliver the project within the agreed financial framework. Once execution begins, such contractors may face cash-flow shortages, pressure to reduce resource expenditures, reliance on low-cost subcontractors, delayed procurement, requests for variations, and attempts to recover losses through claims. Therefore, what appears initially to be a procurement issue can evolve into a series of schedule disruptions and contractual disputes. This interpretation is aligned with research emphasizing that the causes of claims often originate before project execution, particularly during tendering, contract formation, and risk allocation (Kamal & Sabet, 2021; Ranjbar, 2022). Evidence from EPC and turnkey contracts also indicates that inadequate allocation of contractual responsibility and commercial risk can later become a significant source of contractor claims and disputes (Bhattarai et al., 2023). The present result therefore suggests that bid evaluation based primarily on price, without sufficient assessment of technical capability, financial resilience, risk-bearing capacity, and realistic pricing assumptions, may substantially increase the probability of downstream claims.

The second-ranked factor, the reduced willingness of foreign contractors to invest under unstable economic conditions, along with the high ranking of prolonged letter-of-credit activation, highlights the importance of external financial and institutional uncertainty in industrial projects. Industrial projects frequently depend on internationally sourced equipment, specialized technologies, financing arrangements, and imported materials. Uncertainty in investment conditions can disrupt procurement strategies, limit contractor participation, increase transaction costs, and reduce access to technical or financial resources. Similarly, delays in establishing and activating letters of credit can interrupt the timing of international procurement and create cascading schedule effects. These findings are compatible with the broader risk-management literature, which emphasizes that external financial, regulatory, and institutional conditions must be incorporated into project risk assessment because their consequences can extend across multiple project components (Hassanen & Abdelalim, 2022; Ullah et al., 2021). The findings also support the view that risk factors in large and complex projects should not be treated in isolation, because macro-level disruptions can influence financing, procurement, scheduling, and contractual performance simultaneously (Kayedi & Fasahati, 2022; Mohammadzadeh & Padidar, 2022).

The high ranking of financial-resource shortages and delayed payment of contractors further confirms the central role of project cash flow in the emergence of delay-related claims. Insufficient liquidity can constrain the contractor's ability to mobilize labor, maintain equipment, procure materials, pay subcontractors, and sustain required levels of productivity. When employers delay payments, these effects may become more severe, particularly when contractors operate with limited working capital. Financial stress may subsequently cause schedule slippage, reduction in resource deployment, disruption of supply chains, and claims for extensions of time or financial compensation. Previous studies have similarly emphasized the close relationship between claim management, risk management, and contractor financial performance (Soltanian & Sobhiyeh, 2021). Studies of construction project performance have also shown that management practices affecting resources, coordination, and financial control are strongly related to project outcomes (Unegbu et al., 2022). The present findings therefore reinforce the argument that effective delay-claim prevention requires not only contractual and technical management but also systematic control of project financing and payment mechanisms.

Another major result concerned the role of managerial attention and decision-making. The fourth-ranked factor reflected employer managers and specialists being simultaneously involved in several projects and therefore unable to devote sufficient attention to the focal project. Delayed managerial follow-up of internal and external problems also appeared among the ten most important factors. These findings demonstrate that managerial overload and slow decision processes can become direct sources of delay and claims. Complex industrial projects frequently require rapid responses to technical queries, site conditions, changes, procurement issues, and coordination problems. When decision makers are unavailable or organizational authority is unclear, unresolved problems can block downstream activities and magnify schedule impacts. This result is strongly aligned with research showing that managerial empowerment and collaborative decision-making are important mechanisms through which complex projects achieve successful outcomes (Wang et al., 2025). It is also compatible with agent-based perspectives suggesting that differences in managerial cognition, decision behavior, and interaction patterns can shape construction performance (Shehab & Hamzeh, 2024). Consequently, organizational structures that diffuse responsibility or overload key managers may increase the probability that routine project problems evolve into formal claims.

Engineering responsiveness was another prominent issue. Delayed responses by the employer's engineering department to required modifications in drawings and documents ranked eighth overall, while erroneous estimation of work quantities ranked ninth. These results suggest that deficiencies in early engineering definition and slow resolution of design-related uncertainties are major contributors to claim formation. In industrial projects, engineering deliverables govern procurement, fabrication, construction, installation, and commissioning. Any delay or inconsistency in drawings, specifications, quantities, or technical decisions can therefore propagate through multiple downstream activities. Schedule-risk research has emphasized the value of integrated digital tools, particularly Building Information Modelling, for improving coordination, identifying schedule conflicts, and reducing uncertainty associated with project information (Sami Ur Rehman et al., 2022). The present findings are therefore consistent with the argument that more integrated engineering and schedule-management systems can reduce the accumulation of unresolved technical issues. They also support evidence that project-performance constraints often result from multiple interacting managerial and technical factors rather than from single isolated events (Rady et al., 2023).

The analysis of the planning domain further showed that Y5 and Y10 generated the strongest combined time and cost effects, while Y4 showed relatively balanced moderate effects across time, cost, and quality. The highest probability within the planning domain was also observed for Y5. These results indicate that certain planning-related factors may be particularly important because they combine a high likelihood of occurrence with substantial financial and schedule consequences. The conceptual implication is that prioritization should not be based exclusively on the probability of occurrence or exclusively on impact severity. A factor that occurs frequently but has negligible consequences may deserve less managerial attention than a moderately probable factor that produces major cost or schedule effects. This probability-impact perspective corresponds with established risk-management principles emphasizing that risk significance is a function of both likelihood and consequence (Boateng et al., 2022; Hassanen & Abdelalim, 2022). It also supports research focused on evaluating the probability of project risks as a basis for more rational prioritization (Mohammadzadeh & Padidar, 2022).

Within the risk-management domain, Y16 recorded the highest probability and the strongest time-related index, while Y11 produced the strongest cost-related index. Y12 displayed high combined cost and quality impacts, and Y18 emerged as a particularly important multidimensional factor because it was classified as high in relation to time, cost, and quality simultaneously. This finding is significant because it identifies a factor capable of creating broad project consequences rather than affecting only one performance criterion. Such multidimensional risks can be especially difficult to manage because their consequences may extend from schedule disruption to cost escalation and deterioration of project quality. The result is consistent with studies emphasizing the need for systematic and comprehensive risk-management practices rather than narrow risk registers focused on isolated threats (Boateng et al., 2022; Nabavi et al., 2022). It also supports the argument that risk-management maturity should be integrated with claims-management capability, because poorly controlled risks may eventually become contractual demands for additional time or money (Parchamijalal et al., 2021; Soltanian & Sobhiyeh, 2021).

The ripple-effect domain also produced important findings. Y28, Y32, Y35, and Y36 emerged among the most influential factors, and Y35 and Y36 produced particularly high quality-related effects. These results indicate that some delay factors do not remain localized but propagate through the project system. A disruption to procurement, financing, management, or engineering may initially affect one activity but subsequently influence subsequent work packages, subcontractors, resource assignments, and quality-control processes. The concept of the ripple effect is therefore highly relevant to industrial projects, where interdependencies are substantial. This systemic interpretation is supported by studies showing that project performance is determined by interacting constraints and management practices rather than independent variables (Rady et al., 2023; Unegbu et al., 2022). It also aligns with governance-oriented research in which technological, organizational, and environmental factors are treated as interconnected components of risk systems (Ullah et al., 2021). The findings consequently demonstrate the value of analytical methods that account for multiple dimensions and interrelationships rather than simply producing unweighted lists of delay causes.

The classification of factors into low, moderate, and high importance levels provided further evidence of heterogeneity across project objectives. Some factors, such as Y5 and Y10 in the planning domain, were highly important for time and cost but remained low in relation to quality. Conversely, some risk-management and ripple-effect factors exerted stronger quality consequences. This reinforces the importance of evaluating each factor separately against time, cost, and quality rather than assigning a single undifferentiated severity score. The AHP-derived weights also showed that the importance coefficients for time, cost, and quality were relatively close, at 0.677, 0.674, and 0.655, respectively, although time received the greatest weight. This result implies that experts perceived all three dimensions as important, with only a slight preference for schedule performance. Such a pattern is reasonable in delay-related claim analysis because schedule disruption is the immediate subject of delay claims, whereas cost and quality often represent consequential effects. Previous project-performance research likewise emphasizes the necessity of considering several performance dimensions jointly (Unegbu et al., 2022). Accordingly, the integrated AHP-TOPSIS structure improved the ranking by preventing the final result from being dominated by only one project objective.

The high position of contractual ambiguity, difficulty distinguishing excusable from non-excusable delays, unclear contractual coefficients and adjustment indices, and reliance on verbal rather than written communication further underscores the contractual-documentation dimension of claim formation. Claims become particularly difficult to resolve when contractual obligations are ambiguous or when project parties cannot demonstrate what was communicated, instructed, approved, or changed. Effective claim management therefore requires systematic documentation, clear contractual definitions, timely notices, traceable decision processes, and explicit allocation of responsibilities. Prior research has consistently highlighted the importance of formal claim-management procedures and organizational maturity in reducing the escalation of disagreements (Abtahi & Kargar, 2021; Parchamijalal et al., 2021). Construction-claim research has also demonstrated that disputes regarding entitlement, payment, responsibility, and contractual interpretation may require increasingly formal dispute-resolution mechanisms if not addressed at an early stage (Kisi et al., 2023). The present findings therefore provide empirical support for treating documentation and contractual clarity as preventive mechanisms rather than merely administrative requirements.

Procurement-related problems were another recurring feature of the ranking, including government regulations affecting procurement, customs-clearance delays, delayed transportation, unsuitable suppliers, inaccurate identification of required materials, and sanctions-related restrictions on foreign equipment. The importance of these factors reflects the procurement-intensive nature of industrial projects. Procurement activities are often located on or near the critical path because specialized equipment may have long manufacturing and transportation lead times. Consequently, procurement delays can create extensive schedule consequences and may trigger claims even when construction activities themselves are efficiently managed. The findings support the broader literature on schedule-risk management, which stresses the importance of integrating procurement and schedule information into risk analysis (Sami Ur Rehman et al., 2022). They are also compatible with contemporary project-management approaches emphasizing better information integration, adaptive planning, and responsive coordination in complex project environments (Silva et al., 2025; Tamimi & Farhang, 2025).

An important contribution of this study is therefore methodological as well as substantive. The integrated fuzzy approach recognized that expert judgments concerning probability, impact, and importance cannot always be represented accurately through precise crisp values. Project professionals often make evaluations under incomplete information and express their assessments linguistically. Fuzzy representation provides a means of retaining this uncertainty, while AHP and TOPSIS allow several project-performance criteria to be combined into a coherent ranking structure. This type of approach is particularly useful when numerous factors compete for managerial attention and when the decision problem includes both qualitative and quantitative components. The prioritization literature in construction and project risk management similarly demonstrates the value of multi-criteria methods for identifying the most consequential claim and risk factors (Kamal & Sabet, 2021; Kayedi & Fasahati, 2022; Kazemini et al., 2022). Moreover, by linking the ranking process to knowledge derived from project experience, the model can contribute to institutional learning and the systematic reuse of lessons from previous projects, which is consistent with process-oriented knowledge-management approaches in project-based organizations (Zahedi & Ehsanian, 2025).

Overall, the findings suggest that delay-related claims in industrial projects should be understood as the visible contractual outcomes of deeper systemic deficiencies. The most important factors were associated with unrealistic tendering, unstable investment and financing conditions, payment difficulties, managerial overload, procurement constraints, engineering delays, inaccurate estimates, and insufficient problem resolution. Many of these conditions can interact and amplify one another, producing ripple effects across time, cost, and quality. The findings therefore support an integrated approach in which risk management, planning, claim management, procurement control, contractual administration, and organizational decision-making are coordinated rather than treated as separate functions. Such integration is consistent with previous research demonstrating the close relationship between project-management practices and performance (Unegbu et al., 2022), between risk management and financial outcomes (Soltanian & Sobhiyeh, 2021), between collaborative decision-making and project success (Wang et al., 2025), and between claim-management capability and the control of contractual disputes (Abtahi & Kargar, 2021; Karimi, 2022). The present study extends these perspectives by demonstrating how an integrated fuzzy prioritization model can identify the factors that deserve the greatest managerial attention when the objective is to reduce claims arising from industrial project delays.

Several limitations should be considered when interpreting the findings. First, the empirical data were obtained from a relatively limited population of 80 managers and specialists working in selected industrial projects in Assaluyeh, and the resulting rankings may therefore reflect the specific contractual, economic, organizational, and operational environment of these projects. Second, the analysis relied substantially on expert judgments, and although the fuzzy framework was designed to account for uncertainty in such judgments, subjective perceptions and professional experiences may still have influenced the evaluations. Third, the research used a cross-sectional design and therefore captured expert assessments at a particular point in time rather than examining how the importance of delay-related claim factors changes throughout different phases of a project. Fourth, some factors may overlap conceptually or influence one another simultaneously, making strict separation difficult even within an integrated decision-making model. Finally, the model emphasized time, cost, and quality as the principal project-performance outcomes and did not explicitly incorporate other potentially relevant consequences such as safety, environmental performance, stakeholder satisfaction, litigation costs, or organizational reputation.

Future studies should validate the proposed model using larger and more heterogeneous samples from different industrial sectors, geographical areas, contractual systems, and project-delivery arrangements. Comparative research could examine whether the ranking of delay-related claim factors differs between oil and gas, petrochemical, power, transportation, manufacturing, and other large infrastructure projects. Longitudinal designs would also be valuable for determining whether the importance of specific factors changes between engineering, procurement, construction, commissioning, and closeout stages. Researchers could further extend the model by integrating additional decision criteria such as safety consequences, environmental impacts, dispute severity, stakeholder effects, and recovery costs. Future studies may also compare fuzzy TOPSIS with other multi-criteria techniques, including fuzzy DEMATEL, ANP, VIKOR, BWM, or hybrid machine-learning approaches, to examine the robustness of the rankings. Another useful direction would be to integrate actual historical claim records, schedule data, payment records, change orders, and dispute outcomes with expert assessments so that subjective prioritization can be compared with observed project evidence.

Industrial project owners and contractors should use the identified priorities as the basis for proactive claim-prevention strategies rather than relying primarily on dispute resolution after delays occur. Particular attention should be directed toward realistic tender evaluation, assessment of contractors' financial and technical capacity, timely activation of financing arrangements, disciplined payment procedures, adequate managerial staffing, rapid engineering decision-making, accurate quantity estimation, and early resolution of project obstacles. Contract documents should clearly define responsibilities for delay, notification procedures, adjustment mechanisms, payment provisions, changes, extensions of time, and the distinction between excusable and non-excusable delays. Project organizations should also establish formal claim-management and risk-management procedures supported by reliable documentation systems and integrated schedule, procurement, and cost-control processes. High-priority factors identified by the fuzzy ranking model should be incorporated into project risk registers and monitored through early-warning indicators throughout execution. Finally, senior management should periodically review the ranking of claim-generating factors because changing economic, regulatory, procurement, and organizational conditions may alter the relative importance of individual risks during the project life cycle.

Authors' Contributions

Authors contributed equally to this article.

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In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

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