

A Comprehensive Analysis of Building Construction Projects' Delay Using the Analytic Network Process

Ridzky Zul Asdi¹, Dutho Suh Utomo²

^{1,2}Department of Industrial Engineering, Faculty of Engineering, Mulawarman University, Indonesia.

Corresponding Author: asdiridzky@ft.unmul.ac.id

Abstract

Delays in construction projects have emerged as a significant challenge due to their profound impact on costs, quality, and project timelines, all of which ultimately affect the overall success and completion of the project. The primary objective of this study is to identify the factors contributing to delays in building construction projects and to quantitatively assess the extent to which each of these factors influences project delays. To achieve this, a quantitative impact analysis of each identified factor is conducted using the Analytic Network Process (ANP). Five key factors have been identified as major contributors to project delays: design or specification changes, material procurement delays, adverse weather conditions, regulatory and permitting issues, and unforeseen risks. Among these, material procurement delays emerged as the most significant contributor, accounting for 36.13% of the total delay impact. This is followed by design or specification changes, unforeseen risks, regulatory and permitting issues, and adverse weather conditions. Further research is required to develop effective preventive measures to mitigate these delays and enhance project management practices.

Keywords: project management, construction project delays, Analytic Network Process (ANP).

INTRODUCTION

One of the major challenges in building construction projects is project delays. In addition to affecting the cost and time of project completion, delays also affect the final quality. Various factors contributing to project delays, such as design or specification changes, delays in material procurement, bad weather conditions, regulatory and

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IJEBIR, Volume 04 Issue 01, 2025



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permitting issues, and unforeseen risks have been reported (Durdyev & Hosseini, 2019; Fashina et al., 2021; Pourrostam & Ismail, 2012).

Various literatures have examined the factors causing construction project delays. For instance, design changes that frequently occur during the construction phase can result in significant delays (Abebe & Germew, 2021; Othuman Mydin, Sani, Agus Salim, et al., 2014). Additionally, delays in material procurement are often caused by logistics issues and lack of coordination between suppliers and contractors (Kazaz et al., 2012; Othuman Mydin, Sani, Taib, et al., 2014). Bad weather conditions are also an unavoidable factor that can substantially slow down project progress (Rahman et al., 2014; Wilogo & Wiguna, 2018). Regulatory and permitting issues often add complexity to the project, causing delays in the necessary approval processes (Gardezi et al., 2014; Sepasgozar et al., 2019). Lastly, unforeseen risks, such as accidents at the construction site or sudden changes in government policy, can disrupt the planned project schedule (Aziz, 2013; Y. Olawale & Sun, 2013).

The interaction between these factors is also important to understand, as one factor can influence another. For example, delays in material procurement can be exacerbated by bad weather, which in turn may lead to design changes to accommodate these delays (Pai et al., 2020; Yilmaz & Kazan, 2019). Therefore, it is important to analyze how these factors interact and contribute to overall project delays (Abeyasinghe & Jayathilaka, 2022; Pourrostam & Ismail, 2011).

Several literatures have examined the use of the Analytic Network Process (ANP) method in construction management (Ali & Wali, 2019; Stević et al., 2022). This method allows researchers to consider the complex relationships between various factors and provides a deeper understanding of how these factors influence each other (Ali & Wali, 2019; Stević et al., 2022). The goal of this study is to identify the main delay factors in construction projects using the ANP approach in the context of building construction project management in East Kalimantan. The study consists of three stages: the first is identifying the factors causing delays in construction projects; the second is performing ANP analysis to assess each factor quantitatively; and the final stage is analyzing the results with consideration of the benefits in the context of project management.

LITERATURE REVIEW

A review of several studies on the application of the ANP method in construction management shows that ANP is an effective tool for addressing complex and interconnected decision-making problems in construction projects. ANP allows for the

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IJEBIR, Volume 04 Issue 01, 2025



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analysis of relationships between various factors that play a key role in the success of a project, such as risk, cost, completion duration, and more (Nilashi et al., 2015). Nilashi et al. (2015) in their study developed a hybrid multi-criteria model suitable for analyzing the key factors influencing the success of a construction project, including elements affecting the project itself, procurement and selection, project management, project participants, and other external factors (Nilashi et al., 2015).

In addition, a study conducted by Tavassolirizi et al. (2022) shows that ANP can be used to identify and prioritize factors that cause delays in rail transportation projects, which could result in economic losses for various stakeholders (Tavassolirizi et al., 2022). This research integrates the ANP method with DEMATEL to evaluate the interactions between the factors causing delays, thereby providing a deeper understanding for decision-makers (Tavassolirizi et al., 2022). The use of ANP in the context of risk management is also discussed by Wu et al. (2010), who used ANP to identify the bancassurance alliance structure from the perspective of bank executive management. According to Wu et al. (2010), the use of ANP in this research is crucial for obtaining strategies for multiple strategic variables; this aspect can also be applied to construction projects, where many factors interact (Wu et al., 2010).

Various literatures have revealed the use of ANP and related methodologies in analyzing the factors contributing to delays in various types of projects. The interconnected nature of these factors requires a comprehensive approach to project management, where ANP serves as an essential tool for prioritizing and addressing the various challenges faced by construction projects.

RESEARCH METHOD

Figure 1 presents an overview of the approach undertaken in this research. The initial step involves the identification and documentation of various factors contributing to delays in construction projects. This identification process is carried out through an extensive literature review, supplemented by consultations with construction project managers in East Kalimantan Province, ensuring a comprehensive understanding of the delay factors specific to the context of building construction projects. The Analytic Network Process (ANP) model facilitates a rigorous analysis that accounts for the interactions between these factors. Consequently, it is essential to explore these interactions through both the literature review and expert consultations to ensure a thorough evaluation.



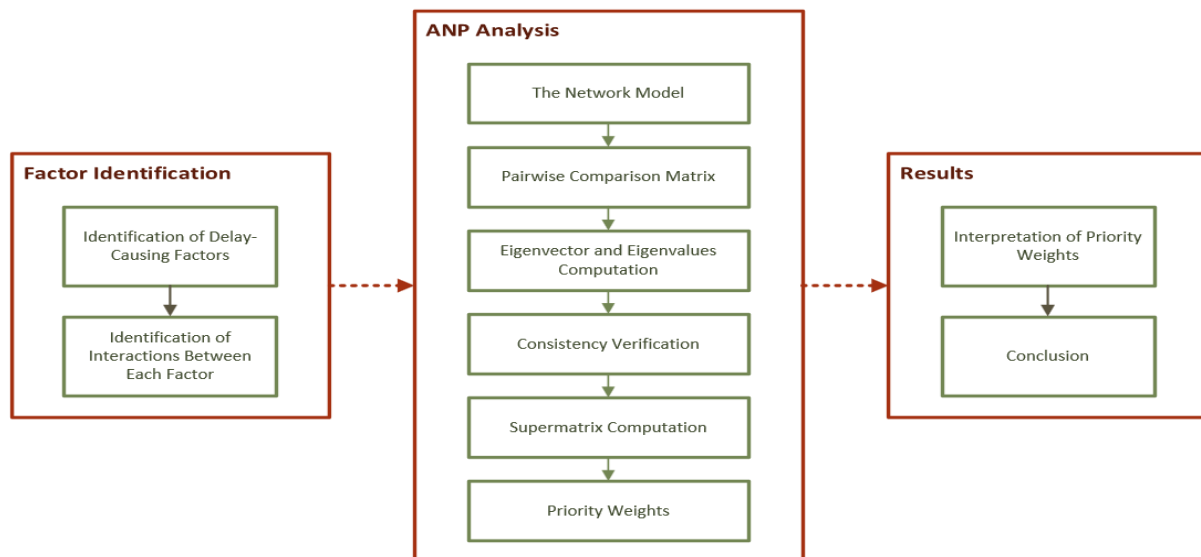


Figure 1: Research Approach

ANP Analysis

Once the factors and interaction among factors have been properly identified, a network model consisting of all factors can be constructed. Figure 2 shows an example of a network with three levels and clusters. Notice that in *criteria* cluster there is a feedback loop which signify inner dependencies, that is, one or more element in that cluster affect other elements within that cluster.

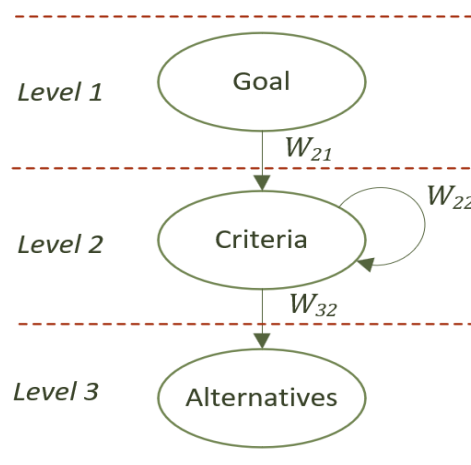


Figure 2: A Network with Three Levels

Pairwise comparison analysis is carried out to compare each element to evaluate its contribution to another cluster (outer dependencies) and interaction among the elements within the same cluster (inner dependencies). The pairwise comparison matrix is constructed by first administering a pairwise comparison questionnaire to project managers. The questionnaire is used as an instrument to measure the impact of each criterion on the other criteria using a scale from 1 to 9. The pairwise comparison questionnaire scale can be seen in Table 1. An example of the questionnaire for factor assessment can be seen in Figure 3.

Table 1: Scale used in Pairwise Comparison Questionnaire

Impact	Scale
Equal impact	1
Equal to moderate impact	2
Moderate impact	3
Moderate to strong impact	4
Strong impact	5
Strong to very strong impact	6
Very strong impact	7
Very strong to extreme impact	8
Extreme impact	9

Criteria	extreme impact equal impact extreme impact																	Criteria
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
1. Design or specification changes	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	1. Design or specification changes
2. Material procurement delays	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2. Material procurement delays
3. Adverse weather conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	3. Adverse weather conditions
4. Regulatory and permitting issues	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	4. Regulatory and permitting issues
5. Unforeseen risks	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5. Unforeseen risks

Figure 3: An Example of Pairwise Comparison Questionnaire

The general form of the pairwise comparison matrix A with criteria comparisons from c_1 to c_n can be seen in Equation (1). The value of each element a_{ij} in the pairwise comparison matrix A depends on the values provided by the respondents in the pairwise comparison questionnaire. A value of $a_{ij} = 1$ indicates that criteria i and j have the same level of influence. A value of a_{ij} from 2 to 9 indicates that criterion i has a greater level of influence than criterion j . A value of a_{ij} of 2^{-1} , 3^{-1} , 4^{-1} , 5^{-1} , 6^{-1} , 7^{-1} , 8^{-1} , 9^{-1} indicates that criterion j has a greater level of influence than criterion i .

$$A = \begin{matrix} & \begin{matrix} c_1 & \cdots & c_n \end{matrix} \\ \begin{matrix} c_1 \\ \vdots \\ c_n \end{matrix} & \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \end{matrix} \quad (1)$$

Equation (2) shows the relationship between the pairwise comparison matrix A , the eigenvector w , and the eigenvalue λ_{max} . The eigenvector w is obtained through the following steps: (1) raising the matrix A to a sufficiently large power, (2) summing the elements of each row in the matrix A , (3) normalizing the vector. These steps are repeated until the vector obtained from raising $A^{(k+1)}$ has a sufficiently small difference compared to the vector obtained from raising A^k . In this study, the difference threshold used must be smaller than 0.00001.

$$A \cdot w = \lambda_{max} \cdot w \quad (2)$$

Consistency verification is necessary to test whether the pairwise comparison judgments have an acceptable level of consistency. Consistency means that if there is a comparison between criteria A, B, and C, and criterion A is more important than B, and B is more important than C, then A must be more important than C. The more criteria compared in a pairwise comparison, the more likely error in judgment can occur, leading to inconsistency.

The following are the steps for performing consistency verification:

1. calculating Consistency Index (CI):



$$\text{Consistency Index (CI)} = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

2. calculating Consistency Ratio CR :

$$CR = \frac{CI}{RI} \quad (4)$$

where RI is the random consistency index, and its value can be seen in Table

2.

Table 2: RI Value for Some Value of n

n	2	3	4	5	6	7	8	9	10
RI	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

A supermatrix is a partitioned matrix, where each submatrix represents the relationships at each level. The general form of the supermatrix can be seen in Equation (5) (Saaty, 2005). As an illustration, the supermatrix for a network with three levels, as shown in Figure 2, will result in a supermatrix as presented in Equation (6).

$$W = \begin{matrix} & \begin{matrix} C_1 & \cdots & C_k & \cdots & C_n \end{matrix} \\ \begin{matrix} e_{11} \\ \vdots \\ e_{1m_1} \\ \vdots \\ e_{k1} \\ \vdots \\ e_{km_k} \\ \vdots \\ e_{n1} \\ \vdots \\ e_{nm_n} \end{matrix} & \begin{bmatrix} e_{11} \cdots e_{1m_1} & \cdots & e_{k1} \cdots e_{km_k} & \cdots & e_{n1} \cdots e_{nm_n} \\ W_{11} & \cdots & W_{1k} & \cdots & W_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{k1} & \cdots & W_{kk} & \cdots & W_{kn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{n1} & \cdots & W_{nk} & \cdots & W_{nn} \end{bmatrix} \end{matrix} \quad (5)$$

$$W_n = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{bmatrix} \quad (6)$$



Due to the interdependence among clusters in a network, the columns in the supermatrix sum to more than one. Therefore, the supermatrix must first be normalized to become stochastic, meaning that each column in the matrix must sum to one. The approach suggested by Saaty (2005) is to determine the relative influence of the clusters in the supermatrix by using the cluster component in the column block (Meade & Sarkis, 1999). This means that the row components with non-zero entries in their respective column blocks are compared based on their impact on the components of the column block (Saaty, 2005). Through pairwise comparisons between the row components and the column components, an eigenvector can be obtained for each column block. For each column block, the first entry of the corresponding eigenvector is multiplied by all elements in the first block of the column, the second entry is multiplied by all elements in the second block of the column, and so on. In this way, the blocks in each column of the supermatrix are weighted. The result is called the weighted supermatrix, which is stochastic.

Raising a weighted supermatrix to a certain power provides the long-term relative influence between elements. To achieve convergence, the weighted supermatrix is raised to the power $W^{(2k+1)}$, where k is an arbitrarily chosen number. This new matrix, called the limit supermatrix (Saaty, 2005), has the same form as the weighted supermatrix, but all its columns become identical. Thus, the final priorities of all elements in the matrix can be obtained.

RESULT AND DISCUSSION

This section will discuss five factors identified as causes of delays: design or specification changes, delays in material procurement, adverse weather conditions, regulatory and permitting issues, and unforeseen risks, supported by relevant literature.

1. Design or specification changes

Design changes are a significant cause of project delays, often resulting from discrepancies between the initial plan and the actual site conditions. Studies show that design errors and omissions can lead to rework, which is a primary cause of schedule delays and cost overruns in construction projects (Choudhry et al., 2018). Additionally, Ojo et al. (2023) emphasizes that variations and deficiencies in design can introduce changes that not only delay project timelines but also increase costs due to the need for additional resources and time. The complexity of construction projects often exacerbates this issue, as each project is unique and may encounter



unforeseen design challenges that require adjustments during execution (Krechowicz, 2017).

2. Material procurement delays

Delays in material procurement are another critical factor that affects construction schedules. Majeed & Erzaij (2020) emphasize that poor procurement practices can lead to significant time delays, especially when there is a shortage of essential materials or delays in delivery. The quality and reliability of suppliers are also crucial; late deliveries can severely impact the project schedule, as construction activities are often dependent on the timely arrival of materials (Sawan et al., 2018). Additionally, Y. A. Olawale & Sun (2010) note that inadequate market observations and political influences can complicate the procurement process, leading to delays.

3. Adverse weather conditions

Adverse weather conditions are an external factor that can unexpectedly affect construction schedules. Although studies specifically focusing on weather-related delays are limited, the consensus in the literature is that weather can significantly disrupt construction activities, leading to project completion delays (Sudirman & Hardjomuljadi, 2011). Sudirman & Hardjomuljadi (2011) highlight that unforeseen environmental factors can pose high risks during the construction phase.

4. Regulatory and permitting issues

Regulatory and permitting issues are often cited as major causes of construction delays. The bureaucratic process of obtaining the necessary permits can be lengthy and complex, leading to significant project delays (Karimi et al., 2020). Leśniak et al. (2018) discuss how contract provisions can cause delays, particularly when there are disputes or misunderstandings regarding the contract terms. Furthermore, research by Hampton et al. (2012) shows that different procurement methods, such as public-private partnerships, can influence the efficiency of the permitting process and thus affect the project schedule.

5. Unforeseen risks

Unforeseen risks, often categorized as "unknown unknowns," can have a profound impact on construction projects. These risks can arise from various sources, including market fluctuations, changes in project scope, or unforeseen site conditions (Qazi et al., 2016). Qazi et al. (2016) emphasize the importance of establishing a proactive risk management culture to effectively address these



unexpected challenges. Additionally, findings by Ying et al. (2018) suggest that managing unforeseen risks during the execution phase is crucial to project success, as these risks can lead to significant delays if not properly addressed.

ANP Analysis Result

Based on the identified factors mentioned in previous section, the network model can then be constructed and is shown in Figure 4. The network structure is divided into two levels. At level 1, the goal cluster, consists of the construction project delay event is caused by factors (criteria) that can be seen at level 2, the *criteria* cluster. It can be observed that there are inner dependencies within the level 2 cluster. A graph illustrating the inner dependencies among criteria at level 2 can be seen in Figure 5.

Pairwise Comparison

To facilitate the discussion, each criterion within the *criteria* cluster of the network model in Figure 4 is assigned a code: c_1 , c_2 , c_3 , c_4 , and c_5 . Six pairwise

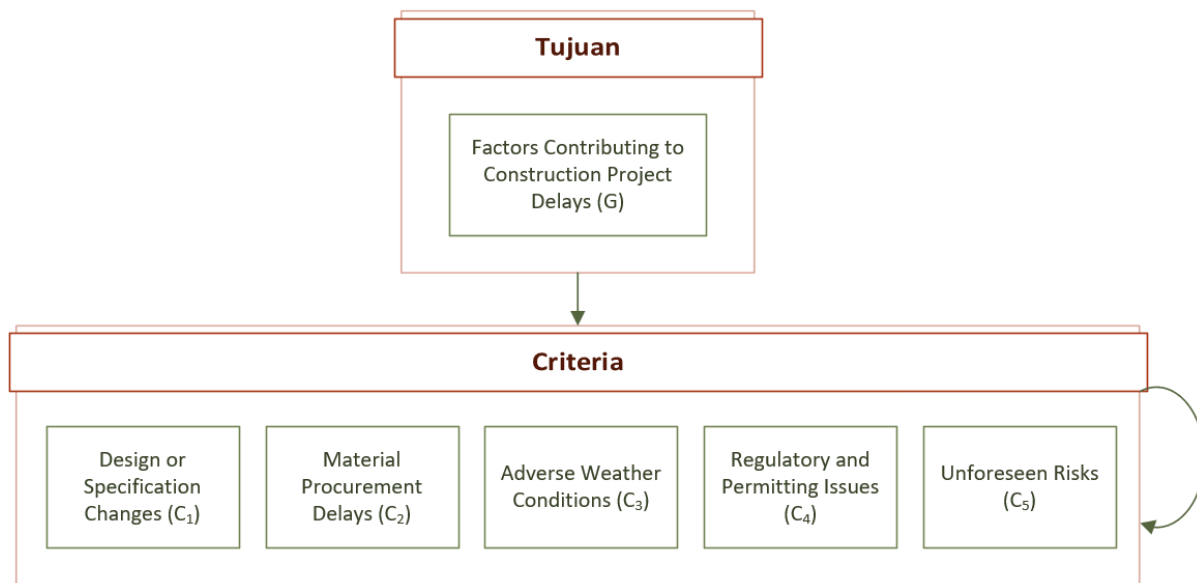


Figure 4: The Network Model

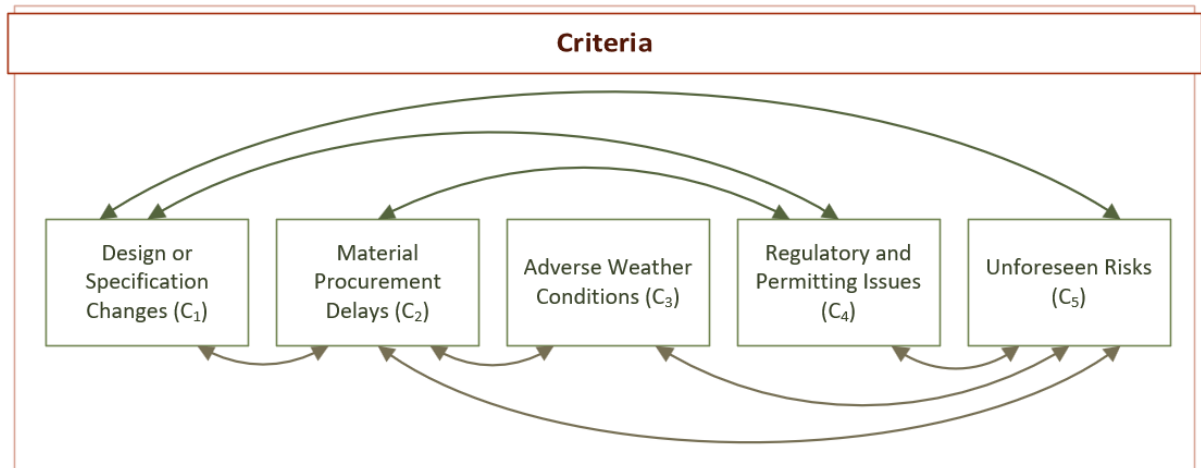


Figure 5: Inner Dependencies Within Criteria Cluster

comparison analyses are conducted. The pairwise comparison matrix A_k and eigenvector w_k , where $k = 1, 2, 3, \dots, 6$ for each comparison, can be seen in Equations (7) to (18).

1. Pairwise comparison between *goal* cluster and *criteria* cluster ($k = 1$)

$$A_1 = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 1 & 1/5 & 3 & 1/3 & 5 \\ 5 & 1 & 7 & 3 & 5 \\ 1/3 & 1/7 & 1 & 1/5 & 3 \\ 3 & 1/3 & 5 & 1 & 9 \\ 1/5 & 1/5 & 1/3 & 1/9 & 1 \end{bmatrix} \end{matrix} \quad (7)$$

$$w_1 = \begin{matrix} & G \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0.13155 \\ 0.48459 \\ 0.06495 \\ 0.27923 \\ 0.03968 \end{bmatrix} \end{matrix} \quad (8)$$

2. Pairwise comparison of criteria affecting c_1 ($k = 2$)

$$A_2 = \begin{matrix} & \begin{matrix} c_2 & c_4 & c_5 \end{matrix} \\ \begin{matrix} c_2 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/4 \\ 1/3 & 4 & 1 \end{bmatrix} \end{matrix} \quad (9)$$

$$w_2 = \begin{matrix} & c_1 \\ \begin{matrix} c_2 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0.62670 \\ 0.09362 \\ 0.27969 \end{bmatrix} \end{matrix} \quad (10)$$

3. Pairwise comparison of criteria affecting c_2 ($k = 3$)

$$A_3 = \begin{matrix} & \begin{matrix} c_1 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} c_1 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 1 & 5 & 7 & 9 \\ 1/5 & 1 & 3 & 5 \\ 1/7 & 1/3 & 1 & 4 \\ 1/9 & 1/5 & 1/4 & 1 \end{bmatrix} \end{matrix} \quad (11)$$

$$w_3 = \begin{matrix} & c_2 \\ \begin{matrix} c_1 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0.65290 \\ 0.20170 \\ 0.10258 \\ 0.04283 \end{bmatrix} \end{matrix} \quad (12)$$

4. Pairwise comparison of criteria affecting c_3 ($k = 4$)

$$A_4 = \begin{matrix} & \begin{matrix} c_2 & c_5 \end{matrix} \\ \begin{matrix} c_2 \\ c_5 \end{matrix} & \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix} \end{matrix} \quad (13)$$

$$w_4 = \begin{matrix} & c_3 \\ c_2 & \begin{bmatrix} 0.75 \\ 0.25 \end{bmatrix} \\ c_5 & \end{matrix} \quad (14)$$

5. Pairwise comparison of criteria affecting c_4 ($k = 5$)

$$A_5 = \begin{matrix} & c_1 & c_2 & c_5 \\ c_1 & \begin{bmatrix} 1 & 1/5 & 1/7 \end{bmatrix} \\ c_2 & \begin{bmatrix} 5 & 1 & 1/3 \end{bmatrix} \\ c_5 & \begin{bmatrix} 7 & 3 & 1 \end{bmatrix} \end{matrix} \quad (15)$$

$$w_5 = \begin{matrix} & c_4 \\ c_1 & \begin{bmatrix} 0.07193 \\ 0.27895 \\ 0.64912 \end{bmatrix} \\ c_2 & \\ c_5 & \end{matrix} \quad (16)$$

6. Pairwise comparison of criteria affecting c_5 ($k = 6$)

$$A_6 = \begin{matrix} & c_1 & c_2 & c_3 & c_4 \\ c_1 & \begin{bmatrix} 1 & 1/5 & 3 & 1/3 \end{bmatrix} \\ c_2 & \begin{bmatrix} 5 & 1 & 7 & 3 \end{bmatrix} \\ c_3 & \begin{bmatrix} 1/3 & 1/7 & 1 & 1/5 \end{bmatrix} \\ c_4 & \begin{bmatrix} 3 & 1/3 & 5 & 1 \end{bmatrix} \end{matrix} \quad (17)$$

$$w_6 = \begin{matrix} & c_5 \\ c_1 & \begin{bmatrix} 0.11750 \\ 0.56501 \\ 0.05529 \\ 0.26220 \end{bmatrix} \\ c_2 & \\ c_3 & \\ c_4 & \end{matrix} \quad (18)$$

Consistency Verification

The result of the consistency verification for each pairwise comparison is summarized in Table 3. It can be observed that in the fourth comparison $k = 4$, the CR

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value is undefined. This is because the RI value for $n = 2$ is 0, so the CR ratio is undefined. However, since the CI value is also 0, this indicates that the fourth comparison has perfect consistency. This is possible due to the small number of criteria in the fourth comparison ($n = 2$). Based on the consistency verification results, all comparisons have acceptable consistency (with CR values $< 10\%$).

Table 3: Consistency Verification Result

k	CI	RI	CR	Consistency Result
1	0.10838	1.11	0.09764	acceptable
2	0.04288	0.52	0.08247	acceptable
3	0.07824	0.89	0.08791	acceptable
4	0	0	undefined	acceptable
5	0.03244	0.52	0.06239	acceptable
6	0.03899	0.89	0.04381	acceptable

Supermatrix and Weight

The supermatrix W , which has been constructed from all eigenvectors w_k , can be seen in Equation (19). The limit supermatrix W_{lim} is obtained by raising the supermatrix W to the power of 64, which results in matrix convergence as shown in Equation (20). The limit supermatrix W_{lim} is also stochastic in each of its columns. These columns represent the final eigenvector.

$$W = \begin{matrix} & \begin{matrix} G & c_1 & c_2 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} G \\ c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0.13155 & 0 & 0.65290 & 0 & 0.07193 & 0.11750 \\ 0.48459 & 0.62670 & 0 & 0.75 & 0.27895 & 0.56501 \\ 0.06495 & 0 & 0.20170 & 0 & 0 & 0.05529 \\ 0.27923 & 0.09362 & 0.10258 & 0 & 0 & 0.26220 \\ 0.03968 & 0.27969 & 0.04283 & 0.25 & 0.64912 & 0 \end{bmatrix} \end{matrix} \quad (19)$$



$$W_{lim} = \begin{matrix} & \begin{matrix} G & c_1 & c_2 & c_3 & c_4 & c_5 \end{matrix} \\ \begin{matrix} G \\ c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0.26506 & 0.26506 & 0.26506 & 0.26506 & 0.26506 & 0.26506 \\ 0.36127 & 0.36127 & 0.36127 & 0.36127 & 0.36127 & 0.36127 \\ 0.08289 & 0.08289 & 0.08289 & 0.08289 & 0.08289 & 0.08289 \\ 0.10942 & 0.10942 & 0.10942 & 0.10942 & 0.10942 & 0.10942 \\ 0.18136 & 0.18136 & 0.18136 & 0.18136 & 0.18136 & 0.18136 \end{bmatrix} \end{matrix} \quad (20)$$

The weights of each criterion relative to the goal are obtained from the column elements in the limit supermatrix W_{lim} , as follows:

$$\begin{matrix} & G \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{matrix} & \begin{bmatrix} 0.26506 \\ 0.36127 \\ 0.08289 \\ 0.10942 \\ 0.18136 \end{bmatrix} \end{matrix} \quad (21)$$

Equation (21) shows the weight of each factor contributing to construction project delays. Factor c_2 , which represents material procurement delays, ranks first as the largest contributor to project delays. This factor contributes 36.13% to the delay in construction projects. The summary of the weight calculations and priority for each factor can be seen in Table 4.

Table 4: Summary of The Weight Calculations

Priority	Factor	Weight
1	Material procurement delays	36.13%
2	Design or specification changes	26.51%
3	Unforeseen risks	18.14%
4	Regulatory and permitting issues	10.94%
5	Adverse weather conditions	8.29%

CONCLUSION

The Analytic Network Process effectively models qualitative conditions into criteria that can be quantitatively assessed, thus minimizing the potential for evaluator bias. This study has quantitatively analyzed the factors contributing to project delays and provided



a ranking for each of these factors using ANP. However, the mitigation strategies for these delay factors are often complex and require careful consideration of multiple factors. Therefore, future research could focus on examining appropriate mitigation measures by integrating both managerial and technical considerations.

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