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Original Article

Identifying and evaluating the key impact factors of selecting formwork in high-rise building construction

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Abstract

The construction cost and duration of erecting a tall building are significantly reliant on the chosen formwork system, among the various systems in use. The selection of an appropriate formwork system requires specialized expertise and opinions from experienced professionals in the field to offer economically efficient solutions for stakeholders. In this study, the Fuzzy Analytical Hierarchy Process (FAHP) method was applied to assess formwork alternatives based on identified criteria derived from the outcomes of primary factors from the previous Exploratory Factor Analysis (EFA) stage. Fuzzy theory was employed to construct pairwise comparison matrices for criteria related to material selection in formwork, using the Analytical Hierarchy Process (AHP) method. The research emphasizes the paramount impact of the initial investment cost on formwork selection and designates plastic formwork as the optimal solution based on expert evaluations. The findings aim to augment managerial understanding of formwork systems, advocating for the integration of decision support tools in high-rise construction projects to enhance planning precision and select of suitable formwork systems tailored to specific projects.

Keywords: formwork selection, factor analysis, fuzzy logic, construction project, Vietnam

1. Introduction

Formwork is defined as the overall support system for newly poured concrete, consisting of molds or sheaths in contact with the concrete, as well as bonding support components, rigid ribs, and necessary braces. Temporary structures are employed to create a suitable space for pouring concrete in the desired geometric shape and to support the concrete until it reaches the required strength, with the capability to withstand its own weight and the design load imposed on it. Currently, prominent formwork manufacturers continuously strive to introduce new enhancements to improve the quality of the formwork system (Sowndharya, & Vidhya, 2022). Nevertheless, each formwork type possesses its own merits and drawbacks, tailored to specific project scopes. Specific descriptions of some types of formwork commonly used today are as follows. Wood formwork is a prevalent choice in construction, assembled on-site using timber materials. While its use is simple, it becomes time-intensive for larger structures, and the plywood facing has a limited lifespan. Wood offers ease of fixation, removal, and is lightweight, making it flexible for any shape and size. In contrast, steel formwork is notable for its extended lifespan and multiple reuses, despite the higher cost, providing a smooth finish for concrete surfaces. It's particularly suitable for circular or curved structures. Aluminum forms, being lighter, are advantageous for repetitive use but lack alterability once constructed. Plastic formwork, with its modular and interlocking system, allows over 100 uses and is favored in modern construction, especially for large-scale housing schemes. The coffor system, a stay-in-place formwork, consists of reinforced filtering grids connected by vertical stiffeners and articulated connectors. This collapsible system, prefabricated at the factory, remains in place post-concrete

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pouring, serving as reinforcement and demonstrating adaptability for diverse structures in contemporary construction (Das *et al.*, 2016).

The formwork selection process in the construction industry faces multifaceted challenges that stem from diverse project demands, economic considerations, material options, technological advances, environmental sustainability goals, skilled labor availability, project scheduling complexities, and the need for reusability and recycling (Son *et al.*, 2023). The industry grapples with finding a delicate balance among these factors to ensure optimal formwork solutions for each construction project. Project requirements can vary significantly, impacting the choice of formwork system, while cost considerations play a pivotal role in decision-making. The dynamic landscape of available materials and emerging technologies adds complexity to the selection process, requiring industry professionals to stay abreast of innovations. Environmental concerns underscore the importance of sustainable practices in formwork, aligning with global efforts toward greener construction. The availability of skilled labor and the intricacies of project schedules further contribute to the challenges, necessitating careful planning and coordination. Emphasizing the reuse and recycling of formwork materials becomes crucial for minimizing environmental impact. Addressing these diverse challenges collectively shapes the landscape of formwork selection, demanding a comprehensive and adaptable approach within the construction industry.

2. Literature Review

In contemporary global construction practices, the use of formwork systems is widespread, propelled by ongoing advances in engineering facilitated by scientific and technological innovations. This evolution has played a substantial role in the diversification and growth of the formwork market. Numerous studies conducted across different nations seek to identify a variety of quantitative and qualitative criteria essential for selecting an appropriate formwork system tailored to the unique needs of a construction project within a specific geographical region. Pawar, Rajput, and Agarwal (2018) conducted a study aimed at assessing the critical factors influencing three distinct formwork systems in building construction projects in India, including cost, quality, cycle time, number of repetitions, and safety (Pawar *et al.*, 2018). In another investigation conducted by Rajeshkumar, Anandaraj, Kavinkumar, and Elango (2021), a compilation of the foremost ten factors exerting a substantial influence on the selection of formwork materials was delineated in the context of construction projects in India (Rajeshkumar *et al.*, 2021). By utilizing mean score analysis, Terzioglu, Polat, and Turkoglu (2021) employed data gathered through an expert survey in formwork engineering to evaluate the relative significances of thirty-five criteria pertinent to the selection of formwork system in Turkish construction (Terzioglu *et al.*, 2021). In another related study, Sowndharya and Vidhya (2022) conducted a comparative analysis focusing on six prevalent types of advanced formwork utilized in contemporary construction practices. This assessment encompassed the evaluation of 30 factors that should be considered in the selection process (Sowndharya & Vidhya, 2022).

3. Research Methodology

3.1. Survey questionnaire

Two survey questionnaires were implemented to gather perspectives from participants engaged in the construction industry. In the qualitative analysis stage, the study draws upon existing domestic and international research to identify a range of factors that impact the decision-making process regarding the formwork selection problem in the construction of tall buildings across various stages of project implementation. The compilation of these factors establishes the foundational framework for the development of the preliminary survey questionnaire within the study. Subsequently, the preliminary survey questionnaire underwent consultation with seasoned experts who were asked to provide their opinions and evaluations regarding the applicability of these factors in the context of Vietnam. The demographic information of the pilot study participants is given in Table 1.

The formal survey questionnaire incorporates details pertaining to the surveyed object, and the influencing factors were evaluated using a 5-point Likert scale. A total of 250 survey questionnaires were disseminated via google form or hard copy to respondents in Vietnam, collecting research data over a 6-month period, yielding a response rate of 81.6%. Out of the responses, 190 satisfactory questionnaires were gathered, constituting 93.1% of the total. The majority of received questionnaires were from individuals employed in construction units (37%), followed by investors (26%) and design consultants (22%). In terms of work experience, respondents with from 3 to 5 years, 5 to 10 years, and more than 10 years comprised 12%, 32%, and 22%, respectively. The range of distribution of respondents presented in Figure 1 demonstrates that the diverse and relatively reliable participant profile aligns with the study's requirements.

The dataset derived from the response sheets deemed satisfactory underwent additional analysis and validation to ensure consistency and objectivity, employing key indicators in a quantitative study. The calculation steps at this stage were executed using Statistical Product and Services Solutions (SPSS version 26) software. The prioritization of factors will be established by evaluating the mean values of responses. Subsequently, Exploratory Factor Analysis (EFA) will be conducted to identify the primary factors influencing the decision to select formwork. The factors identified through

Table 1. Pilot study expert information

Respondents	Profession	Academic background	Position	Experience (on yearly basis)
1	Civil Engineer	Civil Engineering, MSc.	C&I Manager	12 years
2	Civil Engineer	Civil Engineering, PhD.	Project Director	20 years

this step will then function as the inputs for the subsequent development of the Fuzzy Analytical Hierarchy Process (FAHP) model (Figure 2). Drawing from the results of the factor analysis, the formulation of the second survey questionnaire aimed to gather expert opinions in order to discern the prioritization of criteria (latent factors identified in the EFA stage) and alternatives using a FAHP scale ranging from 1 to 9. The reliability and validity of expert feedback, collected from responses to questionnaires, were evaluated using the Consistency Ratio (CR). To gather data for FAHP analysis, face-to-face interviews were carried out with seven construction experts specializing in high-rise building projects, and the demographic details of the experts who took part in the survey are outlined in Table 2. The geometric mean was used to aggregate expert assessments regarding the prioritization of criteria and alternative options on a FAHP scale, as per the theoretical framework expounded in Section 3.2. The inclusion of seven responses is deemed adequate for deriving substantial conclusions in the study, and this overarching judgment is indicative of the collective expert opinion for the multi-criteria decision analysis process.

3.2. Fuzzy analytic hierarchy process (FAHP) approach

The Fuzzy Analytic Hierarchy Process (FAHP) is an extension of AHP to effectively address the blurring of data involved in decision making. FAHP assists decision-makers in formulating assessments and opinions, demonstrating its capability to handle both quantitative and qualitative data in multi-criteria decisions. Moreover, FAHP presents a more adaptable and resilient approach to decision-making when contrasted with AHP, especially in scenarios characterized by ambiguity, uncertainty, or imprecision. It delivers a more realistic portrayal of decision-makers' preferences and is well-suited to address the intricate and multi-dimensional aspects of decision problems.

- Step 1: Collecting experts' judgment
- Step 2: Check Consistency Ratio (CR)
- Step 3: Combination of experts' judgments
- Step 4: Defuzzification

4. Research Results

4.1. Results of the exploratory factor analysis (EFA)

The key groups of factors were labeled by considering the attributes of the observed variables within the underlying groupings and insights garnered from the previous related studies. EFA discovered six key factors, namely Labor productivity; Economic efficiency; Project characteristics; Working ability; Available equipment; Environmental conditions (Figure 3). Additionally, the priority of the observed variable is determined through the mean values of the responses. The findings show that initial investment costs with highest rank is the most critical factor affecting formwork material selection for building construction projects.

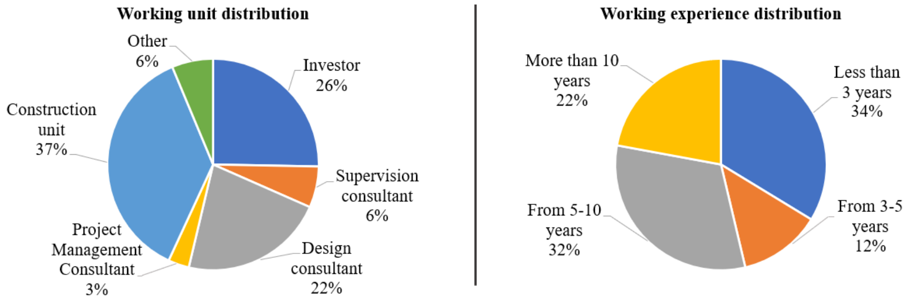

Figure 1. Distribution of survey participants

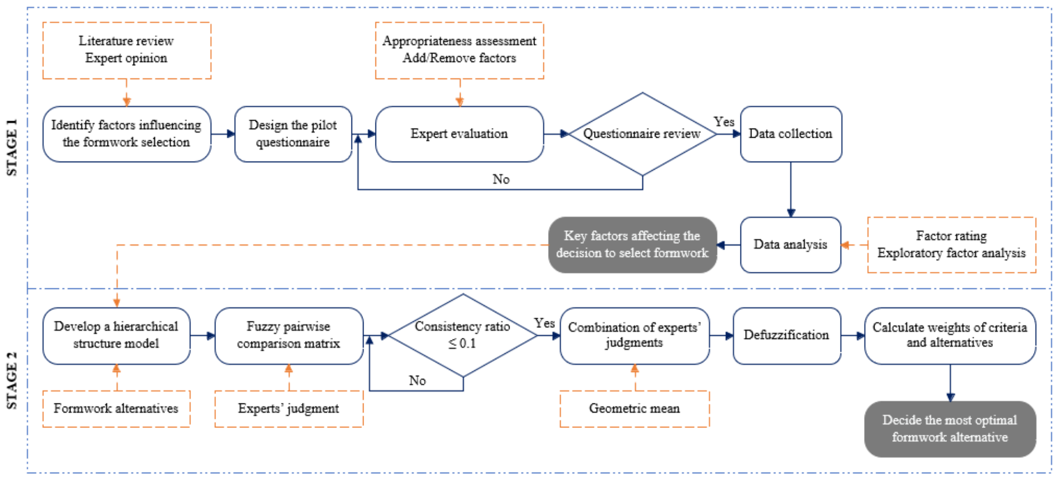

Figure 2. Research framework

Table 2. Demographic information of experts participating in survey for FAHP process

Expert	Position	Industrial experience	Experience in high-rise building projects	Academic background
1	Technical Manager	25 years	19 years	Civil Engineering, PhD.
2	Technical Director	23 years	10 years	Civil Engineering, MSc.
3	Project Manager	20 years	17 years	Civil Engineering, MSc.
4	Project Manager	22 years	14 years	Civil Engineering, BSc.
5	Construction Manager	20 years	15 years	Construction Management, MSc.
6	Construction Manager	26 years	19 years	Construction Management, MSc.
7	Sales Manager	20 years	15 years	Civil Engineering, BSc.

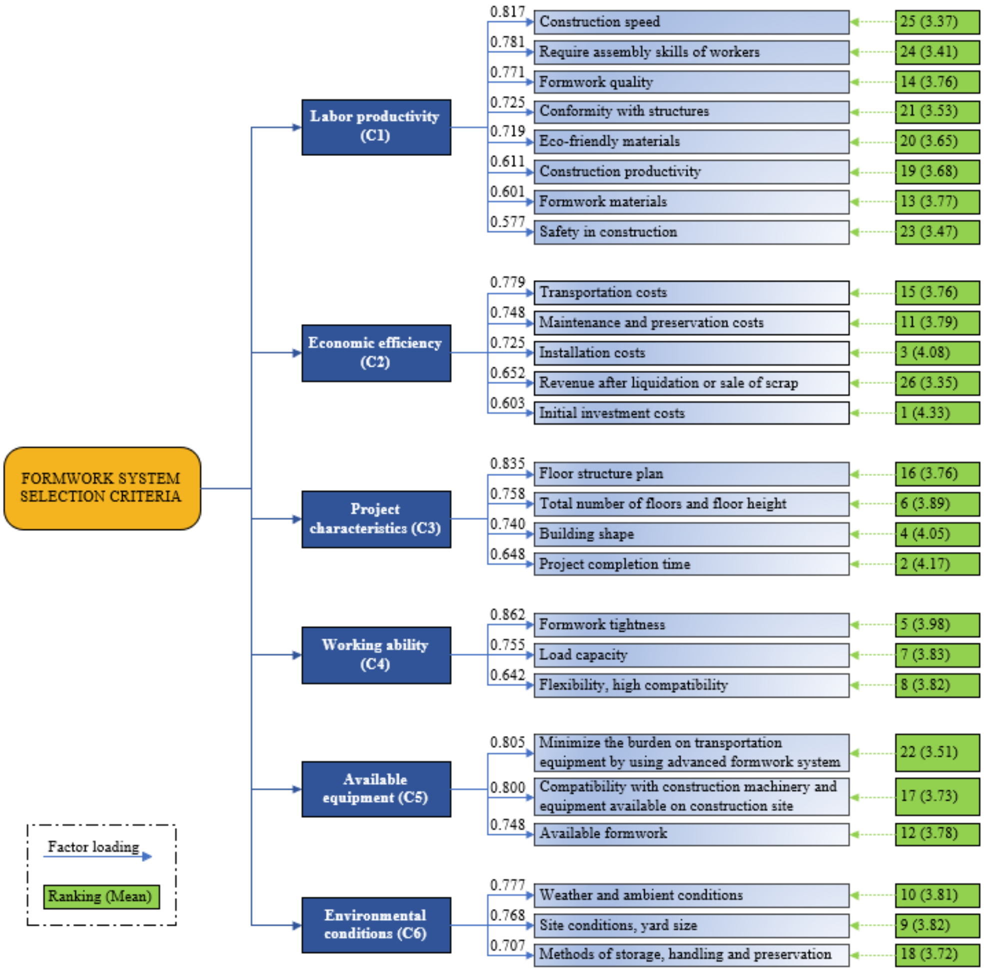

Figure 3. The latent factors affecting the formwork selection problem

- C1. Labor productivity: The observed variables exhibit commonalities in relation to the features of formwork, contributing to improving labor efficiency, increasing the level of safety for workers, simultaneously influencing the time and quality outcomes of construction projects.
- C2. Economic efficiency: These variables are associated with the expenses incurred during the formwork's utilization, encompassing initial investment, transportation, installation, maintenance, and preservation costs, along with the recovery value of the system upon reaching the end of its usability.
- C3. Project characteristics: These variables delineate factors associated with diverse structural design dimensions and construction velocity to ensure completion of the project as required, typically established before selecting formwork.
- C4. Working ability: This factor represents the formwork system's adaptability and flexibility to accommodate dynamic changes in building design, enabling the creation of structural elements in diverse forms, shapes, and positions.

- C5. Available equipment: These variables are associated with maximizing the operational efficiency of available construction resources of contractors, thereby aiding in the optimal allocation of resources throughout the construction process.
- C6. Environmental conditions: The variables are related to the weather conditions, the yard size for the construction process, and area of storage spaces for materials in either warehouses or open-air yards.

4.2. Case study of the FAHP method

In this section, the research formulated a Fuzzy Analytic Hierarchy Process (FAHP) model aimed at the optimal selection of formwork alternatives for high-rise building construction. By taking into account the construction conditions specific to projects in Vietnam, the expert group identified three viable formwork alternatives presented in Table 3, for a detailed examination in a case study, and developing the FAHP model shown in Figure 4.

Utilizing the geometric mean to aggregate expert assessments regarding the prioritization of criteria and alternative options on a FAHP scale, as per the theoretical framework expounded in Section 3.2, the seven responses were deemed adequate for deriving substantial conclusions in the study, and this overarching judgment is indicative of the collective expert opinion for the multi-criteria decision analysis process. The aggregate results are presented in Tables 4 and 5.

The research opted for the average degree of confidence and average attitude towards risk of the decision maker ($\alpha = 0.5$; $\lambda = 0.5$) for weight determination. This choice was deemed acceptable, as these weights exhibited insensitivity to α-cut. Following defuzzification obtained, the subsequent computational steps were executed entirely akin to the traditional Analytic Hierarchy Process (AHP) method, as proposed by Saaty. Determine the alternatives' weights based on each criterion and assess the consistency ratio. Additionally, an examination of the CRs for the aggregated judgment of the 7 responses was carried out, and these ratios were found to be below the threshold 10%.

Finally, based on the specific calculation steps outlined above, the research findings indicate the order of priority of formwork alternatives based on the total score as plastic formwork (0.534), mivan formwork (0.382), and wooden formwork (0.084). Among these, the plastic formwork option, which has the highest total aggregate weight in the final evaluation, is deemed the optimal alternative. This conclusion is drawn from the assessment conducted by the expert group during the second survey stage, where a pairwise comparison of all criteria was carried out using the established FAHP model.

Table 3. Characteristics of formwork alternatives in the case study

A1. Wooden formwork	A2. Mivan formwork	A3. Plastic formwork
Advantages		
- Lightweight (Das *et al.*, 2016) - Low cost of materials (Kareem *et al.*, 2019; Pawar & Atterde, 2014) - High flexibility (Das *et al.*, 2016; Ismail, 2008) - Easy handling and disassemble (Das *et al.*, 2016) - Low experience factor (Pawar & Atterde, 2014)	- Less material wastage (Jayasinghe & Fernando, 2017) - Quality and speed at a high level (Sai & Aravindan, 2020) - Smooth concrete surface, rarely required plastering (Jayasinghe & Fernando, 2017) - High reusability (Poon *et al.*, 2003; Sowndharya & Vidhya, 2022)	- Lighter weight (Das *et al.*, 2016; Prajapati *et al.*, 2014) - Good rigidity and toughness (Luo & Zou, 2023) - Impervious to water (Kareem *et al.*, 2019) - Corrosion, acid, alkali resistance (Luo & Zou, 2023) - Do not rust (Kareem *et al.*, 2019) - Easy to clean (Kareem *et al.*, 2019) - Do not stick with concrete (Kareem *et al.*, 2019) - Multiple reuses (Das *et al.*, 2016; Ismail, 2008; Prajapati *et al.*, 2014) - Low handling and maintenance cost (Sowndharya & Vidhya, 2022)
Disadvantages		
- Short lifespan (Asnan *et al.*, 2023; Das *et al.*, 2016) - Requires extensive labor to erection and dismantling (Al-ashwal *et al.*, 2017; Das *et al.*, 2016; Zhang *et al.*, 2012) - Cannot maintain its shape when exposed to loads (Al-ashwal *et al.*, 2017; Das *et al.*, 2016; Zhang *et al.*, 2012) - Susceptible to corrosion due to climatic and environmental influences (Kareem *et al.*, 2019) - Limited potential reuses (Elbeltagi *et al.*, 2012) - Environmental unfriendly (Prajapati *et al.*, 2014)	- Poor fluidity on site (Luo & Zou, 2023) - Large investment cost (Poon *et al.*, 2003; Thiyagarajan *et al.*, 2017) - More number of components (Thiyagarajan *et al.*, 2017) - High requirements for detailed design drawings (Poon *et al.*, 2003) - Cannot flexibly adapt to structural changes (Gazali, 2018; Luo & Zou, 2023) - No alteration is possible once the formwork is constructed (Das *et al.*, 2016) - Limits in construction projects with non-standard structures (Luo & Zou, 2023)	- Thermal expansion and contraction (Luo & Zou, 2023) - Warping and deformation over time (Luo & Zou, 2023)

Table 4. Pairwise comparisons by expert opions

Criteria	C1	C2	C3	C4	C5	C6	Weight
C1	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	(3.41, 4.48, 5.52) (3.95, 5.00) 4.47	(3.59, 4.62, 5.64) (4.11, 5.13) 4.62	(3.83, 4.90, 5.95) (4.36, 5.43) 4.89	(5.65, 6.66, 7.67) (6.15, 7.16) 6.66	(6.12, 7.15, 7.92) (6.63, 7.53) 7.08	0.426
C2	(0.18, 0.22, 0.29) (0.20, 0.26) 0.23	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	(0.17, 0.21, 0.27) (0.19, 0.24) 0.21	(0.20, 0.25, 0.34) (0.23, 0.30) 0.26	(0.16, 0.19, 0.24) (0.18, 0.22) 0.20	(5.35, 6.38, 7.30) (5.87, 6.84) 6.35	0.073
C3	(0.18, 0.22, 0.28) (0.20, 0.25) 0.22	(3.77, 4.81, 5.85) (4.29, 5.33) 4.81	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	(2.74, 3.47, 4.16) (3.10, 3.81) 3.46	(3.07, 4.21, 5.29) (3.64, 4.75) 4.20	(4.82, 5.92, 6.87) (5.37, 6.40) 5.88	0.216
C4	(0.17, 0.20, 0.26) (0.19, 0.23) 0.21	(2.90, 3.95,4.99) (3.43, 4.47) 3.95	(0.24, 0.29, 0.37) (0.26, 0.33) 0.30	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	(3.67, 4.36, 5.03) (4.02, 4.70) 4.36	(4.30, 5.32, 6.34) (4.81, 5.83) 5.32	0.147
C5	(0.13, 0.15, 0.18) (0.14, 0.16) 0.15	(4.12, 5.15, 6.17) (4.63, 5.66) 5.15	(0.19, 0.24, 0.33) (0.21, 0.28) 0.25	(0.20, 0.23, 0.27) (0.21, 0.25) 0.23	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	(5.22, 6.23, 7.23) (5.72, 6.73) 6.23	0.110
C6	(0.13, 0.14, 0.16) (0.13, 0.15) 0.14	(0.14, 0.16, 0.19) (0.15, 0.17) 0.16	(0.15, 0.17, 0.21) (0.16, 0.19) 0.17	(0.16, 0.19, 0.23) (0.17, 0.21) 0.19	(0.14, 0.16, 0.19) (0.15, 0.18) 0.16	(1.00, 1.00, 1.00) (1.00, 1.00) 1.00	0.028
	RI 1.24		λ_{max} 6.047		CI 0.009		CR 0.8%

Table 5. Result of defuzzification and priority of the alternative options based on each criterion

Criteria	$\overline{Z}_{ij}$			Z_{α}			Z_{α}^{λ}			Weight	CR
C1	(1, 1, 1)	(0.16, 0.20, 0.25)	(0.13, 0.15, 0.18)	(1, 1)	(0.18, 0.22)	(0.14, 0.17)	1	0.2	0.15	0.079	3.3%
	(4.01, 5.07, 6.11)	(1, 1, 1)	(0.43, 0.62, 0.87)	(4.54, 5.59)	(1, 1)	(0.52, 0.74)	5.07	1	0.63	0.367	
	(5.56, 6.59, 7.60)	(1.15, 1.63, 2.32)	(1, 1, 1)	(6.07, 7.10)	(1.39, 1.97)	(1, 1)	6.58	1.68	1	0.554	
C2	(1, 1, 1)	(0.17, 0.20, 0.25)	(0.15, 0.17, 0.21)	(1, 1)	(0.19, 0.23)	(0.16, 0.19)	1	0.21	0.18	0.085	4.4%
	(3.93, 4.94, 5.95)	(1, 1, 1)	(0.45, 0.61, 1)	(4.43, 5.45)	(1, 1)	(0.53, 0.81)	4.94	1	0.67	0.379	
	(4.70, 5.73, 6.74)	(1, 1.63, 2.25)	(1, 1, 1)	(5.21, 6.23)	(1.32, 1.94)	(1, 1)	5.72	1.63	1	0.536	
C3	(1, 1, 1)	(0.17, 0.21, 0.28)	(0.15, 0.18, 0.22)	(1, 1)	(0.19, 0.25)	(0.16, 0.20)	1	0.22	0.18	0.088	3.4%
	(3.58, 4.72, 5.78)	(1, 1, 1)	(0.51, 0.71, 1.04)	(4.15, 5.25)	(1, 1)	(0.61, 0.88)	1.70	1	0.74	0.392	
	(4.63, 5.67, 6.07)	(0.96, 1.40, 1.96)	(1, 1, 1)	(5.15, 6.18)	(1.18, 1.68)	(1, 1)	5.67	1.43	1	0.520	
C4	(1, 1, 1)	(0.16, 0.19, 0.23)	(0.13, 0.16, 0.18)	(1, 1)	(0.17, 0.21)	(0.14, 0.17)	1	0.19	0.16	0.078	2.7%
	(4.34, 5.39, 6.42)	(1, 1, 1)	(0.51, 0.64, 0.91)	(4.86, 5.91)	(1, 1)	(0.57, 0.77)	5.39	1	0.67	0.384	
	(5.41, 6.44, 7.46)	(1.10, 1.57, 1.95)	(1, 1, 1)	(5.93, 6.95)	(1.34, 1.76)	(1, 1)	6.44	1.55	1	0.538	
C5	(1, 1, 1)	(0.16, 0.19, 0.24)	(0.14, 0.17, 0.21)	(1, 1)	(0.18, 0.21)	(0.16, 0.19)	1	0.20	0.17	0.082	5.4%
	(4.20, 5.22, 6.23)	(1, 1, 1)	(0.39, 0.60, 0.96)	(4.71, 5.72)	(1, 1)	(0.50, 0.78)	5.21	1	0.64	0.375	
	(4.83, 5.89, 6.93)	(1.04, 1.67, 2.56)	(1, 1, 1)	(5.36, 6.41)	(1.36, 2.11)	(1, 1)	5.89	1.73	1	0.543	
C6	(1, 1, 1)	(0.24, 0.29, 0.36)	(0.57, 0.70, 0.90)	(1, 1)	(0.27, 0.33)	(0.63, 0.80)	1	0.30	0.72	0.175	3.8%
	(2.77, 3.41, 4.08)	(1, 1, 1)	(1.32, 1.96, 2.78)	(3.09, 3.75)	(1, 1)	(1.64, 2.37)	3.42	1	2.01	0.557	
	(1.11, 1.43, 1.77)	(0.36, 0.51, 0.76)	(1, 1, 1)	(1.27, 1.60)	(0.43, 0.63)	(1, 1)	1.43	0.53	1	0.268	

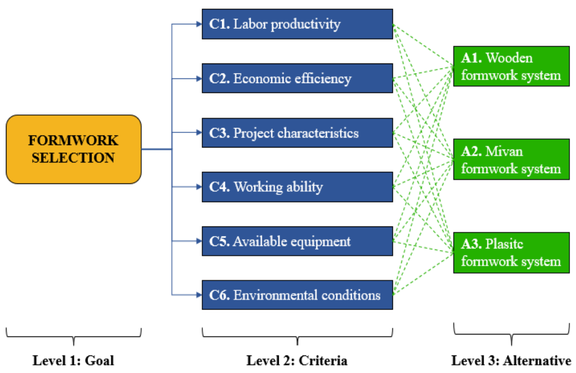

Figure 4. The hierarchical structure model

While being the oldest and most commonly employed formwork type in construction, wooden formwork is progressively falling short of meeting the demands posed by modern tall building projects. This inadequacy has been unambiguously substantiated through the implementation of the multicriteria decision making model FAHP, with results that are consistent with studies conducted in other countries, as shown in Table 6. These findings indicate that traditional wooden formwork is no longer a sufficient solution, and the advance of novel formwork technologies is essential for accelerating and simplifying construction processes.

The summary of the characteristics of the three types of formwork in Table 3, along with the comparative data from related studies in Table 6, further shows that that the use of mivan or plastic formwork helps to overcome most limitations of the traditional wooden formwork, especially the problem in ability to be recycled. While mivan demonstrates an acceptable reuse index, its practicality diminishes when cost considerations are taken into account, making it less attractive. As a result, plastic formwork emerges as the preferred solution to address these concerns, aligning seamlessly with the outcomes generated by the model utilized

Table 6. Summary of some literature related to comparative analysis of formwork systems

Country	Formwork alternative			Rank	Reference
	(1)	(2)	(3)		
Indonesia	Timber	Aluminum	-	(2) > (1)	(Hansen *et al.*, 2020)
Indonesia	Conventional	Aluminum	-	(2) > (1)	(Rivaldo & Putra, 2024)
India	Timber	Steel	Aluminum	(2) > (3) > (1)	(Dhanasekar *et al.*, 2019)
India	Timber	Steel	Plastic	(3) > (2) > (1)	(U Din & Kumar, 2017)
Vietnam	Wood	Steel	Aluminum	(3) > (2) > (1)	(Long *et al.*, 2023)

in the study. This underscores that, from an environmental standpoint, plastic formwork is recognized as an innovative and eco-friendly construction material, aimed at mitigating the depletion of natural wood and metal ores in the construction industry, along with reducing construction material waste and environmental pollution.

In summary, the conclusive findings of the study contribute to confirming the future trajectory of sustainable development in the construction industry. The progress of tall construction should harmonize with the evolution of elements that enhance the built environment, and the integration of a plastic formwork system in tall construction represents a contribution to this collective advancement.

5. Conclusions

Choosing the appropriate formwork solution for a high-rise building involves a complex decision-making process that requires the evaluation of multiple criteria with varying priorities. Each project is characterized by unique design elements, scheduling plans, and construction technologies, posing a challenge in identifying a one-size-fits-all formwork solution. Through a comprehensive analysis of research data obtained from surveys conducted with investors, engineers, and construction managers, this study identified key factors influencing formwork selection in high-rise building construction in Vietnam, including Level of efficiency in use and construction productivity; Economic efficiency over the entire service life; Design features and construction progress of the project; Ability to work to meet engineering design requirements; Suitability for construction equipment available at the construction site; and Construction site and ambient conditions. Among these factors, the initial investment cost stands out as the most influential in the selection decision, directly reflecting investment efficiency and the financial capacity of the enterprise. The study employed the Fuzzy Analytical Hierarchy Process (FAHP) for formwork selection, leveraging insights from expert interviews. Therein, Fuzzy theory was utilized to create pairwise comparison matrices for the criteria considered in material selection for formwork through the Analytical Hierarchy Process (AHP) method. Notably, the research introduced plastic formwork as an option in the comparative calculation model, a material not explored in previous studies. Following the analysis, the formwork systems were rank ordered from best to worst as plastic formwork, mivan formwork, and wooden formwork. Plastic formwork solutions gain prominence in construction, endorsed by experts for advantages such as faster construction speed, low self-weight, minimal maintenance costs, and a smooth surface finish.

The outcomes derived from the FAHP model contribute significantly to providing objective evaluations that align with the current development trends in the construction industry. The study offers stakeholders a comprehensive understanding of impactful aspects to be considered during the selection, planning, and decision-making processes for the appropriate formwork system in specific high-rise building projects. Tailoring decisions to each project's unique characteristics brings benefits such as accelerated progress, cost savings, and enhanced labor efficiency; and it contributes to the overall project success, establishing prestige and value for the enterprise. Project managers can further customize criteria based on rigorous analysis and assessment of suitability for specific project types.

Moreover, future research should address several limitations identified in this study. Firstly, due to constraints in funding and time, the study relied on random and convenient sampling methods, primarily online. To achieve a more comprehensive understanding, future research could explore avenues such as organizing seminars or group discussions with experts. Secondly, the study is limited in scope by focusing solely on the selection of formwork criteria for high-rise building construction projects. The considerations for formwork selection may differ significantly when applied to various construction projects such as industrial or infrastructure projects. Therefore, future research should expand its focus to encompass a broader range of construction types. Thirdly, the limited participation of practitioners in the FAHP survey may have impacted the accuracy and generalizability of the findings. Encouraging greater practitioner involvement in future studies is essential. Finally, the reluctance of some construction companies to adopt the plastic formwork, which was not previously validated, posed challenges. To validate the results of this study, the proposed FAHP approach for formwork selection should be applied to different project types and in diverse geographical locations. Consequently, future studies should include comparisons and validations with the outcomes of this study.

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