A technical viewpoint on evaluating underground construction approaches during the pre-construction phase: An appraisal framework

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Abstract

The objective of this research is to develop an evaluation framework for technically appraising underground methodologies during the pre-construction phase. Initially, technical assessment criteria were derived through a combination of literature review and expert consultations.
A survey was subsequently administered to gather insights from individuals with practical experience in underground building. Factor analysis was conducted to uncover the underlying significance of each criterion. Next, a Fuzzy Analytic Hierarchy Process (Fuzzy AHP) model was constructed to determine the relative importance of each criterion. The assessment framework was then applied to evaluate the underground construction approach for a specific project, and the results were validated by project-involved experts.
The study yielded a Fuzzy AHP model comprising 8 categories of factors and 35 refined criteria, spanning various domains from documentation and resources to geological and hydrological considerations. These factor categories represent original contributions to the field and are pivotal for the technical evaluation of underground construction methods in the pre-construction phase. The findings underscore the efficacy of the model in aiding construction firms in making informed decisions for the successful and safe execution of chosen underground construction methodologies, particularly during the pre-construction phase.

Keywords: *technical factors, assessment model, underground construction method, Fuzzy AHP, PCA*
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1. INTRODUCTION

Construction projects frequently suffer from a negative perception due to their tendency to exceed the expected time frame, (Fakunle & Fashina 2020; Raftery 2003), excessive expenses beyond the budgeted amount (Ahsan & Gunawan 2010; Baloi & Price 2003; Morris & Hough 1987), and damage to the environment (Huang et al. 2018). One of the key factors contributing to these problems is the use of unsuitable underground building techniques. Failing to properly assess or employ acceptable methods might result in delays (Alaghbari, Kadir & Salim 2007; Enshassi, Al-Najjar & Kumaraswamy 2009; Enshassi, Kumaraswamy & Al-Najjar 2010), cost overruns (Adam, Josephson & Lindahl 2017; Durdyev 2021; Enshassi, Al-Najjar & Kumaraswamy 2009), productivity reduction (Hasan et al. 2018), and environmental pollution (Ferrada & Serpell 2014; Pan 2008). In addition, the use of inappropriate underground building methods might present substantial hazards to human lives. Excavation and trenching are highly perilous activities in the field of building. The fatality rate for excavation work is 112% more than the rate for general construction (Arboleda & Abraham 2004; OSHA 2018), and according to the Census of Fatal Occupational Injuries – CFOI, more than 80% of trench collapse accidents occur in the construction industry (Akboga Kale 2021; Ruttenberg, Schneider &

Obando 2019). Hence, it is crucial to thoroughly evaluate various factors such as geological, environmental, and technical limitations linked to subterranean construction endeavours in order to choose suitable approaches that guarantee effective and enduring construction while minimising hazards to human lives and the environment. Although underground building methods are of great importance, most research have mostly concentrated on safety assessment (Ghosh & Jintanapakanont 2004; Liu et al. 2018; Seo & Choi 2008; Wang & Chen 2017), leaving a research gap in technical assessments for selecting suitable underground construction methods.

The pre-construction phase is of utmost importance, particularly for the purpose of choosing construction techniques, as it guarantees an efficient, secure, and timely completion of the construction process, while also minimising the likelihood of potential damages and cost overruns. This study intends to develop a technical assessment model for underground construction methods during the pre-construction stage, addressing the lack of research in this area and recognising its importance. The main goals of this paper are to (1) examine and analyse the technical assessment factors related to underground construction by conducting a thorough review of existing literature and consulting with experts, (2) develop a strong assessment model that considers uncertainties and ambiguities in expert opinions regarding underground construction methods, and (3) evaluate the constructed model by using it to assess the underground construction method used in a real-life project. The paper is comprised of eight sections. Section 1 serves as the introductory part, offering a comprehensive summary of the study. Subsequently, Section 2 provides a comprehensive overview of the existing literature. Section 3 outlines the research technique utilised in this study. Section 4 delineates the variables that influence underground building techniques during the pre-construction phase. Section 5 presents the various elements and sub-factors that affect subterranean building procedures during the pre-construction stage. Section 6 outlines the assessment model used to analyse subterranean construction methods, while section 7 demonstrates how this model is applied to evaluate the underground construction method for a specific project. Finally, section 8 provides the final analysis and summary.

2. PRE-CONSTRUCTION STAGE FACTORS INFLUENCING UNDERGROUND BUILDING TECHNIQUES

Through a comprehensive literature analysis and expert interviews, a total of 45 technical parameters that affect underground building procedures were discovered in this study. Subsequently, a survey is carried out via a questionnaire. The participants provided a total of 217 responses. Nevertheless, 6 responses were deemed invalid throughout the screening process and consequently eliminated, resulting in a total of 211 legitimate responses.

In order to assess the credibility of the survey results, data was collected on participants' professional credentials, job titles and positions, years of experience, years of operation of companies, and the value of the greatest subterranean construction projects. The findings indicate that most of the participants possess a significant level of technical proficiency in the construction industry. All responders have a minimum of three years of experience in the sector, with the majority having worked in the field for over five years. This extensive amount of time allows them to possess a comprehensive understanding of diverse technological challenges. Furthermore, the majority of participants have experience working in organisations that have a significant track record of success and have been involved in substantial underground projects. Regarding the largest underground construction projects that the participants have worked on, the majority of respondents have been involved in projects valued at over 100 billion VND.

The research reveals that the survey results are highly reliable and will be utilised for subsequent actions.

The data collected from 211 legitimate responses was subsequently analysed using mean testing to eliminate any anomalous data. All variables tested had a significance level below 0.05, indicating statistical significance. It may be inferred that the average values of the data greatly deviate from the mean value proposed in the hypothesis (Agyekum et al. 2022; Khanh et al. 2023; Tam et al. 2018).. Consequently, it is imperative that none of the variables are eliminated.

Following the implementation of the mean value approach, the reliability of the measurement scale was assessed using Cronbach's Alpha coefficient. Two iterations of analysis were conducted to eliminate variables that did not fulfil the specified criteria. During the initial round, one component was excluded due to its correlation coefficient being below 0.3 (Kim & Nguyen 2022; Ogunsanya et al. 2022).. Subsequently, all variables satisfied the criterion during the second round. The Cronbach's Alpha coefficient value for this round is 0.912. The value exceeds 0.7, suggesting a high level of dependability in the measuring scale (Dalirazar & Sabzi 2023; Fung et al. 2016; Salami, Ajayi & Oyegoke 2023).. Thus, the outcome is now a dependable measuring scale that fulfils the measurement criteria with 44 suitable elements.

3. BUILDING AN ASSESSMENT MODEL

This project intends to create an assessment model that quantitatively measures the impact of each component and sub-factor on the appropriateness level of underground building methods. The model will be constructed using important evaluation factors and will have a comprehensive scale. In order to do this, the Fuzzy AHP method, as suggested by Tesfamariam and Sadiq (2006) was utilised. The strategy consisted of a step-by-step approach that included the following phases.

First, the hierarchical structure in this paper's analysis is used to generate the overall fuzzy decision matrix and lower-level matrices. This involves considering primary factors and sub-factors. To enhance convenience, the 35 components that were not yet discussed were labelled as sub-factors, while the 8 sets of factors were identified as key factors.

The scale incorporates a fuzzy coefficient known as Δ. The Δ coefficient is used to compute the values of the fuzzy triangular numbers in the comparison matrix. In this investigation, the Δ value is fixed at 1.

Subsequently, a coherence assessment is carried out across specialists since the act of comparing pairings can frequently result in incongruity in the responses provided by experts. In order to tackle this problem, this work utilises a technique introduced by Saaty (1980) to calculate the consistency ratio (CR) for each pairwise comparison. The acceptable CR should be below 10%. Furthermore, as stated by Kearns and Saaty (1985), there may be instances where a CR value surpassing 10% is unavoidable, but it should not go beyond 20%. The CR testing findings indicate that the CR values in the table are less than 10%, suggesting that the experts have displayed consistency in their pairwise comparisons.

Subsequently, the data is consolidated for subsequent analysis, specifically for the purpose of soliciting the perspectives of the specialists. The purpose of this stage is to consolidate the preferences of the group of 12 experts into a unified preference that represents the collective opinion of the full group of experts. An essential concern when making judgements involving numerous elements is the process of amalgamating the preferences of all specialists into a unified preference set that accurately reflects the collective opinion of the entire group. Utilising the geometric mean for synthesis can be a viable choice (Buckley 1985). This study utilised the methodology introduced by Meixner (2009) to combine numerous triangular fuzzy numbers into a single number using the geometric mean.

Once the opinions of numerous experts have been combined into a single evaluation, it is crucial to verify the consistency of this synthesised evaluation. This verification is conducted using the same methodology as each expert evaluation. The results of the synthesised consistency ratio range from 0.017 to 0.058, indicating that the resulting ratio is smaller than the required threshold of 10%.

Defuzzification is the subsequent stage in which a fuzzy comparison matrix, containing elements expressed as fuzzy numbers, is transformed into a precise number. There are numerous techniques suggested for this process, and in this study, the method offered by Deng (1999) is utilised. This method is flexible since it allows for the use of α-cut and λ values in Fuzzy AHP. These values can indicate the decision makers' level of confidence and attitude towards risk, respectively. This study utilises an α-cut value of 0.5 and a λ value of 0.5 to determine the weights of the components.

After performing the defuzzification process, the weights of the components are determined using a method similar to the classic Analytic Hierarchy Process (AHP). The analysis displays the visual representation of the weightings assigned to the sub-factors and factors. The primary factor M5, which pertains to the parameters of underground construction, has been found to have the greatest influence. Within this factor, sub-factor M54, representing the location of the boundary between the underground portion and the surrounding land, is ranked as the most significant in determining the success of the underground construction method during the pre-construction stage.

Ultimately, a sensitivity analysis was performed, which is a technique utilised to assess the fluctuations of one or more variables in diverse circumstances. This study utilises sensitivity analysis to investigate the changes in the weight of each factor when the α-cut and optimism index λ are altered. The α-cut value ranges from 0 to 1, with increments of 0.2, representing the decision maker's attitudes of optimism (λ=1), neutrality (λ=0.5), and pessimism (λ=0). Figure 3 displays the outcomes of the sensitivity analysis. The figure demonstrates that the weights were not affected by the degree of confidence α-cut for λ values of 0, 0.5, and 1.

4. CONCLUSION

This study conducted a literature analysis and consulted with experts to identify and analyse the technical assessment variables that affect the underground construction process during the pre-construction stage. As a result, a comprehensive list of 35 factors was proposed. This publication not only addresses a current deficiency in the understanding of technical aspects that impact the choice of underground construction methods, but also provides a helpful reference for engineers, project managers, and decision-makers engaged in the planning and implementation of underground construction projects.

A hierarchical framework was constructed, categorising these elements into eight distinct groupings. The documents provided include design specifications, building materials, project updates, details about the project region, specifications for subsurface structures, information about the geological and hydrological conditions, resources available inside the company, and resources provided by subcontractors. Subsequently, a comprehensive evaluation framework was developed, taking into account the relative significance of each element. The category with the largest share of elements is Underground specifications, which also includes the factor with the highest proportion, namely the Location of the boundary between surrounding land and underground construction section. This evaluation model makes substantial research contributions by evaluating the appropriateness of subterranean construction methods during the pre-construction phase. Additionally, it offers contractors a thorough and extensive comprehension of the selected approach. This knowledge can assist contractors in identifying and enhancing any components of the construction procedure that are unsuitable, hence boosting the probability of successfully completing the project.

The results obtained from verifying the evaluation model demonstrate its ability to accurately reflect the current state of the practical project. Therefore, the model may be confidently asserted as both dependable and practicable for implementation. Nevertheless, this study exclusively concentrates on the technical evaluation, disregarding the aspects of cost and time. In order for a construction method to be considered practical, it must not only fulfil technical specifications, but also strike a balance between cost and schedule. Hence, additional investigation is required to incorporate the expenses and timeline into the model, in order to offer a more thorough evaluation of underground building techniques during the pre-construction phase.

5. REFERENCES

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