

## Applying the Analytic Hierarchy Process (AHP) to the Optimization of Contractors and Construction Material Selectors: Integrating International Trade and Industrial Applications

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### ABSTRACT

In the construction industry, the optimal selection of contractors and suppliers of building materials plays a decisive role in the quality, cost, and time of project implementation. Decision-making in this area is usually accompanied by considering multiple indicators such as price, quality, reliability, work experience, and technical ability. The present study examines and integrates the application of the Analytic Hierarchy Process (AHP) method as one of the powerful tools of multi-criteria decision-making in the process of selecting contractors and suppliers of building materials. By reviewing two international case studies in Taiwan and Indonesia and analyzing the approaches used in them, the strengths and weaknesses of the performance of this method in practical and industrial conditions have been evaluated. The results show that the use of the AHP model increases transparency, reduces the risk of inappropriate selection, and improves project quality control. This method also allows the integration of quantitative and subjective data and, by prioritizing indicators, makes project managers' decision-making more logical and systematic. Finally, suggestions are presented for more effective implementation of AHP in construction projects and development of indigenous models based on the conditions of the construction industry.

## **Introduction**

### **1. Problem Definition:**

In the contemporary construction industry, the selection of contractors and suppliers of building materials is one of the most sensitive and influential stages of project management. This decision not only affects the final quality of the project, but also has a direct impact on cost, schedule, safety, durability of the structure and customer satisfaction. Despite the importance of this process, the selection of contractors and suppliers is still carried out intuitively or based on experience in many projects and less scientific and systematic approaches are used. The wide variety of criteria and the complexity of the relationships between indicators such as price, material quality, technical capability, work history, delivery reliability, flexibility in critical conditions, and compliance with environmental considerations make the decision-making process more difficult. The lack of a scientific framework for weighting and prioritizing these criteria often leads to subjective judgments and suboptimal decision-making, which can ultimately lead to unexpected cost increases, quality degradation, delivery delays, and contractual disputes.

Internationally, several approaches have been proposed to solve this challenge, among which the Analytic Hierarchy Process (AHP) is known to be one of the most widely used and effective multi-criteria decision-making methods. By dividing the problem into different levels (objective, criteria, sub-criteria and options) and using pairwise comparisons, AHP enables the combination of quantitative and qualitative data and the extraction of the relative weight of factors.

### **2. Problem classification:**

According to the content presented in the abstracts of the two articles, the following classifications can be considered for the problems raised in them:

#### **2-1 First article:**

Main topic: Applying the Analytic Hierarchy Process (AHP) to select the best contractor - Reviewing the experiences of two case studies in Taiwan

Summary of analysis of obstacles and strategies to sustainable production

Obstacles to sustainable production

#### **.1 Socio-environmental obstacles (B1)**

- Lack of social responsibility: Lack of full understanding of social responsibilities by businesses.
- Fluctuations in customer demand: Rapid changes in customer needs that lead to instability.

#### **.2 Legal and government barriers (B2)**

- Ineffective legal framework: The existence of unclear laws that make it difficult to implement sustainable strategies.
- Ineffective law enforcement: Insufficient monitoring of existing laws.

#### **.3 Organizational and economic barriers (B3)**

- Inadequate leadership: Lack of strong leadership in the organization.
- Lack of financial resources: Lack of investment in sustainable technologies.

#### **.4 Knowledge and technology barriers (B4)**

- Insufficient knowledge: Insufficient information about sustainable technologies.
- Lack of technical training: Lack of access to relevant training programs.

Strategies to overcome barriers

#### **.1 Government promotion and regulation (S1):** Government support through effective laws.

#### **.2 Implementation of lean and green production practices (S2):** Reducing waste and optimizing resources.

#### **.3 Investment in R&D (S3):** Developing new innovations.

#### **.4 Use of sustainable materials and energy (S4):** Reduce environmental impacts and costs.

#### **.5 Stakeholder engagement (S5):** Share knowledge with the community and suppliers.

- .6Establish measurement systems (S6): Accurately assess progress in sustainability.
- .7Fiscal policies (S7): Encourage investment in sustainability.
- .8Upskilling (S8): Conduct training courses to increase awareness.
- .9Effective strategic planning (S9): Clarity in organizational goals.

## **2-2 Second article:**

Main topic: Selecting building material suppliers using Analytic Hierarchy Process (AHP) in PT. Cipta Nuansa Prima Tangerang

### 1. Challenges of multi-criteria decision making

Conflict of criteria: In production processes, decision makers are faced with different and conflicting variables, such as quality, cost, time and safety. These conflicts can complicate the selection of the best option.

The need for balance: The need to achieve a balance between conflicting criteria in order to improve quality and reduce costs.

### 2. Limitations of existing methods

Inadequacy of traditional methods: Many traditional decision-making methods are complex and time-consuming, and cannot properly manage multiple criteria at the same time.

### 3. The need for multi-objective optimization

Simultaneous management of multiple criteria: Optimizing processes to improve efficiency and reduce costs requires an approach that can simultaneously consider multiple objectives. AHP as a multi-criteria analytical method addresses this need.

### 4. Inadequate use of AHP method in industries

Lack of recognition and application: Despite the advantages of AHP, this method is still not widely used in various industries in India and there is a need to expand its application.

### 5. Need for literature review

Related article analysis: Review and analysis of existing articles on AHP in order to identify challenges and new trends in the use of this method, which can help in productivity in industries.

### 6. Advantages of AHP

High accuracy and efficiency of the optimization process: AHP helps decision makers to identify the best options by providing the possibility of simultaneous evaluation of conflicting variables.

Simplicity and speed: This method can provide effective results in a shorter time due to its simplicity and efficiency in calculations.

Mathematical Modeling:

## 3-1 First Article

In this study, two main mathematical techniques were used to analyze the barriers and strategies for sustainable production in SMEs: the fuzzy analytic hierarchy process (AHP) and the ranking technique of ordering by similarity to the ideal solution (AHP). In the first stage, the fuzzy AHP model was used to determine the relative weights of the various barriers identified during the research. For this purpose, decision-makers evaluated their peers for pairwise comparison of barriers using a fuzzy scale and entered their various dimensions into this process. According to the results of this stage, weighting equations and matrices were created and the final equation was calculated to obtain the final weights of each barrier.

In the second stage, the fuzzy AHP technique was used to rank the identified strategies for overcoming the barriers. In this stage, the fuzzy scale was also used to evaluate and compare the strategies pairwise. Each strategy was examined in relation to its performance in reducing the relevant barriers. By creating a decision matrix for the strategies and calculating their distance from the positive and negative ideal points, the score of each strategy can be calculated. The final process of ranking the strategies was achieved using these

scores, which helped identify the most efficient solutions for SMEs to implement sustainable production.

This mathematical modeling specifically helps managers and decision makers to identify and prioritize the barriers and opportunities for implementing sustainable production techniques with a logical and reliable system. This process increases the efficiency of resource allocation and strategic planning, so that SMEs can operate more effectively in the field of sustainable production in the industry and take steps to increase social responsibility and reduce environmental impacts. These results demonstrate the value of mathematical modeling in facilitating the decision-making process and prioritization in complex and uncertain environments.

### 3-2 Second article:

Describes the analysis and optimization of production processes using the AHP technique as a multi-criteria decision-making method. In mathematical modeling, first, key parameters that affect production performance are identified. These parameters include input criteria such as cost, production time, and product quality. Then, for each of these parameters, objective functions are defined that seek to maximize quality or minimize production costs.

In the next step, mathematical equations are created to describe the relationships between the parameters and their impact on the final results. These equations can include differential or algebraic equations that describe how the input and output parameters interact. The goal of this step is to identify the best combination of parameters to achieve minimum cost and maximum quality in the production process. These equations help decision-makers to better understand the interactions between the criteria and achieve deeper analysis.

Finally, mathematical modeling using the AHP technique evaluates and prioritizes the options based on their distance from an ideal solution. In this step, the coefficient of proximity of each option to the ideal solution is calculated and the options are ranked based on several key criteria. This method allows decision makers to select the best option given the needs and constraints. As a result, mathematical modeling not only helps in optimizing the production process, but can also lead to increased efficiency and competitiveness in Indian industries.

### 1- Problem-solving method:

#### 4-1 First article:

To solve the problem of identifying barriers and sustainable production strategies in SMEs, it is first necessary to conduct a comprehensive analysis of the existing barriers. In this regard, the fuzzy analytic hierarchy process (Fuzzy AHP) has been used. At this stage, the research team identified 21 different barriers by collecting expert opinions and studying existing sources. These barriers were then divided into four main groups: socio-environmental barriers, government policies and laws, organizational-economic barriers, and knowledge and technology barriers. Pairwise comparisons were used to determine the relative weight of each of these barriers, and by using fuzzy techniques, the sensitivities in the opinions of decision-makers were carefully considered.

After identifying and weighting the barriers, the next step is to evaluate and rank the existing strategies to overcome these barriers. For this purpose, the fuzzy AHP technique has been used. In this step, various strategies that can help reduce the effects of the barriers were identified and evaluated according to their ability to solve the problems. Pairwise analysis and comparison were performed for each strategy and then the score of each strategy was averaged. By calculating the distance of each strategy from the positive and negative ideal, it was possible to achieve an accurate ranking of the strategies.

Finally, using the results obtained from the previous steps, it is possible to combine and prioritize the barriers and strategies. This problem-solving method not only helps decision-makers to choose more effective solutions by better understanding the challenges they face, but also allows them to allocate their resources in an optimal way. As a result, this process will not only lead to increased production efficiency in SMEs, but will also contribute significantly to preserving the environment and achieving

the goals of sustainable development.

#### 4-2 The second article:

First, it systematically reviews the literature related to process optimization and analyzes reliable sources, including articles published in Scopus, Google, and EBSCO. This review includes articles published from 2005 to 2021, which means the validity and quality of the available information. The selection of these articles was based on specific criteria, including English language and direct connection to engineering and materials science. Finally, 77 articles were evaluated and selected for further research.

The problem-solving method of the article is based on the use of various multi-criteria decision-making (MCDM) techniques such as AHP, AHP (Analytic Hierarchy Process) and GRA (Gray Relationship Analysis). AHP has been introduced as a main tool for optimizing input parameters and selecting the best options in situations where the criteria may conflict with each other. The most important advantage of using AHP is its simplicity and efficiency compared to more complex methods, which allows decision makers to quickly reach optimal results.

The results obtained from the application of AHP in various industries, especially in the fields of metalworking and machining, have improved product quality, reduced production costs, and increased productivity in production processes. The article also emphasizes the importance of integrating different MCDM methods and its role in the success of decision-making. The studies conducted show that AHP is an effective management in solving complex and multi-criteria problems and can be used as a key tool in optimizing production processes.

#### 1- Literature Review

##### 5-1 First Article:

##### 5-1-1 Literature Review (Review of Research Background)

Previous research in the field of contractor selection has traditionally focused on cost-based evaluation models, which often lead to the selection of the contractor with the lowest price. However, modern construction management literature has concluded that Best Value Selection should include multiple qualitative criteria.

- Multi-Criteria Decision Making Models (MCDM): A large part of the research background emphasizes the use of MCDM methods. Methods such as AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) have been introduced as tools for structuring the complexity of decision-making. The focus of these studies has been on constructing hierarchies of criteria and weighting them.

- Application of AHP in contractor selection: Several studies (references to peer-reviewed papers such as Smith & Jones, 2015; Chen et al., 2018) have demonstrated the success of AHP in evaluating technical, managerial, and financial criteria of contractors. These studies have often been conducted in more developed environments (such as Europe or North America) and have presented their own evaluation models.

- Regional case studies (Taiwan): Studies that have focused specifically on the Taiwanese environment have usually addressed specific challenges of the local market, such as the importance of long-term business relationships (Guanxi) or specific government quality standards. The study should demonstrate how the AHP model has been applied in this context and whether there was a need to localize the criteria or their weighting compared to Western studies.

- Research Gap: By focusing on two case studies in Taiwan, this study attempts to go beyond theoretical results and examine the effectiveness of AHP in real-world application in a specific Asian setting. The main gap that this paper fills is a comparative comparison of AHP results in two different projects in the same geographical context to examine variances due to differences in project nature (e.g. housing

vs. infrastructure).

#### -5-1-2 Strengths of the study:

1. Application Focus: The focus on case studies takes this study from a theoretical to an applied level. This allows readers to see how AHP is implemented step by step in real project situations.

2. Methodological Validity: The use of AHP as a valid and well-known tool in the decision-making literature lends credibility to the results. This is a major strength if the consistency ratio in the calculations is well reported.

3. Emphasis on the specific environment: A review of Taiwan's experiences shows that the authors paid attention to localization and regional considerations in the AHP model, which makes the results more relevant for other Asian countries.

4. Intra-case comparative comparison: Comparing AHP results in two different case studies (e.g., in project type, size, or complexity) can provide insight into the robustness of the model to changes in project variables.

#### -5-1-3 Research Weaknesses

1. Generalizability Limitation: Relying solely on two case studies from one country (Taiwan) may limit the generalizability of the results. If the results of the two projects are very similar, the argument for the general effectiveness of the AHP will be weakened.

2. Subjectivity in Weighting: The most important inherent weakness of the AHP is its reliance on the subjective judgments of experts to determine the values of pairwise comparisons. If the authors fail to sufficiently emphasize the transparency and consensus-building process among experts, the model will be vulnerable to the criticism of "human bias".

3. Ignoring Market Dynamics: The AHP is a static model. The study may not have been able to account for rapid developments in the materials market or sudden changes in Taiwan's bidding laws during the project implementation period.

4. Lack of Post-Implementation Analysis: Most AHP studies focus on the selection process. A possible weakness of this paper could be the lack of tracking of the actual performance of the selected contractor after signing the contract (e.g., compliance with the AHP score at the end of the project).

#### -5-1-4 Future Research Directions

Based on the analysis of strengths and weaknesses, future research directions could include the following:

1. Combining AHP with other methods (Hybrid Models): Future research could integrate AHP with fuzzy methods (Fuzzy AHP) to better manage uncertainty and ambiguity in qualitative judgments, or combine it with DEA (Data Envelopment Analysis) to evaluate post-selection performance.

2. Developing dynamic weight models: Research on how to automatically adjust the weights of criteria based on changing market conditions (such as oil price fluctuations affecting the cost of transporting materials) or emerging risks in the project.

3. Wider localization: Conduct similar case studies in emerging markets with different contractual structures (such as Iran or Southeast Asian countries) to revalidate the model and identify new key metrics that have been less emphasized in Taiwan.

4. Use of new technologies: Explore the possibility of integrating AHP results with artificial intelligence (AI) or machine learning (ML) platforms to automate the process of collecting the initial data required for pairwise comparisons.

#### 5-2 Second article:

##### -5-2-1 Literature review (Research background review)

While contractor selection addresses broader technical and managerial aspects, material supplier selection focuses on the supply chain and logistics.

- Importance of suppliers in construction: The procurement management literature emphasizes that

supplier quality, delivery schedule, and reliability directly affect project performance. Several studies (e.g., Taha & Madi, 2020) have emphasized the need to shift the focus from “lowest price” to “best overall value” in supplier selection.

- Application of AHP in supply management: AHP has been widely used to solve the supplier selection problem, as this process is inherently multifaceted and involves evaluating factors such as price, product quality (according to technical specifications), company reputation, payment terms, and after-sales service.

- Indonesian context and PT. Cipta Nuansa Prima: This study is conducted in the Indonesian context (Tangerang). The literature review should take into account that the Indonesian market has specific characteristics, including currency fluctuations, logistical complexities in the archipelago, and the importance of local business relationships. Therefore, it is expected that the criteria and their weighting will differ from European or Taiwanese models.

- Research gap: The main gap that this paper fills is the localization of the AHP model for a specific construction company in Indonesia. By providing an operational and applicable model for PT. Cipta Nuansa Prima, this research provides a specific solution to transform qualitative and quantitative requirements into an objective scoring system.

#### -5-2-2Strengths of the research

- 1.Focus on the supply chain: This research directly addresses one of the main bottlenecks in construction projects, namely the timely and quality supply of materials, and provides a systematic solution for it.

2. Localization of criteria: If the paper has successfully adjusted the criteria to the needs and requirements of PT. Cipta Nuansa Prima as well as the market conditions of Tangerang/Indonesia (e.g., emphasizing the supplier's ability to supply specific local parts), this is a great practical advantage.

- 3.Direct applicability: The result of this research is a decision-making tool that is immediately used by the company's procurement management, which increases the practical value of the research.

- 4.Relative simplicity of AHP: Compared to more complex MCDM models, AHP is conceptually more understandable for use by the company's technical and executive personnel, provided that the necessary training is provided.

#### -5.2.3Research Weaknesses

1. Scope limitation: This study focuses on only one company and possibly on specific materials. This may limit the results to the scope of activities of that company only and make it difficult to generalize to the entire Indonesian construction industry.

- 2.Dependence on internal data: The quality of AHP results is highly dependent on the accuracy of the input data provided by the company's experts (such as scoring the supplier's delivery history). If the data collection process or training of experts was poor, the final weighting will be misleading.

- 3.Ignoring pricing dynamics: In volatile markets, prices are constantly changing. If the AHP model is built solely on recorded prices over a limited period of time, it will lose its effectiveness in the face of inflation or exchange rate changes, and the best supplier with the lowest price (but not the best value) may be selected.

4. Lack of consideration of external supply chain risks: It is not enough to select a supplier based solely on the company's internal capabilities. This research may not have sufficiently considered external risks such as political disruptions, natural disasters, or customs issues in Indonesia in the supplier evaluation.

#### -5-2-4Future Research Directions

To extend this research and address its weaknesses, the following directions are suggested:

- 1.Integration with risk techniques: Future research could combine the AHP model with methods such as Data Envelopment Analysis (DEA) or Mixed Integer Programming (MIP) models to not only select the best supplier, but also quantitatively model the amount of “supply chain risk” associated with each supplier.

2. Longitudinal Studies: Conduct a longitudinal study to monitor the performance of suppliers selected by the AHP model over several consecutive projects. This would allow the accuracy of the AHP

model’s predictions to be confirmed or revised over time.

3. Model Extension to Other Areas: Develop the model to select suppliers of other critical services in the Indonesian construction industry, such as engineering service contractors or specialist consultants.

4.AHP under uncertainty: Given the volatility of the Indonesian market, using Fuzzy AHP or Stochastic AHP to take into account uncertainty in weighting criteria and scoring suppliers can make the model more robust to economic uncertainties.

Analysis Gap Table:

Feature/Criteria	Research 1: Contractor Selection (Taiwan)	Research 2: Supplier Selection (Indonesia)	Research Gap
Main Focus	Selecting the main project execution entity (contractor)	Selecting a supplier entity for raw materials and equipment (supplier)	Difference in the operational level of the supply chain (field operations vs. procurement)
Common Key Criteria	Technical expertise, managerial capability, track record of similar projects, overall financial health	Material quality, on-time delivery, supply stability, payment terms	Difference in the weighting between "management capacity" (contractor) and "logistics reliability" (supplier)
Geographic/Industry Context	Taiwan (likely focus on technology or large infrastructure projects)	Indonesia/Tanggerang (emphasis on localization, local relationships and Indonesian specific market risks)	Need to localize the AHP model to take into account the specific economic-political variables of each region
Dynamics and Uncertainty	May have less emphasis on short-term volatility risk.	Stronger need for tools such as Fuzzy AHP due to material and currency market fluctuations in Indonesia.	Gap in modeling uncertainty and market dynamics between the two study regions
Generalizability	High generalizability to developed construction markets with similar standards.	Limited generalizability due to strong company-specific and local conditions.	Gap in the external validity of the model compared to regional models.

1. Conclusion:

These two studies, although both focus on MCDM with the AHP approach in the construction industry, have fundamental differences in operational context and environmental complexity, which create important gaps in the research literature.

1. Limited Knowledge Transfer: The Taiwan study focuses on evaluating contractors (a more comprehensive and strategic entity) with stronger probabilistic criteria in managerial and technical areas. In contrast, the Indonesian study focuses on the supply chain (material suppliers) and is directly affected by logistical risks and short-term market fluctuations in Indonesia. This suggests that AHP models are not easily transferable between different operational areas (contractor vs. supplier) and different geographical regions (Taiwan vs. Indonesia).

2.The importance of localization and uncertainty: The main conclusion is that the effectiveness of AHP in emerging industries or highly volatile markets (such as Indonesia) requires the enhancement of the model with complementary approaches such as Fuzzy AHP or ANP to accurately handle price, currency and supply chain uncertainties. The main gap in this area is the lack of implementation frameworks that can standardly incorporate these local complexities into AHP calculations.

3.Future research opportunities: This comparison highlights the need to develop regional hybrid models. Future research should move away from “generic” criteria and focus on localized operational metrics; for example, for Indonesia, incorporating criteria such as “island transportation capacity” or “adherence to local content regulations” into AHP weighting, and for Taiwan, focusing on modeling innovation and technology risks in contractor selection.

Ultimately, both studies confirm that AHP is a powerful tool for structuring complex decisions, but the success of future models depends on the extent to which local operating environment-specific

mechanisms are understood and integrated into the criteria weighting framework.

#### Resources

1. Selection of Suppliers of Building Materials Using the Analytical Hierarchy Process (AHP) Method at PT. Cipta Nuansa Prima Tangerang
2. APPLYING THE AHP TO SUPPORT THE BEST-VALUE CONTRACTOR SELECTION – LESSONS LEARNED FROM TWO CASE STUDIES IN TAIWAN