Journal of Renewable Engineering
E-ISSN : 3046-7624
https://nawalaeducation.com/index.php/JORE/index
Vol.2.No. 1 February 2025
DOI : https://doi.org/10.62872/17a64y42

Application Of Analytic Hierarchy Process AHP Method In Material Selection For Construction

Warkianto Widjaja[1], Jonggi Harianja.[2], Edison Hatoguan Manurung[3], Suharyanto[4]
Prodi Teknik Industri,Universitas Kebangsaan Republik Indonesia, Indonesia[1], PUPR, Indonesia[2], Universitas MPU Tantular Jakarta, Indonesia [3],

Email : warkiw@yahoo.com

Received: December 31, 2024
Accepted: Feberuary 15, 2025

Revised : January 10, 2025
Published: Februari 28, 2025

ABSTRACT

Material selection in the construction industry is a strategic decision that affects the cost efficiency, durability, and sustainability of a project. This study applies the Analytic Hierarchy Process (AHP) method to determine the best construction material based on four main criteria: mechanical strength, environmental resistance, cost efficiency, and environmental sustainability. The hierarchical structure is built with three levels: material selection objectives, evaluation criteria, and compared material alternatives—namely structural steel, cross-laminated timber (CLT), and reinforced concrete. The assessment uses the Saaty scale (1–9), then the matrix is normalized to obtain priority weights. Consistency tests are carried out by calculating the maximum eigenvalue (λmax), Consistency Index (CI), and Consistency Ratio (CR). The results show that structural steel has the highest weight (0.4888093), making it the best choice compared to CLT and reinforced concrete. This study confirms that the AHP method is able to reduce subjectivity in decision making with a data-driven approach. Integration with technologies such as Building Information Modeling (BIM) and Artificial Intelligence (AI) can improve the accuracy of the analysis. Thus, this method can be a solution in selecting construction materials that are more systematic and sustainable.

Keywords: Analytic Hierarchy Process (AHP), construction materials, structural steel, data-driven decisions, sustainability

INTRODUCTION

In the construction industry, material selection is not just a technical aspect, but also a strategic decision that has an impact on cost efficiency, project sustainability, and infrastructure durability. According to research by Gusty et al (2024), inappropriate material selection can increase the risk of structural failure, accelerate building degradation, and waste resources. Factors such as price, durability, and sustainability must be considered comprehensively in order to produce a balanced decision between quality and economic efficiency. Therefore, a systematic method is needed to evaluate and compare various material options to avoid decision-making based solely on intuition or experience.

Furthermore, effective material selection also has a direct impact on sustainability and environmental aspects. According to a study by Lee et al (2020) in Materials for Sustainable Construction, materials with high energy efficiency and low carbon emission levels are increasingly becoming a priority in sustainable development. In addition, safety and comfort factors are also major concerns, considering that poor materials can cause structural instability and endanger building users. With the increasing complexity of modern construction projects, data-driven approaches such as the Analytic Hierarchy Process (AHP) are effective tools in establishing a hierarchy of material selection criteria, resulting in more objective and evidence-based decisions.

However, in its implementation, the AHP method also has its own challenges, especially in the subjectivity of the assessment that can affect the final results. According to Chen's research (2020), although AHP offers a systematic comparison structure, the weight given to each criterion still depends on the preferences of the individuals or groups involved in the decision-making process. This can lead to inconsistencies in the assessment, especially if there is no clear standard in determining the weight between criteria. Therefore, validation of the results through sensitivity analysis is needed to ensure that the decisions taken remain consistent even though there are changes in initial preferences.

In addition, the effectiveness of AHP in selecting construction materials also depends on the quality of the data used. According to Firoozi et al (2024), accurate decision making requires empirical data that reflects real conditions in the field, such as material resistance to environmental factors and the availability of raw materials in the market. Without reliable data, AHP can produce biased decisions that are less relevant to the needs of the construction project. Therefore, the integration of AHP with other methods, such as Life Cycle Assessment (LCA) to assess environmental impacts or Cost-Benefit Analysis (CBA) to evaluate economic efficiency, is a crucial step in improving the accuracy and effectiveness of construction material selection holistically.

To overcome the limitations of subjectivity in the AHP method, a more comprehensive data-based approach is needed. According to Amrulloh (2024) the combination of AHP with other data-based methods, such as Fuzzy AHP or Delphi Method, can increase the validity of the results by reducing subjective bias from decision makers. In the context of selecting construction materials, the use of this technique allows the calculation of criteria weights based on more structured historical data or expert opinions (Syarfi, 2018). Thus, the resulting decisions are not only more objective, but also more adaptive to changes in industry conditions and increasingly stringent construction regulations.

Furthermore, the integration of AHP with digital technologies such as Building Information Modeling (BIM) and artificial intelligence (AI) is a progressive step in increasing the effectiveness of material selection analysis. BIM, as explained by Aladeyleh & Aladaileh (2024) can provide real-time data on materials, including technical performance and environmental impact, thereby minimizing the risk of selecting inappropriate materials. Meanwhile, AI can be used to process big data to identify patterns in material selection based on previous projects. With this approach, the AHP method is no longer just a static analysis tool, but can be transformed into a dynamic and evidence-based decision-making system, which is able to answer complex challenges in modern construction (Rai, 2022).

The selection of strong construction materials is a crucial aspect in the planning and implementation of building projects, considering factors such as structural strength, service life, and cost efficiency (Napitupulu et al., 2025; Fernando et al., 2025). The selected materials must be able to withstand structural loads, extreme weather, and environmental degradation to ensure the safety and sustainability of the building in the long term. Based on research by Imran (2018), the ideal material for construction must have a balance between mechanical strength, corrosion resistance, and ease of manufacturing and installation processes. Therefore, material selection must be carried out systematically by considering various technical and economic parameters to achieve optimal results.

In this context, there are several main criteria used in selecting strong construction materials. First, mechanical strength, which includes resistance to pressure, tension, and shear, so that the material is able to withstand the expected structural load. Second, environmental resistance, which includes resistance to corrosion, temperature changes, and high humidity so that the material is not easily degraded. Third, cost efficiency, which includes material prices, transportation costs, and ease of installation and maintenance. Fourth, environmental sustainability, namely the extent to which the material has a low environmental impact, including resource sustainability and ease of recycling. Based on these criteria, some materials that can be used in construction are reinforced concrete, which has high compressive strength; structural steel, which excels in tensile strength and flexibility; and cross-laminated timber (CLT), which offers high mechanical strength with a lower environmental impact. By considering these materials, construction selection can be done more objectively and based on data, resulting in stronger, more durable, and more economical buildings (Oktavia et al., 2019; Bate'e et al., 2024).

METHOD

The Analytic Hierarchy Process (AHP) method is applied to determine the best construction material based on key criteria such as mechanical strength, environmental resistance, cost efficiency, environmental sustainability (Farhan, 2024). This process begins with the preparation of a hierarchical structure, where the first level is the purpose of material selection, the second level contains the evaluation criteria, and the third level includes alternative materials to be compared (Noviani et al., 2021). Furthermore, structural steel, cross-laminated timber (CLT), reinforced concrete are arranged using the Saaty scale (1–9) to assess the relative importance between criteria.

After that, the matrix is normalized by summing each column and dividing each element by the total of its columns, so that the priority weight is obtained. To ensure valid results, a consistency test is carried out by calculating the maximum eigenvalue (λmax), then determining the Consistency Index (CI) using the formula:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Next, the Consistency Ratio (CR) is calculated by comparing the CI to the Random Index (RI). If CR <0.1, then the analysis results are considered consistent. The material alternative with the highest priority value is then selected as the best option for the construction project. This AHP method ensures that material selection is carried out systematically and based on data, reducing subjectivity in decision making.

RESULT AND DISCUSSION

The following are the results of data processing that has been carried out in the selection of construction materials.

Comparison of Average Criteria Matrix

Criteria	Mechanical Strength	Environmental Resistance	Price Efficiency	Environmental Sustainability
Mechanical Strength	1	3.28	4.40	1.05
Environmental Resistance	0.30	1	3.70	1.00
Price Efficiency	0.23	0.27	1	0.42

Environmental Sustainability	0.95	1.00	2.39	1
Amount	2.48	5.55	11.49	3.47

Average Comparison Average Comparison of Mechanical Strength Criteria

Alternative	Structural Steel	**Cross Laminated Wood**	Reinforced concrete
Structural Steel	1	1.46	2.78
Cross Laminated Wood	0.69	1	3.63
Reinforced concrete	0.36	0.28	1
Amount	2.05	2.73	7.41

Average Comparison Average Comparison of Environmental Resistance Criteria

Alternative	Structural Steel	Cross Laminated Wood	Reinforced concrete
Structural Steel	1	1.27	2.93
Cross Laminated Wood	0.79	1	2.14
Reinforced concrete	0.34	0.47	1
Amount	2.13	2.74	6.07

Average Comparison Average Comparison CriteriaPrice Efficiency

Alternative	Structural Steel	Cross Laminated Wood	Reinforced concrete
Structural Steel	1	2.11	3.56
Cross Laminated Wood	0.47	1	2.44
Reinforced concrete	0.28	0.41	1
Amount	1.75	3.53	7.00

Average Comparison Average Comparison of Environmental Sustainability Criteria

Alternative	Structural Steel	Cross Laminated Wood	Reinforced concrete
Structural Steel	1	1.64	3.14
Cross Laminated Wood	0.61	1	2.10
Reinforced concrete	0.32	0.48	1
Amount	1.93	3.12	6.24

The following is a consistency calculation to find the CI and CR values:

a. Based on the table, the largest eigenvalue (λ max) is obtained as follows:
   λ max = (average eigenvalue)
   = ((4.35709+4.129899+4.08104+4.154148)/4)
   = 4.180544336
   Because the matrix is of order 4, the consistency index (CI) value is as follows: CI = (λmaks−n) / (n−1)
   = (4.180544336-4) / (4-1)
   = 0.060181445
   Because n=4, the RI value = 0.9 (according to the Random Consistency Index table) so that the Consistency Ratio value is obtained as follows:
   CR = CI / RI
   = 0.060181445 / 0.9

= 0.066868273

The CR value obtained is 6.6868273%, because CR < 10% then the results of the assessment and calculation of pairwise comparisons in the matrix between criteria are consistent and acceptable.

b. Based on the table, the largest eigenvalue (λ max) is obtained as follows:
λ max = (average eigenvalue)
= ((3.061271+3.059023+3.018416)/3)
= 3.046236584
Because the matrix is of order 3, the consistency index (CI) value is as follows: CI = (λmaks−n) / (n−1)
= (3.046236584-3) / (3-1)
= 0.023118292
Because n=3, the RI value = 0.58 (according to the Random Consistency Index table) so that the Consistency Ratio value is obtained as follows:
CR = CI / RI
= 0.023118292/ 0.58
= 0.039859124
The CR value obtained is 3.9859124%, because CR < 10% then the results of the assessment and calculation of pairwise comparisons in the criteria matrixMechanical Strengthbetween alternatives are consistent and acceptable.

c. Based on the table, the largest eigenvalue (λ max) is obtained as follows:
λ max = (average eigenvalue)
= ((3.000765+3.00058+3.000267)/3)
= 3.000537638
Because the matrix is of order 3, the consistency index (CI) value is as follows: CI = (λmaks−n) / (n−1)
= (3.000537638-3) / (3-1)
= 0.000268819
Because n=3, the RI value = 0.58 (according to the Random Consistency Index table) so that the Consistency Ratio value is obtained as follows:
CR = CI / RI
= 0.000268819/ 0.58
= 0.000463481
The CR value obtained is 0.0463481%, because CR < 10% then the results of the assessment and calculation of paired comparisons in the criteria matrixEnvironmental Resistancebetween alternatives are consistent and acceptable.

d. Based on the table, the largest eigenvalue (λ max) is obtained as follows:
λ max = (average eigenvalue)
= ((3.0252+3.014438+3.00616)/3)
= 3.015266021
Because the matrix is of order 3, the consistency index (CI) value is as follows: CI = (λmaks−n) / (n−1)
= (3.015266021-3) / (3-1)
= 0.00763301
Because n=3, the RI value = 0.58 (according to the Random Consistency Index table) so that the Consistency Ratio value is obtained as follows:
CR = CI / RI
= 0.00763301/ 0.58
= 0.013160363
The CR value obtained is 1.3160363%, because CR < 10% then the results of the assessment and calculation of pairwise comparisons in the criteria matrixPrice Efficiencybetween alternatives are consistent and acceptable. Based on the table, the largest eigenvalue (λ max) is obtained as follows: λ max = (average

eigenvalue)

= ((3.001474+3.00094+3.000455)/3)

= 3.000956291

Because the matrix is of order 3, the consistency index (CI) value is as follows: CI = (λmaks−n) / (n−1)

= (3.000956291-3) / (3-1)

= 0.000478145

Because n=3, the RI value = 0.58 (according to the Random Consistency Index table) so that the Consistency Ratio value is obtained as follows:

CR = CI / RI

= 0.000478145/ 0.58

= 0.000824389

The CR value obtained is 0.0824389%, because CR < 10% then the results of the assessment and calculation of pairwise comparisons in the criteria matrixEnvironmental Sustainabilitybetween alternatives are consistent and acceptable.

The next step is to determine the calculation for decision making by multiplying the priority weights in the normalization table by the existing criteria weights.

Priority Weights in Criteria Matrix

So the following results are obtained:

Criteria / Alternative	Mechanical Strength	Environmental Resistance	Price Efficiency	Environmental Sustainability	Amount	Priority weight
Structural Steel	0.47	0.47	0.56	0.52	0.47	0.47
Cross Laminated Wood	0.40	0.36	0.30	0.32	0.40	0.36
Reinforced concrete	0.14	0.17	0.14	0.16	0.14	0.17

X

Criteria weight
0.42
0.23
0.09
0.26

Alternative	**Total weight of alternatives**	**Priority**
Structural Steel	0.49	**I**
Cross Laminated Wood	0.36	**II**
Reinforced concrete	0.15	**III**

Based on calculations using the AHP method with a total of 67 respondents, it was stated that the alternative for selecting good construction materials is structural steel.

CONCLUSION

Based on the results and discussions that have been carried out, it can be concluded that in determining the selection of construction materials with four assessment criteria including mechanical strength, environmental resistance, cost efficiency and environmental sustainability with a total of 67 respondents, namelyStructural Steelbecause the calculation results state thatStructural Steelhas the highest ranking compared to cross-laminated timber (CLT) and reinforced concrete. The calculation results obtained on the traveloka application are 0.4888093 using the Analysis Hierarchy Process (AHP) method so that it can be an alternative in selecting construction materials.

REFERENCES

Aladayleh, K. J., & Aladaileh, M. J. (2024). Applying Analytical Hierarchy Process (AHP) to BIM-Based Risk Management for Optimal Performance in Construction Projects. Buildings, 14(11), 3632.

Amrulloh, I. H. (2024). Implementasi fuzzy analytical hierarchy process (F-AHP) dalam sistem pendukung keputusan penentuan kelas (Doctoral dissertation, Universitas Islam Negeri Maulana Malik Ibrahim).

Bate'e, E. K., Laoli, E. S., Zebua, D., Halawa, I. H., Ziliwu, P. I. A. P., Halawa, S. J., & Lase, F. (2024). Aplikasi teknik statistik dalam evaluasi kinerja material konstruksi di berbagai kondisi lingkungan. Jurnal Ilmu Ekonomi, Pendidikan dan Teknik, 1(1), 48-56.

Chen, C. H. (2020). A novel multi-criteria decision-making model for building material supplier selection based on entropy-AHP weighted TOPSIS. Entropy, 22(2), 259.

Farhan, M. (2024). Keseimbangan Risiko dan Imbal Hasil Dalam Strategi Investasi Berkelanjutan: Pendekatan Integratif Terhadap Faktor Lingkungan, Sosial, dan Tata Kelola Perusahaan (ESG). Currency: Jurnal Ekonomi dan Perbankan Syariah, 2(2), 243-264.

Fernando, R., Sulaiman, L., Raditya, R., Taurano, G. A., & Hakim, T. (2025). EVALUASI KEKUATAN BETON MUTU TINGGI DENGAN MENGGUNAKAN KOMBINASI FLY ASH DAN SILICA FUME SEBAGAI SUBTITUSI SEMEN. Orbith: Majalah Ilmiah Pengembangan Rekayasa dan Sosial, 20(3), 245-255.

Firoozi, A. A., Firoozi, A. A., Oyejobi, D. O., Avudaiappan, S., & Flores, E. S. (2024). Emerging trends in sustainable building materials: Technological innovations, enhanced performance, and future directions. Results in Engineering, 103521.

Gusty, S., Asriadi, M., Idrus, M., Iswady, I., Muslika, M., Yoom, L. I., ... & Putri, M. M. (2024). Korosi dan Perlindungan Material.

Imran, M. (2018). Material Konstruksi Ramah Lingkungan Dengan Penerapan Teknologi Tepat Guna. Radial, 6(2), 146-157.

Lee, D., Lee, D., Lee, M., Kim, M., & Kim, T. (2020). Analytic hierarchy process-based construction material selection for performance improvement of building construction: The case of a concrete system form. Materials, 13(7), 1738.

Napitupulu, A., Saputra, A., & Siburian, M. T. (2025). Rekayasa Teknologi Konstruksi dan Manufaktur: Optimalisasi Material dan Strategi Teknikal dalam Infrastruktur Sumatera Utara. ELASTICITY: Journal of Applied Engineering Science, 2(1), 01-11.

Noviani, D., Lasalewo, T., & Lahay, I. H. (2021). Pengukuran Kinerja Supplier Menggunakan Metode Analitycal Hierarchy Process (AHP) di PT. Harvest Gorontalo Indonesia. Jambura Industrial Review (JIREV), 1(2), 83-93.

Oktavia, C. W., Nathalia, C., & Tjhong, S. G. (2019). Pendekatan metode interpretive structural modeling dalam penentuan kriteria kunci pemilihan supplier pada perusahaan konstruksi. Jurnal Tiarsie, 16(3), 100-106.

Rai, N. B. (2022). Strategic decision making: applying the analytic hierarchy process (decision engineering).

Syarfi, R. G. (2018). Pemilihan Logistic Hub Barang Impor Untuk Industri Hulu Minyak Dan Gas Dengan Menggunakan Metode AHP (Doctoral dissertation, Institut Teknologi Sepuluh Nopember)..