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Analysis of Sand Material Selection for Making Concrete at Ready-Mixed Concrete Suppliers in Lombok Island

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Abstract. Lombok Island is experiencing an increase in demand for construction materials in line with the development of national strategic projects. One of the main materials in ready-mix concrete production is sand, the quality of which significantly affects the quality of the concrete. This study aims to analyze the weighting of criteria and sub-criteria and determine the best sand alternative. The method used combines the Analytical Network Process (ANP) to determine the importance of criteria and sub-criteria, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to determine the ranking of mining alternatives. The results are then adjusted for laboratory testing. The results of the criteria weighting using the ANP method show that the mining permit carries the highest weighting at 45%, followed by quality (44%), price (5.1%), and delivery (5%). Meanwhile, for the sub-criteria weighting, mining legality (IUP) is the most dominant with a weighting of 39%, followed by mud content at 31%. Based on the TOPSIS method, sand from the Aikmel mine ranks highest, followed by Korleko, Kalijaga, Aik Dalem, and Pengadangan. Meanwhile, the Tampes mine ranks last. These results are consistent with laboratory testing, where the Aikmel area demonstrated mud content, gradation, and specific gravity that met standards, while the Tampes area failed to meet the required technical criteria. However, there are discrepancies between the TOPSIS ranking results and laboratory testing results at the other three mines, indicating other factors such as legality and price. The results are expected to serve as a practical reference for the construction industry in improving concrete quality and material selection efficiency.

Introduction

The increasing use of ready-mix concrete has directly impacted the use of sand as a primary ingredient, the quality and availability of which significantly impact concrete quality. One of the main challenges in the sand material selection process on Lombok Island is the high silt content of most local sand sources. Research results show that the average silt sand content in the area is 4.8% [1]. In addition, in terms of quality, according to research, the mineral composition of Lombok Island sand varies significantly depending on the extraction location [2]. Petrographic analysis has identified a variety of mineral types, such as calcite and lithic fragments. Its grain size varies from very fine to very coarse, which will affect its mechanical properties, such as the compressive and tensile strength of the resulting concrete.

The general perception of price and quality of building materials is often the most important factor in the decision-making process. Yet, each individual or institution has various criteria or other factors that form the basis for decision-making. Therefore, a specific study is needed to analyze sand material selection at ready-mix concrete companies on Lombok Island using a comprehensive scientific approach.

Price is identified as one of six important criteria in selecting a supplier, along with quality, product timeliness, delivery, warranty policy, and responsiveness to claims[3]. Sand quality has a significant impact on the compressive strength and durability of concrete; good sand should have the appropriate gradation, be free from organic matter, and have a low silt content. Based on research shows that sand with a mud content of 5.4% produces a concrete compressive strength of 17.2 MPa, while sand with a mud content of 7% and 7.9% produces a concrete compressive strength of 12.5 MPa and 12.4 MPa, respectively[4]. In addition, it is important to choose a sand supplier that has an official permit to support sustainable construction practices.

Considering these various factors, the analysis of sand material selection using the Multi-Criteria Decision Making (MCDM) method becomes very relevant. The MCDM method is one way to select the best option from several choices based on various criteria. Two approaches frequently used in MCDA are ANP and TOPSIS. The ANP method allows for complex relationships between elements of a system, including dependencies and feedback between these elements [5]. ANP is implemented as an approach to address complex problems through a synthesis mechanism that considers several factors simultaneously, with priority scale determination to find the greatest influence among available alternatives. This approach allows for more informed decision-making because it considers the interconnections and dependencies between system elements. As for TOPSIS, the basic principle of this method is that the best alternative must have the closest distance from the positive ideal solution (PIS) and the furthest distance from the negative ideal solution (NIS) [6]. Conducted research on the selection of suppliers of raw sand for the concrete industry using the AHP and TOPSIS integration methods [7]. The research showed that quality had the highest weighting (0.29) as the main criterion, while the sub-criterion of company cooperation history received the highest weighting (0.56). The best supplier with the highest preference value was PT TTJ with a score of 0.69.

This study aims to analyze the weighting of each criterion against the types of sand obtained from several quarries. This will then determine the most optimal sand alternative for use in construction based on the criteria and sub-criteria. The results of the two alternative selection methods will then be analyzed using laboratory testing.

The use of ANP is considered appropriate because it accommodates the interdependence between criteria, allowing for comprehensive consideration of every aspect affecting sand quality. Meanwhile, TOPSIS allows for more objective decision-making by comparing alternatives to both positive and negative ideal solutions, resulting in a ranking of sand materials that best meet construction needs. Thus, this study makes a unique contribution by providing a systematic and comprehensive evaluation framework for sand material selection, particularly for ready-mix suppliers on Lombok Island. The results are expected to serve as a practical reference for the construction industry in improving concrete quality and material selection efficiency.

Method

Data collection. In this stage, two surveys were conducted to support the accuracy of the selection of sand. The first survey aims to obtain primary data related to criteria, subcriteria, and alternative types of sand commonly used on Lombok Island. The criteria used include prices, quality, mining permits, and shipping, with subcriteria such as transportation, mud content, gradation, specific gravity, legality, delay, and accuracy of volume. Alternative quarry locations analyzed are Aikmel, Kalijaga, Borem, Aik Dalem, Tampes, and Korleko.

The second survey was conducted more thoroughly through observation, interviews with experts (ready mix people), as well as the distribution of questionnaires, both online and offline. The aim is to verify the structure of ANP and obtain comparative data in pairs. The results of this survey strengthen the weight of the criteria used and ensure that the final decision reflects practical and scientific views. Expert respondents come from three ready mix suppliers: PT. Utama Beton Perkasa, Damai Indah Utama (Diu) Concrete, and PT. Tunas Jaya Sanur (SJU).

Data processing. The ANP model is structured by placing the main objective at the first level, criteria and sub-criteria at the second level, and alternative sand types at the third level. This model allows for reciprocal relationships (feedback) between elements. This ANP network structure is an important basis for developing a pairwise comparison questionnaire, which will be used to measure the relative importance of each element in the network. The pairwise comparison questionnaire was created using

SuperDecision 2.10 software. It is important to ensure that respondents' answers are logically consistent. Therefore, Super Decisions automatically calculates the Consistency Ratio. If the CR value is below 0.1 (or 10%), then the assessment is considered consistent and can be used for the next process. However, if the CR value is ≥ 0.1, then respondents will be asked to clarify or revise their assessment. The fundamental scale commonly used in ANP can be seen in **Table 1** of the fundamental assessment scale in ANP. The table includes levels of importance intensity from 1-9.

After the priority weight of each criterion is obtained through the ANP method, the next step is to evaluate the available alternatives based on these weights using the TOPSIS method. The data processing process is carried out with the help of Microsoft Excel. The initial step in this method is to distribute the TOPSIS questionnaire to respondents/experts, to provide an assessment of the 6 alternatives that are the object of the study. The assessment is given using a scale of 1-5, where: 1 = Very Poor, 2 = Poor, 3 = Fairly Good, 4 = Good, and 5 = Very Good. After all respondents provide an assessment, the next step is to calculate the average value of all respondents. This average value is used to determine the score of each Alternative and evaluate its performance level.

Table 1. Fundamental Assessment Scale in ANP

Intensity of Interest	Definition	Explanation
1	Real Importance	Both elements have the same effect
2	Weak Slight	Values between scales 1 and 3
3	Moderate Importance	One of the elements is slightly more important than the others
4	Moderate Plus	Scores between 3 and 5
5	Strong importance	One element is clearly more mportant than its partner
6	Strong plus	Scores between 5 and 7 on a scale
7	Very strong or demonstrated importance	One element is absolutely more important than the other elements
8	Very, very strong	Scores between 7 and 9 on a scale
9	Extra importance	One element is absolutely more important than the other elements

The results of this comparison are used to automatically calculate local and global eigenvectors, thus obtaining the priority weights for each element. To ensure logical consistency of the assessment, SuperDecisions also calculates a consistency ratio (CR), where a CR value ≤ 0.1 indicates acceptable consistency. After all data is processed, the software presents global alternative priorities based on the influence of all criteria and sub-criteria. The TOPSIS method begins by creating a decision matrix containing the assessment of each alternative against each criterion. The next step is to normalize the decision matrix to eliminate scale differences between criteria, so that all values are in comparable units. After the normalization process, these values are multiplied by the weights of each criterion to produce a weighted normalized matrix. From this matrix, positive and negative ideal solutions are determined, which represent the best and worst values for each criterion. Then, the distance of each alternative to the positive and negative ideal solutions is calculated using the Euclidean method. The preference value or proximity coefficient of each alternative is calculated based on the ratio between the distance to the negative solution and the total distance to both ideal solutions. The higher the proximity coefficient value, the better the alternative. Finally, the alternatives are ranked based on these preference values to determine the best choice.

Results and Discussion

Network Model. This network model was built using Super Decisions software version 2.10, which supports visualization and structured mathematical calculations. ANP allows for complex interrelationships among the elements of a system, including dependencies and feedback between them, thus enabling the identification of interrelated sub-criteria within the model both within the same group (inner dependence) and across different groups (outer dependence).

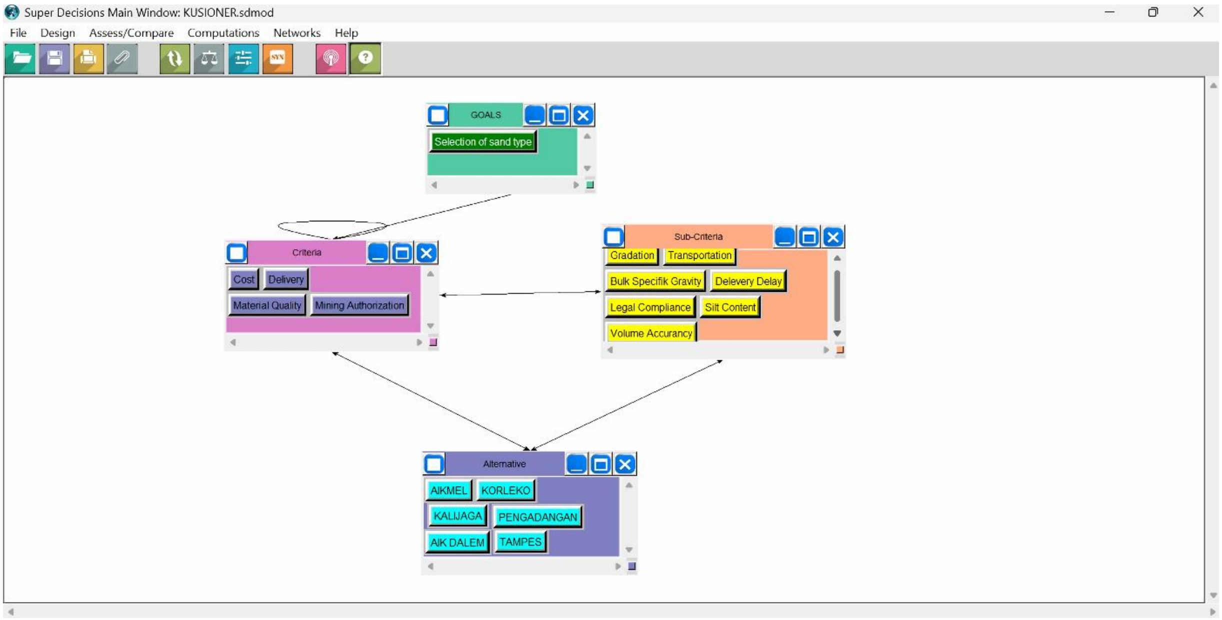

Fig. 1. ANP Network Model

Criteria Aspects. The criteria compared here are quality, mining permits, price, and delivery. The results are shown in the following figure:

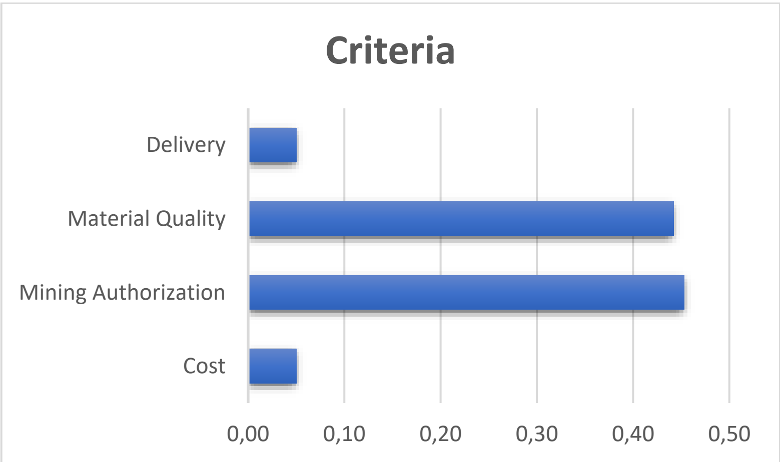

Fig. 2. Results of Criteria Aspect Data Processing

Based on the results of data processing using the ANP method, priority weights were obtained for each criterion that influences the selection of sand material. The visualization of the weighting results is shown in **Fig. 2**. From the graph, it can be seen that quality and mining permits are the two criteria with the most dominant weights, each approaching 0.45 or around 45% of the total weight. This indicates that, according to experts, technical aspects of sand, such as gradation, mud content, and legality of origin of the mine (IUP), are the main considerations in the decision-making process. Meanwhile, delivery and price criteria show much lower weights, each only around 5–6%. The low weight of price indicates a paradigm shift that quality and legality are more important to ensure the quality and sustainability of construction projects, rather than simply short-term cost efficiency.

To assess the level of agreement between the respondents' or experts' answers, a test was conducted using Kendall's Coefficient of Concordance (W; $0 < W \leq 1$). If the W value reaches 1 ($W = 1$), this indicates that there is full agreement between the respondents' assessments. Conversely, if the W value is at or close to 0, this indicates a low level of agreement or significant variation in the respondents' assessments. In this study, the value of the coefficient of agreement (W) obtained for the analyzed criteria was 0.8222, which indicates that the level of agreement between respondents' answers is included in the fairly high category.

Sub-Criteria Aspects. In each criteria, there are several sub-criteria where the results of the data processing can be seen in **Fig. 3**, the results of data processing for the sub-criteria.

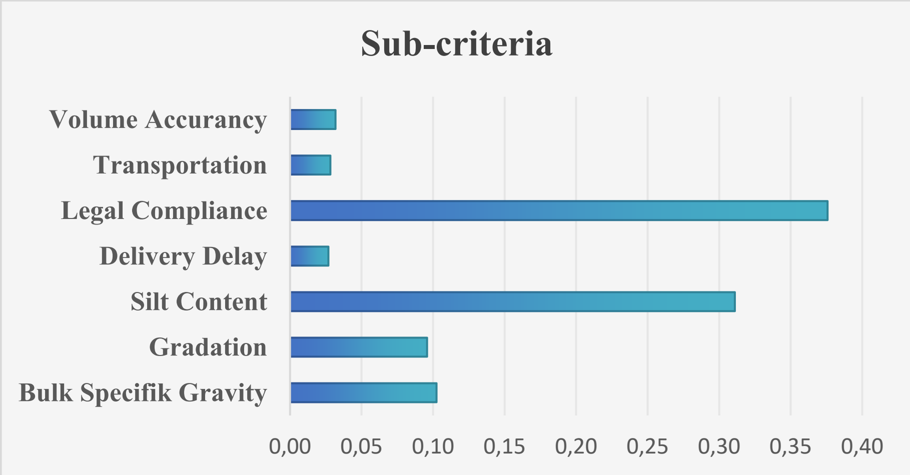

Fig. 3. Results of Data Processing for Sub-Criteria Aspects

Based on the weighting diagram for each sub-criterion influencing the selection of sand material, the legality sub-criterion (IUP) emerged as the most dominant element with a weight approaching 0.39 or around 39%. The next sub-criterion with a high weight is mud content, which obtained a weight of around 0.31. High mud content is known to reduce the compressive strength and durability of concrete, making it a highly regarded quality indicator. Meanwhile, other sub-criteria, such as gradation and specific gravity, have relatively lower weights, ranging from 0.09 to 0.10, indicating that although influential, their role is not as large as the previous two aspects. The sub-criteria of transportation, delay, and volume accuracy occupy the lowest weight positions, below 0.05, which means their influence is considered small in the context of decision-making by practitioners in the field.

Alternative Priority Order. After obtaining the weights for each criterion and sub-criterion using the ANP method, the next step is to rank each alternative using the TOPSIS method. The final results of this calculation are presented in **Table 2**, which presents the ranking order of each location or alternative based on its relative proximity value.

Table 2. Results of Relative Proximity Calculations

Alternative	Preference (V)	Rank
Aik Dalem	0,4531	4
Aikmel	0,6816	1
Kalijaga	0,5945	3
Korleko	0,6122	2
Pengadangan	0,3859	5
Tampes	0,3442	6

Table 2 shows the ranking of sand alternatives based on the TOPSIS calculation results, which illustrates the Closeness Coefficient (Ci) value of each alternative to the ideal solution. This value indicates how close the alternative is to the best ideal condition based on predetermined criteria (price, quality, legality, and delivery). Based on the table, it can be observed that Aikmel obtained the highest score among all alternatives, with a closeness coefficient approaching 0.65. This indicates that sand from the Aikmel location is the option closest to the ideal solution. The Ci values of Pengadangan and Tampes are below 0.40, indicating that these two alternatives are relatively far from the ideal

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solution. These low scores are most likely influenced by substandard sand quality, such as high mud content or poor gradation distribution, as well as mining legal factors that do not meet the criteria.

Laboratory Test Results

Fine Aggregate Gradation. Fine aggregate gradation is a critical parameter affecting the workability, density, and strength of concrete. In this study, gradation testing was conducted on each sand sample from each quarry location to determine the fine aggregate grain size distribution. The testing process was conducted through sieve analysis in accordance with SNI standards, and the results were used to determine the gradation zones and the sand's suitability to the required specifications. The complete gradation test results are presented in **Table 3** recapitulation of fine aggregate gradation results.

Table 3. Recapitulation of Fine Aggregate Gradation Results

No	Quarry	MHB	Grading Region
1	Aikmel	4,022	II
2	Tampes	2,337	I
3	Kalijaga	4,160	I
4	Aik Dalem	3,794	II
5	Pengadangan	4,382	I
6	Korleko	3,801	II

Specific Gravity of Fine Aggregate. In this study, the physical properties of sand were tested, including specific gravity in saturated surface dry (SSD) conditions, dry specific gravity, and water absorption rates from six different quarry locations. The tests were conducted using the methods listed in SNI 03–1970–2008, with a soaking procedure of 15 to 24 hours. The calculation results for the six sand samples can be seen in **Table 4**, Summary of Sand Specific Gravity Calculation Results.

Table 4. Summary of Sand Specific Gravity Calculation Results

No	Quarry	SSD Specific Gravity (g)	Oven-dry Specific Gravity	Absorption (%)
1	Aikmel	2,530	2,414	4,821
2	Tampes	2,779	2,615	6,290
3	Kalijaga	2,480	2,347	5,654
4	Aik Dalem	2,895	2,763	4,783
5	Pengadangan	2,895	2,770	4,490
6	Korleko	2,297	2,179	5,422
Standard		2,5-2,7	≥2,5	Max 5%

Test results showed that sand from the Aikmel quarry had a specific gravity (SSD) of 2.530, while the Aik Dalem and Pengadangan quarries recorded a relatively high value of 2.895. Based on literature and standard requirements, the ideal range for bulk specific gravity under SSD conditions for fine aggregate is between 2,5 and 2,7. Therefore, only the sand from the Aikmel quarry fell within this standard range, while the sand from the Aik Dalem and Pengadangan quarries was considered denser than the ideal value. On the other hand, the Korleko quarry showed a low SSD specific gravity of 2,297, indicating a relatively low density. For dry specific gravity, which is required to be ≥ 2,5, only the sand from the Aikmel and Aik Dalem quarries met this criterion.

Table 5. Summary of Sludge Content Calculation Results

No	Quarry	Silt Content (%)
1	Aikmel	4,560
2	Tampes	5,567
3	Kalijaga	4,320

4	Aik Dalem	3,737
5	Pengadangan	3,740
6	Koreleko	5,893

Silt content. The silt content in fine aggregate is a determining factor in concrete quality, as fine particles like silt can disrupt the bond between cement and aggregate. Silt levels exceeding the threshold can reduce concrete strength and inhibit the hydration process. The results of silt content testing at each quarry are shown in **Table 5**.

Laboratory tests on sand samples taken from six different quarries in the Lombok Island region revealed an average silt content of 4.63%. This figure indicates that most of the sand samples are close to the maximum permissible limit in the national technical standard, which is 5% as stated in SNI 03-2834-2000. When compared with the results of previous studies, which recorded an average silt content of 4.8%, the findings in this study indicate a consistent pattern. Both studies indicate that local sand on Lombok Island tends to have a fairly high content of fine particles (mud or silt), which can affect the quality and performance of concrete if not handled properly.

Conclusion

The analysis results show that in selecting sand as a raw material for concrete on Lombok Island, mining permit (legality) and technical quality are the most dominant factors. Meanwhile, the sub-criteria of mining legality (IUP) and silt content are the primary determinants, indicating that legal compliance and the physical quality of the sand significantly influence the selection decision. Based on the TOPSIS method, Aikmel sand is the best alternative, supported by good technical quality, despite being within the maximum silt and absorption thresholds. Conversely, Tampes sand is ranked lowest due to its low technical quality. For ready-mix concrete suppliers on Lombok Island, these results have important practical implications: prioritizing sand that not only possesses good technical quality but also meets the required legal requirements. Sand with clear legality and controlled quality will be more readily accepted in construction projects, minimizing legal risks and quality failures in the field. Furthermore, discrepancies such as those encountered with Aik Dalem sand demonstrate that selection decisions cannot be based solely on a single technical parameter, but require a comprehensive consideration of all factors, including price and legality. Therefore, this ANP-TOPSIS-based approach can be an effective decision-making tool for suppliers in selecting the most technically and administratively feasible sand material.

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