A Fuzzy AHP-Based Framework for Performance Assessment and Evaluation of Ready-Mix Concrete Suppliers

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Abstract

The Jakarta–Cikampek II Selatan Toll Road Construction Project Package IIB is part of a National Strategic Project that plays a significant role in enhancing regional connectivity and supporting economic growth. In its implementation, one of the major work items that significantly influences project progress is the procurement of ready-mix concrete. Supply failures by appointed vendors, such as delivery delays by PT XXX, have disrupted project schedules and resulted in financial losses for the project contractor consortium, namely KSO PT Adhi Karya (Persero) Tbk – PT Acset Indonusa. This study aims to develop an evaluation model for ready-mix vendor selection using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method as an effort to minimize the risk of recurring supply failures in future projects. The Fuzzy AHP method was selected because it is capable of accommodating uncertainty and subjectivity in the decision-making process through the use of fuzzy numbers, which cannot be effectively addressed by the conventional AHP method. The study identified several key criteria for vendor selection based on a literature review and project-specific conditions, including price, concrete quality, delivery punctuality, batching plant production capacity, regulatory compliance, quality certification, and continuity supply assurance. Data were collected through questionnaires distributed to experts and project practitioners and subsequently analyzed using the Fuzzy AHP method to determine the priority weights of each criterion and establish vendor rankings. and price (3.2%).The proposed model provides an objective and systematic basis for the main contractor in selecting the most suitable ready-mix concrete vendor and contributes to improving the effectiveness of material procurement processes in large-scale construction projects.

1. Introduction

The construction industry is highly dependent on the availability of materials of the right quality, the right quantity, and the right time. One of the main materials that has a significant influence on the success of a project is ready-mix concrete. Delays in supply, concrete quality that does not meet specifications, or administrative discrepancies from suppliers can cause decreased productivity, cost overruns, and delays in project completion. Ready Mix Concrete (RMC) is ready-mix concrete produced in a batching plant and transported using a mixer truck to the project site. Unlike manual concrete mixed on site, ready mix concrete guarantees more consistent quality because the mixing process is carried out in a measured and controlled manner. This type of concrete is widely used in large-scale construction projects such as high-rise buildings, toll roads, bridges, and other infrastructure because of its time efficiency and guaranteed quality, one example is the Jakarta - Cikampek II Selatan Toll Road Construction Project Package IIB Sukaragam - Bojongmangu Section (STA 17 + 750 - STA 30 + 750).

The Jakarta - Cikampek II South Toll Road Construction Project Package IIB Sukaragam - Bojongmangu Section (STA 17 + 750 - STA 30 + 750) has a scope of work for the Construction of a 13 Km Toll Road and the Construction of the Sukaragam and Mulyasejati Interchanges located in Bekasi, West Java where the Toll Road uses Rigid specifications using Ready Mix Concrete materials requiring a supply of Ready Mix concrete with a total volume of 306,520 m^3 consisting of several concrete quality classes with a total value of the Ready Mix procurement contract of Rp.242,491,387,287-,. The large amount of this need makes the process of selecting a ready mix vendor an important factor in ensuring the smooth implementation of the project. With this data as a reference basis for the KSO PT. Adhi Karya (Persero) Tbk. - PT. Acset Indonusa for the procurement of Ready Mix concrete materials.

During the project implementation period, there were several incidents where PT.XXX as the appointed party for the readymix material supply vendor had several times not supplied the material that should have been scheduled by the PT.XXX production team. This disrupted the work schedule and caused financial losses to the KSO PT. Adhi Karya (Persero) Tbk. - PT. Acset Indonusa. The table detailing the schedule shifts is attached as below:

Table 1. Schedule Table of Planned and Actual Supply of Readymix Concrete Materials

No	Spec Description	Units	Volume	Location	Supply Plan	Supply Actualization	Day Deviation	Lost Cost
1	Fc 30' Mpa/Class	m3	250	Zona 1	05- Jan-26	07-Jan-26	2 Day	204.025.000,00
2	Fc 15' Mpa / Class D	m3	350	Zona 2	10-Jan-26	11-Jan-26	1 Day	245.245.000,00
							Total Loss	449.270.000,00

Based on Table 1, it can be seen that the shift in the readymix concrete material supply schedule which was initially planned according to schedule was due to internal problems at PT.XXX resulting in supply failures which impacted the schedule of other work items in the production team. Of course, this caused material losses in the January 2026 period with a total value of Rp.449,270,000, as well as immaterial losses to the KSO PT. Adhi Karya (Persero) Tbk. - PT. Acset Indonusa. With the problems that arise as above, the Company needs to minimize them by tightening the selection of material vendors.

Previous research that discussed vendor selection using the Fuzzy AHP method has been conducted,[4]examining the selection of gear motor company suppliers. GAP focuses on evaluating the manufacturing industry, not considering the characteristics of construction material suppliers, especially ready mix.[5]researching construction material suppliers. The GAP focuses on construction material suppliers in general, but is not yet specific to ready-mix concrete vendors with operational criteria for batching plants and concrete distribution.[6]researching M-Sand Suppliers in the construction industry. The GAP focuses on aggregate materials (M-Sand), not yet examining ready mix vendors who have more critical quality and delivery time risks.

Based on these conditions, this study aims to evaluate and assess ready mix supply vendors using the Fuzzy AHP method by considering several main criteria that influence the success of concrete supply in construction projects. The results of the study are expected to be the basis for more objective, measurable, and systematic decision-making in determining the best ready mix vendor.

The novelty of this research lies in the differences in the criteria studied. Previous researchers examined common criteria such as Quality, Price, Production Capacity, Delivery, Service, Management. While the current novelty is research that integrates the criteria of price, concrete quality, timely delivery of construction operations such as batching plant capacity, quality certification, regulatory compliance, and guarantee of continuity of ready mix concrete supply which have not been widely used simultaneously in research.

Logistics and Supply Chain Management (SCM) are strategic functions that play a role in ensuring the smooth flow of materials, information, and resources from suppliers to end users. In the construction industry, the effectiveness of SCM influences project success because a large portion of costs are allocated to material procurement. Therefore, the procurement process is a critical activity that includes identifying needs, selecting vendors, evaluating, negotiating, and managing cooperative relationships. Accurate vendor selection contributes to achieving project costs, quality, and time, while errors in vendor selection can lead to delivery delays, increased costs, and decreased work quality.[7].

Various studies have applied the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method to support the supplier selection process.[4]shows that quality is the main criteria in selecting suppliers in the manufacturing industry.[5]identify quality, cost, delivery time, and supplier capability as dominant factors in construction materials, while[6]demonstrated that the combination of Fuzzy AHP with other multi-criteria methods can improve the objectivity and accuracy of supplier evaluation. Other research in Indonesia also shows that quality, price, service, and production capacity are key factors in the supplier selection process.[10]However, these studies generally focus on the manufacturing sector or construction materials in general, thus failing to account for the operational characteristics of ready-mix concrete vendors, such as batching plant capacity, quality certification, regulatory compliance, and guaranteed supply continuity.

2. Research Methods

This research uses the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method with the Extent Analysis Method approach developed by[1]This method was chosen because it can accommodate uncertainty and subjectivity in the assessments of 15 experts in their fields through the use of Triangular Fuzzy Numbers (TFN), resulting in more representative priority weights than the conventional AHP method. According to Saaty[2], AHP and Fuzzy AHP prioritize the quality of experts over the number of respondents so that 10–15 experts are considered adequate.

The object of this research is the process of selecting ready-mix concrete material vendors for the Jakarta–Cikampek II South Toll Road Construction Project Package IIB. The research data was obtained through literature studies, project procurement documents, and questionnaires distributed to respondents who have competence in the field of procurement and implementation of construction projects.

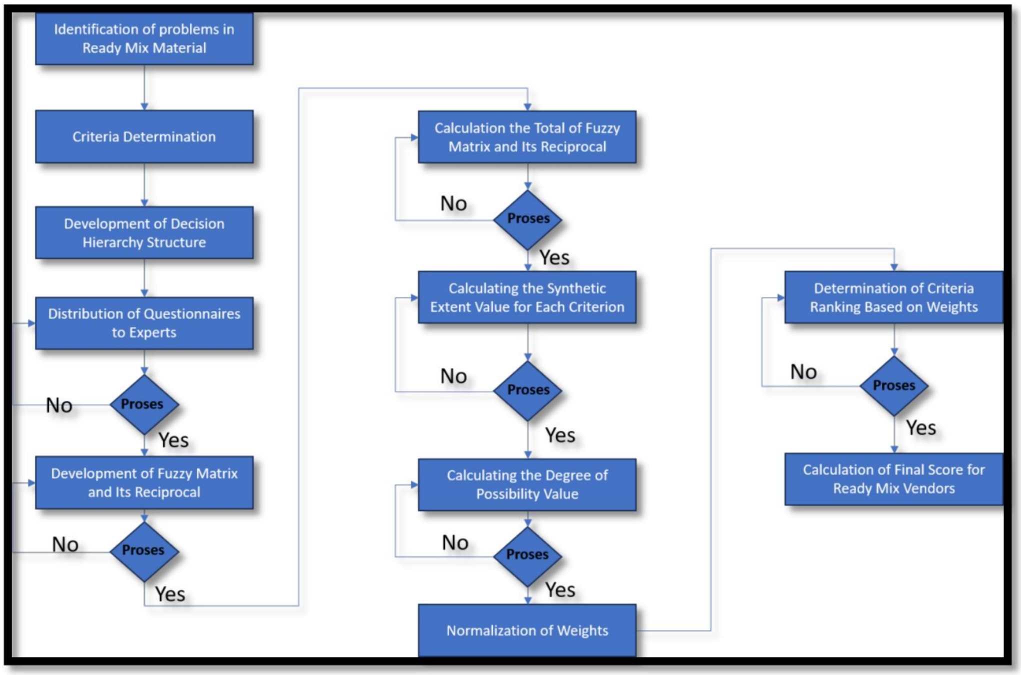

Fig 1. Flow Chart of Fuzzy AHP Ready Mix

2.1 Expert Respondents

To obtain the data, a questionnaire of 21 questions was filled out to 15 experts who each have their own fields and expertise with work experience of ≥ 10 years. The experts include Project Manager, Deputy Project Manager, Project Commercial Manager, Project Engineering Manager, Project Production Manager, Project Procurement Manager, Project Finance Manager, Project QHSE Manager, Quality Control Officer, Project Procurement Officer, Equipment Coordinator, Quantity Surveyor Officer, Cost Control Officer, QHSE Officer, Production Officer.

Criteria Description:

- Price Criteria = P
- Quality Criteria = Q
- Timeliness Criteria = O
- Production Capacity Criteria = PC
- Regulatory Compliance Criteria = R
- Quality Certification Criteria = QC
- Continuity Assurance Criteria = C

Table 2. Table of Expert Questionnaire Results

No	P-Q	P-O	P-PC	P-R	PQC-S	P-C	Q-O	Q-PC	Q-R	Q-QC	Q-C	O-PC	O-R	O-QC	O-C	PC-R	PC-QC	PC-C	R-QC	R-C	QC-C
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.200	0.333	0.200	1.000	0.333	3.000	5.000	5.000	1.000	5.000	3.000	1.000	3.000	3.000	3.000	1.000	3.000	0.333	0.333	0.333	3.000
3	1.000	1.000	5.000	5.000	1.000	1.000	1.000	3.000	5.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	0.200	1.000	3.000	0.143	0.143	1.000	1.000	5.000	1.000	1.000	1.000	3.000	1.000	0.333	1.000	0.200	0.333	1.000	1.000	1.000	5.000
5	1.000	0.200	0.333	0.200	0.143	5.000	5.000	3.000	0.333	1.000	5.000	1.000	0.333	0.200	3.000	0.333	0.333	5.000	0.333	3.000	5.000
6	1.000	0.200	0.111	0.200	0.200	0.200	9.000	1.000	1.000	1.000	7.000	1.000	5.000	0.200	7.000	9.000	0.143	7.000	0.200	0.200	1.000
7	1.000	1.000	0.111	1.000	0.200	1.000	5.000	1.000	5.000	3.000	1.000	1.000	1.000	1.000	1.000	1.000	0.333	3.000	0.143	1.000	5.000
8	0.333	0.200	0.200	0.333	0.200	0.200	0.200	1.000	1.000	3.000	1.000	5.000	3.000	1.000	5.000	1.000	3.000	0.200	1.000	0.333	0.333
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	0.200	0.333	0.333	3.000	0.200	0.200	5.000	5.000	5.000	9.000	5.000	3.000	3.000	0.143	0.200	5.000	0.333	0.333	0.200	1.000	1.000
12	0.200	1.000	1.000	0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.333	0.333	1.000	1.000	0.333	1.000	1.000	1.000	1.000
13	0.200	1.000	0.200	0.200	0.111	0.200	1.000	9.000	1.000	0.111	1.000	7.000	0.111	0.111	0.111	0.111	0.111	0.111	0.111	9.000	9.000
14	0.111	0.111	0.111	0.143	0.111	0.111	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	0.200	0.200	0.200	0.200	0.200	0.200	5.000	5.000	0.200	1.000	5.000	5.000	0.200	0.200	1.000	3.000	5.000	0.333	3.000	0.333	0.200
Total	0.422	0.486	0.434	0.520	0.291	0.605	1.778	2.059	1.152	1.289	1.690	1.758	0.929	0.511	1.139	1.000	0.678	0.849	0.569	0.898	1.435

In Table 4, the results of the expert questionnaire have been converted into numerical values of the paired comparison assessment scale (AHP) which will then become the data basis for the Fuzzification process.

2.2 Determining the validity test results of CI and CR consistency experts

With the AHP method that uses the Decision Maker's perception as its input, inconsistency may occur because humans have limitations in expressing their perceptions consistently, especially when having to compare many criteria. Consistency tests are carried out on each pairwise comparison matrix to check whether the judgment given is consistent or not. The measurement of consistency of a matrix is based on the maximum eigenvalue. With the consistency ratio equation as follows:

$$CR = \frac{CI}{RI} \qquad (1)$$

CR = Consistency Ratio
CI = Consistency Index
RI = Random Index (Random Index)

If the pair-wise comparison matrix has a CR value ≤ 0.1, then the inconsistency of opinion from the decision-making process is still acceptable and if not, the assessment needs to be repeated. This is in accordance with[2],that the level of consistency can be measured using the Consistency Index (CI) and Consistency Ratio (CR). A pairwise comparison matrix is declared consistent if the Consistency Ratio (CR) value is ≤ 0.10.

The consistency index formula equation is as follows:

$$CI = \frac{(t-n)}{(n-1)} \qquad (2)$$

CI = *Consistency Index*
t = The largest normalized value of a matrix of order n
n = Matrix Order/Number of Criteria

Table 3. Pair-wise consistency test matrix table

Criteria	P	Q	O	PC	R	QC	C	Importance	Normalization	Max Normalization
P	1,000	0,422	0,486	0,434	0,520	0,291	0,605	0,503	0,067	7,137
Q	2,371	1,000	1,778	2,059	1,152	1,289	1,690	1,553	0,208	7,166
O	2,059	0,562	1,000	1,758	0,929	0,511	1,139	1,014	0,136	7,184
PC	2,304	0,486	0,569	1,000	1,000	0,678	0,849	0,866	0,116	7,189
R	1,924	0,868	1,076	1,000	1,000	0,569	0,898	0,988	0,113	7,114
QC	3,440	0,776	1,957	1,475	1,758	1,000	1,435	1,528	0,205	7,132
C	1,653	0,592	0,878	1,177	1,113	0,697	1,000	1,000	0,134	6,825
Total								7,452	1,000	49,747

Based on Table 5, the total maximum normalization is 49.747. Next, the largest normalization value of the n-order matrix (7 criteria) is sought using the equation formula:

$$t = \frac{\text{Total max } Norm}{n} \qquad (3)$$

$$t = \frac{49{,}747}{7} = 7.1 \qquad (4)$$

$$CI = = 0.02 \frac{(7{,}1 - 7)}{(7 - 1)} \quad (5)$$

$$CR = = = 0.01 \frac{CI}{RI} \frac{0{,}02}{1{,}32} \quad (6)$$

After conducting a consistency test, a consistency ratio value of 0.01 was obtained, which means that the experts' opinions can be accepted.

2.3 Constructing a Pairwise Comparison Matrix with a Fuzzy Scale

The assessment of the level of importance between criteria was conducted using a pair-wise comparison method. Respondents were asked to compare the level of importance of each criterion using a linguistic scale. The linguistic values were then converted into Triangular Fuzzy Numbers (TFN) according to the scale.[1].

The formula equation for pair-wise comparison is as follows:

$$\text{Ai} = \begin{bmatrix} 1 & \widetilde{a_{12}} & \cdots & \widetilde{a_{1n}} \\ \widetilde{a_{21}} & 1 & \cdots & \widetilde{a_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a_{n1}} & \widetilde{a_{n2}} & \cdots & 1 \end{bmatrix} \quad (7)$$

Table 4. Expert Pairwise Comparison Matrix

Criteria	P	Q	O	PC	R	QC	C
P	equ	Non-str	Non-str	Non-str	Non-mod	Non-str	Non-mod
Q	str	equ	mod	mod	mod	mod	mod
O	Mod	Non-mod	equ	mod	Non-mod	Non-str	mod
PC	Str	Non-str	Non-mod	equ	equ	Non-str	Non-mod
R	Mod	Non-mod	mod	equ	equ	Non-str	Non-mod
QC	Str	Non-mod	mod	od	mod	Equ	mod
C	mod	Non-mod	Non-mod	mod	mod	Non-mod	equ

Information
Equ: Equal Strong : Str
Mode: Moderate Very Strong : Vstr

2.4 Conversion to Triangular Fuzzy Number (TFN)

All linguistic values are converted into triangular fuzzy numbers (l,m,u)

Table 5. TFN Conversion

Linguistik	TFN
Equ	(1,1,1)
Mod	(1,3,5)
Str	(3,5,7)
Vstr	(5,7,9)

For the opposite or inverse, use the formula

$$(l, m, u)^{-1} = \left(\frac{1}{u}, \frac{1}{u}, \frac{1}{u}\right) \qquad (8)$$

Table 6. Reverse TFN Conversion

Linguistik	TF-N
Non-Mod	(0.2, 0.333, 1)
Non-Str	(0.143, 0.2, 0.333)
Non-Vstr	(0.111, 0.143, 0.2)

2.5 Constructing Fuzzy Matrices and Their Inverse Matrices

In Table 9, converted with the Fuzzy AHP scale, the Decision matrix becomes the fuzzy matrix below:

Table 7. Fuzzy Matrix

Criteria	P	Q	O	PC	R	QC	C
P	(1,1,1)	(0.14, 0.20, 0.33)	(0.14, 0.20, 0.33)	(0.14, 0.20, 0.33)	(0.20, 0.33, 1)	(0.14, 0.20, 0.33)	(0.20, 0.33, 1)
Q	(3,5,7)	(1,1,1)	(1,3,5)	(1,3,5)	(1,3,5)	(1,3,5)	(1,3,5)
O	(1,3,5)	(0.20, 0.33, 1)	(1,1,1)	(1,3,5)	(0.20, 0.33, 1)	(0.14, 0.20, 0.33)	(1,3,5)
PC	(3,5,7)	(0.14, 0.20, 0.33)	(0.20, 0.33, 1)	(1,1,1)	(1,1,1)	(0.14, 0.20, 0.33)	(0.20, 0.33, 1)
R	(1,3,5)	(0.20, 0.33, 1)	(1,3,5)	(1,1,1)	(1,1,1)	(0.14, 0.20, 0.33)	(0.20, 0.33, 1)
QC	(3,5,7)	(0.20, 0.33, 1)	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,1)	(1,3,5)
C	(1,3,5)	(0.20, 0.33, 1)	(0.20, 0.33, 1)	(1,3,5)	(1,3,5)	(0.20, 0.33, 1)	(1,1,1)

The matrix formula equation is as follows:

2.6 Calculating the Number of Criteria Rows

$$\text{H} \quad : (1, 1, 1) + (0.14, 0.2, 0.333) + (0.14, 0.2, 0.33) + (0.14, 0.2, 0.33) + (0.2, 0.333, 1) + (0.14, 0.2, 0.33) + (0.2, 0.333, 1) = (1.97, 2.47, 4.33) \qquad (9)$$

$$\text{K} \quad : (3, 5, 7) + (1, 1, 1) + (1, 3, 5) + (1, 3, 5) + (1, 3, 5) + (1, 3, 5) + (1, 3, 5) = (9.00, 21.00, 33.00) \qquad (10)$$

$$\text{W} \quad : (1, 3, 5) + (0.2, 0.333, 1) + (1, 1, 1) + (1, 3, 5) + (0.2, 0.333, 1) + (0.14, 0.2, 0.33) + (1, 3, 5) = (4.54, 10.87, 18.33) \qquad (11)$$

$$\text{P} \quad : (3, 5, 7) + (0.143, 0.2, 0.333) + (0.2, 0.333, 1) + (1, 1, 1) + (1, 1, 1) + (0.143, 0.2, 0.333) + (0.2, 0.333, 1) = (5.69, 8.07, 11.67) \qquad (12)$$

$$\text{R} \quad : (1, 3, 5) + (0.2, 0.333, 1) + (1, 3, 5) + (1, 1, 1) + (1, 1, 1) + (0.143, 0.2, 0.333) + (0.2, 0.333, 1) = (4.54, 8.87, 14.33) \tag{13}$$

$$\text{S} \quad : (3, 5, 7) + (0.2, 0.333, 1) + (1, 3, 5) + (1, 3, 5) + (1, 3, 5) + (1, 1, 1) + (1, 3, 5) = (8.20, 1833, 29.00) \tag{14}$$

$$\text{J} \quad : (1, 3, 5) + (0.2, 0.333, 1) + (0.2, 0.333, 1) + (1, 3, 5) + (1, 3, 5) + (0.2, 0.333, 1) + (1, 1, 1) = (38.54, 80.60, 129.66) \tag{15}$$

Total rows of the matrix of all criteria and their inverses.

$$\begin{aligned} \text{Total criteria} &= (1.97, 2.47, 4.33) + (9.00, 21.00, 33.00) + (4.54, 10.87, 18.33) \\ &\quad + (5.69, 8.07, 11.67) + (4.54, 8.87, 14.33) + (8.20, 1833, 29.00) \\ &\quad + (38.54, 80.60, 129.66) \\ &= (38.54, 80.60, 129.66) \end{aligned} \tag{16}$$

$$\begin{aligned} \text{Inverse} &= \left(\frac{1}{129.66}, \frac{1}{80.60}, \frac{1}{38.54}\right) \\ &= (0.008, 0.012, 0.026) \end{aligned} \tag{17}$$

2.7 Calculating Fuzzy Priority Weights (Synthetic Extent Value – SE)

The Synthetic Extent value is calculated using Chang's method:

$$S_i = \left(\sum_{j=1}^{m} Mij\right) \otimes \left(\sum_{i=l}^{n} \sum_{j=1}^{m} Mij\right)^{-1} \tag{18}$$

Here, a∼ij is a fuzzy number in the comparison matrix between criteria iii and jjj.
The result is a weight in fuzzy form: W∼i=(li,mi,ui)

$$\begin{aligned} SH &= (1.97, 2.47, 4.33) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.015, 0.031, 0.112) \end{aligned} \tag{19}$$

$$\begin{aligned} SK &= \\ &(9.00, 21.00, 33.00) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.069, 0.261, 0.856) \end{aligned} \tag{20}$$

$$\begin{aligned} SW &= \\ &(4.54, 10.87, 18.33) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.035, 0.135, 0.476) \end{aligned} \tag{21}$$

$$\begin{aligned} SP &= (5.69, 8.07, 11.67) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.044, 0.100, 0.303) \end{aligned} \tag{22}$$

$$\begin{aligned} SR &= (4.54, 8.87, 14.33) \text{ x } (0.008, 0.012, 0.026) \\ &= (4.54, 8.87, 14.33) \text{ x } (0.008, 0.012, 0.026) \end{aligned} \tag{23}$$

$$\begin{aligned} SS &= (8.20, 1833, 29.00) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.063, 0.227, 0.752) \end{aligned} \tag{24}$$

$$\begin{aligned} SJ & \\ &= (38.54, 80.60, 129.66) \text{ x } (0.008, 0.012, 0.026) \\ &= (0.035, 0.136, 0.493) \end{aligned} \tag{25}$$

2.8 Determining the Degree of Possibility

The degree of possible dominance between criteria is calculated using:

Then search for : $V\ (M2\ \geq\ M1) = \dfrac{l2 - u1}{(m1 - u1) + (m2 - l2)}$ (26)

For all criteria : $d'(Ai)\ =\ min\, V\ (Si\ \geq\ Sk)$ (27)

Degree of Possibility SH

$d'(SH) = \min(0.157, 0.426, 0.497, 0.493, 0.200, 0.421)$
$= 0.157$ (28)

Degree of Possibility SK

$d'(SK) = 1$ (29)

Degree of Possibility SW

$d'(SW) = \min 0.866, 1, 1, 1.060, 0.817, 0.996)$
$= 0.817$ (30)

Degree of Possibility SP

$d'(SP)$
$= \min(1, 0.592, 0.885, 0.964, 0.653, 0.880)$ (31)
$= 0.592$

Degree of Possibility SR

$d'(SR) = \min(1, 0.668, 0.931, 1, 0.724, 0.927)$
$= 0.668$ (32)

Degree of Possibility SS

$d'(SS) = \min(1, 0.954, 1, 1, 1, 1)$ (33)
$= 0.954$

Degree of Possibility SJ

$d'(SJ) = \min(1, 0.773, 1, 1, 1, 0.825)$ (34)
$= 0.773$

Weight vector

$W' = (d'(SH), d'(SK), d'(SW), d'(SP), d'(SR), d'(SS), d'(SJ))$ (35)
$= (0.157, 1, 0.817, 0.592, 0.668, 0.954, 0.773)$

2.9 Weight Normalization

Priority weight is obtained by:

$W = (d'(H), d'(K), d'(W), d'(P), d'(R), d'(S), d'(J))$
$W' = (0.157, 1, 0.817, 0.592, 0.668, 0.954, 0.773)$ (36)

$$\text{Amount} = 0.157 + 1 + 0.817 + 0.592 + 0.668 + 0.954 + 0.773 = 4{,}961 \quad (37)$$

$$\text{Then normalized}: w_i = \frac{d'(i)}{\sum d'(i)} \quad (38)$$

$$\text{Weight H} = \frac{0.157}{4.961} = 0.032 \quad (39)$$

$$\text{K Weight} = \frac{1}{4.961} = 0.202 \quad (40)$$

$$\text{W Weight} = \frac{0.817}{4.961} = 0.165 \quad (41)$$

$$\text{Weight P} = \frac{0.592}{4.961} = 0.119 \quad (42)$$

$$\text{R Weight} = \frac{0.668}{4.961} = 0.135 \quad (43)$$

$$\text{Weight S} = \frac{0.954}{4.961} = 0.192 \quad (44)$$

$$\text{J Weight} = \frac{0.773}{4.961} = 0.156 \quad (45)$$

Table 8. Normalization of Weights

Weight Normalization		
Criteria	**Code**	**Weight**
Price	P	0,032
Quality	Q	0,202
On-Time Delivery	O	0,165
Production Capacity	PC	0,119
Regulatory Compliance	R	0,135
Quality Certification	QC	0,192
Continuity Assurance	P	0,156

In Table 10, the weighting results for all criteria are obtained (Price, Quality, Timeliness, Production Capacity, Regulatory Compliance, Quality Certification, Continuity Assurance). The weighting results for all criteria will then be ranked to determine which criteria are the most dominant.

Table 9. Criteria Weight Ranking

Criteria Weight Ranking			
No	**Criteria**	**Code**	**Weight**
1	Quality	Q	0,202
2	Quality Certification	QC	0,192
3	On-Time Delivery	O	0,165

4	Continuity Assurance	C	0,156
5	Regulatory Compliance	R	0,135
6	Production Capacity	PC	0,119
7	Price	P	0,032

Based on Table 11, it can be seen that the order from top to bottom is based on the weight of the criteria from the largest value to the smallest weight value, where the "quality" criterion has the largest weight and the "Price" criterion has the smallest weight among the other criteria.

3. Results and Discussion

In this chapter, the author will simulate to find the highest score for a sample of 3 vendors (Vendor A, Vendor B, Vendor C) by using existing vendor evaluation data from the KSO company PT. Adhi Karya (Persero) Tbk. - PT. Acset Indonusa with vendor assessment (scale 10-100) as in table 12, below.

Table 10. Assessment of the Company's Existing Vendors

No	Vendor	CRITERIA						
		Price	Quality	On-Time Delivery	Production Capacity	Regulatory Compliance	Quality Certification	Continuity Assurance
1	Vendor A	90	85	80	75	85	80	75
2	Vendor B	80	95	90	90	90	95	90
3	Vendor C	95	75	85	80	75	75	80

Based on Table 12, the existing score is the next step for the author to combine the data based on the weighting results of the 7 criteria based on the calculation results using the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method.

Formula :

$$Skor = \sum (Bobot\ x\ Nilai) \qquad (46)$$

Vendor A

$$\begin{aligned} &= (0.032 \text{ x } 90) + (0.202 \text{ x } 85) + (0.165 \text{ x } 80) + (0.119 \text{ x } 75) + (0.135 \text{ x } 85) + \\ &\quad (0.192 \text{ x } 80) + (0.156 \text{ x } 75) \\ &= 2{,}857 + 17{,}133 + 13{,}167 + 8{,}956 + 11{,}439 + 11{,}439 + 15{,}380 + 11{,}692 \\ &= 80{,}622 \end{aligned} \qquad (47)$$

Vendor B

$$\begin{aligned} &= (0.032 \text{ x } 80) + (0.202 \text{ x } 95) + (0.165 \text{ x } 90) + (0.119 \text{ x } 90) + (0.135 \text{ x } 90) + \\ &\quad (0.192 \text{ x } 95) + (0.156 \text{ x } 90) \\ &= 2{,}539 + 19{,}148 + 14{,}813 + 10{,}346 + 12{,}112 + 18{,}263 + 14{,}030 \\ &= 91{,}652 \end{aligned} \qquad (48)$$

Vendor C

$$\begin{aligned} &= (0.032 \text{ x } 95) + (0.202 \text{ x } 75) + (0.165 \text{ x } 85) + (0.119 \text{ x } 80) + (0.135 \text{ x } 75) + \\ &\quad (0.192 \text{ x } 75) + (0.156 \text{ x } 80) \\ &= 3{,}015 + 15{,}117 + 13{,}990 + 9{,}553 + 10{,}093 + 14{,}418 + 12{,}471 \\ &= 78{,}657 \end{aligned} \qquad (49)$$

Table 11. Vendor Score Assessment

No	Vendor	CRITERIA

		Price	Quality	On-Time Delivery	Production Capacity	Regulatory Compliance	Quality Certification	Continuity Assurance	Total Score
1	Vendor A	2,857	17,133	13,167	8,956	11,439	15,380	11,692	80,622
2	Vendor B	2,539	19,148	14,813	10,747	12,112	18,263	14,030	91,652
3	Vendor C	3,015	15,117	13,990	9,553	10,093	14,418	12,471	78,657

Based on the Fuzzy AHP weighting results in Table 13, the concrete quality criteria received the highest weighting of 20.2%, followed by quality certification (19.2%), on-time delivery (16.5%), guaranteed supply continuity (15.6%), regulatory compliance (13.5%), production capacity (11.9%), and price (3.2%). These results indicate that respondents prioritized quality, operational reliability, and supply certainty over price efficiency in the process of selecting ready-mix concrete vendors. This finding is in line with research[4][5]which states that quality is the dominant factor in supplier evaluation. However, the results of this study differ from[9], which prioritizes price as a primary criterion. This difference is thought to be influenced by the characteristics of toll road projects, which place greater emphasis on supply reliability and concrete quality than on cost alone.

The aggregation results of the vendor assessments show that Vendor B obtained the highest score of 91.652, followed by Vendor A with 80.622, and Vendor C with 78.657. This ranking indicates that Vendor B has the best performance because it excels in criteria that have high priority weights, namely concrete quality, quality certification, on-time delivery, and guaranteed supply continuity. Conversely, although Vendor C offers a more competitive price, the relatively low price weight causes this advantage to have no significant impact on the final score. This finding confirms that the selection of ready-mix concrete vendors for toll road projects is more influenced by the vendor's ability to guarantee product quality and supply reliability than by price factors.

4. Conclusions

This study aims to develop an evaluation model and selection of the best ready mix vendor using the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method on the Jakarta–Cikampek II South Toll Road Project Package IIB. Based on the results of data processing and analysis that have been carried out, it can be concluded that the Fuzzy AHP method can be used as a systematic and objective decision-making tool in determining the level of importance of vendor selection criteria and evaluating available vendor alternatives. Through this approach, the subjectivity of expert assessments can be accommodated using fuzzy numbers, resulting in a more representative criteria weighting of the actual project conditions.

The results of the study indicate that quality criteria are the factors with the highest level of importance in the ready mix vendor selection process with a weight of 20.2%, followed by quality certification (19.2%), on-time delivery (16.5%), guaranteed continuity of supply (15.6%), regulatory compliance (13.5%), production capacity (11.9%), and price (3.2%). These findings indicate that the success of ready mix material procurement in toll road construction projects is more influenced by the vendor's ability to guarantee product quality, operational reliability, and supply continuity than by price alone. Thus, quality is the main consideration in the vendor selection process because it has a direct influence on the quality of the structure, the smoothness of work implementation, and the overall success of the project.

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