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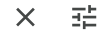
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Application of Fuzzy Analytical Hierarchy (FAHP) for Choosing Best Project Cost Estimation in Gresik District

Nia Saurina[1], Siswoyo[2], Lestari Retnawati[3]

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ABSTRACT

The purpose of this research is made application for cost estimation of road construction projects in the Gresik district. This project is collaboration with civil engineering and informatics to made an application use Fuzzy Analytical Hierarchy Process (FAHP). Many time the project manager gets bids from many contractors to complete a single project. Cost estimation is a determinant element and becomes a guide to formulating policies that can be taken primarily in determining the amount of investment costs or the budget that must be allocated annually and can made best suggestion to project manager which contractor that can provide the greatest benefit to the project manager. There are several studies that have developed applications for cost estimation, and some have even involved experts to validate the output of the application. However, this study combines 5 (five) studies as FAHP calculations and two experts to assess the results of the application. FAHP in this research have five criteria, there are drainage, earth works, grained pavement and cement pavement, paved pavement, structure. The Fuzzy Analytical Hierarchy Process (FAHP) method can be implemented in selecting the best project that can provide the lowest raw material purchase price and give the best profit to project manager, which can be shown by the Application FAHP with the lowest Total Score value. This process is carried out by the admin doing pairwise comparisons with the AHP scale, transforming the pairwise comparison matrix into the TFN scale, calculating the fuzzy synthesis value (Si), the vector value (V) and the defuzzification ordinate (d '), input the project budget that has been implemented (or last year), normalization, calculating the consistency ratio, and calculating the best cost estimation as a total score FAHP

Keywords: best project, project cost estimation, fuzzy analytical hierarchy process

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1. Introduction

A construction project in general that requires a lot of budgets, and inaccuracy in carrying out "an earthquake" that results in the project work overload, and those could be the main cause of losses and sub-optimal results, even the construction project could be stopped. This condition has an unfavorable effect on the parties involved in it. Functionally, "earthquake" in costs is also used for the preparation of a payment system, scheduling, and predicting events in the process of implementing a construction project. Contractors with no experience of cost components, including indirect costs, and increase the risk might be happened (Ibrahim, 2011).

The cost estimate has a very significant effect and is one of the important benchmarks in evaluating the success of a construction project. In addition, cost estimation is also a determinant element and becomes a guide to formulating policies that can be taken primarily in determining the amount of investment costs or the budget that must be allocated annually (Seyit, et.al., 2019).

Therefore, making good decisions with satisfaction of various criteria is one of the main conditions to achieve business objectives. All important decisions which are made in the construction project management and construction industry have multiple character criteria. The crucial decisions, which concern to the large projects, have long-term consequences on all aspects of realization and exploitation of a project. Many time the project manager gets bids from many contractors to complete a single project. Cost estimation is a determinant element and becomes a guide to formulating policies that can be taken primarily in determining the amount of investment costs or the budget that must be allocated annually and can made best suggestion to project manager which contractor that can provide the greatest benefit to the project manager.

In practice, contractor selection is normally had two-stage process whereby contractors are first pre-qualified (for example, to get onto a select list or be invited to tender for a given project). Subsequently, their tender submissions are evaluated in the second stage. In this research describe application for choosing the best project and give best suggestion using Fuzzy Analytical Hierarchy Process (FAHP) to the project manager.

Analytic hierarchy process (AHP) was proposed by Thomas Saaty (Saaty, 1997; Saaty, 1980) and found wide applications in many areas. The main advantage of AHP is its possibility to be combined with other methods, including linear programming, fuzzy logic, etc (Vaidya, 2005). In order to model the uncertainty of this human preference, the AHP method is combined with the pair comparison of fuzzy sets. The FAHP facilitates decision-making procedures with precise definitions. Abbasimehr (Abbasimehr, 2017) is an early researcher of FAHP, who used the triangular membership function to represent pair fuzzy ratios to figure out the partial fuzzy priority through the method of least squares (later the geometric mean method).

FAHP has been used in the literature by researchers in many different fields including project selection by assigning weights to selected project characteristics or criteria based on importance (Kubler, et.al., 2017). Bilgen (Bilgen and Sen, 2012) used a FAHP to develop a selection tool for six sigma projects. Their selection tool used resources, benefits, and effects as the major characteristics for their FAHP project selection tool. Nguyen and Tran (Nguyen, 2017) studied the use of FAHP in construction projects for site selection, contractor selection, construction methods, risk assessment, and other areas related to construction projects. Other examples exist in the literature utilizing the FAHP methodology in project selection (Hatefi, 2018)

2. Literature Review

2.1 Fuzzy AHP

The triangular fuzzy numbers are used in studies of FAHP. The fuzzy triangular numbers are shown as (l / m, m / u) or (1, m, u). For a fuzzy case, l; the smallest possible value, m; the largest value that can be taken and u; the widest possible value

represents (Baslıgil, 2005). The linear representations of each triangular number can be defined as the left and right sides with the membership function in equation (1) ([Kahraman, et. al., 2015](#)).

$$\mu\left(\frac{x}{\tilde{M}}\right) = \begin{cases} 0, x < 1, \\ \frac{x-l}{m-l}, \; l \leq x \leq m, \\ \frac{(u-x)}{(u-m)}, m \leq x \leq u, \\ 0, x > u, \end{cases} \tag{1}$$

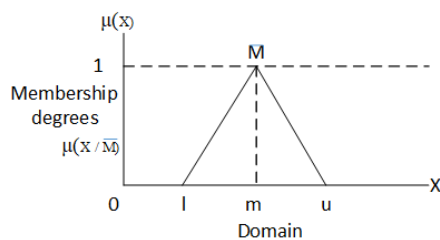The geometric representation of the fuzzy number X from Equation (1) is shown in [Fig. 1](#).

Fig. 1. A triangular fuzzy number (TFN) (Chang, 1996)

Definition value of intensity of AHP into interest priority of fuzzy AHP, can be seen at [Table 1](#).

Table 1. Interest Priority of Fuzzy AHP

No	Interest Priority of Fuzzy AHP	Triangular Fuzzy Number (TFN)	Retrocal (l, m, u)
1	Just Equal = 1	(1, 1, 1)	(1, 1, 1)
2	First	(1/2, 1, 3/2)	(2/3, 1, 2)
3	Intermediate = 2	(1, 3/2, 2)	(1/2, 3/2, 1)
4	Moderately Important = 3	(3/2, 2, 5/2)	(2/5, 1/2, 3/2)
5	Second Intermediate = 4	(2, 5/2, 3)	(1/3, 2/5, 1/2)
6	Strongly important = 5	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
7	Third Intermediate = 6	(3, 7/2, 4)	(1/4, 2/7, 1/3)

2.2 Project Cost Estimation

Several methods of cost estimation are as follows:

Parameter Method, is a method that relates costs to certain physical characteristics of objects, for example: area, length, weight, volume and so on ([Sayadi, et.al., 2015](#)).

Using a list of price indexes and information on previous projects, namely by looking for a comparison between prices at one time (certain year) against prices at that time (year) which is used as a basis. Also the use of data from manuals, hand books, catalogs, and periodicals, is very helpful in estimating project costs ([Marsha, et.al., 2021](#)). The method of analyzing the elements (Elemental Cost Analysis), namely by describing the project scope into elements according to their function ([Fragkakis, et.al., 2015](#)). The factor method, using the assumption that there is a correlation between the price of the main equipment and the related components ([Shane, et.al., 2019](#)). Quantity take-off, namely by making cost estimates by measuring the quantity of project components from drawings, specifications, and plans ([Marinelli, et.al., 2015](#)).

The unit price method, namely by estimating costs based on unit prices, is carried out if the number indicating the total volume of work cannot be determined with certainty, but the cost per unit (per square meter, per cubic meter) can be calculated ([Makovšek, 2014](#)). Using the relevant project data and information, which is a method that uses input from the project being handled, so that the figures obtained reflect the actual situation ([Kim, 2011](#))

3. **Methodology**

In this research, there are five criteria used as the basis for calculating the analytical hierarchy process. There are drainage, earth works, grained pavement and cement concrete, paved pavement and structure. On drainage criteria, there are alternatives which is (1) procurement of box culvert, (2) box culvert installation, (3) Batu kali installation, (4) plastering / shading work. On earth work criteria, there are alternatives which is (1) regular excavation, (2) heap of sand, (3) hard soil excavation, (4) ordinary soil fill. On Grained Pavement and Cement Concrete criteria, there are alternative which is (1) aggregate base class A, (2) aggregate base class B, (3) aggregate base class A, (3) aggregate base class CTB. On Paved Pavement criteria, there are alternatives which is (1) binder absorb layer, (2) adhesive layer, (3) Laston Lapis Aus (AC-WC), (4) Laston lapis Aus between two side. On structure criteria, there are alternative which is (1) Bamboo Trucuk Diameter 10-meter, (2) pair of Batu Kali, (3) unloading the paving. The result of this application is smallest fuzzy AHP because those values mean the winner of the tender who will provide the biggest profit to the contractor. These criteria and alternatives can be seen in [Fig. 2](#).
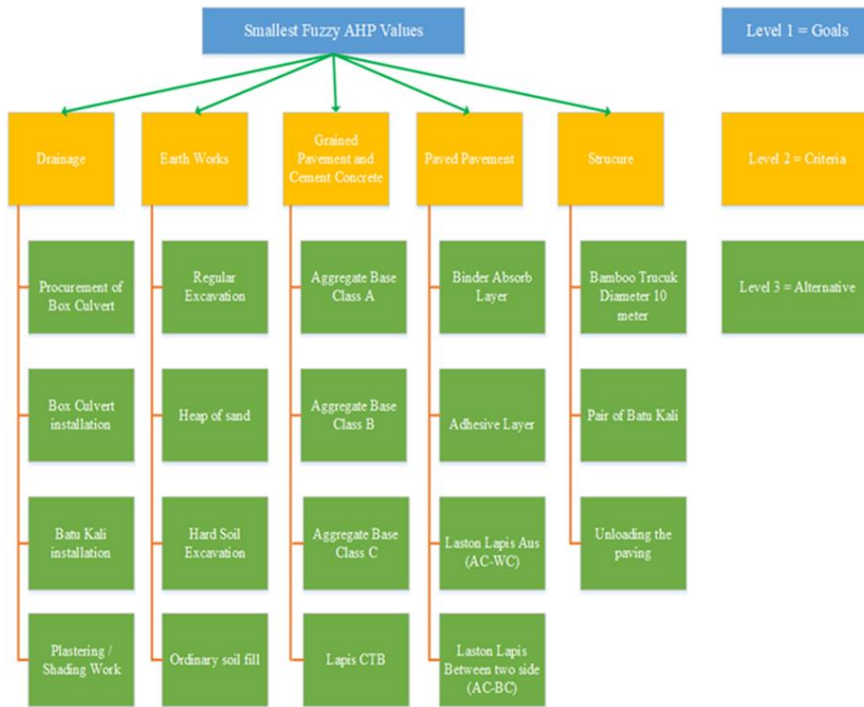
Fig. 2. Design of Fuzzy Analytical Hierarchy Process in this research

On this application of FAHP, there are 2 actor which is administrator and project manager. Administrator must login first to use this application using username and password. Administrator could manage road improvement project criteria data according to figure 3 on second level. Administrator could add value of FAHP according to table 1. After that administrator could manage the project cost budget and could view result of FAHP. This process could be seen in Fig. 3.
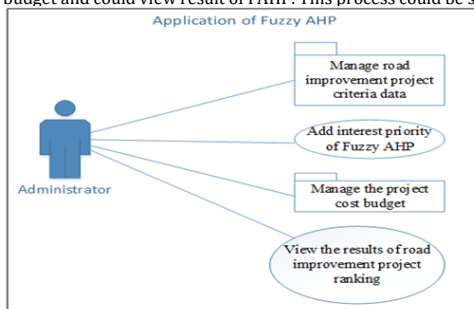
Fig. 3. Use Case Diagram of Administrator

Project manager could view the result of road improvement project ranking and could view detailed ranking result and could view help to read instruction how to use this application, and this process can be seen in Fig. 4.
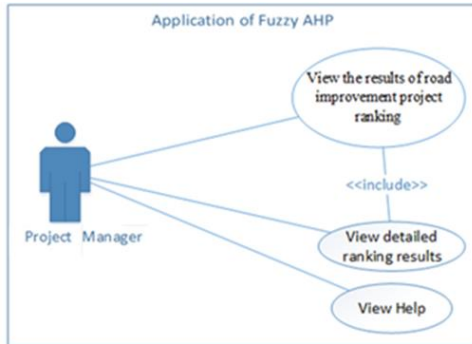
Fig. 4. Use Case Diagram of Project Manager

4. Findings

The Application of FAHP for weight calculation are running by localhost because this application stores important data for company and can only be accessed by admins and project manager. When admin open application of FAHP, admin can see the dashboard of this application, which can be seen in Fig. 5.
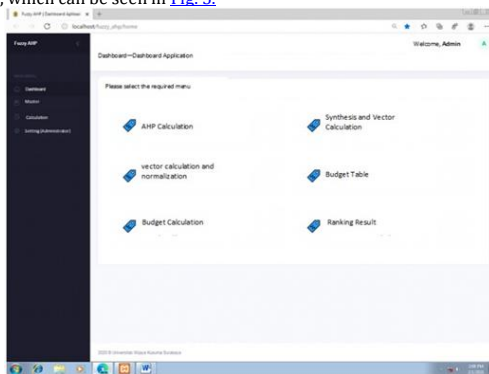

Fig. 5. Dashboard of Application of Fuzzy AHP

After defining the five sustainable project criteria, as shown in the previous subsection, the first step in determining the priority weights of these criteria is collecting the opinions of experts in sustainability and sustainable development regarding the relative importance of these criteria in sustainable project selection. In this research, some literature publications related to sustainable project selection and sustainable development as well as some prominent projects management literature covering the chosen criteria were selected and evaluated, as part of the Literature review for this research, to serve as the voice of experts in determining preferences among the seven different criteria shown in Table 1. These studies were closely reviewed to determine the relative importance of these criteria and preference pattern, as represented by the authors of those publications. The list of the chosen literature publication is shown in Table 2.

Table 2. Selected expert literatures used for the evaluation of criteria.

No	Expert	Source(s)
1	E1	(Oliver, et.al., 2016)
2	E2	(Debarshi, et.al., 2020)
3	E3	(Roche, 2017)
4	E4	(Kwon and Melles, 2017)
5	E5	(Brenning, et.al., 2011)

The second step in determining the priority weights of the five sustainable project criteria is utilizing the expert opinions from the literature in Table 2 based on the linguistic variables and triangular fuzzy numbers (TFNs), shown in Table 1. In this step, expert opinions are gathered from the literature and translated into the linguistic variables. After creating the pairwise comparison matrix representing the opinions of each of the ten experts shown in Table 1 using the linguistic variables, these seven matrices are then combined to form the combined pairwise comparison matrix shown in Table 2. Numbers in red indicate the criteria meet the criteria themselves, so the value automatically displays "1". The implementation of Table 2 are shown in Fig. 6, where five sustainable project criteria are combined with TFNs.

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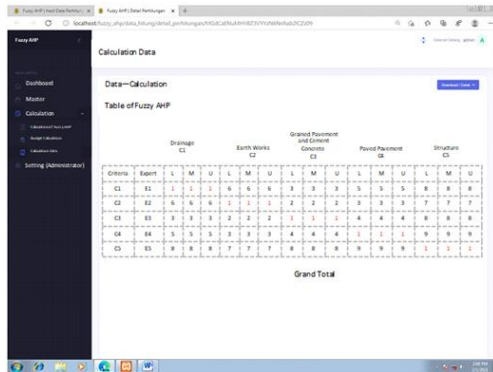Figures and tables should be addressed before being located in the text. **:Dikomentari [ns2]**

Fig. 6. Pairwise comparison matrix using linguistic variables.

Determine the value of priority fuzzy synthesis (Si) with equations 2, 3, and 4.

$$Si = \sum_{j=1}^{m} M_{gj}^{j} X \left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gj}^{j} \right]^{-1}$$

Where   (2)

$$\sum_{j=1}^{m} M_{gj}^{j} = \left[\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj \right]$$

                                                                                                             (3)

While
                                                                                                             (4)

$$\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{i}^{j}} = \left(\frac{1}{\sum_{i=1}^{n} ui}, \frac{1}{\sum_{i=1}^{n} mi}, \frac{1}{\sum_{i=1}^{n} li} \right)$$

Where $\sum_{j=1}^{m} M_{gi}^{j}$ is the sum of the rows in the paired matrix, $Mi\ jm\ j = 1\ n\ i = 1$ is the sum of the columns in the paired matrix ratio.

Note :

M = (Criteria, Sub criteria, or alternative)

i = row i,

j = column j,

l = lower score,

m = medium score,

u = upper score

The fuzzy synthetic extent or the fuzzy relative importance weights resulting from applying the same process to the remaining criteria as shown in Fig. 7.

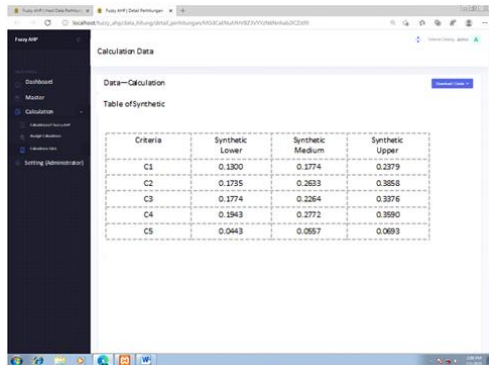Heading should be supported by proper numbering. **:Dikomentari [ns3]**

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Fig. 7. Fuzzy synthetic extent of sustainable project selection criteria.

Determine the vector value (V) and defuzzification ordinate value (d '). If the results obtained are on a fuzzy matrix, M2 ≥ M1 where M1 = (l1, m1, u1) and M2 = (l2, m2, u2) then the vector value can be solved by equation (5).

$$V(M2 \geq M1) = \left\{ \begin{array}{c} 1 \\ 0 \\ \dfrac{l1 - u2}{(m2 - u2) - (m1 - l1)} \end{array} \right\}$$

(5)

Where sub is the smallest upper limit of the minimum vector result. Or as shown in equation (6) to determine the vector value.

(6)

$$V(M2 \geq M1) = sup\left[min\left(\mu M1(x), \min\left(\mu M1(y)\right)\right)\right]$$

If the resulting fuzzy value is greater than k, Mi, (i = 1,2,, k) then the vector value can be defined as equation (7).

$$V(M \geq M1, M2, \dots, Mk) = V(M \geq M1) \text{ and } V(M \geq M2) \text{ and } V(M \geq Mk) = \min V(M \geq Mi)$$

(7)

The defuzzification ordinary is defined in the equation (8).

$$d'(Ai) = minV(Si \geq Sk)$$ (8)

For k = 1,2,…, n; k ≠ i, then the vector weight value is obtained as in equation (9).

(9)

$$W' = \left(d'(A1), d'\left(A2d'(An)\right)T\right)$$

Where Ai = 1,2,…n is a fuzzy vector or weight (W)

The vector value of the criteria C1 to C5 using equations (5) and (6) can be seen in Fig 8, after that it can produce the defuzzification value of equation (8) and the Weight value of equation (9) can be seen in Fig. 8. Numbers in red indicate the criteria meet the criteria themselves, so the value automatically displays "1,000".
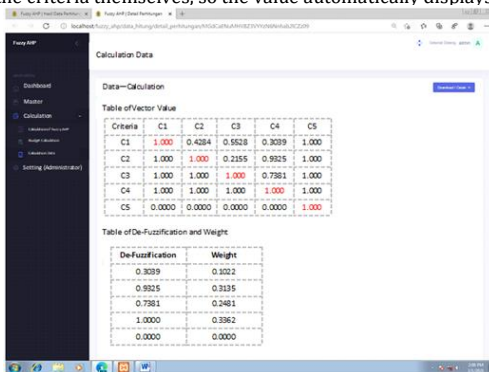

Fig. 8. Vector Value, De-Fuzzification and Weight

After getting the weight value, the admin can input the budget according to the road repair project in Gresik Regency which is used to calculate the normalization value. In this study, the Road Repair Project used is 3 years,

namely 2018, 2019 and 2020. The Fuzzy AHP application provides facilities for admins to input a budget project for a minimum of 2 years and a maximum of 5 years. After that application FAHP could give output a normalization of the fuzzy vector weight value (W). The normalization of equation (10), is used to the normalized vector weight value is like equation (10):

(10)

$$W(d(A1), d(A2), …, d(An),)T$$

Application of FAHP for Choosing Best Road Repair Project in Gresik District give result that project budget in 2019 is ranked first, project budget for 2018 is ranked second, and project budget for 2020 is ranked third. This is because the fuzzy AHP value in 2019 has the smallest value, which means that the application FAHP give best profit to project manager than project budget in 2018 or 2020, can be seen in Fig. 9.
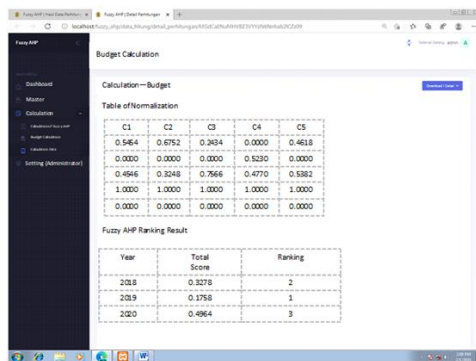

Fig. 9. Normalization and Fuzzy AHP Ranking Result

5. Conclusion

FAHP implementation has been widely developed in various fields, but in making FAHP modeling has criteria that are tailored to each individual's needs. According to (Bilgen, 2012) FAHP has been combined with Six Sigma to reduce the energy cost, and they used material transferring heat loss in an automotive supplier industry as criteria in their FAHP modelling. In (Abbasimehr, 2017) using FAHP with five critical phases for ranking reviewers in terms of credibility and combined with fuzzy inference system. In collecting data processing, they used web of trust data, data about users review and users' contribution as criteria in their FAHP modelling. In addition, according to the proposed framework, to compute a realistic credibility score based on trustworthiness and expertise, a cognitive approach was followed and a fuzzy inference system was designed. According to (Hatefi, 2018) FAHP method using criteria of sustainable development in three aspects of economy, society, and environment using literature and experts' ideas. Then two questionnaires related to fuzzy AHP and improved GRA were designed. According to (Kubler, 2016) FAHP modelling were been used to carry out a literature review of 190 application papers (i.e., applied research papers), published between 2004 and 2016, by classifying them on the basis of the area of application, the identified theme, the year of publication, and so forth.

This research has five criteria used as criteria in our FAHP modelling. There are drainage, earth works, grained pavement and cement concrete, paved pavement and structure. On drainage criteria, there are alternatives which is (1) procurement of box culvert, (2) box culvert installation, (3) Batu kali installation, (4) plastering / shading work. On earth work criteria, there are alternatives which is (1) regular excavation, (2) heap of sand, (3) hard soil excavation, (4) ordinary soil fill. On Grained Pavement and Cement Concrete criteria, there are alternative which is (1) aggregate base class A, (2) aggregate base class B, (3) aggregate base class A, (3) aggregate base class CTB. On Paved Pavement criteria, there are alternatives which is (1) binder absorb layer, (2) adhesive layer, (3) Laston Lapis Aus (AC-WC), (4) Laston lapis Aus between two side. On structure criteria, there are alternative which is (1) Bamboo Trucuk Diameter 10-meter, (2) pair of Batu Kali, (3) unloading the paving. This research implements the FAHP method to choosing best project and give lowest cost estimation. This selection tool can be applied by any project manager when evaluating different sustainable project alternatives for selection regardless of the type, environment, and location of these projects. The criteria chosen in this research are novelty, uncertainty, team skill and experience, technology information transfer, and project cost. Prioritizing these criteria based on relative importance helps project manager identify more important project elements that require additional attention, better allocate resources, as well as improve the selection process when evaluating different sustainable project alternatives. This research utilizes the existing literature examined as part of the literature review process to represent the voice of experts on the relative importance of the selected criteria.

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A benchmarking should be added **:Dikomentari [ns6]** to your work. It means that you should evaluate your results by comparison with other published papers in the field.

The FAHP method can be implemented in selecting the best project that can provide the lowest raw material purchase price and give the best profit to project manager, which can be shown by the Application FAHP with the lowest Total Score value. This process is carried out by the admin doing pairwise comparisons with the AHP scale, transforming the pairwise comparison matrix into the TFN scale, calculating the fuzzy synthesis value (Si), the vector value (V) and the defuzzification ordinate (d '), input the project budget that has been implemented (or last year), normalization, calculating the consistency ratio, and calculating the final alternative weight value to give result total score FAHP.

The limitations associated with this research include the small sample size of literature considered to act as the voice of experts in the pairwise comparison of the chosen criteria. A larger sample size in the future could yield more accurate results regarding the relative importance of the selected criteria. It is also important to note that these results are limited to the knowledge and experiences of the chosen experts. Another potential limitation of this research is the use of literature to act as the voice of experts. This could add another layer of uncertainty and subjective judgment that stems from the interpretations and opinions of the researchers utilizing the literature, which is not accounted for by the FAHP. Future research should focus on gathering input data from sustainable project researchers and practitioners in an effort to gather direct input and, thus, eliminating any need for interpretation by the researchers.

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References are dated. **:Dikomentari [ns7]**

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Above 80% of references must **:Dikomentari [ns9]** include valid DOIs.