Selection of subcontractor vendor using analytic hierarchy process (AHP) method in construction company

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Abstract. Sub-contractor vendor is the one of the most important aspects for the construction company to finish the project. Failures in vendor selection could lead to severe impact of project on time, on quality and on budget. The selection of subcontractor criteria is the initial stage in the decision-making process by procurement. This research uses multi criteria decision making, with Analytic Hierarchy Process method. Super Decision Software is used to help in obtaining weight and ranking values. The purpose of this research is to determine the criteria in selecting vendor and choosing the best sub-contractor vendor. Criteria in selecting subcontractors shall comply Indonesia's Government law & policies which classify into six aspects, namely legal aspects, technical aspects, financial aspects, managerial aspects, safety aspects, and aspects of the vendor's reputation. Based on company data, there are 3 candidates of sub-contractor vendors who will be selected in doing project work. The results showed that the priority on the criteria for safety aspects gained a weighting of 33.9%, the priority in the sub-criteria was coordination in the project with a weight of 63%, and the priority of the vendor which was vendor B with a weight of 36.7%.

Keywords: Analytic Hierarchy Process, Criteria, Sub-criteria, Subcontractor Vendor.

1. Introduction

Sub-contractor vendor is one of the most important aspects of the construction company in the running of the project. For the company, to make its goals in completing development properly and on time, of course the company must have vendors who could do work according to the specified deadlines. It is crucial to identify subcontractors based on construction company’s criteria so that the project can be completed on time, on quality and on budget [1]. In construction company, a significant job volume, more than 80% was executed by sub-contractor vendor, therefore the project fulfillment within time, quality and budget depend largely to sub-contractor vendor [2]. The determination of subcontractors frequently experiences issues, for example, trouble in the project coordination by subcontractors, the determination of wrong subcontractors, over budget, and uncontrol bid [3]. Such issues may be brought about by inadequate time for execution, poor data channels or muddled systems. Therefore, significant for development organizations to control the subcontractor choice activity and try to lead it in a reasonable and objective.
The study case carried out on a construction company, PT Brantas Abipraya, who experienced delays in doing project work, which majority project job executed by subcontractor vendor, PT. XYZ. The project failure impacted to PT. XYZ became blacklisted from the list of capable partners. Therefore, PT Brantas Abipraya had to conduct selection of sub-contractor vendors. As sub-contractor is crucial vendor for construction company, very important to define a methodology to evaluate with simple design and easy-to-use check sheet for subcontractor selection [3].

Based on company regulations, if a vendor is negligent in carrying out his work, it will be followed up according to the agreement that is contracted with the vendor, such as a warning letter and even a fine or blacklist from the company’s vendor list. The consequences of vendor negligence will be affected the course of the project taken by the main contractor or be subject to fines by the company who gives the project. To prevent negligence, it is necessary to select a good vendor.

The research aim are, first, Selection of vendors criteria which comply to Indonesia’s construction law and company policies. Second, selecting the winner among sub-contractor vendors candidate A, B and C, use the Analytic Hierarchy Process method, with software Super Decision.

The criteria that are taken in subcontractor selection are based on the Indonesia’s Presidential Regulation Number 16 of 2018 concerning Government Procurement of Goods / Services, Regulation of the Minister of Public Works Number 07/PRT/M/2019 concerning Standards and Guidelines for Procurement of Construction Services Through Providers, and Procedures for Procurement and Control Products of PT Brantas Abipraya (PRO-42/01) where these criteria classify into six groups of aspects, namely legality aspects, technical aspects, financial aspects, managerial aspects, safety aspects, and vendor reputation aspects.

2. Literature Review
Analytic Hierarchy Process (AHP) is an alternative decision making with many criteria created by the Saaty. AHP in making decisions is characterized by numerous interrelated and often competing factors and sets priorities among decision factors to reach a decision [4]. AHP approach is subjective and the weight of the priority elements can be obtained from the company’s decision makers using direct question and answer method or questionnaire [5].

The advantages using AHP is that it allows a larger set of alternatives out of nine, avoiding ranking reversals, and giving overall priority based on ideal priority [6]. Another advantage of using AHP is that although AHP is qualitative criteria in making decisions, the end result is quantitative with mathematical techniques [7]. A Multi criteria Decision Making, AHP and its variation, fuzzy AHP method has proven to be a powerful way to select vendors in various business groups, such as construction [1-4] and general industries [5-8].

3. Research Methodology
3.1. AHP Process
In determining the AHP, a hierarchy diagram is needed to show several factors that need to be considered and alternative decisions are made. After defining the hierarchy, proceed to define alternatives and define the basic matrix according to the level of preference [8] shown in Table 1.

| Interest Intensity | Information                                      |
|-------------------|-------------------------------------------------|
| 1                 | Both elements are equally important             |
| 3                 | One element is slightly more important than the other |
| 5                 | One element is more important than the other    |
| 7                 | One element is absolutely essential to the other |
| 9                 | One element is clearly more important than the other |
| 2, 4, 6, 8        | Values between two close consideration values   |
If the number of respondents is more than one person, the geometric average calculation can be done with the following formula [8]:

\[ GM = \sqrt[n]{X_1 \times X_2 \times X_3 \ldots \times X_n} \]

Calculate the normalized criteria comparison by dividing the value of each element in the geometric mean of the matrix by the total value for each column. Furthermore, calculate the eigenvalues by average of each row (row average) on normalized criteria comparison. Eigen value was calculated using the following equation [9]:

\[ Eigen = \frac{A_{ij}}{\sum A_{ij}} \]

The next step is to determine the weight sum vector by multiplying the row average normalize matrix with the basic matrix and the consistency vector by dividing it by the weighted sum vector and row average. Lambda and consistency index can be calculated after getting the consistency vector value.

Lambda was calculated using the following equation[10]:

\[ \lambda = \frac{\sum Consistency \ Vector}{N} \]

Consistency index was calculated using the following equation[11]:

\[ CI = \frac{\lambda - N}{N - 1} \]

Consistency ratio was calculated using the following equation[12]:

\[ CR = \frac{CI}{RI} \]

Where RI or Random Index can be determined based on Table 2 [8]:

| n  | Random Index (RI) |
|----|-------------------|
| 2  | 0.00              |
| 3  | 0.58              |
| 4  | 0.90              |
| 5  | 1.12              |
| 6  | 1.24              |
| 7  | 1.32              |
| 8  | 1.41              |
| 9  | 1.45              |
| 10 | 1.49              |
| 11 | 1.51              |
| 12 | 1.58              |
3.2. Step of Research

a. Determine the company to be observed, namely PT BrantasAbipraya which is a large construction company in Indonesia.

b. Getting problems in the company that is found problematic sub-contractor vendor so that the company can have an impact on losses.

c. Find out the AHP method, an qualitative with mathematical result, fair and objective selection process to analyze criteria and choose the winner among subcontractor candidate.

d. Data collection was carried out inPT BrantasAbipraya during August to October 2019, respondent are Board of Project Manager, Site Manager, Procurement Manager, Technical Manager, and Quality Manager. Data are collecting by:
   ✓ Brainstorming and interview, based on Indonesia’s construction law and internal company policies to obtain six criteria: legality aspects, technical aspects, financial aspects, managerial aspects, safety aspects, and vendor reputation aspects. Six aspect determined as the second level, to select criteria, the third level contains sub-criteria, and the fourth level contains the prospective vendors to be selected as shown in Figure 1.
   ✓ The questionnaire of pair comparisons sends to company expert respondent (Board of project manager). The questionnaire is divided into 3 parts, namely a questionnaire for the selection priority of criteria, sub-criteria, and vendors.

e. The questionnaire result analyzes using the Analytic Hierarchy Process (AHP) method for calculations and decision making. The comparison matrix from the questionnaire results of each expert was made using Microsoft Excel while ranking and weighting was done using Super Decision software [13].

f. From the processed data, it will be analyzed to make decisions in determining the priority criteria in choosing a vendor based on the literature study that has been done.

g. The research will produce conclusions to answer the purpose of this research and also the suggestions that can be given to the company.

![Hierarchy Diagram](image-url)

*Figure 1. Hierarchy Diagram*
4. Result and Analysis

4.1. Ranking and Weighting of Aspects Criteria

The initial stage is decision making of criteria weighted. The comparison process is carried out to determine the priority of the criteria. Based on the questionnaire data obtained, using the Excel, supermatrix of the aspect criteria shown in Table 3:

| Criteria       | Legal | Financial | Work Safety | Technical | Managerial | Vendor Reputation |
|----------------|-------|-----------|-------------|-----------|------------|-------------------|
| Legal          | 1.00  | 0.24      | 0.19        | 0.47      | 0.64       | 2.06              |
| Financial      | 4.21  | 1.00      | 0.34        | 0.96      | 2.14       | 4.79              |
| Work Safety    | 5.23  | 2.91      | 1.00        | 0.67      | 3.87       | 6.19              |
| Technical      | 2.14  | 1.05      | 1.50        | 1.00      | 2.11       | 3.76              |
| Managerial     | 1.57  | 0.47      | 0.26        | 0.47      | 1.00       | 3.48              |
| Vendor Reputation | 0.49  | 0.21      | 0.16        | 0.27      | 0.29       | 1.00              |
| Sum            | 14.64 | 5.87      | 3.45        | 3.83      | 10.05      | 21.28             |

After obtained supermatrix of aspect criteria, use Super Decision software for the ranking results that shown in Figure 2 and Table 4:

![Figure 2. Super Decision Software](image)

From the results of weighting against the criteria for aspects, the results are obtained in the order of the criteria for work safety, technical, financial, managerial, legal, and vendor reputation. From the weighting results, work safety obtained a weight value of 33.9%, then continued with technical 23.8%, financial 20.3%, managerial 10.5%, legality 7.2%, and vendor reputation 4.3%. The work safety aspect is the most important aspect in determining which vendor can minimize work accidents that may occur while the project is running. While the last priority aspect, namely the aspect of vendor reputation, also needs attention because to deciding the selected vendor to find out the good and bad backgrounds of the vendor.
Table 4. Weighted result and criteria ranking

| Code | Criteria          | Weight (%) | Ranking |
|------|-------------------|------------|---------|
| A    | Work Safety       | 33.9%      | 1       |
| B    | Technical         | 23.8%      | 2       |
| C    | Financial         | 20.3%      | 3       |
| D    | Managerial        | 10.5%      | 4       |
| E    | Legal             | 7.2%       | 5       |
| F    | Vendor Reputation | 4.3%       | 6       |

The weighting of the aspect criteria has an inconsistency ratio or a consistency ratio of 0.05. The value of the consistency ratio on the aspect criteria is not more than 0.10 (CR ≤ 0.10) so it is stated to be consistent and the assessment given by respondents to the data is deemed appropriate.

4.2. Ranking and Weighting of Sub-criteria
By using the Super Decision software, the weighting and sub-criteria ranking results are obtained that shown in Table 5:

Table 5. Weighted result and sub-criteria ranking

| Code | Criteria                      | Weight (%) | Ranking |
|------|-------------------------------|------------|---------|
| D.1  | Project Coordination          | 63%        | 1       |
| A.1  | SMK3L Certificate             | 61.0%      | 2       |
| F.1  | Not Blacklisted               | 44.2%      | 3       |
| F.2  | Experience with Demands/Claims| 39.7%      | 4       |
| E.1  | ISO 9001 Certificate          | 33.6%      | 5       |
| B.1  | Problem Solving Techniques    | 30.2%      | 6       |
| E.2  | OHSAS 18001 Certificate       | 29.8%      | 7       |
| C.1  | Vendor Capital                | 29.3%      | 8       |
| B.2  | Experts                       | 27.2%      | 9       |
| A.2  | HaveSMK3L SOP’s               | 24.1%      | 10      |
| D.2  | Quality Guarantee             | 24.0%      | 11      |
| B.3  | Work Experience               | 23.4%      | 12      |
| C.2  | Payment Method                | 22.7%      | 13      |
| E.3  | ISO 14001 Certificate         | 20.9%      | 14      |
| C.3  | Bank Reference                | 19.2%      | 15      |
| B.4  | Equipment Owned               | 19.2%      | 16      |
| F.3  | Frequency of Vendor Failure   | 16.1%      | 17      |
| E.4  | Vendor Detail                 | 15.7%      | 18      |
| A.3  | Comply with SMK3L Regulation  | 14.9%      | 19      |
The weighting results obtained sub-criteria priority, namely project coordination in the managerial aspect with a weight of 63%, having an SMK3L (Occupational Health, Safety and Environmental Management System) certificate in the work safety aspect with a weight of 61%, and not being included in the blacklist in the aspect of vendor reputation with a weight of 44.2%. The weighting of the aspect criteria must be tested for the inconsistency or consistency ratio. Table 6 shown the inconsistency value against the aspect criteria:

| Code | Sub-criteria         | Inconsistency |
|------|----------------------|---------------|
| A    | Work Safety          | 0.09          |
| B    | Technical            | 0.08          |
| C    | Financial            | 0.10          |
| D    | Managerial           | 0.07          |
| E    | Legal                | 0.06          |
| F    | Vendor Reputation    | 0.08          |

The weighting of the sub-criteria for each aspect criterion has an inconsistent value or consistency ratio, namely the work safety aspect with 0.09, the technical aspect 0.08, the financial aspect 0.10, the managerial aspect 0.07, the legality aspect 0.06, and the aspect of company reputation 0.08. The value of the consistency ratio for each criterion was not more than 0.10 (CR ≤ 0.10), so it was stated that it was consistent, and the assessment given by the respondents to the data was deemed appropriate.

From the results of the overall data processing shows that the highest priority criteria is work safety while the lowest priority is vendor reputation. Meanwhile, the sub-criteria with the highest priority is project coordination and the lowest priority is supervision. The highest priority on the criteria and sub-criteria are related to each other even though they are not in the same cluster. The criteria and sub-criteria for the highest position show that they influence each other in determining the criteria for choosing a vendor by paying attention to the safety criteria and coordination sub-criteria in the project.

4.3. Ranking and Weighting of Vendor
Based on the acquisition of the vendor, the priority of the vendor for each sub-criteria is obtained. Table 7 shown the weighted result and vendor ranking:

| Vendor | Weight (%) | Ranking |
|--------|------------|---------|
| Vendor B | 36.7%      | 1       |
| Vendor A | 35.4%      | 2       |
| Vendor C | 27.9%      | 3       |

In the sub-criteria complying with SMK3L regulations, having SMK3L certificates, having SMK3L SOP’s, ISO 9001 certificates, ISO 14001 certificates, and OHSAS 18001 certificates all subcontractor vendors have them so that each one gets a weight of 33%. Whereas in the sub-criteria,
the frequency of vendor failure, and not being included in the blacklist, each vendor has never experienced so it gets a weight of 33%. Vendor A is a priority in the bid price (67%), experience with the demands/claims (52.9%), work experience (63.8%), and experts (60.5%). Vendor B is a priority in the sub-criteria for payment methods (48.2%), bank references (56.8%), company details (42.8%), quality guarantee (54%), project coordination (51.9%), supervision (47.9%), equipment owned (65%), and problem-solving techniques (51.5%). Vendor C is a priority in the company's capital sub-criteria (57.8%), and balance sheet & financial statements (38.4%). From this weighting, vendor B was chosen as the first priority with a weight of 36.7%. The reason for choosing vendor B is because vendor B is a priority in many sub-criteria and is also a priority in the projects coordination sub-criteria which are priority sub-criteria. Then vendor A is the second priority with a weight of 35.4%, and vendor C is the last priority with a weight of 27.9%.

### Table 8. Inconsistency value against aspect vendor

| Code | Criteria                          | Inconsistency |
|------|-----------------------------------|--------------|
| D.1  | Project Coordination              | 0.05         |
| A.1  | SMK3L Certificate                 | 0.00         |
| F.1  | Not Blacklisted                   | 0.00         |
| F.2  | Experience with Demands/Claims    | 0.03         |
| E.1  | ISO 9001 Certificate              | 0.00         |
| B.1  | Problem Solving Techniques        | 0.08         |
| E.2  | OHSAS 18001 Certificate           | 0.00         |
| C.1  | Vendor Capital                    | 0.05         |
| B.2  | Experts                           | 0.04         |
| A.2  | Have SMK3L SOP’s                  | 0.00         |
| D.2  | Quality Guarantee                 | 0.04         |
| B.3  | Work Experience                   | 0.01         |
| C.2  | Payment Method                    | 0.07         |
| E.3  | ISO 14001 Certificate             | 0.00         |
| C.3  | Bank Reference                    | 0.08         |
| B.4  | Equipment Owned                   | 0.07         |
| F.3  | Frequency of Vendor Failure       | 0.00         |
| E.4  | Vendor Detail                     | 0.07         |
| A.3  | Comply with SMK3L Regulation      | 0.00         |
| C.4  | Bid Price                         | 0.10         |
| C.5  | Balance Sheet and Financial Statement | 0.02   |
| D.3  | Supervision                       | 0.08         |

The vendor weighting for each sub-criteria has a value of inconsistent or consistency ratio that shown in Table 8, namely project coordination with a weight of 0.05, SMK3L certificate with a weight of 0, not on the blacklist with a weight of 0, experience with demands/claims a weight of 0.03, ISO 9001 certificate with a weight of 0, problem solving techniques with a weight of 0.08, OHSAS
certificate 18001 with a weight of 0, company capital with a weight of 0.05, experts with a weight of 0.04, SMK3L SOP’s with a weight of 0, quality guarantee with a weight of 0.04, work experience with a weight of 0.01, payment method with a weight 0.07, ISO 14001 certificate with a weight of 0, bank references with a weight of 0.08, equipment& equipment with a weight of 0.07, frequency of vendor failure with a weight of 0, company details with a weight of 0.07, SMK3L regulations with a weight of 0, and monitoring a weight of 0.08. The value of the consistency ratio for each criterion was not more than 0.10 (CR ≤ 0.10), so it was stated that it was consistent and the assessment given by the respondents to the data was deemed appropriate.

4.4. Discussion result
Construction company in fact, more than 80% work was doing by subcontractor, hence successful project in time, in quality and in budget, majority depend on subcontractor. Therefore, initial process to selection subcontractor vendor was important, especially to comply Indonesia’s construction law and internal construction policies. The study result show safety aspect has the highest rank among criteria with sub criteria project coordination as the highest rank. Follow with technical aspect with sub criteria comply SMK3L. Therefore to select subcontractor vendor who comply Indonesia’s contractor Law and policies, vendor shall prioritize safety with strong project coordination and technical aspect which strong SMK3L compliance.

5. Conclusion
The result of the research is the criteria that need to be considered in determining the vendor are safety aspects with a weight of 33.9% and in sub-criteria priority there is project coordination in managerial aspects with a weight of 63%. The best vendor based on the research is vendor B with a weight of 36.7%. Vendor B was chosen because vendor B was a priority in many sub-criteria and was also a priority in the project coordination sub-criteria which was a priority for the sub-criteria. To determine priorities in determining criteria and vendors, the company can use the Analytical Hierarchy Process method because this method is a method that is easy to use by companies.

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