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Subcontractors Selection of Building Construction Project Using Analytical Hierarchy Process (AHP) and Technique for Others Reference by Similarity (TOPSIS) Methods

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Abstract

Objective: This research aims to identify the most important qualification criteria for selecting subcontractors in the construction supply chain.
Design/Methods/Approach: The criteria calculations were analyzed based on the Analytical Hierarchy Process (AHP) method applied to obtain the weight of the subcontractor selection criteria. The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method was used to evaluate the different subcontractors against 22 sub-criteria indicators. The research sample is the Project Manager and Commercial Manager, who are the decision-makers in selecting subcontractors**.**
Findings: Quality, Health, Safety, and Environment (HSE) and Price are the highest priority criteria for subcontractor selection, with the most influential sub-criteria being quality work specifications, tender prices, and having an HSE supervisor on the project.
Originality: Selection of the right Subcontractor is very important for the successful completion of the project and the continuity of the contractor's business as most of the construction project work is carried out by subcontractors. This research on subcontractor selection is to reduce errors in the selection of subcontractors in construction projects and to understand multi-criteria decision-making using the AHP and TOPSIS methods.

Keywords: AHP, Construction, MCDM, Subcontractor, TOPSIS

JEL Classification: L74, C44, N6

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1. Introduction

Construction projects such as apartments, hotels, and offices generally have high complexity in their implementation (Zheng et al., 2021). Due to a large number of work items must involve many parties, such as suppliers and specialist subcontractors, in the implementation process (Akintan & Morledge, 2013). According to research (Tan et al., 2017), subcontractors carried almost 70% of the total value of construction work. Selecting the appropriate Subcontractor is critical to the project completion and the continuity of the contractor's business (El-khalek et al., 2019). The main contractor's lack of experience in specialist work makes the role of subcontractors critical because it can reduce project implementation costs through higher productivity based on the ability of subcontractors to work more effectively by using a specialized workforce (Sujoko, 2019; Tan et al., 2017).

Shifting most of the project work to subcontractors is safe and convenient for the main contractor. Still, the failure of subcontractors can also be one of the reasons behind the collapse of the entire project (Lew et al., 2020; Adinyira et al., 2020). The contractor must carefully select the Subcontractor because mistakes in the section will disrupt the project implementation process (Ayettey & Danso, 2018). Subcontractor selection on the criteria that become the standard and the requirements that must meet. The criteria used in selecting subcontractors differ according to the focus or interests of each project or company (Kog & Yemen, 2014; Pinamang et al., 2018). As in previous research, seven criteria in selecting subcontractors: quality, finance, company reputation, work safety, managerial, technical, and general aspects (Zulaihah, 2016). While research (Tanuwijaya & Tamtana, 2018) mentioned that the factors that influence the main contractor in selecting subcontractors in the implementation of construction projects are company performance, resources, company achievements, marketing, information, and cooperative relationships. The financial aspect of the Subcontractor is also the most important in the subcontractor selection process (Muhendra et al., 2018). The selection of subcontractors also cannot be seen from one criterion alone. Still, it must be by following several standards that best match the wishes of a project or company in achieving its goals (Monyane & Emuze, 2015).

Of the several criteria used in the selection and the alternative subcontractors to be selected, an appropriate and accurate technique to determine the requirements that become the priority for picking and choosing an ideal Subcontractor. The criteria used in selecting subcontractors need to be made more detailed and given weight to each standard to produce the best decision that will also impact the project's sustainability and the company's business. The weight of criteria and sub-criteria based on the level of importance between criteria and between sub-criteria can be measured using the Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods.

The AHP method was developed by Thomas Saaty in the 1970s as an effective multi-criteria decision-making tool for complex problems by accelerating and simplifying the decision-making process that divides into several parts or groups (Fernando & Siagian, 2021; Kumar et al., 2018). Based on the research of Leal, (2020); Abhishek Kumar et al. (2017), stated that the AHP method was the most widely used method for selecting suppliers and vendors. At the same time, the TOPSIS is a decision-making method introduced by Yoon and Hwang in 1981 to solve multi-criteria problems (Chen, 2021; Marzouk & Sabbah, 2021). The TOPSIS method provides a solution with the best and the worst alternative to the alternative problems (Marbun & Sinaga, 2019). The best and worst option obtained from the scores illustrated by the alternative assessment. If the decision-maker gives a different score, then the scale of the alternatives will also be different. So TOPSIS provides an evaluation of the perfect solution by taking into account the perspective of each decision-maker (Chaharsooghi & Ashrafi, 2014). The combination of the two AHP and TOPSIS methods can produce maximum decisions (Ishak & Parindori, 2019). Using the AHP and TOPSIS methods is expected to create the most appropriate decisions to reduce or avoid errors in selecting subcontractors. The choice of the two ways to previous research on selecting sustainable suppliers in the construction supply chain (Marzouk & Sabbah, 2021).

Based on previous research, there are many criteria for selecting subcontractors and suppliers in the construction sector. Thus, researchers conducted this research to determine the requirements that become a priority in the selection of subcontractors and also to recommend the ideal alternative subcontractors for building construction projects. This study reduces errors in selecting subcontractors in construction projects and understanding multi-criteria decision-making using the AHP and TOPSIS methods.

2. Literature review

Project Management

Project management is a method used to manage a complex project involving several activities (Nusraningrum et al., 2020). Project management is a strategy that needs to carry to achieve the efficiency and effectiveness of a project (Arianie & Puspitasari, 2017). By introducing management practices that can optimize resources of project management. Project management can support the achievement of project and company objectives and assure stakeholders that resources are being managed effectively (Sitanggang et al., 2019). Each project implementation has a triple constraint: cost, quality, time limitations, material equipment, labour, and Health, Safety, and Environment (HSE). Project implementation challenges are time-effective and cost-efficient planning without compromising quality. In addition to

quality, cost and time are two essential things in the implementation of construction work because the costs incurred at the time of performance are very dependent on the time of execution of the work (Ridwan & Ajiono, 2017).

Construction Supply Chain

Supply chain management is an integrated method between parties to produce products or services. This process starts with getting raw materials from suppliers, and the production process, until the product is used by the customer (Sholeh, 2020). The construction supply chain is a network of organizations from upstream to downstream that carry out activities to produce goods and services (output) of valuable construction products for the final customer (Aditya Dei et al., 2017). The concept of a supply chain in the construction industry can reduce the cost and duration of work. The current supply chain is not just an activity but has led to an effective performance called a sustainable supply chain.

Within the construction supply chain, there are eight main cross-organizational business processes, including project management, supplier relationship management, client service management, construction flow management, demand management, order fulfilment, environmental management, and research and development (Hatmoko & Kistiani, 2017). A reliable construction supply chain management is needed. Construction supply chain management can define as a system in which contractors, suppliers, architects, and clients work together under the coordination of the main contractor to produce, assemble, deliver and use information, materials, equipment, and other resources for a construction project (Bakhtiarizadeh et al., 2019).

Procurement Management

Procurement provides input for goods or services needed in production or other company activities (Nugroho & Iskandar, 2020). de Oliveira et al. (2021) defines it as a process in which price, quality, and other factors in the selection process and evaluation reduce the impact and improve performance and long-term value for construction. The procurement process must be equitable, fair, competitive, and transparent between the different owners and bidders to produce cost-effective results in terms of price, time, and quality and allow the system to be controlled and managed. A good strategy in procurement procedures is needed (Lahdenperä, 2015).

The most straightforward is to use the procurements procedure on the contractor's construction performance only. However, in some procurement processes, owners and employers look for ways to consider more than price factors. Qualitative and quantitative factors encourage contractors to improve performance and skills during the construction and build value into the final construction product (de Oliveira et al., 2021). Evaluation criteria can devise, such as timeliness of performance, quality of performance, customer satisfaction, performance within budget, ability to minimize job changes and prepare plans, qualifications, technical capacity, and ability to assess and reduce risk.

Subcontractor Selection

Selecting subcontractors is a strategic process to reduce risk in a construction supply chain (Ishak & Parindori, 2019). The selection of subcontractors is a matter of final decision-making involving multi-person and multi-criteria. The process of selecting subcontractors with a subjective approach is based on the experience and intuition of those considered competent in selecting subcontractors. The selection of subcontractors uses a complex multi-criterion where each criterion has different importance. Information about these criteria is not known precisely, so a method is needed to overcome them (Kurniawan et al., 2017). Several measures are required for select subcontractors to describe the Subcontractor's performance, which adds value both now and in the future. For example, a company involved in a project can increase prospects by selecting the appropriate project team (Marzouk & Sabbah, 2021). The selection of subcontractors is intended to avoid losses due to various errors. The existing selected subcontractors must also be regularly monitored and assessed for their performance to maintain and improve their performance. Subcontractor criteria will differ for each company, depending on the goals and expectations the company wants to achieve. Muhendra et al. (2018) mentions that the requirements for selecting subcontractors can be grouped into seven aspects, namely general aspects, financial aspects, technical aspects, managerial aspects, work safety aspects, company reputation aspects, and quality aspects which are considered sufficient to provide information regarding the performance of subcontractors.

Research conducted by Tanuwijaya & Tamtana (2018) states there are six factors that most influence the selection of subcontractors, namely the suitability of the Subcontractor's working period with the implementation schedule, length of experience carrying out similar projects, available resources, frequency of communication, competitive bidding prices and the duration of the cooperative relationship. Determination of subcontractors is something that must be considered in starting the activities of a construction project. Companies always want subcontractors who can meet the company's needs.

3. Method

Selection Criteria

The researcher conducted this research by applying a quantitative descriptive research method pattern based on the Analytic Hierarchy Process (AHP) calculation method and the Technique For Others Reference by Similarity to

Ideal Solution (TOPSIS). Quantitative descriptive research is research on data that is collected and expressed in the form of numbers. It is also equipped with qualitative data to support it, such as words or sentences arranged in a questionnaire (Hutabarat, 2019). In this research, the researcher will identify the critical variables to develop a classification system or an emerging theory and then phase out a quantitative test or examine these results in more detail. In the classification development model, the qualitative phase produces special categories or relations. This particular category or reference is then used to continue the research questions and data collection used in the second phase, namely the quantitative phase (Samsu, 2017). Researchers will use the criteria and sub-criteria proposed by El-khalek et al. (2019).

Table 1. Subcontractor selection criteria

Criteria	Sub criteria	Definition	Measuring scale
Cost	a) Tender price b) Financial stability c) Flexible in payment	a) Subcontractor submission price to carry out the construction project b) The ability of subcontractors in financial matters that may cause problems in project implementation c) Subcontractors are willing and able to adjust the situation if there is a delay in payment due to certain conditions	1. Saaty comparison scale to calculate the weight of criteria and sub-criteria 2. Likert scale to get subcontractor scores from each sub-criterion
Quality	a) Standard quality b) Quality control program c) Specification quality	a) The Subcontractor has a recognized quality certificate b) Subcontractors have quality supervisors on project implementation c) The Subcontractor can meet the requirements/job specifications	
Technical	a) Warranty b) Qualified & experienced technical employees c) Good competency of labourers d) Equipment availability & suitability	a) Subcontractors can provide work guarantees (installation & materials) b) Subcontractors have experienced and qualified technical employees c) Subcontractors can meet the needs of workers or artisans who are competent in their fields. d) Subcontractors have equipment and machines that can fulfil and support the implementation of project work.	
Management	a) Company, structural organization b) Qualified & experienced management employees c) Management ability	a) Subcontractors have a transparent company organizational structure. b) Subcontractors have qualified and experienced management employees. c) Subcontractorhave good management skills that can support the project implementation process	
Health, Safety, and Environment (HSE)	a) HSE Standard b) HSE Program c) Waste material management	a) The Subcontractor has Health, Safety, and Environment standard. b) The Subcontractor has Health, Safety, and Environment program and a supervisor at the project site. c) The Subcontractor has good waste management from the use of construction materials.	

Reputation	a) Company reputation b) Commitment to the project completion c) History of similar projects	a) The Subcontractor has a good reputation in the construction industry b) The Subcontractor is committed to completing the work until the project handover stage c) The percentage of success of subcontractors on previous similar projects is greater than the percentage of failures
Time	a) On-time schedule b) Flexible & cooperative c) Handling critical activities	a) Subcontractors can complete the work according to the planned schedule b) Subcontractors can cooperate / cooperatively in working with other subcontractors c) Subcontractors can handle critical activities during the project implementation process

The population of this study are individuals or individuals who have positions or play a role in selecting and evaluating subcontractors in a company engaged in construction services as a contractor in Indonesia (PT XYZ). Positions that play a role in establishing and assessing subcontractors are Project Manager, Commercial Manager, Site Manager, Engineer, and Quantity Surveyor. This research was conducted on architectural work because, in general, it has the most significant percentage of work in a building construction project, so it is crucial for contractors to choose the right Subcontractor. The sample is the amount taken from part of the population to be used as data. The sampling technique is carried out by purposive sampling. Namely, the researcher determined the sampling technique according to the object of this research. In applying the AHP method, the quantity of respondents does not affect the study's results, but the priority is the quality of the data from the respondents. Therefore, the AHP assessment requires an expert as a respondent to make decisions in selecting alternatives. The experts in question are people who control, are competent, influence policymaking, or know the information needed. The number of respondents in the AHP method does not have a specific formulation, but there is a minimum limit of two participants (Alitra, 2019). Respondents from this research are 7 Project Managers and 7 Commercial Managers, with a total of 14 respondents from the projects currently under construction.

Analysis Method

The Analytic Hierarchy Process (AHP) method and the Technique For Others Reference by Similarity to Ideal Solution (TOPSIS) method are decision-making methods to determine the best alternative from several alternatives based on specific criteria. Each criterion's weighting process is carried out using the AHP method, followed by the TOPSIS method to determine or decide the best alternative Subcontractor. The AHP method is used to solve multi-criteria problems that detail a complex or unstructured situation into components and then arrange parts or variables from these components into a hierarchical arrangement, assigning a numerical value to this consideration to determine which variable has the highest priority (Saaty, 1994). The TOPSIS method is used to resolve or decide alternative subcontractor options based on assessing the overall criteria and sub-criteria. The TOPSIS method is based on the concept that the chosen alternative has the shortest distance from the positive ideal solution and the farthest distance from the negative answer from a geometric point of view. By using Euclidean distance to determine the relative proximity of an alternative with the optimal solution. The positive solution is the sum of all the best values for each attribute. In contrast, the negative ideal solution consists of all the worst values achieved for each point.

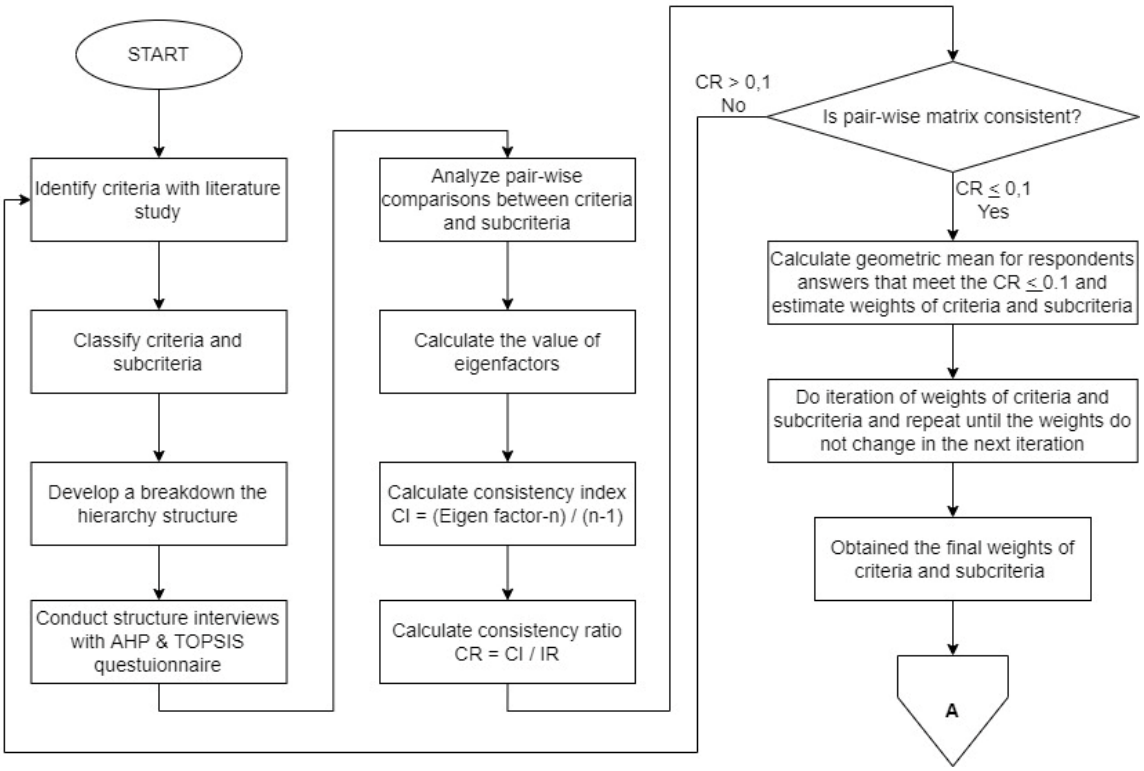

Figure 1. Flowchart of the proposed model (1)

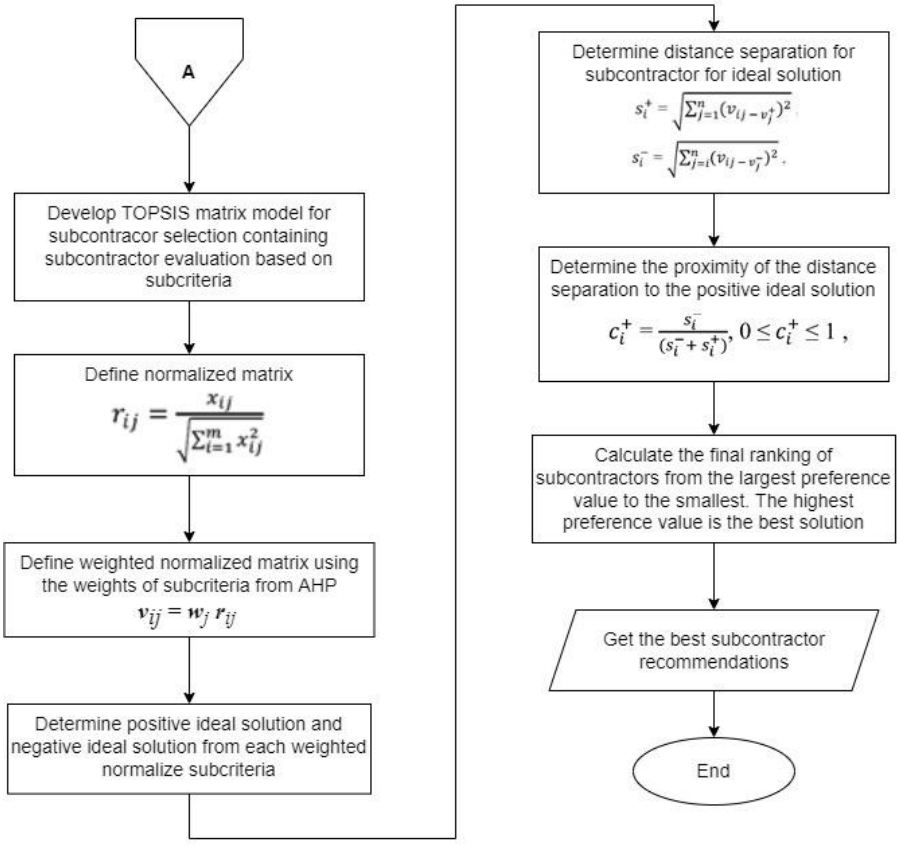

Figure 2. Flowchart of the proposed model (2)

4. Results

AHP Model Implementation

The initial step taken by the researchers was to collect primary data by visiting research respondents who are the parties with the highest positions in building construction projects. They are directly involved in the selection process or subcontractor tender, namely the Project Manager and Commercial Manager of each project. Respondents are also parties with a policy in making decisions in selecting subcontractors. The researcher interviewed respondents using a structured questionnaire with a Saaty comparison scale model. Respondents' answers were then tested for consistency at the level of criteria to meet the requirements for Consistency Ratio (CR) < 0.1 (Kristy & Zagloel, 2020). This test aims to determine the level of consistency of the respondents' answers. Suppose the results of the calculation of the respondent's answer meet the value of the ratio. In that case, the degree of consistency of the answer is satisfactory or means that the answer can produce an optimal solution or choice. However, if the CR consistency test calculation results are > 0.1, the respondent must revise the assessment, or the questionnaire cannot be used for the next calculation stage. The results of the entire questionnaire that meet the criteria can then be calculated using the Geometric Mean calculation. This calculation is carried out in the Analytical Hierarchy Process method to find one answer or synthesize answers from more than one respondent. After the Geometric Mean results are obtained, then the next step is to calculate the Priority Vector,

The next stage is weighting the priority criteria by calculating iterations (matrix multiplication). Weighting priority determines the order of importance selected from the weighting of all the requirements being compared. The iteration calculation is done by multiplying the sum for each column with the addition for each row to get a new matrix of iteration results. Iteration calculations are repeated until the difference in priority values between the two iterations is relatively tiny or < 0.00001 (Padmowati, 2015). This calculation is repeated on the sub-criteria to get the global weights in Table 2.

Table 2. Global priority weight with the AHP method

Criteria	Weight	Priority	Sub-Criteria	Weight	Priority	Global Weight	Global Priority
Cost	0.1972	III	Tender price	0.6628	I	0.1307	2
			Finance capability	0.1539	III	0.0303	12
			Flexibility in payment	0.1833	II	0.0362	9
Quality	0.2755	I	Quality certificates	0.1288	III	0.0355	11
			QC supervisor	0.2995	II	0.0825	5
			Meet quality specifications	0.5717	I	0.1575	1
Technical	0.0686	V	Product warranty	0.3324	II	0.0228	14
			Qualified technical staff	0.1258	III	0.0086	18
			Qualified labour	0.4225	I	0.0290	13
			Plants & equipment	0.1193	IV	0.0082	19
Management	0.0548	VI	Subcontractor's structure organization	0.1078	III	0.0059	20
			Qualification & experience management st	0.2329	II	0.0128	17
			Management Capability	0.6593	I	0.0361	10
HSE	0.2298	II	HSE standard	0.3250	II	0.0747	6
			HSE supervisor on the project	0.4613	I	0.1060	3
			Waste materials management	0.2137	III	0.0491	7
Reputation	0.0279	VII	Subcontractor's reputation	0.2029	II	0.0057	21
			Commitment to complete	0.6238	I	0.0174	15
			Experience with similar project	0.1733	III	0.0048	22
Time	0.1464	IV	On-time schedule	0.5908	I	0.0865	4
			Flexible & Cooperative	0.1078	III	0.0158	16
			Dealing with critical activities	0.3014	II	0.0441	8

The results showed that of the seven criteria used to select subcontractors, the Quality criteria became the top priority with a weight of 0.2755. These results strengthen the previous research conducted by (Ulubeyli & Kazaz, 2016), which indicates that the Quality criteria are the criteria that will have the most significant impact on the project work and the prime contractor's business reputation. However, it is different from (El-khalek et al., 2019)in his research which identified criteria for construction subcontractors that had an impact on project success. The study shows that the most influential standard in selecting subcontractors is Time of Work. It is also supported by (Nusraningrum & Priyono, 2018), who prove that work time is an influential factor in project performance. Temporary (Olanrewaju et al., 2021) showed that the price criterion is the most important when selecting subcontractors for construction projects. The differences between the results of this study and previous studies indicate that the requirements for selecting subcontractors may differ depending on each company's goals and interests. So before choosing a subcontractor, the company must review and determine the criteria to be used.

Then after the Quality criteria become the main criteria, the HSE criteria become the next priority with a weight of 0.2298. As in research (Widyanty et al., 2020)which states that HSE is a competitive advantage for a contractor in a construction project, this must also be supported by subcontractors to implement and maintain HSE considering the high-risk working conditions. After that, the following criteria are Price criteria with a weight of 0.1972, Work Time criteria with a weight of 0.1464, Job Technical criteria with a weight of 0.0686, Company Management criteria with a weight of 0.0548, and the last one is the Company Reputation criteria with a weight of 0.0279.

AHP-TOPSIS Implementation

After the overall priority weight calculation is obtained using the Analytical Hierarchy Process (AHP) method, the final step is to make the best alternative subcontractor decision using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) process. The data that will be used at this stage is the priority weight of each sub-criteria and the results of the respondents' assessment of the subcontractors using a Likert scale questionnaire with an ordinal scale value. The data is also the result of assessing respondents who have worked with or evaluated subcontractors.

Table 3. Normalized matrix of subcontractor valuation

SUB-CRITERIA	CEILING WORK				STEEL DOOR WORK			
	SCORE		NORMALIZED SCORE		SCORE		NORMALIZED SCORE	
	S1	S2	S1	S2	S1	S2	S1	S2
Tender price	3	2	0.832	0.555	3	2	0.832	0.555
Finance capability	3	3	0.707	0.707	3	3	0.707	0.707
Flexibility in payment	3	3	0.707	0.707	3	3	0.707	0.707
Quality certificates	3	3	0.707	0.707	3	4	0.600	0.800
QC supervisor	3	3	0.707	0.707	2	3	0.555	0.832
Meet quality specifications	3	3	0.707	0.707	2	3	0.555	0.832
Product warranty	4	3	0.800	0.600	3	3	0.707	0.707
Qualified technical staff	3	4	0.600	0.800	2	3	0.555	0.832
Qualified labour	4	3	0.800	0.600	3	3	0.707	0.707
Plants & equipment	4	3	0.800	0.600	3	3	0.707	0.707
Subcontractor's structure organization	3	3	0.707	0.707	3	3	0.707	0.707
Qualification & experience management	3	3	0.707	0.707	2	3	0.555	0.832
Management Capability	3	4	0.600	0.800	3	2	0.832	0.555
HSE standard	3	3	0.707	0.707	3	3	0.707	0.707
HSE supervisor on the project	3	3	0.707	0.707	3	3	0.707	0.707
Waste materials management	3	2	0.832	0.555	2	3	0.555	0.832
Subcontractor's reputation	4	3	0.800	0.600	3	3	0.707	0.707
Commitment to complete	4	3	0.800	0.600	2	3	0.555	0.832
Experience with similar project	4	4	0.707	0.707	2	3	0.555	0.832
On-time schedule	4	3	0.800	0.600	3	3	0.707	0.707
Flexible & Cooperative	4	3	0.800	0.600	3	3	0.707	0.707
Dealing with critical activities	4	3	0.800	0.600	3	3	0.707	0.707

The initial stage of the calculation is to determine the concentration (central tendency) of the results of the respondents' assessment of each Subcontractor with different values. In this study, the researcher used a subcontractor

assessment questionnaire with an ordinal scale, so the measure of concentration is the mode value or the value with the most significant frequency in a data set. (Budiaji, 2013). From the results of the attention of tendencies (Table 3), calculate the normalization matrix and the weighted normalization decision matrix and determine the positive ideal solution and negative ideal solution (Table 4).

Table 4. Subcontractor weighted normalization matrix

SUB-CRITERIA	WEIGHT	WEIGHT NORMALIZED SCORE		A+	A-
		S1	S2		
Tender price	0.131	0.109	0.072	0.109	0.072
Finance capability	0.030	0.021	0.021	0.021	0.021
Flexibility in payment	0.036	0.026	0.026	0.026	0.026
Quality certificates	0.035	0.025	0.025	0.025	0.025
QC supervisor	0.083	0.058	0.058	0.058	0.058
Meet quality specifications	0.157	0.111	0.111	0.111	0.111
Product warranty	0.023	0.018	0.014	0.018	0.014
Qualified technical staff	0.009	0.005	0.007	0.007	0.005
Qualified labor	0.029	0.023	0.017	0.023	0.017
Plants & equipment	0.008	0.007	0.005	0.007	0.005
Subcontractor's structure organization	0.006	0.004	0.004	0.004	0.004
Qualification & experience management	0.013	0.009	0.009	0.009	0.009
Management Capability	0.036	0.022	0.029	0.029	0.022
HSE standard	0.075	0.053	0.053	0.053	0.053
HSE supervisor on the project	0.106	0.075	0.075	0.075	0.075
Waste materials management	0.049	0.041	0.027	0.041	0.027
Subcontractor's reputation	0.006	0.005	0.003	0.005	0.003
Commitment to complete	0.017	0.014	0.010	0.014	0.010
Experience with similar project	0.005	0.003	0.003	0.003	0.003
On-time schedule	0.086	0.069	0.052	0.069	0.052
Flexible & Cooperative	0.016	0.013	0.009	0.013	0.009
Dealing with critical activities	0.044	0.035	0.026	0.035	0.026

Table 5. Separation of positive ideal (Se A+) and negative model (Se A-)

SUB-CRITERIA	A+	A-	Se A+		Se A-	
			S1	S2	S1	S2
Tender price	0.109	0.072	0.0000	0.0013	0.0013	0.0000
Finance capability	0.021	0.021	0.0000	0.0000	0.0000	0.0000
Flexibility in payment	0.026	0.026	0.0000	0.0000	0.0000	0.0000
Quality certificates	0.025	0.025	0.0000	0.0000	0.0000	0.0000
QC supervisor	0.058	0.058	0.0000	0.0000	0.0000	0.0000
Meet quality specifications	0.111	0.111	0.0000	0.0000	0.0000	0.0000
Product warranty	0.018	0.014	0.0000	0.0000	0.0000	0.0000
Qualified technical staff	0.007	0.005	0.0000	0.0000	0.0000	0.0000
Qualified labor	0.023	0.017	0.0000	0.0000	0.0000	0.0000
Plants & equipment	0.007	0.005	0.0000	0.0000	0.0000	0.0000
Subcontractor's structure organization	0.004	0.004	0.0000	0.0000	0.0000	0.0000
Qualification & experience management	0.009	0.009	0.0000	0.0000	0.0000	0.0000
Management Capability	0.029	0.022	0.0001	0.0000	0.0000	0.0001
HSE standard	0.053	0.053	0.0000	0.0000	0.0000	0.0000
HSE supervisor on the project	0.075	0.075	0.0000	0.0000	0.0000	0.0000
Waste materials management	0.041	0.027	0.0000	0.0002	0.0002	0.0000
Subcontractor's reputation	0.005	0.003	0.0000	0.0000	0.0000	0.0000
Commitment to complete	0.014	0.010	0.0000	0.0000	0.0000	0.0000
Experience with similar project	0.003	0.003	0.0000	0.0000	0.0000	0.0000
On-time schedule	0.069	0.052	0.0000	0.0003	0.0003	0.0000
Flexible & Cooperative	0.013	0.009	0.0000	0.0000	0.0000	0.0000
Dealing with critical activities	0.035	0.026	0.0000	0.0001	0.0001	0.0000

TOTAL	**0.0001**	**0.0020**	**0.0020**	**0.0001**
DISTANCE	**0.0074**	**0.0442**	**0.0442**	**0.0074**

Table 6. Subcontractor preferences

Subcontractor	Total Distance	Preferences	Ranking	Description
S1	0.0517	0.8563	1	Ideal A+ Subcontractor
S2	0.0517	0.1437	2	Ideal A- Subcontractor

From the matrix of positive and negative ideal solutions, calculate the separation of alternative distances from positive and negative to find the furthest and closest reaches for each Subcontractor on each criterion (Table 5). After getting the most distant and nearest, the alternative ranking is obtained as in Table 6, which shows that S1 is the best ideal solution for the first rank closest to the criteria with a preference of 0.8563. Respondents' answers indicate that S1 is superior in price, quality, technical work, HSE, company reputation, and working time. While in the second rank is Master, with a preference of 0.1437 and excellence on only one criterion, namely the company management criteria.

At this stage of selecting subcontractors, subcontractors should have good judgment on indicators of quality work specifications and tender prices and have an HSE supervisor on the project. The three indicators are sub-criteria with the highest weight from the quality, HSE, and Price criteria. Suppose the Subcontractor has a superior score on this indicator. In that case, it is most likely that the Subcontractor is the most suitable for the company and has a higher preference value. The calculations at this stage prove that subcontractors' selection cannot be based on high ratings alone. The decision must be made based on a thorough assessment multiplied by the weight of the sub-criteria. The three indicators are sub-criteria with the highest importance from the quality, HSE, and Price criteria. Suppose the Subcontractor has a superior score on this indicator. In that case, it is most likely that the Subcontractor is the most suitable for the company and has a higher preference value.

It can solve by using the AHP or TOPSIS method. Both of these methods have their respective strengths and weaknesses. One of the strengths of the AHP method is that it can parse priority weights from most significant to most minor and build a decision hierarchy. Thus the method can enable decision-making by looking at the importance of each criterion and making it possible to eliminate unimportant criteria in the following selection. However, TOPSIS cannot perform priority weight calculations as AHP does. In the AHP method, the criteria weights are obtained through a sequence of pairwise comparisons based on the measurement of the 1-9 comparison scale (Saaty scale). The scale can show that the greater the weight value (score 9), the more critical the criterion is, and the smaller the weight value (score 1), the two standards are equally important.

Meanwhile, the TOPSIS method cannot do this. So, in the absence of determining the priority weights that become priority calculations against applicable criteria to increase validity, the TOPSIS method should be combined with other methods, for example, in this study with the AHP method to produce maximum decisions as recommended in the study. Sutoyo & Dewi Nusraningrum, 2020 state that the weighting with the AHP method is more accurate.

The AHP method can also be used to select alternative subcontractors. It is by comparing subcontractors with each other based on criteria using the Saaty comparison scale. The final result obtained is also in the form of subcontractor assessment weights. The greater the priority weight obtained from the alternative, the alternative is the ideal Subcontractor for the company. However, using the AHP method in selecting subcontractors will be difficult if many participating subcontractors are in a tender. Managers or positions with authority to assess or choose will find it difficult because they have to repeatedly compare one Subcontractor with other subcontractors based on the criteria used. In addition, if the comparison results from each alternative Subcontractor are inconsistent, then the assessment must be repeated from the beginning, or it is considered not to meet the consistency test. Therefore, the TOPSIS method is used in determining the ideal alternative Subcontractor. The TOPSIS method can calculate simpler and is easier to understand (Chaharsooghi & Ashrafi, 2014). The TOPSIS method only requires subcontractor evaluation of each criterion and allows the contractor to assess the Subcontractor directly. The TOPSIS method has also gained popularity due to its simple troubleshooting steps and easy-to-understand approach (Chakraborty et al., 2019). In this study, the two methods above were combined to combine the strengths of each technique to achieve maximum decisions as suggested by the research (Ishak & Parindori, 2019).

5. Conclusion

The results of this research are proposed criteria and methods that focus more on decision-making at the management level to choose the Subcontractor. It can be used as input and consideration for the management of PT XYZ in selecting subcontractors for future projects so that losses such as those in Project X can be avoided and can become a new business strategy for the company to improve quality. It also identifies that problem-solving in multi-criteria selection can use the AHP method and TOPSIS method so that the election results can be more accurate or to company goals. The two methods can be used individually or in combination in problem-solving, according to the needs

or the number of multi-criteria chosen. The differences between the findings of this study and previous studies indicate that each project has a different type and purpose, which may affect the criteria and sub-criteria for selecting subcontractors. Measures and sub-criteria can be adjusted in each selection and can review the weight of each bar.

There are some limitations experienced and can be a factor that can be paid more attention to by future researchers in further refining their research. The number of respondents is only 14 people, which is still insufficient to describe the company's overall state, so the following analysis is expected to include more respondents from each level and director. The object of study is only focused on architectural work subcontractors, which is only one of many aspects of work in construction projects. It is recommended that in the future, this method can be used in the selection of all subcontractors.

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Author Contribution
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The authors declare that the research was conducted without any commercial or financial relationships construed as a potential conflict of interest.

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