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Selection of Coal Terminal Port Spare Parts Suppliers Using the AHP-Topsis Method

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Abstrak. In the coal mining industry, the conveyor system is a vital component in ensuring the smooth distribution of coal from the stockpile to barges at the terminal port. PT X, one of the leading coal mining companies in Indonesia, faces challenges regarding the sustainability of conveyor operations, particularly in spare part procurement. Dependence on specific suppliers without continuous evaluation can pose risks such as delivery delays, price fluctuations, and operational downtime, which affect the company's productivity. This study aims to develop a supplier selection model for spare parts at the Coal Terminal Port of PT X using the Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. AHP is employed to determine the priority weights of criteria based on expert assessments through pairwise comparisons, while TOPSIS is used to rank suppliers based on their relative closeness to the ideal solution. The AHP results indicate that the highest weighted criteria are Quality (35,59%), Services (29.59%), Delivery (15,93%), Cost (12,98%), and Profile (5,91%), while the top sub-criteria are Specification (19,30%), Certification (16,28%), followed by After-Sales Service (15,63%) and Warranty (13,97%) with a consistency ratio < 0,1. Supplier S1 ranks the highest with a preference value of 0,8837. Furthermore, to ensure the robustness of the TOPSIS ranking results, a sensitivity analysis was conducted by increasing or decreasing weights by 1%, and the top-ranked supplier remained unchanged. Thus, the TOPSIS method in this study is proven to be robust.

Keywords: AHP-TOPSIS, spare part supplier, coal, sensitivity analysis

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INTRODUCTION

The coal mining industry is one of the strategic sectors that has an important role in the Indonesian economy, both as a domestic energy provider and a leading export commodity. In supporting the smooth operation of their operations, coal mining companies are highly dependent on various infrastructures and heavy equipment, one of which is the conveyor system. The conveyor serves as the main means of transportation to move coal material from the stockpile area to the barges at the terminal port. With high operational intensity, conveyor systems are one of the main determinants of productivity and efficiency of the company's supply chain (Görçün, 2019; Heitasari & Adi, 2023; Torgul et al., 2018).

However, the operational sustainability of conveyor systems often faces technical challenges, especially due to delays or errors in the procurement of critical spare parts. Components such as belts, rollers, pulleys, and gearboxes are vital elements that must be available in a ready-to-use condition. Reliance on certain suppliers without continuous evaluation can pose operational risks, such as supply disruptions, price fluctuations, and delivery delays, which ultimately lead to downtime and increased production costs (Chi & Trinh, 2016; Daulay & Dinariyana, 2021; Li et al., 2021).

As PT X's coal production increases, the reliability of the conveyor system becomes increasingly crucial. As shown in Figure 1.1, PT X's coal production has experienced a significant increase in production since the beginning of its operations, both for export purposes and domestic needs. By 2024, the production volume will have reached more than 30 million tons, with a portion of domestic consumption of 30% of total production. This increase confirms the importance of the continuity of the coal transportation process, which is highly dependent on the performance of the conveyor system (Daulay & Dinariyana, 2021; Sumanto et al., 2021). With this trend of increasing production, failure or delay in the procurement of conveyor spare parts can cause significant losses, both in terms of productivity, delivery, and the achievement of the company's business targets. PT X, as one of the leading coal mining companies in Indonesia, recognizes the importance of strategic evaluation in the selection of spare parts suppliers (Karabayir et al., 2020; Kurniawan et al., 2022).

Supply Chain Management (SCM) business process of PT X to conduct general procurement. In the vendor selection section, there are three methods, namely direct appointment, minor tender and major tender, in this study focuses on the vendor selection process on the direct appointment method (Karabayir et al., 2020; Shojaei & Bolvardizadeh, 2020). To anticipate potential decision-making errors in the appointment of suppliers, an objective, measurable, and adaptive approach is needed. This research will help the process of selecting spare parts suppliers to be easier, planning for future purchases, and the final results of supplier ratings can be used as a consideration in certain conditions, for example if there is an increase in price due to increased demand and the selected stock supplier requires a long order time (Karabayir et al., 2020; Shojaei & Bolvardizadeh, 2020).

The decision-making process in this study uses a combination of the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). AHP is a multi-criteria decision-making method developed by Saaty in (2008). This method is used to solve complex problems by outlining the hierarchical structure from objectives, criteria, sub-criteria, to alternatives. AHP uses a paired comparison approach to determine the relative priority weights of each element and examine the logical consistency of those assessments (Dweiri et al., 2016; Geng et al., 2017).

Meanwhile, TOPSIS is a decision-making method in the Multi-Attribute Decision Making (MADM) category that aims to select the best alternatives based on its proximity to the positive ideal solution and as far as possible from the negative ideal solution (Chanpuypetch et al., 2024). TOPSIS measures the relative performance of each alternative by calculating the Euclidean distance to the ideal solution, then ranking it based on the relative proximity value (Roszkowska, 2011). However, since TOPSIS requires criterion weights as inputs, this method is combined with AHP to obtain more objective and consistent weights (Sharma et al., 2020).

The combination of AHP and TOPSIS is considered efficient and optimal because AHP provides a weight of criteria derived from expert considerations, while TOPSIS offers transparent mathematical calculations in determining supplier priority order (Sharma et al., 2020). Therefore, this study aims to develop a spare parts supplier selection model using the AHP-TOPSIS approach, taking into account strategic criteria that are relevant for the continuity of PT X Coal Terminal Port operations. It is hoped that this research can help companies in making decisions about choosing the right spare parts supplier (Kaur & Singh, 2021; Kilic & Yalcin, 2020; Lo et al., 2018).

Based on the background explanation provided earlier, the research problems in this study are as follows: 1) What are the priority factors influencing the selection of spare parts suppliers at the Coal Terminal Port of PT X? 2) How can the distribution of weights in the criteria or sub-criteria for spare parts supplier selection affect the decision-making process at the Coal Terminal Port of PT X? 3) How can the application of the developed method impact the determination of the priority ranking of spare parts suppliers at the Coal Terminal Port of PT X? The objectives of this study, based on the problem formulation and background, are: 1) To identify the criteria and sub-criteria factors that influence the spare parts supplier selection decision; 2) To assess the weight of each important criterion in the existing supplier selection procedure; 3) To determine the priority ranking of spare parts suppliers using the developed method. This study is expected to provide the following benefits: 1) It can contribute to PT X by offering considerations for spare parts supplier selection using the AHP-TOPSIS approach; 2) It enables researchers to understand the criteria and sub-criteria involved in spare parts supplier selection; 3) It allows companies to optimize operations through the selection of appropriate spare parts suppliers.

METHOD

The research methods used to collect data are observation, questionnaires, and literature studies. The results of the data obtained will then be processed using the combined AHP-TOPSIS method. The decision-making process uses the AHP to assess the importance of each criterion as well as determine a preference for each decision alternative considering all criteria. Meanwhile, the TOPSIS method is used to evaluate alternatives based on the alternative priority scale measured from the distance between the positive ideal solution and the negative ideal solution.

Literature studies are conducted to obtain information about previous studies that have researched similar phenomena. Previous studies can be used as a reference regarding the results of the research to be obtained. The questionnaire is made with a series of pre-formulated written questions. The study respondents chose answers in a limited number of alternatives. The questionnaire used in the study was distributed to experts involved in the selection of spare parts suppliers at the PT X Coal Terminal Port.

Data collection is carried out by observation and discussion to obtain data directly by collecting evidence related to the phenomenon that is used as the object of research. The data obtained through observation techniques and discussions in this study is about information on potential suppliers at the PT X Coal Terminal Port.

The types of data collected in this study include the following:

1. Primary data in this study is data obtained directly through discussions and the dissemination of questionnaires provided directly by experts. The primary data used includes the best criteria in supplier selection.
2. Secondary data in this study was obtained from the company including information related to the profile and number of suppliers, delivery time, domestic component level, environmental management system procedures, and other information. The data analysis used in this study is the AHP-TOPSIS method. AHP and TOPSIS are combined for decision-making in multi-criteria problem-solving.

RESULTS AND DISCUSSION

Normalization of the Matrix

Table 1. Criteria for *Suppliers* of Normalization Results

Supplier	Profil			Biaya			Pengiriman		Kualitas		*Servcices*	
	FS	CoI	Reputasi	Harga	Biaya Transport	Metode Pembayaran	Tepat Waktu	Leadtime	Sertifikasi	Spesifikasi	Purna Jual	Garansi
S1	0,3841	0,5698	0,5185	0,3841	0,6402	0,3841	0,6868	0,4932	0,4789	0,4789	0,4975	0,6019
S2	0,6402	0,5698	0,5185	0,6402	0,6402	0,6402	0,4121	0,1644	0,4789	0,4789	0,4975	0,3612
S3	0,3841	0,3419	0,3111	0,3841	0,1280	0,3841	0,1374	0,4932	0,2873	0,2873	0,0995	0,1204
S4	0,3841	0,3419	0,5185	0,3841	0,3841	0,3841	0,4121	0,4932	0,4789	0,4789	0,4975	0,3612
S5	0,3841	0,3419	0,3111	0,3841	0,1280	0,3841	0,4121	0,4932	0,4789	0,4789	0,4975	0,6019

Resource: Prosecced Data

The data in this matrix will then be multiplied by their respective priority weights that have been obtained with the previous AHP method using the following formula, thus forming a weighted normalization matrix contained in the next section.

$$v_{ij} = w_{ij}.r_{ij} \quad (4.8)$$

Weighted Normalization Matrix

Table 2. Weighted Normalization

Supplier	Profil			Biaya			Pengiriman		Kualitas		*Servcices*	
	FS	Col	Reputasi	Harga	Biaya Transport	Metode Pembayaran	Tepat Waktu	Leadtime	Sertifikasi	Spesifikasi	Purna Jual	Garansi
S1	0,0091	0,0071	0,0120	0,0204	0,0362	0,0077	0,0567	0,0378	0,0780	0,0924	0,0777	0,0841
S2	0,0151	0,0071	0,0120	0,0339	0,0362	0,0129	0,0340	0,0126	0,0780	0,0924	0,0777	0,0504
S3	0,0091	0,0042	0,0072	0,0204	0,0072	0,0077	0,0113	0,0378	0,0468	0,0555	0,0155	0,0168
S4	0,0091	0,0042	0,0120	0,0204	0,0217	0,0077	0,0340	0,0378	0,0780	0,0924	0,0777	0,0504
S5	0,0091	0,0042	0,0072	0,0204	0,0072	0,0077	0,0340	0,0378	0,0780	0,0924	0,0777	0,0841
A^+	0,0151	0,0071	0,0120	0,0339	0,0362	0,0129	0,0567	0,0378	0,0780	0,0924	0,0777	0,0841
A^-	0,0091	0,0042	0,0072	0,0204	0,0072	0,0077	0,0113	0,0126	0,0468	0,0555	0,0155	0,0168

Resource: Prosecced Data

In the table above, the value of A Max() is the maximum value of the benefit attribute and the minimum value of the cost attribute is taken for the positive ideal solution, while A Min() is the minimum value of the benefit attribute and the maximum value of the cost attribute is taken for the negative ideal solution using the following formula$A^+ A^-$.

$$A^+ = \{(\Sigma_i^{max} v_{ij} \mid j \in J), (\Sigma_i^{min} v_{ij} \mid j \in J')\} \quad (4.9)$$

$$A^- = \{(\Sigma_i^{min} v_{ij} \mid j \in J), (\Sigma_i^{max} v_{ij} \mid j \in J')\} \quad (4.10)$$

Through the values of A Max and A Min, a positive and negative squared weighted matrix will be formed which will later be used to calculate the distance of alternative solutions, the equation to compile the positive and negative weighted matrix is as follows.

$$S_i^+ = (A^+ - x_{ij})^2 \quad (4.11)$$

$$S_i^- = (x_{ij} - A^-)^2 \quad (4.12)$$

Dimana; S_i^+ is a positive squared weighted matrix and is a negative squared weighted matrix. The results of the calculation can be seen in the table below.S_i^-

Table 3. Positive Square Weighted Matrix

Supplier	Profil			Biaya			Pengiriman		Kualitas		*Servcices*	
	FS	CoI	Reputasi	Harga	Biaya Transport	Metode Pembayaran	Tepat Waktu	Lead time	Sertifikasi	Spesifikasi	Purna Jual	Garansi
S1	0,000037	0,000000	0,00000000	0,00018	0,0000	0,00003	0,0000	0,0000	0,0000	0,0000	0,0000	0,00000
S2	0,000000	0,000000	0,00000000	0,00000	0,0000	0,00000	0,0005	0,0006	0,0000	0,0000	0,0000	0,00113
S3	0,000037	0,000008	0,00002290	0,00018	0,0008	0,00003	0,0021	0,0000	0,0010	0,0014	0,0039	0,00452
S4	0,000037	0,000008	0,00000000	0,00018	0,0002	0,00003	0,0005	0,0000	0,0000	0,0000	0,0000	0,00113
S5	0,000037	0,000008	0,00002290	0,00018	0,0008	0,00003	0,0005	0,0000	0,0000	0,0000	0,0000	0,00000

Resource: Prosecced Data

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Supplier	Profil			Biaya			Pengiriman		Kualitas		*Servcices*	
	FS	CoI	Reputasi	Harga	Biaya Transport	Metode Pembayaran	Tepat Waktu	Lead time	Sertifikasi	Spesifikasi	Purna Jual	Garansi
S1	0,000000	0,000008	0,000023	0,00000	0,00084	0,00000	0,0021	0,0006	0,0010	0,0014	0,0039	0,00452
S2	0,000037	0,000008	0,000023	0,00018	0,00084	0,00003	0,0005	0,0000	0,0010	0,0014	0,0039	0,00113
S3	0,000000	0,000000	0,000000	0,00000	0,00000	0,00000	0,0000	0,0006	0,0000	0,0000	0,0000	0,00000
S4	0,000000	0,000000	0,000023	0,00000	0,00021	0,00000	0,0005	0,0006	0,0010	0,0014	0,0039	0,00113
S5	0,000000	0,000000	0,000000	0,00000	0,00000	0,00000	0,0005	0,0006	0,0010	0,0014	0,0039	0,00452

Resource: Prosecced Data

Sensitivity Analysis

Sensitivity analysis in the AHP-TOPSIS method is the process of evaluating the extent to which changes in the weight or value of the criteria used in the calculation may affect the final result or alternative rating. In this context, AHP (Analytic Hierarchy Process) is used to measure the weight of criteria, and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is used to calculate the supplier rating of spare parts.

Sensitivity analysis allows users of the AHP-TOPSIS method to understand how stable and consistent their alternative ranking results are against variations in the weights of the criteria or values used. This helps decision-makers in measuring the level of uncertainty in the selection of spare parts suppliers. In the density analysis, the weight of the criteria will be changed by increasing or decreasing the weight of each sub-criterion by 1% because the smallest criterion weight is 1.24% so as to prevent any sub-criteria that have a weight below 0% when lowered. When one of the sub-criteria weights is changed, the other sub-criteria weights will also change so that the total weight remains at 100%. Here are the results of the sensitivity analysis.

Sensitivity analysis is an important part of the multi-criteria evaluation process that aims to assess the extent to which the stability of ranking results is affected by changes in the weight of the sub-criteria. In this study, sensitivity was analyzed by increasing and decreasing the weight of each sub-criterion by 1% in turn, resulting in a total of 24 sensitivity scenarios (12 increase scenarios and 12 weight loss scenarios). Each weight change is accompanied by a proportional adjustment to the weight of the other sub-criteria so that the total weight remains 100%.

Results from 24 sensitivity scenarios showed that in 22 scenarios, there was no change in the alternate ranking sequence. This shows that the AHP-TOPSIS model used has a high level of stability to small variations in the weight of the sub-criteria. However, there are 2 scenarios that cause a change in ranking, which is when the weight of the following sub-criteria is changed: Transportation Cost (1% weight increase) and Leadtime (1% weight decrease).

Table 5. Rank Changes After Weight Gain and Decrease

Sub-Kriteria	Bobot Perubahan	S1	S2	S3	S4	S5
Semua Sub-Kriteria	Tanpa perubahan	1	4	5	3	2
Biaya Transportasi	Naik 1%	1	3	5	4	2
Leadtime	Turun 1%	1	3	5	4	2

Resource: Prosecced Data

From the table above, S1 is consistent in the first ranking, showing total stability against the change in the weight of the sub-criteria. This makes S1 the *most dominant and* robust *supplier* to change decision preferences. In contrast, S2 experienced an increase in ranking when the weight of transportation costs was increased by 1% and *leadtime* was lowered by 1%. His position rose from fourth to third. This shows that S2 is very sensitive to the direction of weighting, particularly to the aspects of transportation costs and *leadtime*. S4 actually experienced a decline in ranking**,** from third to fourth position, displaced by the increase in S2 preferences. This indicates that although S4 competes closely with S2, it performs comparatively weaker in the sub-criteria of transportation cost and *leadtime*. S5 remains in second place, demonstrating its stability to the sub-criterion weight changes tested in this scenario. This shows that the S5 has a fairly strong preference and is not significantly affected by adjustments in terms of cost or time. S3 remained consistent in ranking fifth in all scenarios, indicating that it was not competitive in both normal conditions and when the weight of the sub-criteria was changed. This indicates that S3 has an overall low preference value in the aspects of evaluation used.

This stage is the final stage to find the relative proximity value of each alternative to the ideal solution. The preference value of each *supplier* will later be sorted in a ranking order based on the highest to lowest relative proximity preference value () to the lowest. The formula for calculating the value of preferences can be seen in the following equationV_i^*.

$$V_i^* = {D^-}/{D^+ + D^-} \quad (4.15)$$

So that the results of the values listed in the following figure and table are obtained.

Tabel 6. Nilai Preferensi dan Ranking *Supplier*

Nilai Preferensi		
Alternatif	**Preferensi (V)**	**Ranking**
S1	0,8837	1
S2	0,6648	4
S3	0,1761	5
S4	0,6702	3
S5	0,7295	2

Resource: Prosecced Data

From the results of the calculation of the preference value of supplier priority sequencing, it was found that the S1 *supplier* alternative had the highest rating with a preference value of 0.8837 which made *the S1* supplier the main *supplier* that could be considered in the selection of *spare parts suppliers*.

CONCLUSIONS

This study concludes that the decision to select spare parts suppliers is influenced by five main criteria—**Profile, Cost, Delivery, Quality, and Services**—which are further divided into twelve sub-criteria. Among these, *Quality* emerged as the most critical factor (35.59%), followed by *Services* (29.59%), *Delivery* (15.93%), *Cost* (12.98%), and *Profile* (5.91%). At the sub-criteria level, *Specification* (19.30%) and *Certification* (16.28%) held the highest influence, followed closely by *After-sales service* (15.63%) and *Warranty* (13.97%). These results, validated through the Analytical Hierarchy Process (AHP) method with a consistency ratio below 0.1, underscore the significance of product quality and service assurance in supplier evaluation. Furthermore, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) analysis identified **Supplier S1** as the top-performing alternative with a preference score of 0.8837, making it the most suitable choice for spare parts procurement.

For future research, it is recommended to expand the scope by incorporating additional qualitative factors such as supplier innovation capabilities or sustainability practices, which are increasingly relevant in modern supply chain strategies. Further, integrating fuzzy logic or other multi-criteria decision-making methods could offer comparative insights and enrich the robustness of supplier selection frameworks.

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