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9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Integrated ABC–AHP–TOPSIS Model for Used Distribution Material Management at PLN UP3 Mamuju

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Abstract

The management of used distribution materials at PT PLN UP3 Mamuju faces challenges related to idle inventory, dead stock, subjective decision-making, and the absence of a systematic prioritization framework. These issues reduce material utilization and limit the recovery of asset value. This study develops an integrated multi-criteria decision-making model by combining ABC Classification, the Analytical Hierarchy Process (AHP), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to support objective and structured management of used distribution materials. The novelty of this study lies in the integration of inventory classification, multi-criteria weighting, and alternative ranking within a single decision-support framework for distribution material management, complemented by an economic feasibility evaluation. ABC Classification was used to identify economically significant materials, AHP to determine the relative importance of decision criteria, and TOPSIS to prioritize management alternatives, including reuse, redistribution, scrap, and disposal. The results indicate that safety is the most influential decision criterion, while conductors and distribution cables represent the highest-priority materials for reuse. The proposed model improves decision consistency, increases material utilization, reduces inventory losses, and generates significant economic benefits with a highly feasible investment. Overall, the integrated ABC–AHP–TOPSIS framework provides a practical decision-support tool for improving operational efficiency, optimizing asset value recovery, and supporting sustainable distribution material management in electric utility companies.

Keywords: ABC Classification, AHP, TOPSIS, used distribution materials.

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1. Introduction

Electricity is a critical infrastructure that supports economic growth, industrial activities, public services, and social welfare[1], [2]. The increasing demand for electrical energy, driven by population growth and infrastructure development, requires power distribution systems to be reliable, efficient, and sustainable[3], [4], [5]. Within the electricity distribution network, Medium Voltage Overhead Distribution Lines (SUTM) play a vital role in delivering electricity from substations to end users. Consequently, their reliability directly influences service quality and supply continuity [6], [7], [8]. To maintain system reliability, construction, component replacement, and maintenance activities are continuously carried out throughout the distribution network.

These activities generate various types of used materials, including conductors, cables, insulators, transformers, and other distribution components. Such materials possess diverse characteristics; some remain technically suitable for reuse, others retain economic value as scrap materials, while the remainder require asset disposal procedures. From a modern asset management perspective, used materials should be regarded as recoverable assets that still possess economic and operational value for the company [4]. However, in practice, the management of used materials is often not performed optimally, resulting in material accumulation, asset value depreciation, and the loss of potential economic benefits.

At PLN UP3 Mamuju, the management of used distribution materials faces several challenges, including a high volume of idle materials, the accumulation of dead stock, limited storage capacity, and the absence of a structured decision-making system. Furthermore, the extensive and geographically dispersed service area reduces the efficiency of material recording, transportation, and utilization processes. As a result, reusable materials are not promptly utilized for maintenance activities, while scrap materials are unable to contribute optimally to revenue generation. These conditions lead to low asset utilization, increased procurement costs for new materials, and missed opportunities for revenue recovery [5]. Internal data from PLN UP3 Mamuju indicate that the estimated depreciation in the value of used distribution materials reached approximately IDR 2.08 billion in 2025, highlighting the significant economic impact of ineffective material management and the need for a more systematic and value-oriented decision-making approach.

Recent studies have shown that Multi-Criteria Decision-Making (MCDM) techniques, including the Analytical Hierarchy Process (AHP), TOPSIS, and their integrated approaches, have been widely applied to inventory prioritization, spare-part management, supplier selection, and asset management because they enable decision-making based on multiple technical, economic, and operational criteria.

Likewise, recent inventory management studies have demonstrated that ABC analysis remains an effective approach for identifying high-value inventory items and improving resource allocation when integrated with decision-support methods. Despite these advances, existing studies have primarily focused on inventory control, procurement optimization, and spare-part management in manufacturing and logistics sectors [9]. Applications of integrated ABC–AHP–TOPSIS models for managing used distribution materials in electric utility companies remain limited. Moreover, previous studies rarely incorporate economic value, technical condition, operational risk, and asset recovery alternatives into a unified decision-support framework. This research addresses these gaps by developing an integrated decision-making model specifically designed for used distribution material management at PLN UP3 Mamuju.

Therefore, this study aims to develop a decision-making model for used distribution material management through the integration of ABC Classification, the Analytical Hierarchy Process (AHP), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) at PLN UP3 Mamuju. The proposed model is intended to support the prioritization and evaluation of used materials based on their economic value, technical feasibility, and operational considerations [7], [8].

The impairment analysis indicates that the 150 mm² AAAC conductor contributes the highest financial loss, followed by the 9-meter steel pole and 70 mm² NYY cable, demonstrating that primary distribution assets account for the largest share of impairment costs due to their high acquisition value and continuous exposure to operational and environmental stresses [6], [7]. Moderate impairment values were observed for transformer units and other conductor types, whereas supporting accessories such as insulators and connectors exhibited comparatively lower losses. These findings suggest that impairment costs are concentrated in a limited number of high-value assets, highlighting the importance of risk-based asset management, preventive maintenance, and condition monitoring to optimize maintenance planning, reduce asset depreciation, and improve the financial sustainability and reliability of the medium-voltage distribution network.

Ultimately, the model is expected to enhance material utilization, improve operational efficiency, optimize asset management practices, and increase revenue recovery from used materials generated through the construction and maintenance of electricity distribution networks.

2. Methods

This study employed a quantitative approach by integrating ABC Classification, the Analytical Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Cost–Benefit Analysis

(CBA) to develop a decision-making model for used distribution material management at PLN UP3 Mamuju. The research consisted of five stages: problem identification, literature review, data collection, data analysis, and formulation of conclusions and recommendations.

Primary data were collected through field observations, semi-structured interviews, and questionnaires involving warehouse supervisors, maintenance supervisors, safety supervisors, construction managers, and the UP3 manager. Secondary data included inventory records, material prices, salvage values, maintenance costs, and operational reports related to used distribution materials.

The first stage of analysis applied ABC Classification to categorize materials according to their adjusted economic value, calculated from material usage, condition, and unit price. Based on the Pareto principle, materials were classified into Class A, B, and C, representing high-, medium-, and low-value items, respectively. The classification results were used as the basis for subsequent AHP, TOPSIS, and CBA analyses. The annual value of each material was calculated as follows:

Adjusted Value = Usage × Condition (Decimal condition, e.g. 75% = 0.75) x Unit Price (Rp)

Where : Adjusted Value (considering material condition and usage).

The second stage employed AHP to determine the weights of five decision criteria: economic value (C1), material condition (C2), safety (C3), environmental impact (C4), and lead time (C5). Pairwise comparisons were completed by experts using Saaty's nine-point scale. The consistency of expert judgments was evaluated using the Consistency Index (CI) and Consistency Ratio (CR), where a CR < 0.10 indicated acceptable consistency. The resulting criterion weights were used as inputs for the TOPSIS analysis. To ensure the reliability of the judgments, consistency testing was performed using the Consistency Index (CI) and Consistency Ratio (CR):

$$CI = \frac{\lambda maks - n}{n - 1} \qquad CR = \frac{CI}{RI} \tag{1}$$

The third stage applied TOPSIS to rank four management alternatives: reuse, scrap, redistribution, and disposal. The procedure included decision matrix normalization, weighted normalization, determination of positive and negative ideal solutions, calculation of separation distances, and estimation of the relative closeness coefficient (Ci). The alternative with the highest Ci value was selected as the preferred management strategy because it was closest to the positive ideal solution and farthest from the negative ideal solution.

Finally, Cost–Benefit Analysis (CBA) was conducted to evaluate the economic feasibility of the selected strategy. Financial performance was assessed using the Benefit–Cost Ratio (BCR) by comparing the expected benefits and implementation costs. Three management scenarios—existing practice, reuse–scrap, and reuse–scrap–vendor recycle—were compared to identify the most economically beneficial approach. The CBA results provided financial justification for the recommended strategy and supported sustainable asset management at PLN UP3 Mamuju.

3.Results and Discussion

This chapter will outline the analysis and discussion of the data processing in the previous chapter. Then, this chapter will explain in detail the sub-chapters, namely ABC Interpretation, AHP Interpretation, TOPSIS Interpretation, and Comparison of Analysis Results with Managerial Implications at PLN (existing), Comparison of Improvement Impacts, and Comparison of Before and After Results.

3.1 ABC Classification Results Analysis

The ABC classification results show that PLN's used materials are divided into three main categories, namely class A (high priority), class B (medium priority), and class C (low priority). Based on the calculation results in table, class A materials cover approximately 80% of the total economic value, even though the number of items is relatively smaller, as shown in **Figure 1**. This indicates a Pareto pattern (80/20), where a small portion of materials contributes the largest value to total assets. The Pareto diagram is shown in the figure below:

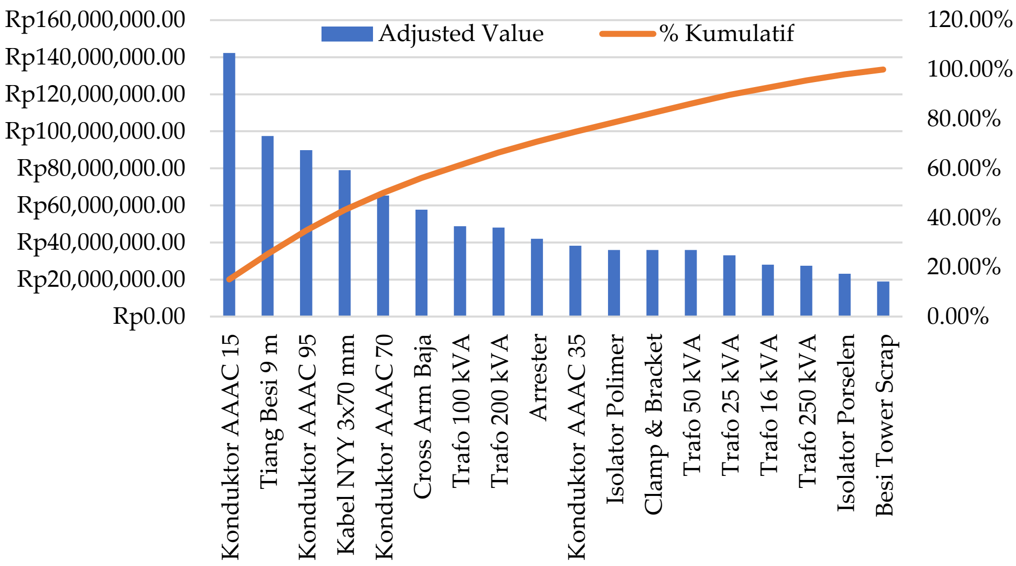

Figure 2. ABC Pareto Graphic

Class A materials, including AAAC conductors, NYY cables, and steel poles, have the highest economic value and reuse potential, making them the primary priority for inventory control and asset utilization. Class B materials require further technical evaluation before reuse or repair, whereas Class C materials have limited economic value and are more suitable for scrap or disposal.

The existing material management process at PLN UP3 Mamuju is mainly based on the physical condition and administrative status of materials. Although operationally effective, this approach does not explicitly consider the economic value of materials, leading to inefficient inventory utilization and the accumulation of low-value items.

To address this limitation, ABC Classification was applied based on the Pareto principle to prioritize materials according to their economic value. As described by Heizer et al. (2020), ABC analysis enables organizations to focus management efforts on high-value inventory items. In this study, Class A materials accounted for approximately 80% of the total inventory value, despite representing only a small proportion of the inventory.

These findings indicate that ABC Classification provides a practical basis for prioritizing monitoring, reuse, and inventory control of high-value materials while simplifying the management of lower-value items, as shown in **Table 1**. This approach improves resource allocation, enhances asset utilization, and supports more effective decision-making in the management of used distribution materials at PLN UP3 Mamuju.

Table 2. Implementation of Inventory Management Strategies Based on ABC Classification

Class	Material Category	Inventory Management Strategy	Monitoring Frequency
A	AAAC Conductors, NYY Cables, Steel Poles	Prioritized reuse and immediate redistribution	Daily / Weekly
B	Cross Arms, Clamps, Small Transformers	Periodic evaluation, maintenance, and repair	Monthly
C	Scrap Materials and Damaged Insulators	Scrap processing or disposal	As required

ABC classification serves not only as a grouping tool but also as a basis for strategic decision-making in materials management. Knowing that the majority of economic value is concentrated in Class A materials allows companies to allocate greater resources, time, and attention to this group. This aligns with modern inventory control concepts that emphasize the selective management of high-value items.

3.2 Analysis of AHP Results

The criteria weights were determined using the Analytical Hierarchy Process (AHP) through pairwise comparisons based on Saaty's fundamental scale. This method was employed to evaluate the relative importance of each criterion in the decision-making process for managing used distribution materials at PLN UP3 Mamuju.

Five criteria were considered in the analysis, namely economic value (C1), material condition (C2), frequency of demand (C3), repair cost (C4), and ease of utilization (C5). Expert judgments were obtained from four key stakeholders, including the Assistant Manager of Construction, Assistant Manager of Network Operations, Logistics Team Leader, and Maintenance Team Leader (shown in **Table 3**). Each expert assessed the relative importance of criteria using Saaty's nine-point scale, where a value of 1 indicates equal importance and a value of 9 indicates extreme importance of one criterion over another.

Table 4. AHP Variable

Code	Criteria	Operational Definition	Type
C1	Economic Value	Financial value of used materials representing potential benefits from reuse, repair, or scrap recovery	Benefit
C2	Material Condition	Technical feasibility based on physical and functional condition	Benefit
C3	Safety	Occupational and operational risk associated with material reuse	Cost
C4	Environmental Impact	Potential environmental impact arising from material utilization or disposal	Cost
C5	Procurement Lead Time	Time required to procure replacement materials	Benefit

Matrix normalization is done by dividing each matrix element by the total of each column, as shown in **Table 3**. The purpose of normalization is to obtain the relative importance of each criterion.

Table 3. Normalized Matrix and Priority Weights of AHP Criteria

Criteria	C1	C2	C3	C4	C5	Weight
C1: Economic Value	0.105	0.094	0.101	0.154	0.118	0.114
C2:Material Condition	0.211	0.188	0.167	0.231	0.235	0.206
C3: Safety	0.526	0.563	0.505	0.385	0.471	0.490
C4: Environmental Impact	0.053	0.062	0.101	0.077	0.059	0.070
C5:Procurement Lead Time	0.105	0.094	0.126	0.154	0.118	0.119

Once the weights are obtained, the next important step is to test their consistency by calculating the Consistency Ratio (CR). If the CR value is <0.10, the assessment is considered consistent, and the weights can be used in further analysis such as TOPSIS. The data processing for the Consistency test is shown in the Table 4 below:

Table 4. AHP Consistency Test Results

Criteria	Matrix × Weight	λi
C1: Economic Value	0.59	5.18
C2: Material Condition	1.05	5.09
C3: Safety	2.52	5.14
C4: Environmental Impact	0.36	5.14
C5: Procurement Lead Time	0.61	5.13
λmax		5.136
Consistency Index (CI)		0.034
Random Index (RI)		1.12
Consistency Ratio (CR)		0.03

The AHP analysis identified safety (C3) as the most important decision criterion, with a weight of 0.490, followed by material condition (C2) (0.206) and lead time (C5) (0.119). The Consistency Ratio (CR) was 0.03, which is below the acceptable threshold of 0.10, indicating that the expert judgments were consistent and suitable for subsequent TOPSIS analysis. At the sub-criterion level, failure risk received the highest priority within the safety criterion, followed by accident risk and system impact. This result indicates that the likelihood of technical failure is the primary consideration in determining whether a used material should be reused, repaired, redistributed, or disposed of. Likewise, physical condition was the dominant sub-criterion for material condition, while procurement time was the most influential factor within the lead time criterion, emphasizing the importance of maintaining both technical reliability and material availability in electricity distribution systems.

These findings are consistent with Saaty 2008 [6], who proposed that AHP effectively prioritizes multiple decision criteria through pairwise comparisons. They also support the work of Ishizaka and Labib (2011), who highlighted the capability of AHP to incorporate qualitative expert judgment into quantitative decision-making under conditions of uncertainty and risk. Therefore, the weighting structure developed in this study provides a reliable foundation for risk-based management of used distribution materials and serves as an appropriate input for the subsequent TOPSIS analysis.

3.3 Analysis of TOPSIS Results

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is used to determine the best used material alternative based on its proximity to the positive ideal solution and its furthest distance from the negative ideal solution. The criteria weights used are derived from the AHP results, making the assessment process more objective and measurable. The stages are as follows:

The TOPSIS analysis evaluated each material alternative based on its distance from the positive ideal solution (A^+) and the negative ideal solution (A^-). A^+ represents the most desirable condition, characterized by low safety risk, good material condition, and high availability, whereas A^- represents the least desirable condition. After normalization and weighting using the AHP results, Euclidean distances were calculated and converted into a Closeness Coefficient (CC) ranging from 0 to 1, where higher values indicate alternatives that are closer to the ideal solution.

The results show that AAAC conductors and NYY cables achieved the highest CC values, indicating the most favorable combination of safety, material condition, and availability. Consequently, these materials were prioritized for reuse. In contrast, materials with high safety risk and poor technical condition obtained very low CC values and were more suitable for repair, scrap, or disposal. Although transformers may have high economic value, their higher operational risk reduced their overall preference ranking.

Among the evaluated strategies, reuse emerged as the best alternative because it achieved the highest preference value compared with redistribution, scrap, and disposal. The dominance of reuse is largely influenced by the AHP weighting, where safety received the highest priority, as shown in Table 5. Reuse offers both technical and economic advantages by reducing procurement needs, accelerating material availability, increasing inventory utilization, reducing idle stock, and lowering material losses. These findings demonstrate that the integrated AHP–TOPSIS approach provides a more objective and risk-based framework for selecting the optimal management strategy for used distribution materials.

Table 5. AHP weight (refined)

Code	Sub-Criteria	Global Weight
C3.1	Failure Risk	0.264
C3.2	Accident Risk	0.146
C3.3	System Impact	0.08
C2.1	Physical Condition	0.115
C2.2	Technical Functionality	0.066
C2.3	Remaining Service Life	0.025
C5.1	Procurement Lead Time	0.077
C5.2	Market Availability	0.027
C5.3	Import Dependency	0.015

The decision matrix was normalized using the vector normalization method to eliminate differences in measurement scales among criteria and ensure comparability across alternatives. The results indicate the relative performance of each material, where alternatives with higher initial values retain higher normalized scores compared to those with lower values. The normalized matrix (R) was subsequently used as the basis for calculating the weighted normalized matrix in the TOPSIS analysis.

The weighted normalized matrix was obtained by multiplying each normalized value by its corresponding AHP weight. This process incorporates the relative importance of each criterion into the evaluation, ensuring that more critical criteria have a greater influence on the final results. The weighting results indicate that safety (C3) has the highest contribution to the overall score, reflecting its dominant role in the decision-making process.

The TOPSIS method was applied to rank used materials based on their proximity to the positive ideal solution (A^+) and distance from the negative ideal solution (A^-). The positive ideal solution represents the most desirable condition, characterized by the lowest safety risk (cost criterion) and the highest material condition and availability (benefit criteria), as shown in **Table 6**. In contrast, the negative ideal solution represents the least desirable condition, characterized by high risk, poor material condition, and low availability. Therefore, TOPSIS evaluates each alternative by simultaneously considering its closeness to the best possible condition and its distance from the worst possible condition, enabling a more comprehensive and objective ranking of material management alternatives.

Table 6. Positive and Negative Ideal Solutions in TOPSIS

Sub-Criteria	Positive Ideal Solution (A^+)	Negative Ideal Solution (A^-)
C3.1 Failure Risk	0.039	0.156
C3.2 Accident Risk	0.022	0.087
C3.3 System Impact	0.013	0.039
C2.1 Physical Condition	0.023	0.009
C2.2 Technical Functionality	0.013	0.005
C2.3 Remaining Service Life	0.005	0.002
C5.1 Procurement Lead Time	0.016	0.008
C5.2 Market Availability	0.006	0.004
C5.3 Import Dependency	0.003	0.002

The distances to the positive ideal solution (D^+) and negative ideal solution (D^-) were calculated to evaluate the relative performance of each material alternative. A smaller D^+ value indicates that a material is closer to the ideal condition, whereas a larger D^- value indicates that it is farther from the worst condition, as shown in **Table 7**. The results show that materials such as AAAC 150 conductors have low D^+ and high D^- values, indicating high suitability for reuse, while scrap materials exhibit the opposite pattern and therefore receive lower priority in the decision-making process.

The Closeness Coefficient (CC) was calculated to determine the final ranking of each material alternative. The CC values range from 0 to 1, where values closer to

1 indicate higher suitability for reuse, as shown in **Table 8**. The results show that AAAC 150 mm, AAAC 95 mm, and AAAC 70 mm conductors achieved the highest CC values, making them the highest-priority materials for reuse. In contrast, transformers obtained moderate rankings due to their higher safety risks, while scrap materials received the lowest CC values, indicating that they are unsuitable for reuse and should be directed toward recycling or disposal.

Table 7. Distance D^+ and D^- (Details Per Material)

Material	D^+	D^-
Conductor AAAC 150 mm	0.0031	0.0936
Conductor AAAC 95 mm	0.0161	0.0779
Conductor AAAC 70 mm	0.0161	0.0779
Conductor AAAC 35 mm	0.0322	0.0619
Cable NYY 3x70 mm	0.0168	0.0776
Iron Pole 9 m	0.0303	0.0641
Cross Arm Baja	0.0318	0.0629
Clamp & Bracket	0.0318	0.0629
Arrester	0.0463	0.0477
Isolator Polimer	0.0463	0.0477
Isolator Porselen	0.0623	0.0317
Trafo 16 kVA	0.0461	0.0481
Trafo 25 kVA	0.0461	0.0481
Trafo 50 kVA	0.0461	0.0481
Trafo 100 kVA	0.0606	0.0354
Trafo 200 kVA	0.0606	0.0354
Trafo 250 kVA	0.0606	0.0354
Iron Tower Scrap	0.0939	0

The TOPSIS results show that safety-related criteria have the greatest influence on the ranking of material management alternatives, consistent with the AHP results that identified safety as the highest-priority criterion. This confirms that integrating AHP and TOPSIS provides a consistent and reliable framework by combining criterion weighting with alternative ranking.

These findings are consistent with Hwang and Yoon (1981), who stated that TOPSIS selects the alternative closest to the positive ideal solution and farthest from the negative ideal solution. They also support [1] , who reported that integrating TOPSIS with weighting methods such as AHP improves the effectiveness and reliability of multi-criteria decision-making.

Overall, the integrated AHP–TOPSIS approach provides an objective and practical decision-support framework by simultaneously considering economic, technical, and safety aspects, thereby supporting more efficient and risk-based management of used distribution materials at PLN UP3 Mamuju.

Table 8. Preferensi Value (Closeness Coefficient/CC)

Priority Level	Materials	CC Range	Recommended Strategy
Very High Priority	AAAC 150	0.968	Immediate Reuse
High Priority	AAAC70, AAAC95, NYY Cable	0.822 s/d 0.829	Reuse
Suitable for Reuse	Steel Pole, Cross Arm, Clamp, AAAC 35	0.658 s/d 0.679	Reuse / Redistribution
Requires Evaluation	Transformer 16–50 kVA	0.511	Technical Evaluation
Moderate Risk	Arrester, Polymer Insulator	0.507	Further Inspection
High Risk	Transformer 100–250 kVA	0.368	Repair or Limited Use
Low Priority	Porcelain Insulator	0.337	Scrap / Disposal
Not Suitable for Reuse	Scrap Tower Steel	0	Recycling / Disposal

3.4 Cost Benefit Analysis

Cost–Benefit Analysis (CBA) was conducted to evaluate the economic feasibility of implementing the proposed ABC–AHP–TOPSIS framework. The analysis compares the total economic benefits generated by the system with the associated implementation costs over the evaluation period, as shown in Table 9. Economic benefits include increased material utilization, reduced procurement of new materials, and revenue recovery from scrap sales, while implementation costs consist of system development, training, data integration, and operational maintenance expenses.

To assess financial viability, the Benefit–Cost Ratio (BCR) was calculated as the ratio of total benefits to total costs. A BCR value greater than one indicates that the expected benefits exceed the implementation costs, demonstrating that the proposed system is economically feasible. Therefore, CBA provides financial justification for the adoption of the integrated ABC–AHP–TOPSIS approach in improving asset utilization, operational efficiency, and revenue recovery at PLN UP3 Mamuju.

Table 9. Cost–Benefit Analysis (Revenue-Oriented)

Component	Value (IDR)
Total Benefits (Revenue Increase)	598,320,000
Annual Operating Cost	20,000,000
Net Benefit	**578,320,000**
Initial Implementation Cost	65,000,000
Payback Period	**≈ 1.3 Months**
Benefit–Cost Ratio (BCR)	**22.15**

The Cost–Benefit Analysis (CBA) demonstrates that the proposed ABC–AHP–TOPSIS framework is economically feasible, as the expected benefits substantially exceed the implementation costs. The high Benefit–Cost Ratio (BCR) and short payback period indicate that the framework provides a financially attractive solution for improving used material management.

Beyond its economic benefits, the framework enhances operational performance by increasing material utilization, reducing dead stock, accelerating maintenance response, and supporting more efficient inventory management [10]. The integration of ABC Classification, AHP, and TOPSIS enables objective and transparent decision-making while incorporating economic, technical, and safety considerations into a unified evaluation process.

These findings are consistent with previous studies on cost–benefit analysis in asset and inventory management, which demonstrate that decision-support systems can improve resource utilization while generating long-term economic value. Overall, the proposed framework offers a practical and sustainable approach for improving asset utilization, maximizing revenue recovery, and supporting more effective material management at PLN UP3 Mamuju.

4. Conclusion

This study developed an integrated ABC–AHP–TOPSIS framework to support decision-making for the management of used distribution materials at PLN UP3 Mamuju. The proposed framework successfully classified materials according to their economic value, prioritized decision criteria based on expert judgment, and ranked the most appropriate management alternatives by simultaneously considering economic, technical, and safety aspects. The results identified AAAC conductors and NYY cables as the highest-priority materials for reuse, while safety was confirmed as the most influential decision criterion.

The implementation of the proposed framework improved material utilization, reduced inventory losses, and accelerated the decision-making process, demonstrating its effectiveness in supporting more efficient and objective material management. The economic evaluation further confirmed that the proposed approach is financially feasible, providing significant cost savings and asset value recovery with a favorable Benefit–Cost Ratio (BCR).

Overall, the integration of ABC Classification, AHP, TOPSIS, and Cost–Benefit Analysis provides a practical and risk-based decision-support framework for optimizing used distribution material management. The proposed model contributes to improving operational efficiency, enhancing asset utilization, and supporting sustainable resource management in electricity distribution companies. Furthermore, the framework can serve as a reference for other power utilities facing similar challenges in managing used distribution materials.

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Authors' Declaration

Authors' contributions and responsibilities - The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

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