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A Multi-Criteria Decision-Making Model for Determining Material Storage Locations Using the AHP–TOPSIS Method: A Study at PT PLN (Persero) UP2D Lampung

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Abstract

PT PLN (Persero) UP2D Lampung faces limitations in internal warehouse capacity, requiring some materials to be stored at other units located up to 46.8 km away. This situation increases storage and transportation costs and reduces the efficiency of inventory management. This study aimed to develop a multi-criteria decision-making model for determining the optimal material storage location by integrating the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS). The evaluation criteria were identified through discussions with subject-matter experts and materials management personnel, resulting in four criteria and six sub-criteria. The four evaluation criteria were land capacity, resources, management quality, and operational efficiency. The six sub-criteria comprised warehouse area, the number of employees and outsourced personnel, the availability of truck drivers, maturity level, inventory turnover (ITO), and service area. The AHP method was used to determine the weights of the criteria and sub-criteria, whereas TOPSIS was applied to evaluate and rank the alternative warehouse locations. A total of five candidate storage locations were evaluated. The results indicated that the Tanjung Karang Warehouse was the preferred material storage location, achieving the highest preference score of 0.695. These findings demonstrate that integrating AHP and TOPSIS provides an objective, systematic, and measurable decision-making framework for determining material storage locations and offers a practical decision-support tool for warehouse management at PT PLN (Persero).

INTRODUCTION

PT PLN (Persero) UP2D Lampung is one of PLN's operational units responsible for regulating and monitoring the 20 kV electricity distribution network throughout the Lampung Province service area. As an operational unit responsible for electricity distribution, PT PLN (Persero) UP2D Lampung plays a critical role in maintaining the reliability and stability of the electricity supply to support social, economic, and industrial activities across the province. The 20 kV distribution network is supplied through feeders originating from primary substations (GI) and distribution substations (GH). These feeders serve customers managed by four Customer Service Implementation Units (UP3). As presented in Table 1.1, PT PLN (Persero) UP2D Lampung operates 362 feeders, 878 keypoint assets, and 23 distribution substations.

Despite its operational importance, PT PLN (Persero) UP2D Lampung faces significant challenges in asset and material management (Alviansyah & Tarigan, 2026; Putra & Putri, 2025; Yasri & Syahrizal, 2025). The unit manages 362 feeders and 878 key assets, including 290 reclosers, 545 Load Break Switches with Monitoring (LBSMs), 23 distribution substations

(GH), and 20 PMCBs. These assets are distributed across a wide geographic area throughout Lampung Province, where electricity demand continues to increase. This growth has driven the expansion of the electricity distribution network to support economic development and improve public welfare (Alviansyah & Tarigan, 2026; Putra & Putri, 2025; Yasri & Syahrizal, 2025).

The expansion of the distribution network has directly increased the demand for materials required for both new network construction and the maintenance of existing infrastructure (Azmi et al., 2022; Oskouei et al., 2022). These challenges are further compounded by the limited storage capacity of PT PLN (Persero) UP2D Lampung, which has a warehouse site area of only 326.8 m² and a warehouse building area of 1,042 m². As a result, incoming materials cannot always be accommodated efficiently. Inadequate storage capacity, when combined with ineffective inventory management, may lead to various forms of operational waste, reduce space utilization efficiency, and hinder warehouse operations (Dai et al., 2019).

Suboptimal warehouse management, including inefficient storage layouts, unsystematic material placement, and poor inventory management, can increase material handling distances, retrieval time, and warehouse operating costs (Kocaoğlu et al., 2019; Tannady et al., 2019). Moreover, warehouses are no longer viewed merely as storage facilities but as strategic components of the supply chain that contribute significantly to distribution efficiency, service responsiveness, and overall operational performance (Kumar et al., 2021).

Since the end of April 2024, PT PLN (Persero) UP2D Lampung has collaborated with PT PLN (Persero) UP3 Metro by temporarily storing a portion of its materials at the UP3 Metro warehouse as an initial solution to overcome storage capacity limitations. However, this arrangement has created additional logistical challenges, particularly related to transportation and material distribution because the storage warehouse is located a considerable distance from the operational center (Figure 2). Consequently, material delivery for maintenance activities may be delayed, potentially affecting operational performance.

To address these challenges, a structured decision-making approach is required to optimize material storage management. One potential solution is to integrate the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS). AHP facilitates the determination of priority weights based on multiple evaluation criteria, whereas TOPSIS ranks alternative locations according to their relative proximity to the ideal solution (Saaty & Vargas, 2021). The integration of these two methods provides a systematic, objective, and data-driven framework for supporting material storage location decisions.

Several previous studies have applied AHP and TOPSIS to logistics and facility location problems. Bachtiar and Ratnasari (2023) applied the AHP–TOPSIS approach to prioritize distribution transformer installation locations at PT PLN ULP Pangkalan Bun. Sitohang (2023) used the AHP–TOPSIS method to prioritize keypoint installation locations at PT PLN UP2D North Sumatra. Tabak, Yıldız, and Yerlikaya (2019) proposed an integrated CRITIC–AHP–VIKOR framework for logistics facility location selection. Kumar and Singh (2022) developed a hybrid fuzzy AHP–TOPSIS model for evaluating manufacturing relocation decisions. Zhao, Wang, and Chen (2025) proposed a hybrid fuzzy AHP–TOPSIS approach to support material selection in green building projects. However, most previous studies have

focused on installation location selection, manufacturing relocation, or general logistics facility decisions. Research specifically addressing strategic material storage location selection in electricity distribution companies, particularly those operating under warehouse capacity constraints and geographically dispersed distribution networks, remains limited.

The research gap lies in the absence of a comprehensive decision-support model that simultaneously considers physical capacity, human resources, governance quality, and operational efficiency in determining strategic material storage locations for state-owned electricity distribution companies. Although AHP and TOPSIS have been widely applied in supplier selection, facility location, and warehouse management within the manufacturing and retail sectors, their application to strategic material storage decisions in electricity distribution companies remains underexplored. Previous studies, including Bachtiar and Ratnasari (2023) and Sitohang (2023), focused primarily on transformer installation and keypoint location selection rather than strategic warehouse location decisions within geographically dispersed, multi-warehouse electricity distribution systems.

The novelty of this study lies in the integration of AHP and TOPSIS to determine strategic material storage locations within an electricity distribution company, a context that differs substantially from manufacturing and retail logistics. Unlike previous studies that focused on warehouse layout optimization, inventory management, or equipment installation locations, this study evaluates warehouse location alternatives by simultaneously considering physical capacity, human resources, governance quality, and operational efficiency. Furthermore, the study incorporates warehouse capacity projection analysis to complement the AHP–TOPSIS evaluation, providing a more comprehensive assessment of the long-term sustainability of the recommended storage locations. This integrated framework offers a context-specific decision-support model for state-owned electricity distribution companies facing similar warehouse capacity constraints.

The importance of this study stems from PT PLN (Persero) UP2D Lampung's increasing need to improve material and asset management in response to the growing demand for electricity throughout Lampung Province. The combination of geographically dispersed assets, increasing material requirements, and limited warehouse capacity has the potential to reduce operational efficiency, increase logistics costs, and delay maintenance activities. Given PLN's strategic role in supporting social and economic development, a data-driven decision-making framework such as the AHP–TOPSIS approach is needed to support structured, efficient, and accountable material storage decisions.

This study aimed to identify the optimal material storage location among several alternatives within PT PLN (Persero) UP2D Lampung using the integrated AHP–TOPSIS approach. The findings are expected to contribute to the literature on multi-criteria decision-making in logistics management, particularly within state-owned electricity distribution companies, by extending the application of AHP and TOPSIS to the relatively underexplored problem of strategic material storage location selection. From a practical perspective, the proposed framework provides a decision-support model for PT PLN (Persero) UP2D Lampung to optimize material storage locations, reduce logistics costs, improve inventory management efficiency, and ensure material availability for network maintenance and expansion. The framework may also serve as a reference for other electricity distribution companies facing similar warehouse capacity and logistics optimization challenges.

METHOD

Types of Research

This study employed a descriptive quantitative case study design. Numerical data were analyzed using the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) to support the selection of the optimal material storage location. The study was conducted from February to May 2025 at PT PLN (Persero) UP2D Lampung in Bandar Lampung, Lampung Province.

Respondents were selected using purposive sampling based on the following criteria: experience in material management, logistics, or distribution operations; knowledge of the material management process at PT PLN (Persero) UP2D Lampung; involvement in material procurement planning or decision-making; and willingness to complete the questionnaire. The study involved 10 respondents holding the positions presented in Table 3.2. Data were collected using a pairwise comparison questionnaire based on Saaty's 1–9 scale. The responses were analyzed using AHP to determine the weights of the evaluation criteria and sub-criteria, which were subsequently used as inputs for the TOPSIS analysis.

Data Collection Methods

In this study, data collection was carried out using two types of data, namely primary data and secondary data. Primary data was obtained directly from respondents through questionnaires and interviews, while secondary data was obtained from company documents and other supporting sources relevant to the research where each has an important role in achieving research objectives related to the determination of material storage and operational efficiency at PT PLN (Persero) UP2D Lampung.

1. Data primer

It was collected directly from respondents involved in decision-making related to materials and daily distribution operations through filling out questionnaires and in-depth interviews. This interview aims to obtain information about the existing conditions of material management, the process of determining storage locations, operational constraints, and obtaining input in the preparation of research criteria and subcriteria. The questionnaire was used to obtain expert judgment on the level of importance of each criterion and subcriteria using the Analytical Hierarchy Process (AHP) method. In addition, field observations were also carried out in related locations, such as material warehouses and distribution areas, which aimed to obtain a factual picture of the operational conditions that were the object of the research.

2. Data seconds

Secondary data was obtained from various documents available at PT PLN (Persero) UP2D Lampung as well as scientific sources relevant to the research. The company's internal documents used include warehouse capacity data, warehouse area area, number of employees and outsourcing personnel, availability of operational car drivers, Maturity Level values, Inventory Turn Over (ITO) data, work area area, and other operational documents related to material management. The data is used as a basis for the preparation of alternatives and performance assessments of each material storage location.

In addition to the company's internal documents, this research also utilizes various scientific sources in the form of books, scientific articles, proceedings, and national and international journals that discuss Multi-Criteria Decision Making (MCDM), Analytical

Hierarchy Process (AHP) method, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), warehousing management, logistics management, and material storage location determination. The literature study is used to strengthen the theoretical foundation, develop research criteria, and support the process of analysis and discussion of research results.

Data Analysis

The data obtained in this study was analyzed using the Multi-Criteria Decision Making (MCDM) approach through a combination of the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. The AHP method is used to determine the priority weight of each criterion and sub-criterion based on the results of expert judgment, while the TOPSIS method is used to rank alternative material storage locations based on the weights generated from the AHP method.

In addition to the analysis using the AHP-TOPSIS method, this study also conducts an analysis of warehouse capacity trends to project material storage capacity needs in the coming period. This analysis is carried out as a support in the preparation of recommendations for material storage locations that not only consider current conditions, but also pay attention to the development of storage needs in the future.

The stages of data analysis in this study include AHP analysis, TOPSIS analysis, and warehouse capacity trend analysis which are described in the following sub-chapters.

RESULTS AND DISCUSSION

Relevance of Criteria and Sub-criteria in Material Storage Decision Making at PT PLN (Persero) UP2D Lampung

The selection of criteria and sub-criteria in this study is a stage that greatly determines the quality of the decision-making process, because all the results of the analysis use the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method depending on the suitability of the variables used. The selected criteria and sub-criteria were not only compiled based on a literature review on warehousing management, logistics management, and Multi-Criteria Decision Making (MCDM), but were also validated through expert judgment from practitioners who understand the material management process at PT PLN (Persero) UP2D Lampung. Thus, the variables used not only have a theoretical basis, but are also relevant to the company's operational needs.

The land capacity criteria were chosen because storage capacity is one of the main factors that determine the ability of warehouses to accommodate material inventory. According to Richards (2021), warehouse capacity has a direct effect on operational flexibility, space utilization efficiency, and the company's ability to anticipate increased storage needs in the future. In the environment of PT PLN (Persero) UP2D Lampung, warehouse capacity is a very important aspect considering that electric power distribution materials have various dimensions and characteristics, ranging from conductors, power poles, distribution transformers, to network protection equipment. Therefore, the sub-criterion of warehouse area area (K1.1) is seen as able to represent the physical capacity of the warehouse in supporting the smooth operation of logistics.

The resource criteria also have high relevance because the effectiveness of material management is not only determined by the availability of facilities, but also by the readiness of human resources who carry out warehouse operational activities. Frazelle (2018) explained

that warehousing productivity is influenced by the adequacy of personnel, clear division of tasks, and the support of internal transportation facilities. Based on operational conditions at PT PLN (Persero) UP2D Lampung, the two sub-criteria that are considered to be the most representative of this aspect are the number of employees and outsourced personnel (K2.1) and the availability of Gold car drivers (K2.2). These two sub-criteria affect the speed of material distribution services, especially in routine maintenance conditions and handling network disturbances that require a quick response.

The management quality criteria are represented through the Maturity Level (K3.1) value sub-criteria. The selection of this sub-criterion is based on the consideration that the success of warehouse management is not only influenced by physical resources, but also by the level of maturity of business processes and organizational governance. The higher the level of management maturity, the better the organization's ability to implement standardized work procedures, control operational risks, and make continuous improvements. In the context of PT PLN (Persero), the Maturity Level indicator has become part of the unit performance evaluation mechanism so it is relevant to be used as one of the indicators in this study.

Furthermore, the operational efficiency criteria were chosen because the main goal of material management is not only to provide storage space, but also to ensure that materials can be distributed quickly, precisely, and economically. Therefore, this study uses two sub-criteria, namely Inventory Turn Over (ITO) (K4.1) and the area of work (K4.2). Inventory Turn Over reflects the effectiveness of inventory turnover, while the area of work illustrates the scope of material distribution services that must be supported by each warehouse. The wider the service area, the greater the coordination challenges, distribution travel time, and the need for operational resources. Therefore, in this study, the area of the work area is categorized as a cost attribute, while Inventory Turn Over is a benefit attribute.

When viewed as a whole, the four criteria and six sub-criteria used have been able to represent the three main dimensions in warehouse management, namely infrastructure capacity, resource readiness, and operational performance. These three dimensions complement each other so that they produce a more comprehensive evaluation framework than if the decision is based on only one specific indicator. This approach is in line with the concept of Multi-Criteria Decision Making which states that strategic decision-making needs to consider various interrelated aspects in order to produce more objective and accountable decisions.

The results of this study also show that the criteria used are in accordance with the operational characteristics of PT PLN (Persero) UP2D Lampung as an organization responsible for the reliability of the electric power distribution system. Unlike manufacturing companies that focus more on the efficiency of the production process, material management in the PLN environment requires a balance between storage capacity, resource readiness, quality of governance, and speed of distribution services. Therefore, the selection of criteria and sub-criteria in this study is considered to be able to describe the real needs of the company as well as be an adequate basis in the application of the AHP-TOPSIS method to support decision-making on material storage locations.

Table 1. Relevance of Criteria and Sub-criteria to the Operational Conditions of PT PLN (Persero) UP2D Lampung

Criteria	Sub-Criteria	Relevance to Operations
Land Capacity	Warehouse Area	Determine material storage capability and capacity expansion readiness.
Resources	Number of Officers & Outsourcing	Supports material receiving, storage, and distribution activities.
Resources	Availability of Gold Car Drivers	Supports rapid material mobilization, especially during maintenance and disruption.
Quality Management	Maturity Level	Describe the level of governance maturity and effectiveness of business processes.
Operational Efficiency	Inventory Turn Over (ITO)	Demonstrate the effectiveness of material inventory management.
Operational Efficiency	Work Area Area	Reflects the complexity of material distribution services.

Source: Researcher's analysis based on literature review and expert validation (2025)

Analysis of Priority Weights of Criteria and Sub-criteria Using the Analytical Hierarchy Process (AHP) Method

The determination of the priority weight of criteria in decision-making on material storage locations in warehouse units at PLN UP2D Lampung was carried out using the Analytical Hierarchy Process (AHP) method which is theoretically designed to solve multicriteria decision problems by delineating complex problems into hierarchical structures, conducting paired comparisons, and synthesizing decision-makers' preferences into numerical weights (Saaty, 2020). In the context of logistics and warehousing, AHP is seen as relevant because it is able to integrate the dimensions of physical infrastructure, human resource capabilities, governance quality, and operational performance indicators into one coherent evaluation framework (Büyüközkan & Göçer, 2021). Based on the results of the AHP calculation, the priority weight of the sub-criteria as presented in Table 4.5 was obtained. The results show that the Warehouse Area (K1.1) obtained the highest weight of 0.29, followed by the Maturity Level (K3.1) of 0.23, the Number of Employees and Outsourcing Personnel (K2.1) of 0.21, the Inventory Turn Over (ITO) (K4.1) of 0.13, the Work Area (K4.2) of 0.10, and the Availability of Drivers Mobil Gold (K2.2) by 0.05. This weighting structure shows that the structural aspect (physical infrastructure) is positioned as the main foundation of decision-making, followed by the organizational aspect (Maturity Level Value), while operational efficiency is seen as the outcome of the integration of the previous aspects.

The dominance of land capacity weight (0.29) is in line with the theory of facility capacity planning which emphasizes that the adequacy of storage space and layout flexibility are the main determinants of smooth material flow, bottleneck prevention, and risk mitigation of inventory buildup (Wang & Hu, 2022). In research on warehouse optimization under demand uncertainty, physical capacity limitations have proven to be a limiting factor in logistics performance even though management systems and human resources have been adequate.

The sub-criterion with the second largest weight is the Maturity Level Value (K3.1) of 0.23. This value shows that the level of maturity of business processes and operational governance has a huge influence on the effectiveness of material management. Warehouses

with a better level of organizational maturity generally have more standardized work procedures, more effective inventory control systems, and higher capabilities in maintaining the quality of logistics services. This condition is important considering that the management of electrical materials requires a high level of accuracy so that materials are always available when needed in operation and network maintenance activities.

Furthermore, the number of Employees and Outsourcing Personnel (K2.1) gained a weight of 0.21. These results show that the availability of human resources is one of the important factors in supporting logistics activities, ranging from material receipt, storage, inventory control, to the distribution process to the implementing unit. The more adequate the number of personnel available, the greater the ability of the warehouse to carry out operational processes effectively and on time.

Meanwhile, Inventory Turn Over (ITO) (K4.1) gained a weight of 0.13. This value indicates that the efficiency of inventory turnover remains one of the considerations in determining the location of material storage, although the effect is not as large as warehouse capacity or management quality. A high ITO value reflects the ability of warehouses to manage inventory optimally so that materials are stored for too long and inventory utilization levels become more efficient.

The Sub-criterion of Working Area Area (K4.2) has a weight of 0.10. This shows that the coverage of the service area remains one of the factors considered, especially since each warehouse has different distribution area characteristics. Warehouses that serve a wider area require capacity support and better logistics management so that material needs can be met in a timely manner.

On the other hand, the Availability of Gold Car Drivers (K2.2) received the lowest weight, which was 0.05. This low weight shows that respondents do not view the existence of operational vehicle drivers as a strategic factor in determining material storage locations. This can be understood because distribution needs can still be met through fleet scheduling mechanisms and personnel support from other units, so the effect is relatively small compared to warehouse capacity, human resources, and management quality.

In addition to producing priority weights, the AHP method also produces a measure of respondents' assessment consistency. Based on the calculation results, the λmax value was 6.106, the Consistency Index (CI) was 0.021, and the Consistency Ratio (CR) was 0.017. The CR value of < 0.10 indicates that the respondents' assessment has a very good level of consistency, so that the priority weights produced can be declared valid and feasible to be used as a basis for weighting in the TOPSIS method.

Overall, the results of the AHP analysis show that the decision on the location of material storage at PT PLN (Persero) UP2D Lampung is more influenced by storage capacity factors, management maturity, and availability of human resources than other supporting operational factors. These findings indicate that the effectiveness of a company's logistics system depends not only on the availability of physical facilities, but also on the organization's ability to manage resources and business processes in an integrated manner. Therefore, the priority weights generated through the AHP method provide an objective basis in the process of determining the best warehouse location alternatives using the TOPSIS method.

Alternative Analysis of Material Storage Locations Using the TOPSIS Method.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is

used to determine the most optimal alternative material storage location based on the priority weight generated from the AHP method. The basic concept of TOPSIS states that the best alternative is the one that has the closest distance to the positive ideal solution (Positive Ideal Solution) and at the same time has the farthest distance to the negative ideal solution (Hwang & Yoon, 1981). Thus, the decision-making process not only considers the advantages of an alternative on one particular criterion, but evaluates all criteria simultaneously based on their level of importance.

Based on the results of the TOPSIS calculation, a preference value (Vi) was obtained for each alternative as presented in Table 4.12. The preference value indicates the degree of proximity of each alternative to the ideal solution, so that the greater the preference value obtained, the higher the level of feasibility of the alternative to be chosen as a material storage location.

The results showed that the UP3 Tanjung Karang Warehouse obtained the highest preference value of 0.695, followed by the UP3 Kotabumi Warehouse of 0.673, the UP3 Pringsewu Warehouse of 0.667, the UP3 Metro Warehouse of 0.646, and the UP2D Lampung Warehouse of 0.351. The difference in preference values shows that each alternative has a different level of balance in meeting all the sub-criteria used in this study.

The first rating obtained by the UP3 Tanjung Karang Warehouse shows that the unit has the closest combination of characteristics to ideal conditions. Although it is not the largest capacity warehouse, this warehouse has a good balance between storage capacity, the number of human resources, the maturity level, the efficiency of inventory management, and the area of service. These results indicate that the effectiveness of a warehouse location is not solely determined by the amount of physical capacity, but is more influenced by the ability of the warehouse to optimize all its resources in an integrated manner.

On the other hand, the UP3 Kotabumi Warehouse obtained a preference value of 0.673 and ranked second. This value is supported by the advantages of this warehouse in the aspect of storage capacity which is the sub-criterion with the highest weight in the AHP method. However, the superiority of this capacity has not been fully able to produce the highest preference value because there are still several other aspects that contribute to the final result, such as the level of organizational maturity and operational efficiency. This shows that in the TOPSIS approach, excellence in one indicator does not necessarily produce the best alternative if it is not balanced by good performance in other indicators.

The UP3 Pringsewu Warehouse is ranked third with a preference value of 0.667. Although it has a smaller warehouse capacity than Kotabumi and Tanjung Karang, this warehouse shows relatively good performance in terms of Maturity Level and Inventory Turn Over (ITO). These results show that the quality of operational management is able to increase the competitiveness of an alternative even though it has limitations in the physical aspect. These findings show that improving the quality of governance can be an effective strategy in improving warehouse performance without always having to expand capacity.

Furthermore, the UP3 Metro Warehouse obtained a preference value of 0.646 and was in fourth place. This value shows that this warehouse has relatively balanced characteristics, but has not been able to achieve the level of proximity to the ideal solution as the previous three alternatives. These results indicate that there are still several aspects that can be improved, especially in indicators that have high weight in the AHP method, so that warehouse logistics

performance can be more optimal.

Meanwhile, the UP2D Lampung Warehouse received the lowest preference value, which was 0.351. The value indicates that this alternative is relatively far from the positive ideal solution. This condition is mainly influenced by very limited warehouse capacity, relatively small number of human resources, and the unavailability of operational vehicle drivers. However, this warehouse has the highest Inventory Turn Over (ITO) value compared to other alternatives. The findings show that the efficiency of inventory turnover has not been able to compensate for the limited capacity and resources available, especially since these two aspects receive greater priority weight in the AHP method.

Overall, the results of the TOPSIS ranking show that the decision on material storage locations cannot be based on just one indicator, but must consider the balance of all aspects that affect the effectiveness of the logistics system. This approach produces recommendations that are more comprehensive than conventional assessment methods because they are able to accommodate the characteristics of each alternative based on the level of importance of each criterion.

The findings of this study are in line with the concept of TOPSIS put forward by Hwang and Yoon (1981) in Multiple Attribute Decision Making: Methods and Applications, which states that the best alternative is an alternative that has the maximum proximity to the positive ideal solution and the maximum distance to the negative ideal solution. In addition, the results of this study also support the findings of Behzadian et al. (2012) in the State-of-the-Art Survey of TOPSIS Applications, which show that TOPSIS is very effective in location selection and logistics decision-making because it is able to integrate various conflicting criteria into one objective measure of preference.

From the operational perspective of PT PLN (Persero) UP2D Lampung, the results of this study imply that the UP3 Tanjung Karang Warehouse is the most feasible alternative as a priority location for strategic material storage. Nevertheless, these results do not mean that other alternatives are not feasible. The UP3 Kotabumi, UP3 Pringsewu, and UP3 Metro warehouses still have a relatively high level of preference so that they can function as supporting warehouses according to the characteristics of their respective service areas. On the other hand, the UP2D Lampung Warehouse is more appropriately directed as a supporting warehouse with limited storage functions considering that the physical capacity and resources it has are not adequate to become the main material distribution center.

To provide a more comprehensive picture, each alternative is analyzed based on its advantages and limitations by taking into account the characteristics of each sub-criterion used in the study. Thus, the resulting recommendations are not solely based on preference values, but also consider the operational implications for the effectiveness of future material management. The managerial interpretation of each alternative is presented in the following table.

Table 2. Managerial interpretation of each alternative

Rank	Alternative	Vi Value	Managerial Interpretation
1	UP3 Tanjung Karang Warehouse	0,695	The alternative is most recommended because it has the best balance between warehouse capacity, resources, management quality, and operational efficiency.

Rank	Alternative	Vi Value	Managerial Interpretation
2	UP3 Kotabumi Warehouse	0,673	It is very feasible to be the main alternative because it has a large warehouse capacity and is supported by adequate resources.
3	UP3 Pringsewu Warehouse	0,667	It is worthy of being considered as a supporting alternative with relatively balanced performance on all criteria.
4	UP3 Metro Warehouse	0,646	It performs quite well, but some sub-criteria are still below the higher-ranked alternatives.
5	UP2D Warehouse Lampung	0,351	Less recommended as a primary material storage center due to warehouse capacity and limited resources despite having a very high ITO value.

Source: Researcher's analysis based on TOPSIS ranking results and operational considerations at PT PLN (Persero) UP2D Lampung (2025)

The ranking results using the TOPSIS method provide information about the level of preference of each alternative based on its proximity to the positive ideal solution and its distance to the negative ideal solution. Although the preference value (Vi) has indicated an alternative priority order quantitatively, the results need to be further interpreted in the operational context of PT PLN (Persero) UP2D Lampung. This interpretation is important so that the results of the analysis are not only mathematical, but also provide practical meaning as a basis for decision-making in determining the location of material storage.

Analysis of Warehouse Capacity Projections to Support Material Storage Location Decisions

The ranking results used the Analytical Hierarchy Process (AHP) method and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) produces alternative material storage priorities based on existing conditions and predetermined criteria. Nevertheless, the decision on material storage locations needs to consider not only current conditions, but also the ability of each warehouse to accommodate the increased storage needs of the future. Therefore, the analysis of warehouse capacity projections is carried out as a complement to the AHP–TOPSIS results to assess sustainability (sustainability) recommended alternatives in supporting the material management of PT PLN (Persero) UP2D Lampung.

Based on the results of capacity projections until 2029, all alternative warehouses are estimated to experience an increase in storage capacity compared to 2024 conditions. The UP3 Kotabumi warehouse is projected to remain the warehouse with the largest capacity, which will increase from 4,032 m² to 4,355 m² or an increase of 323 m² (8.01%). The UP3 Metro Warehouse and the UP3 Tanjung Karang Warehouse each increased from 4,000 m² to 4,319 m² with a growth of 319 m² (7.98%), while the UP3 Pringsewu Warehouse increased from 3,325 m² to 3,582 m² or an increase of 257 m² (7.73%). Meanwhile, the UP2D Lampung Warehouse is projected to increase from 12 m² to 16 m² or by 33.33%, but the increase is influenced by the relatively small initial capacity so that it cannot be interpreted as a need for larger storage space than UP3 warehouses.

The results of the Compound Annual Growth Rate (CAGR) analysis show that the

growth of warehouse capacity in UP3 units is relatively stable, which is in the range of 1.50%-1.55% per year. This condition indicates that the increase in storage space needs is gradual and can still be anticipated through measurable capacity planning. On the other hand, UP2D Lampung Warehouse has a CAGR value of 6.27% per year. Although it is the highest value among all alternatives, the high percentage is mainly due to the very small initial capacity that needs to be interpreted proportionately taking into account the magnitude of the absolute capacity.

If the results of the capacity projection are compared with the results of the TOPSIS ranking, it can be seen that there is a mutually supportive relationship between the capacity of the warehouse and the priority alternatives produced. The UP3 Tanjung Karang warehouse that obtained the highest preference value (Vi = 0.695) is projected to have a capacity of 4,319 m² by 2029, showing that the warehouse not only has the best characteristics based on multicriteria evaluation, but is also still able to accommodate the increased storage needs in the planning period. Similarly, the UP3 Kotabumi Warehouse, which ranks second (Vi = 0.673), still has the largest capacity until 2029 at 4,355 m², so it has the potential to play a role as the main material storage center for certain operational areas. On the other hand, the UP2D Lampung Warehouse which obtained the lowest preference value (Vi = 0.351) had limited storage capacity despite showing a high percentage of growth. This condition indicates that the warehouse is more suitable to function as a supporting warehouse or buffer storage rather than as the main material distribution center.

The findings show that warehouse capacity cannot be used as the only basis in determining the location of material storage. A warehouse with the largest capacity is not necessarily the best alternative if it is not supported by other factors such as the availability of human resources, management quality, Inventory Turn Over (ITO) performance, and the size of the work area. On the other hand, the multicriteria approach used in this study was able to evaluate each alternative more comprehensively so that the resulting decision not only considered storage capacity, but also other operational aspects that affect the effectiveness of material management.

To provide a more comprehensive picture of the relationship between the results of alternative rating using the TOPSIS method and the results of warehouse capacity projections, a synthesis of the two analysis results was carried out. This synthesis aims to show that warehouse alternatives that obtain high priority not only excel based on multicriteria evaluation of existing conditions, but also have adequate capacity to support material storage needs in the planning period. The results of the synthesis are presented in the following table.

Table 3. Synthesis of each alternative

Alternative	Rank	Vi Value	Projected Capacity 2029 (m²)	Growth 2024–2029	Managerial Interpretation
UP3 Tanjung Karang Warehouse	1	0,695	4.319	7,98%	The main alternative is that it has the best balance between the results of the multicriteriaevaluation and the adequate capacity to support medium-term operational needs.

Alternative	Rank	Vi Value	Projected Capacity 2029 (m^2)	Growth 2024–2029	Managerial Interpretation
UP3 Kotabumi Warehouse	2	0,673	4.355	8,01%	It has the largest capacity so it has great potential as a material storage center for areas with high logistics needs.
UP3 Pringsewu Warehouse	3	0,667	3.582	7,73%	Feasible as a supporting alternative with stable capacity growth and adequate storage capability.
UP3 Metro Warehouse	4	0,646	4.319	7,98%	It has a large enough capacity to support the distribution of materials according to operational needs.
UP2D Warehouse Lampung	5	0,351	16	33,33%	It is more suitable as a supporting warehouse because the absolute capacity is relatively small despite showing a high percentage of growth.

Source: Researcher's synthesis based on TOPSIS ranking results and warehouse capacity projection analysis (2025)

Based on Table 3, it can be seen that the ranking results using the TOPSIS method are consistent with the results of warehouse capacity projections. Alternatives that obtain high ratings generally have relatively large storage capacity and stable capacity growth through 2029. On the other hand, UP2D Lampung Warehouse, which has the smallest absolute capacity, still received the lowest ranking despite showing the highest percentage of growth. This shows that the decision on material storage locations is not only influenced by the rate of capacity growth, but also considers the actual capacity and the results of the overall multi-criteria evaluation.

From a managerial perspective, the results of the capacity projection provide important information for PT PLN (Persero) UP2D Lampung in preparing a plan to develop logistics facilities in stages. Information on capacity growth trends can be used as a basis for determining investment priorities for warehouse development, preparing material redistribution strategies between units, and evaluating storage space needs in accordance with the development of the electricity distribution network in Lampung Province. Thus, material storage decisions are not only oriented to current operational needs, but also consider the readiness of the warehouse infrastructure to support future operational needs.

Conceptually, the results of this study are in line with the view of Christopher (2022) in Logistics & Supply Chain Management who states that warehouse capacity planning is an important part of the logistics strategy to maintain a balance between storage capacity, service levels, and operational needs. In addition, Ivanov (2021) explained that decisions regarding the capacity of logistics facilities need to consider the system's ability to deal with changes in demand and operational dynamics so as to be able to increase supply chain resilience. In the context of this study, the integration of warehouse capacity analysis results with the AHP-

TOPSIS method provides a more comprehensive basis for decision-making because it considers both existing operational conditions and capacity needs in the planning period.

Based on the overall results of the discussion, it can be concluded that the analysis of warehouse capacity projections plays a supporting role as a supporting instrument in validating the results of alternative rating obtained through the AHP-TOPSIS method. By integrating the results of multicriteria evaluation and projected capacity needs, PT PLN (Persero) UP2D Lampung obtains a more objective decision-making basis in determining material storage locations while planning sustainable warehouse capacity development in accordance with the company's operational needs.

CONCLUSION

Based on the results of the AHP and TOPSIS analyses, this study identified four primary criteria for determining material storage location priorities at PT PLN (Persero) UP2D Lampung: land capacity, resources, management quality, and operational efficiency. These criteria were represented by six sub-criteria: warehouse area, number of employees and outsourced personnel, availability of truck drivers, maturity level, inventory turnover (ITO), and service area. The AHP results indicated that warehouse area (0.29) was the highest-priority sub-criterion, followed by maturity level (0.23), number of employees and outsourced personnel (0.21), inventory turnover (0.13), service area (0.10), and availability of truck drivers (0.05). The consistency ratio (CR) was 0.017, indicating that the respondents' judgments were consistent. The TOPSIS analysis ranked the UP3 Tanjung Karang Warehouse as the preferred alternative, with the highest preference score (0.695), followed by the UP3 Kotabumi Warehouse (0.673), the UP3 Pringsewu Warehouse (0.667), the UP3 Metro Warehouse (0.646), and the UP2D Lampung Warehouse (0.351). Warehouse capacity projections through 2029 indicated that all candidate warehouses were expected to experience capacity growth, with the UP3 warehouses projected to increase steadily by approximately 7.73%–8.01%. These findings suggest that material storage decisions should consider not only current warehouse conditions but also future capacity requirements to better accommodate long-term operational growth.

Based on these findings, PT PLN (Persero) UP2D Lampung is recommended to use the AHP–TOPSIS rankings as the basis for strategic material storage location planning, with the UP3 Tanjung Karang Warehouse designated as the highest-priority location. Periodic evaluations of warehouse conditions are also recommended to ensure that storage decisions remain aligned with operational requirements. For future system development, the AHP–TOPSIS framework should be integrated into a decision support system linked to the company's logistics information system to enable faster, more objective, and data-driven evaluation and selection of material storage locations. Future research should expand the number of evaluation criteria and alternative locations by incorporating additional factors, such as logistics costs, disaster risk, transportation accessibility, and distribution service levels. Further methodological development may also integrate approaches such as Fuzzy AHP, the Analytic Network Process (ANP), the Decision-Making Trial and Evaluation Laboratory (DEMATEL), the Best–Worst Method (BWM), or Geographic Information Systems (GIS) to develop a more comprehensive decision-support model.

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