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Optimization of Electricity Distribution Priorities to Reduce Energy Not Served Losses Using Analytic Hierarchy Process

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Abstract

Purpose: This study aims to design a Decision Support System (DSS) to optimize electric energy distribution priorities at PLN Unit *Pelaksana Pengatur Distribusi* (UP2D) Lampung, specifically to minimize Energy Not Served (ENS) losses.

Methodology: The research employs the Analytic Hierarchy Process (AHP) method. The criteria used include Customer Volume, Customer Type, Power Load, and Outage Frequency, focused on the Bandar Lampung region using Asset Management Optimization (AMO) and ENS Key point data.

Results: The implementation of the AHP algorithm successfully transforms complex technical parameters into objective priority rankings. The system provides a strategic tool for managers to identify high-impact locations, effectively reducing unsold energy and mitigating data-entry fraud risks.

Conclusions: The AHP-based DSS improves the objectivity and accuracy of electricity distribution prioritization by integrating multiple criteria into a structured decision-making process, thereby supporting optimal distribution and reducing Energy Not Served (ENS).

Limitations: The scope is limited to the Bandar Lampung distribution network, specifically evaluating four primary customer categories and focusing on ENS reduction as the main optimization goal.

Contributions: This research contributes a data-driven strategic framework for PLN Management to enhance operational efficiency and minimize corporate financial losses.

Keywords: *Analytic Hierarchy Process, Decision Support System, Electric Energy Distribution, Energy Not Served*

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1. Introduction

Decision-making in a highly dynamic and continuously changing environment represents a complex challenge, particularly when decisions involve strategic issues that influence large communities, organizations, or public services. The continuity of policies, institutional sustainability, organizational performance, and even national development outcomes are strongly influenced by the quality of decisions made by decision-makers. Fundamentally, decision-making is a systematic process of selecting the most appropriate alternative from several available options based on relevant

information, objectives, and evaluation criteria. Effective decision-making requires not only experience and intuition but also the availability of accurate data and analytical approaches to reduce uncertainty and improve decision quality (Büyüközkan & Göçer, 2021).

Humans are essentially decision-makers because almost every activity performed in daily life involves a decision process, either consciously or unconsciously. In organizational contexts, leaders and managers are frequently required to make decisions regarding operational problems, resource allocation, risk management, and strategic planning. Therefore, information availability and data-based analysis become essential components in supporting rational decisions. Reliable information enables decision-makers to identify problems, evaluate alternatives, predict consequences, and select solutions that provide optimal outcomes (Alinezhad et al., 2021).

In general, decision-making situations can be categorized into three conditions based on the level of knowledge regarding possible outcomes. The first condition is decision-making under uncertainty, where several possible outcomes may occur, but the probability of each outcome is unknown. The second condition is decision-making under risk, where multiple outcomes are possible, and their probabilities can be estimated based on available information or historical data. The third condition is decision-making under certainty, where decision-makers have complete knowledge regarding the consequences of each alternative. These conditions demonstrate that decision-making processes require appropriate analytical methods, particularly when uncertainty, complexity, and multiple evaluation criteria are involved.

The complexity of decision-making does not only arise from limited information but also from the interrelationship among various factors that influence the final decision. Many real-world problems involve multiple criteria, conflicting objectives, and various stakeholder considerations, making conventional decision approaches insufficient. Consequently, Multi Criteria Decision Making (MCDM) approaches have become increasingly important because they provide structured frameworks for evaluating alternatives based on several quantitative and qualitative criteria simultaneously. MCDM methods have been widely applied in energy management, infrastructure planning, and operational decision-making because they are capable of integrating technical, economic, and managerial considerations within a single analytical framework (Mardani et al., 2021; Bohra & Anvari-Moghaddam, 2022). A systematic literature review of MCDM applications in energy management further confirms that these methods have become an established analytical foundation for addressing planning problems that involve competing technical, economic, and environmental objectives (de Oliveira et al., 2022).

One of the widely applied MCDM methods is the Analytical Hierarchy Process (AHP), which enables decision-makers to prioritize alternatives through pairwise comparisons and systematic weighting processes. AHP is considered effective in solving complex decision problems because it transforms problems into hierarchical structures consisting of objectives, criteria, and alternatives while evaluating the consistency of decision-maker judgments (Saaty & Vargas, 2022). Recent methodological reviews confirm that maintaining an acceptable consistency ratio remains one of the central challenges in AHP applications, as inconsistent pairwise judgments can distort the resulting priority weights (Pant et al., 2022). The integration of AHP with other decision-making approaches has also demonstrated effectiveness in selecting optimal alternatives in energy systems by considering multiple criteria and expert preferences, as reflected in a combined data envelopment analysis and grey-based multi-criteria approach used for solar power plant site selection in Vietnam (Wang et al., 2022) and in an improved AHP-information entropy method applied to evaluate distributed integrated energy systems in China (Xuan et al., 2022).

One sector that requires accurate and strategic decision-making is the electricity distribution system. Electricity distribution involves a complex infrastructure network that begins from power generation facilities and continues through transmission and distribution networks before reaching consumers.

Power plants, including Hydroelectric Power Plants *Pembangkit Listrik Tenaga Air* (PLTA), Solar Power Plants *Pembangkit Listrik Tenaga Surya* (PLTS), Steam Power Plants *Pembangkit Listrik Tenaga Uap* (PLTU), Gas Power Plants (*Pembangkit Listrik Tenaga Gas* (PLTG), and Nuclear Power Plants *Pembangkit Listrik Tenaga Nuklir* (PLTN), generate electricity that is transmitted through high-voltage networks to distribution substations before being supplied to residential, industrial, and public users. The reliability of electricity distribution systems is strongly dependent on effective operational planning, network management, and timely decision-making regarding maintenance and service priorities. (Ahmad et al., 2022). Beyond prioritization approaches such as AHP, other optimization techniques including genetic algorithms have also been explored to improve the efficiency of electrical energy distribution systems, reflecting the broader methodological diversity available for addressing distribution network problems (Anasta et al., 2024).

Electricity transmission requires voltage transformation processes to minimize energy losses during long-distance transmission. Electricity generated at approximately 6-24 kV is increased through step-up transformers before entering high-voltage transmission networks. Subsequently, the voltage is reduced through step-down transformers at substations to ensure that electricity can be safely distributed to consumers. This process requires continuous monitoring and prioritization because disruptions within distribution networks may significantly affect service reliability, operational efficiency, and customer satisfaction (Mansour et al., 2023).

The reliability of electricity distribution is also closely related to the ability of utility companies to identify critical areas requiring immediate intervention. Failure to determine appropriate priorities may result in Energy Not Served (ENS), which represents the amount of electricity demand that cannot be supplied due to system disturbances or operational limitations. Outage frequency and the volume of energy not delivered have themselves been shown to function as reliable indicators of medium-voltage network reliability, reinforcing their inclusion as core evaluation criteria in this study (Rusliadi & La Elo, 2024). Identifying the root causes of such energy losses, for instance through Failure Mode and Effect Analysis of distribution equipment, provides complementary diagnostic evidence that can inform the criteria used in a prioritization model. Therefore, decision-support systems are required to assist managers in evaluating distribution alternatives and determining priority locations based on objective criteria. Decision Support Systems (DSS) supported by MCDM methods have been widely recognized as effective tools for improving infrastructure management decisions because they integrate analytical models with managerial judgment (Kurniawan et al., 2024). Recent evidence from a web-based multicriteria DSS developed for portfolio-level resource allocation in energy companies further demonstrates that structured decision-support platforms can help utilities balance competing sustainability and regulatory demands under uncertainty.

Furthermore, decision support systems have increasingly been implemented in electricity distribution management to improve network reliability and operational resilience. These systems enable utility operators to analyze potential failures, evaluate alternative strategies, and determine priority actions for maintaining service continuity. Previous studies have shown that decision-support approaches can assist power system operators in identifying critical network components and developing more effective operational strategies (Françozo et al., 2023).

In electricity distribution systems, prioritization problems often involve selecting critical loads, determining maintenance priorities, and allocating limited operational resources. AHP-based approaches have been applied in power system management because they can rank alternatives based on multiple technical and operational indicators. For example, a gray-number-based multi-criteria decision-making framework has been used to determine reliability-centered maintenance priorities in electrical utilities by integrating technical and economic indicators into a structured decision hierarchy, enabling more objective decision-making during system disturbances (Jahani et al., 2022). Similarly, multicriteria analysis has been applied to determine the optimal placement of protective

devices such as reclosers in electrical distribution systems, using Monte Carlo scenario generation to evaluate reliability indicators including System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), and Average Energy Not Supplied (AENS) (Téllez et al., 2023).

In Indonesia, PT PLN (Persero) plays an important role in maintaining electricity availability and distribution reliability throughout the country. One of its operational units, PLN *Unit Pelaksana Pengatur Distribusi* (UP2D) Lampung, is responsible for managing distribution system operations within the Lampung region. PLN UP2D Lampung operates under the Distribution Main Unit (UID) Lampung and is responsible for planning, controlling, and maintaining 20 kV distribution systems to ensure electricity reliability and achievement of operational performance targets.

PLN UP2D Lampung consists of several organizational units, including the Planning Division, Operations Facilities Division, Distribution System Operations Division, Maintenance Division, Finance and General Affairs Section, Procurement Implementation Section, and Occupational Health, Safety, Environment, and Security Section *Keselamatan dan Kesehatan Kerja serta Lingkungan (*K3L). The unit is managed by the UP2D Manager, who is responsible for supervising distribution operations and ensuring that electricity supply reliability meets established standards. With a workforce consisting of 41 personnel, including managers, assistant managers, team leaders, and functional staff, PLN UP2D Lampung requires effective decision-making mechanisms to support operational performance.

However, determining electricity distribution priorities remains a challenging process because managers must consider multiple factors, including network conditions, service urgency, operational risks, and potential energy losses. Decisions based solely on individual judgment may lead to subjective assessments and inconsistent prioritization. Therefore, an analytical decision-support system is required to provide objective recommendations based on measurable criteria.

The Analytical Hierarchy Process (AHP) method provides an appropriate approach for this problem because it can transform complex decision problems into hierarchical structures consisting of objectives, criteria, and alternatives. Through pairwise comparisons and consistency evaluation, AHP can generate priority rankings that assist managers in selecting the most appropriate alternative (Saaty & Vargas, 2022). Previous studies have demonstrated the effectiveness of AHP in various infrastructure and energy management problems, particularly in determining priorities under complex decision environments (Bohra & Anvari-Moghaddam, 2022). This effectiveness has also been confirmed in broader multi-criteria reviews, which report a steady rise in AHP-based applications across energy management, sustainability assessment, and infrastructure prioritization problems over the past decade (Sahoo & Goswami, 2023).

Based on this background, this study aims to design a decision support system for determining electricity distribution alternatives at PLN UP2D Lampung using the Analytical Hierarchy Process (AHP) method. The proposed system is expected to assist managers in identifying critical distribution locations that require priority handling, thereby reducing potential losses caused by Energy Not Served (ENS) and improving the effectiveness of electricity distribution management.

2. Literature Review

2.1 Analytical Hierarchy Process (AHP) Method

The Analytical Hierarchy Process (AHP), developed by Thomas L. Saaty, is a decision-support method designed to decompose complex, unstructured problems into a hierarchical structure. This method is capable of integrating subjective judgments with both quantitative and qualitative variables through pairwise comparison (Rimantho et al., 2016). In its application, AHP transforms qualitative assessments into numerical values using a standardized scale of 1-9 to determine priorities among elements. A bibliometric review covering four decades of AHP research confirms that the method has

remained one of the most consistently applied multi-criteria decision-making tools across engineering, management, and public-policy domains, reflecting its continued relevance for structured priority setting (Madzík & Falát, 2022).

The primary strength of AHP lies in its ability to systematically rank decision alternatives when decision-makers are faced with various competing criteria. By constructing a hierarchical structure and synthesizing diverse considerations, AHP enables the identification of variables with the highest priority that most significantly influence the final outcome. This makes AHP a highly effective tool for strategic decision-making, ranging from economic issues to energy distribution management involving numerous technical and social factors. Recent developments have also produced web-based group decision-support platforms that automate the AHP pairwise comparison and consistency-checking process, making the method more accessible for decision-makers who must coordinate judgments from multiple experts (Françozo et al., 2023). Similarly, taxonomy-based decision support tools have been proposed to help analysts select the most suitable multi-criteria method, including AHP, according to the structure and requirements of a specific decision problem (Cinelli et al., 2022).

2.1.1 Principles of Analytical Thinking

According to Saaty, problem-solving through the Analytical Hierarchy Process (AHP) method by Astuti and Fatma (2017) is based on three primary principles of analytical thinking. The first is decomposition, or hierarchical construction, which is the ability to break down complex realities into fundamental, interrelated elements within a hierarchical structure; this allows the human mind to acquire detailed knowledge by grouping objects or ideas from a general level to more specific levels. The second is comparative judgment, or priority setting, namely the ability to assess the relative importance of a pair of elements based on specific criteria through pairwise comparison, with the results of these assessments then synthesized through a logical process to obtain a comprehensive overview of the system. The third principle is logical consistency, which is the ability to group objects homogeneously and relevantly so that the relationships between ideas or objects remain coherently linked; consistency in AHP guarantees that the intensity of preferences provided in the assessment is logically justified. Together, these three principles form the conceptual foundation that allows AHP to move systematically from a complex, unstructured problem toward a defensible, well-ordered set of priorities.

2.1.2 Stages of Using AHP

The application of AHP for complex problems generally involves four stages (Roper-Lowe & Sharp, 1990). The first stage is decomposing complex problems into a number of small selection elements and subsequently arranging them into a hierarchical form. The issue is broken down into specific elements, namely criteria and alternatives, which are then organized into a hierarchical structure, allowing a complex decision to be structured into a hierarchy ranging from the overall objective to various criteria and sub-criteria, down to the lowest level. The decision objective is displayed at the top level, while the decision alternatives are listed at the final level of the hierarchy. According to Saaty, a hierarchy can be constructed through creative thinking, memory, and human perspective, and he noted that there is no fixed set of procedures for generating the levels to be included in a hierarchy. Based on this analysis, the first step of the AHP process is therefore to construct the hierarchy of the problem at hand by establishing the objective, which represents the overall system goal at the top level. The resulting hierarchical structure is illustrated in Figure 1.

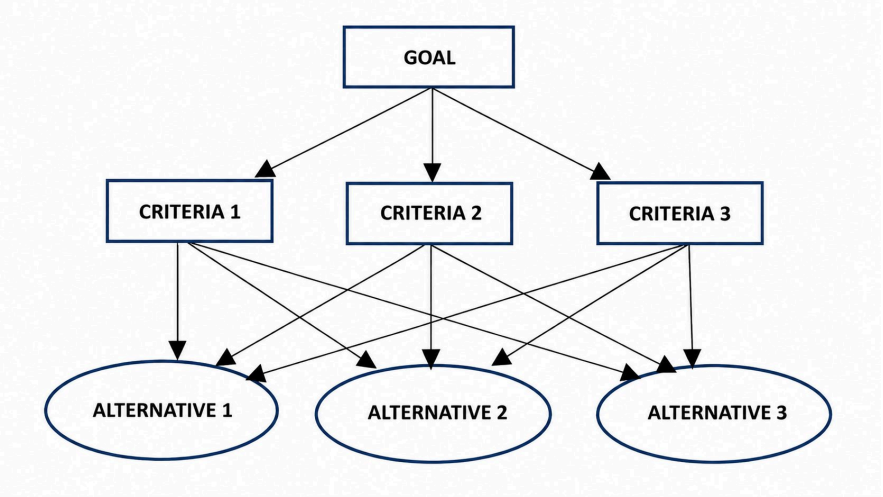


Figure 1. AHP hierarchical structure

The second stage is conducting a series of pairwise comparisons between elements based on a ratio scale. Once the hierarchy is established, the next step is to determine the priority of each element at every level. A series of comparison matrices for all elements within a hierarchical level is constructed by referring to an element from the higher level as a priority, converting individual comparison judgments into a measurement scale using a 9-point scale (Wirasta & Setiarini, 2021). Comparable fuzzy extensions of this scale have also been applied in GIS-integrated site-suitability analyses, where the standard 1-9 intensity scale is converted into fuzzy membership values to accommodate uncertainty in expert judgment (Tarife, Nakanishi, Zhou, Estoperez, & Tahud, 2023; Akusta, & Cergibozan, 2024). The values and definitions of qualitative opinions from Saaty's comparison scale are presented in Table 1.

Table 1. AHP pairwise comparison scale and its interpretation

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favor one element over another.
5	Very strong or demonstrated importance	Experience and judgment strongly favor one element over another.
7	Extreme importance	An element is favored very strongly; its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values	Values given when a compromise is needed between two adjacent judgments.

The third stage is using the eigenvalue method to estimate the relative weights of each element. Pairwise comparisons produce a relative ranking matrix for each level of the hierarchy, and the number of matrices depends on the number of elements at each level, while the arrangement of the matrix at each level depends on the number of elements at the lower level connected to it. After all matrices are constructed and all pairwise comparisons are obtained, the relative weights, overall weights, and the maximum eigenvalue (λmax) for each matrix are calculated and then summed. The procedure for obtaining the eigenvalue involves calculating the sum of each row followed by normalization, a process that terminates once the difference between two consecutive calculations

falls below a specified threshold (Fadjar, Kusumaningsih, & Yanto, 2021). The maximum eigenvalue (λmax) serves as a critical validation parameter used to determine the Consistency Ratio (CR), which evaluates the integrity of the pairwise comparison matrix. The calculation steps include determining λmax for a matrix of size n, computing the Consistency Index using the formula *CI = (λmax - n) / (n - 1)* to ensure response validity, and finally deriving the CR through the formula *CR = CI / RI*, a ratio that acts as a verification tool to ensure that the pairwise comparisons were performed consistently, utilizing the Random Index (RI) values provided by Oakridge Laboratory as a reference. Maintaining an acceptable consistency ratio remains one of the central methodological concerns in AHP applications, since inconsistent pairwise judgments can distort the resulting priority weights and undermine the reliability of the final ranking (Pant, Kumar, Ram, Klochkov, & Sharma, 2022). The Random Index (RI) values used to compute the Consistency Ratio for matrices of different sizes are presented in Table 2.

Table 2. Random Index (RI) values for different matrix sizes in AHP

N	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

The fourth and final stage is synthesizing the relative weights to determine the final measurement of the given decision alternatives. AHP is a powerful and flexible multi-criteria decision-making tool designed to solve complex problems where both qualitative and quantitative aspects must be considered, assisting analysts in organizing the critical aspects of a problem into a hierarchical structure. To perform pairwise comparisons at a specific level, a matrix A is constructed by placing the results of the pairwise comparison between element i and element j into position Aij, as shown in Figure 2.

$$A = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ . \\ C_n \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & . & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & . & a_{1n} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & . & a_{2n} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & . & a_{3n} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & . & a_{4n} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & . & a_{5n} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & . & a_{6n} \\ . & . & . & . & . & . & 1 & . \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{21} & a_{21} & . & 1 \end{bmatrix} \end{array}$$

Figure 2. Pairwise comparison matrix structure

n = number of criteria to be evaluated
Ci = the i-th criterion
Aij = the importance level of criterion i relative to criterion j

The AHP method was developed by Thomas L. Saaty, a mathematician, and serves as a framework for effective decision-making in complex problems by simplifying and accelerating the process. It achieves this by decomposing problems into constituent parts, organizing them into a hierarchical structure, assigning numerical values to subjective judgments regarding the importance of each variable, and synthesizing these judgments to determine the variables with the highest priority that influence the outcome of a given situation (Andrian, Rahyu, Warudoyong, Sukabumi, & Barat, 2025).

Furthermore, the AHP method facilitates the resolution of complex issues through a hierarchical structure of criteria, stakeholders, and outcomes by drawing on various considerations to develop weights or priorities. This method also integrates the strengths of both intuition and logic relevant to various problems, subsequently synthesizing diverse considerations into results that align with intuitive estimates as presented in the established judgments (Joyokusumo, Fatchurrahman, Putra, & Maulana, 2020). Beyond AHP, other structured multi-criteria techniques such as the Simple Multi-Attribute Rating Technique (SMART) offer comparable transparency and ease of interpretation for decision-makers, although each method carries distinct advantages and limitations depending on the structure of the decision problem (Taherdoost & Mohebi, 2024).

2.1.3 Advantages of Using AHP

The Analytic Hierarchy Process (AHP) offers several advantages that make it one of the most widely used multi-criteria decision-making methods for solving complex problems. AHP provides a unified and flexible framework that transforms unstructured decision problems into a hierarchical model, making them easier to understand and analyze. The method integrates deductive reasoning with systems thinking while accommodating interdependence among decision criteria without requiring linear relationships. In addition, AHP reflects the natural cognitive process of organizing problems into hierarchical levels, enabling decision-makers to evaluate criteria systematically, measure their relative importance, and establish priority rankings based on pairwise comparisons. The method also includes a consistency assessment that helps ensure the reliability and logical coherence of expert judgments throughout the evaluation process.

Beyond its analytical capabilities, AHP synthesizes multiple criteria into a comprehensive evaluation of decision alternatives, allowing organizations to identify the most appropriate option based on predefined objectives. The method also accommodates diverse expert opinions without requiring complete consensus and supports iterative refinement, enabling decision-makers to improve both problem definition and judgment quality as new information becomes available. These strengths have been demonstrated across a wide range of recent applications beyond the energy sector, including AHP–TOPSIS-based prioritization of forest road networks for wildfire prevention planning and structured multi-criteria evaluations of decision-support methods for all-hazards threat prioritization in public health (Zhao et al., 2022). Such evidence highlights the robustness, flexibility, and broad applicability of AHP as a decision-support method, supporting its use in optimizing electricity distribution priorities in this study (Stergiadou et al., 2024).

2.2 Electricity Distribution

The process of electricity distribution to residential areas originates from power plants. The PLTA, PLTS, PLTU, PLTG, and PLTN all function as facilities that convert various forms of energy into electrical energy using generators. Power plants generate electricity at a voltage of approximately six to 24 kilovolts (kV). These plants are typically located far from residential areas. The electrical energy produced is then delivered to homes and schools through a transmission system. The electricity generated by the power plant is subsequently stepped up in voltage using a step-up transformer. The voltage increase is intended to reduce energy losses during long-distance transmission. Step-up transformers raise the voltage from the initial 6-24 kilovolts to 70-150 kilovolts. The high-voltage electricity is then transmitted to transmission substations.

Transmission substations are connected to overhead transmission lines, such as *Saluran Udara Tegangan Ekstra Tinggi* (SUTET), *Saluran Udara Tegangan Rendah* (SUTR) *Saluran Udara Tegangan Tinggi* (SUTT). These transmission lines transfer electrical energy from power plants to substations within the distribution system. High-voltage transmission lines deliver electricity both within and outside urban areas and can span distances ranging from 60 to 250 kilometers, crossing mountainous and forested regions. After long-distance transmission, the voltage is reduced before entering the distribution system. At the substation, the voltage is stepped down using a step-down transformer, typically from 150 kV to 20 kV for medium-voltage distribution.

Electricity that has undergone voltage reduction then enters distribution substations or main substations. Transmission substations utilize air-insulated systems. Electricity at 150 kilovolts is supplied to industries that require large amounts of power, while electricity at 20 kilovolts is distributed to residential areas, public and social facilities, and small-scale businesses. Before reaching residential consumers, the voltage is further reduced to 220 volts at the substation level. This voltage reduction is carried out using a step-down transformer. The 220-volt electricity is then transmitted through power poles and cables to homes, schools, mosques, street lighting, and other public facilities. Comparable prioritization challenges have been documented internationally, where multi-criteria decision-making has been used to evaluate and rank power generation and distribution technologies according to sustainability, reliability, and cost criteria by Manirambona, Talai, and Kimutai (2022), reinforcing the relevance of a structured decision-support approach for distribution planning of the kind proposed in this study.

3. Research Methodology

3.1 Requirements Analysis and Workflow

The analysis was conducted to identify solutions for data invalidity and the risk of reporting manipulation in energy distribution, both of which affect the company's performance targets. The current process involves data extraction by the Tech Ren Scadatel unit, verification by the Team Leader, and oversight by the Assistant Manager and Manager. The existing monitoring workflow for electrical energy distribution is illustrated in Figure 3. This structured, multi-stage validation workflow is consistent with recent decision-support frameworks developed for sustainable smart grid planning, which similarly emphasize the importance of transforming raw operational data into transparent, auditable decision inputs before they are used for prioritization (Ouled Amor et al., 2026).

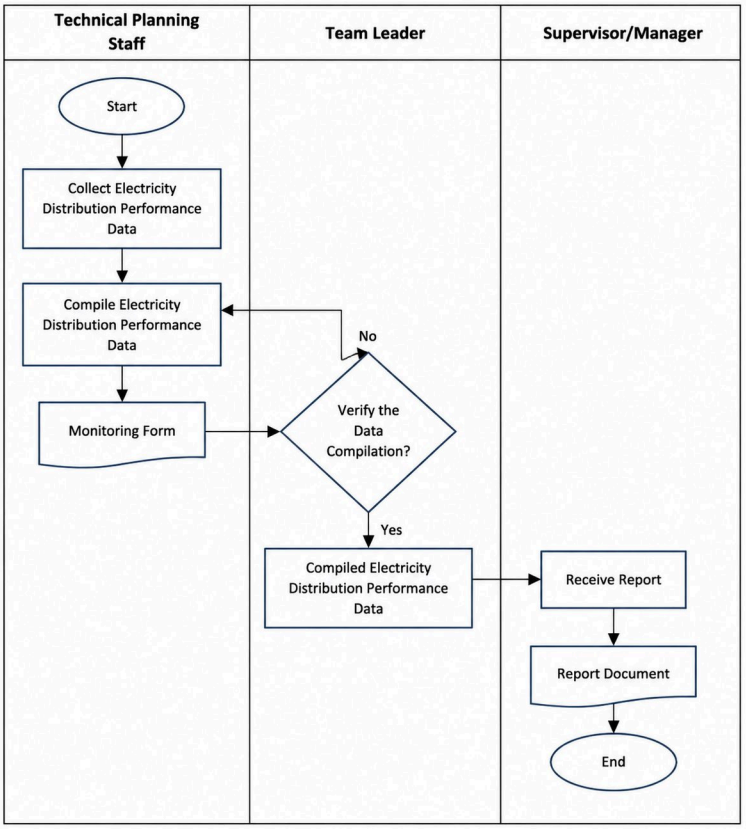


Figure 3. Flowchart of slectrical energy distribution monitoring and reporting

As shown in Figure 3, the Electrical Energy Distribution Monitoring and Reporting workflow begins with data extraction, in which the Technical Planning (Tech Ren) Scadatel unit extracts the electrical

energy distribution monitoring data and prepares a report for the Team Leader (TL) Ren Scada. The monitoring report is then verified by the TL Ren Scada, and if any potential data invalidity is identified, the report is forwarded to the TL Scadatel for further review. However, if the data is deemed valid, it proceeds to validation and approval, in which it is submitted to the Assistant Manager (Asman) Ren and Asman Fasop for validation; once validated, it is sent to the Manager and relevant team members. This sequential flow of extraction, verification, and validation ensures that only data that has passed multiple layers of review is used as input for the subsequent AHP-based prioritization process.

4. Results and Discussions

4.1 Result

This study produced a Decision Support System (DSS) model based on the Analytic Hierarchy Process (AHP) method to determine electricity distribution priorities aimed at reducing Energy Not Served (ENS) in the service area of PLN UP2D Lampung, particularly in Bandar Lampung City. Based on the requirements analysis and processing of Asset Management Optimization (AMO) data and ENS Key Point reviews, four main criteria were identified for determining distribution priorities: Number of Customers (*Jumlah Langganan/Pelanggan* or JLP), Customer Type (*Jenis Pelanggan* or JNP), Electrical Load (*Beban Daya* or BD), and Outage Frequency (*Frekuensi Padam* or FP). These criteria were structured into an AHP hierarchy with the primary objective of optimizing electricity distribution and minimizing ENS.

4.2 AHP Method Implementation

This research establishes four main criteria for determining energy distribution priorities: Number of Customers, Customer Type, Electrical Power Load in kWh, and Outage Frequency, which are detailed in the following table 3 and Figure 4.

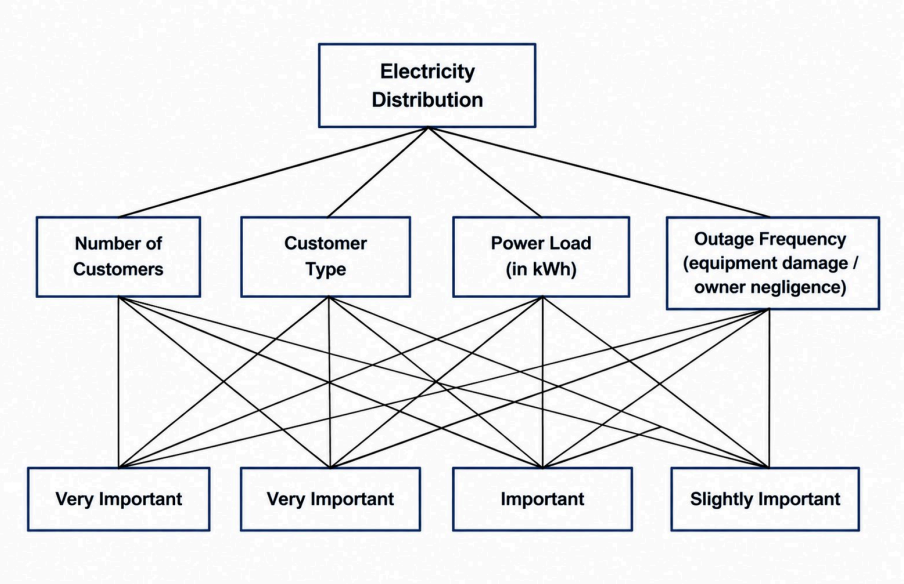


Figure 4. Criteria and sub-criteria

Table 3. Criteria and sub-criteria for energy distribution prioritization

Criteria	Sub-Criteria
Customer Volume	Absolutely Very Important (MSP), Very Important (SGP), Important (PTG), Slightly Important (SDP)
Customer Type	Absolutely Very Important (MSP), Very Important (SGP), Important (PTG), Slightly Important (SDP)

Criteria	Sub-Criteria
Electrical Power Load	Absolutely Very Important (MSP), Very Important (SGP), Important (PTG), Slightly Important (SDP)
Outage Frequency due to Equipment Failure/Maintenance	Absolutely Very Important (MSP), Very Important (SGP), Important (PTG), Slightly Important (SDP)

Table 3 presents the four main criteria alongside their respective sub-criteria, which classify the level of importance for each criterion into four ordinal categories, namely Absolutely Most Important (*Mutlak Sangat Penting* or MSP), Very Important (*Sangat Penting* or SGP), Important (*Penting* or PTG), and Slightly Important (*Sedikit Penting* or SDP). This structure translates each criterion into a set of measurable sub-criteria that can subsequently be scored during the pairwise comparison process.

4.3 Pairwise Matrix Comparison

The weighting process is conducted by comparing the relative importance of each criterion using an intensity scale of 1 to 9 (Saaty, 1977). The relationships between the matrix elements aij are represented in the following table Table 4.

Table 4. Pairwise comparison matrix of energy distribution criteria

Code	Number of Customer (JLP)	Customer Type (JNP)	Electrical Load (BD)	Outage Frequency (FP)
JLP	1	1	1	1
JNP	1	1	1	1
BD	1	1	1	1
FP	1	1	1	1
Total	4	4	4	4

From the pairwise comparisons above, the priority of each criterion can be calculated based on its contribution to the overall goal. This is achieved by dividing each element of the matrix by its respective column total, and then averaging the elements in each row to obtain the weight of each criterion. These criteria weights are subsequently used to assess the priority level of each criterion (Nurhidayanto & Dewi, 2024). The priorities for each criterion are presented in the following normalization table Table 5.

Table 5. Normalized pairwise comparison matrix and criteria priority weights

Code	Number of Customer (JLP)	Customer Type (JNP)	Electrical Load (BD)	Outage Frequency (FP)	Jumlah	Prioritas	Eigen
JLP	0.25	0.25	0.25	0.25	1	0.25	4
JNP	0.25	0.25	0.25	0.25	1	0.25	4
BD	0.25	0.25	0.25	0.25	1	0.25	4
FP	0.25	0.25	0.25	0.25	1	0.25	4

The weighting process was conducted using pairwise comparisons among the criteria. The normalization results indicate that each criterion has an equal priority weight of 0.25. This finding suggests that all criteria contribute equally to achieving the objective of reducing ENS and improving distribution effectiveness. The resulting criterion weights were then applied to evaluate distribution area alternatives, producing a priority ranking of locations. Areas with the highest priority values were identified as having the greatest potential impact on ENS and therefore require immediate attention in distribution planning and disturbance handling. The implementation of the AHP method within the DSS successfully transformed complex technical parameters into objective and measurable priority

values. These results provide decision-makers at PLN UP2D Lampung with a structured and data-driven basis for determining electricity distribution priorities.

4.4 Discussion

The results demonstrate that the application of the AHP method is effective in supporting electricity distribution decision-making. The inclusion of both technical factors (electrical load and outage frequency) and customer-related factors (number and type of customers) enables a comprehensive evaluation of variables contributing to high ENS values. The equal weighting of the criteria indicates that ENS reduction cannot rely on a single dominant factor but requires an integrated approach that balances operational conditions and customer characteristics. This reflects real operational conditions at PLN, where disturbances in areas with high loads or strategic customer segments can lead to significant energy losses.

Compared to the previous priority determination process, which tended to be subjective and vulnerable to data invalidity, the AHP-based DSS offers a more transparent and systematic evaluation mechanism. Decision-making is based on clearly defined criteria and weights, thereby reducing the risk of data manipulation and improving accountability in reporting. This finding is consistent with broader evidence that structured multi-criteria decision-support platforms improve transparency and auditability in resource allocation decisions within energy companies operating under competing regulatory and sustainability constraints.

From an operational perspective, the findings provide strategic value for PLN UP2D Lampung management in determining focus areas during distribution constraints or network disturbances. By prioritizing high-impact locations, the company can effectively reduce ENS, improve supply reliability, and minimize potential financial losses due to undelivered electrical energy. This pattern mirrors findings from other national contexts, where multi-criteria decision-making has similarly been used to rank and prioritize power infrastructure investments according to reliability, sustainability, and cost considerations (Manirambona et al., 2022). Overall, this study confirms that the AHP-based Decision Support System is a relevant and practical tool for optimizing electricity distribution and supporting strategic decision-making within PLN.

5. Conclusions

5.1 Conclusion

This study concludes that the implementation of a Decision Support System (DSS) based on the Analytic Hierarchy Process (AHP) method is effective for optimizing electricity distribution priorities to reduce Energy Not Served (ENS) at PLN UP2D Lampung. By integrating AMO data and ENS Key Point analysis, the proposed system is able to transform complex technical and operational parameters into objective and measurable priority rankings. The use of four main criteria, Number of Customers, Customer Type, Electrical Load, and Outage Frequency, provides a comprehensive framework for evaluating distribution priorities. The equal weighting of these criteria indicates that ENS reduction requires a balanced consideration of both customer-related and technical factors. This approach supports more transparent, consistent, and accountable decision-making compared to conventional subjective methods. Overall, the AHP-based DSS serves as a strategic tool for management in identifying high-impact distribution areas, improving supply reliability, reducing unsold energy, and minimizing potential financial losses due to undelivered electrical energy.

5.2 Research Limitations

This study has several limitations that should be considered. First, the research scope is limited to the electricity distribution network managed by PLN UP2D Lampung, particularly the Bandar Lampung area. Therefore, the findings may not fully represent electricity distribution characteristics in other regions with different network structures, customer profiles, and operational conditions. Second, the decision model only considers four primary criteria, namely Number of Customers, Customer Type, Electrical Load, and Outage Frequency. Although these criteria represent important factors affecting

ENS, other potential variables such as network asset conditions, maintenance priorities, infrastructure age, operational costs, weather conditions, and customer satisfaction levels were not included in the current model.

Third, the AHP weighting process depends on the judgment and preferences of decision-makers. Although AHP provides a structured mechanism for evaluating priorities, subjective assessments may still influence the resulting weights. Therefore, variations in expert judgment may produce different priority outcomes. Finally, this study focuses primarily on reducing ENS as the main optimization objective. Other electricity distribution performance indicators, such as reliability indices, service quality, operational costs, and long-term infrastructure planning, were not extensively evaluated.

5.3 Suggestions and Directions for Future Research

Future research is recommended to expand the proposed DSS model by incorporating additional criteria related to electricity distribution performance, such as network asset conditions, maintenance costs, infrastructure reliability, and customer satisfaction indicators. These additional variables may improve the accuracy and comprehensiveness of electricity distribution priority assessments. Furthermore, future studies may apply the proposed AHP-based DSS framework to other PLN operational regions with different distribution characteristics. This broader implementation can evaluate the adaptability and effectiveness of the model in supporting electricity distribution management and reducing ENS on a wider scale. Future research may also consider integrating more comprehensive operational data and real-time monitoring information to improve the accuracy of priority determination and support more responsive decision-making processes.

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Author Contributions

ASR contributed to the conceptualization, methodology development, data collection, implementation of the Analytic Hierarchy Process (AHP) model, data analysis, interpretation of results, and preparation of the original manuscript draft. FA contributed to system analysis, validation of the Decision Support System (DSS) framework, technical evaluation, research visualization, and critical revision of the manuscript. SYI contributed to research supervision, validation of the research methodology, refinement of the discussion and conclusions, and final review of the manuscript. All authors have read and approved the final version of the manuscript.

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