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An Integrated AHP–TOPSIS Model to Enhance the Effectiveness of Disaster Logistics Distribution (Case Study: Regional Disaster Management Agency of Minahasa)

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Abstract: *This study is motivated by the challenges faced by the Regional Disaster Management Agency (BPBD) of Minahasa Regency in determining the priority of disaster logistics distribution in a rapid, accurate, and objective manner under constraints of limited resources and time, where decisions often rely on manual processes that are susceptible to subjective bias. The objective of this study is to design and implement an integrated model of the Analytical Hierarchy Process and the Technique for Order Preference by Similarity to Ideal Solution as a Disaster Logistics Management Information System to support structured and measurable decision-making. The research method involves the development of an AHP–TOPSIS integration model, in which AHP is utilized to determine the weights of priority criteria, while TOPSIS is applied to generate a ranking of affected areas based on priority levels. The findings indicate that the integrated AHP–TOPSIS-based system enhances the objectivity and accuracy of logistics distribution decisions, making them data-driven and grounded in accountable mathematical calculations. The implementation results demonstrate that this approach effectively addresses the limitations of manual decision-making, producing consistent and accountable aid allocation decisions. In conclusion, the AHP–TOPSIS integration model serves as a significant strategic solution in improving the effectiveness, targeting accuracy, and efficiency of aid distribution processes at BPBD Minahasa. It is recommended that the application of this method be further developed by adapting it to the specific needs and geographical conditions of affected areas, as well as ensuring data accuracy to maintain the validity of priority analysis results..*

Keywords: *Disaster Logistics Management Information System, AHP, TOPSIS, Method Integration, Logistics Distribution Priority.*

1. Introduction

Indonesia, as a country located within the Pacific Ring of Fire, is highly prone to natural disasters, including floods, landslides, and earthquakes. Rapid and effective response is therefore essential, and one of the most critical aspects of disaster management is logistics management. Timely and well-targeted logistics distribution is key to mitigating the adverse impacts of disasters and ensuring the safety and recovery of affected populations. Logistics, in general, is defined as the process of planning, implementing, and controlling the flow of goods, services, and information from the point of origin to the point of destination in an efficient and effective manner [1], [2]. However, in the context of disasters, logistics assumes a far more specific and critical role. According to Regulation of the Head of the National Disaster Management Agency (BNPB) No. 13 of 2008, disaster logistics encompasses all aspects related to equipment, supplies, inventory, and essential needs required to support the entire process of disaster management operations [3],[13].

Disaster logistics represents one of the most crucial components in disaster management, as it is directly associated with fulfilling the basic needs of affected communities, ensuring the availability of supplies to sustain victims' survival, and supporting the continuity of disaster response operations. This study adopts the Regional Disaster Management Agency (BPBD) of Minahasa Regency as a case study. The selection is based on the geographical characteristics and relatively high disaster vulnerability of the region. BPBD Minahasa is specifically required to maintain a high level of preparedness in responding to disaster logistics needs, which may arise suddenly and on a large scale.

A Decision Support System (DSS) is defined as a computer-based system specifically designed to assist decision-makers in addressing semi-structured and unstructured problems. According to Dous et al., (2018), a DSS supports decision-makers by providing relevant information, models, and analytical tools to enhance the effectiveness of decision-making, without replacing the role of the decision-maker. The main characteristics of a DSS, as identified by Keen and Scott Morton 1978 in Mosavi (2024), include its interactive, flexible, and adaptive nature, enabling users to conduct in-depth analysis, explore various alternatives, and evaluate multiple scenarios before reaching a decision [4], [5].

Sprague and Carlson 1982 in Stanek, (2022) emphasize that DSS is intended to help decision-makers utilize two primary components data and models to address unstructured problems. In the modern context, DSS plays a vital role in integrating data from multiple sources and processing complex criteria [6], [19]. The integration of multi-criteria decision-making (MCDM) methods, such as the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), with DSS has become increasingly prevalent, although its application in disaster logistics remains relatively limited [7]. This integration is particularly relevant, as DSS must be capable of accommodating MCDM approaches to generate richer information and support more accurate decision-making compared to traditional information systems.

In the context of disaster management, DSS is a critical component in humanitarian logistics due to its ability to handle coordination complexity, high levels of uncertainty, and the involvement of multiple stakeholders [20]. DSS facilitates the integration of data from diverse sources, accelerates emergency response, and optimizes resource allocation. The benefits of DSS in disaster logistics distribution decision-making include improved effectiveness (more targeted decisions), enhanced efficiency (in terms of time and cost), and greater transparency [8]. Studies indicate that DSS functions not merely as a reporting system but as an analytical tool that enables real-time and adaptive decision-making, for instance, through the development of Spatial DSS based on TOPSIS to assess evacuation site feasibility or to determine logistics distribution priorities [9].

In disaster situations, decision-making related to distribution priorities often faces challenges such as limited data availability, time pressure, and urgent needs. Without a structured and objective system to support priority determination, there is a risk of inter-regional conflict or misallocation of resources, which may reduce the effectiveness of the assistance provided. The AHP is a widely recognized multi-criteria decision-making method that is highly effective in determining the relative importance or priority weights of various criteria [10]. In the context of disaster logistics distribution, AHP is applied to establish a robust, consistent, logical, and accountable weighting framework for the criteria influencing distribution priorities [11]. This is achieved through a pairwise comparison approach, which enables the assessment of the relative importance of each criterion, such as the number of affected victims, the level of damage, regional accessibility, and the availability of transportation infrastructure.

After determining the criteria weights using AHP, the TOPSIS is employed to rank distribution priorities. TOPSIS operates by evaluating decision alternatives namely, logistics distribution locations based on their relative closeness to the positive ideal solution (the best possible outcome) and their distance from the negative ideal solution (the worst-case scenario) [12]. By applying TOPSIS, the resulting priority ranking reflects the level of need in each affected area, thereby enabling faster, more accurate, and mathematically grounded decision-making.

The integration of AHP and TOPSIS produces a highly objective, transparent, and adaptive decision-making approach suited to dynamic field conditions. AHP functions as a tool for generating proportional and justifiable criterion weights, while TOPSIS utilizes these weights to derive the final priority ranking. The combination of these two methods results in a complementary decision-making model in which logistics distribution decisions are based on data and mathematical computation rather than subjective judgment alone. This AHP–TOPSIS integration aims to enhance coordination effectiveness, optimize resource utilization, and ensure that aid is delivered promptly and accurately to those in need.

To address these challenges, this study proposes a strategic solution through the development of a Disaster Logistics Management Information System that integrates two MCDM methods, namely the AHP and the TOPSIS. This integration aims to provide a structured and measurable basis for evaluation. In this study, AHP is employed to determine the criteria and weights for logistics distribution priorities. It provides a systematic and quantifiable evaluation framework by considering various relevant factors, such as the number of affected victims, the level of damage, regional accessibility, and the urgency of needs in the field.

Subsequently, the weighting results obtained from AHP are integrated with the TOPSIS method. TOPSIS is utilized to generate an objective and accurate ranking of logistics distribution priorities. By combining these two methods, the distribution process can be conducted in a more objective and transparent manner, ensuring that aid is allocated according to the level of urgency and actual needs in affected areas.

The main objective of this study is to design an integrated AHP–TOPSIS model, determine priority criteria and weights, and implement the model within the disaster logistics distribution system at BPBD Minahasa. The implementation of this system is expected to enhance effectiveness, targeting accuracy, and efficiency in aid distribution, while also supporting the principles of transparency and accountability.

To ensure the rigor, transparency, and reproducibility of the proposed model, this study is grounded in a clearly defined empirical framework. The determination of decision criteria was conducted through a structured qualitative process involving eight experts, consisting of BPBD Minahasa personnel (logistics coordinators and field officers) and two academic experts in disaster management and decision support systems. These experts were selected using purposive sampling based on their direct experience in disaster logistics decision-making.

The criteria were identified through two stages, namely semi-structured interviews and a Focus Group Discussion (FGD). In the first stage, initial criteria were explored from practitioner insights. In the second stage, the FGD was used to validate, refine, and finalize the criteria set through consensus. As a result, five main criteria were established, including the number of affected victims, level of damage, accessibility, urgency of needs, and availability of logistics. For the decision alternatives, this study evaluates six disaster-affected locations within Minahasa Regency, selected based on recent disaster reports and logistical relevance. These locations represent realistic decision scenarios faced by BPBD in the field.

The quantitative data used in the model were collected through field assessment forms completed by BPBD officers, supported by secondary data from official disaster reports. Each alternative location was scored against all criteria using a standardized rating scale. To ensure data reliability, the scoring process was conducted by three independent field assessors, and the final values were obtained using an average aggregation method. Furthermore, in the AHP phase, expert judgments were collected through pairwise comparison questionnaires, and consistency ratio (CR) testing was applied to ensure the logical consistency of the weighting process. These steps collectively strengthen the methodological transparency and enhance the reliability and reproducibility of the study. This study is expected to provide practical contributions to BPBD Minahasa in optimizing logistics distribution processes, as well as to contribute academically to the field of Information Systems. Furthermore, this report is prepared as a requirement for the completion of a final project, with the expectation that it may serve as a reference for the development of similar information systems in other regions facing comparable challenges.

2.Methods

The type of research employed in this study is Applied Research. This approach is selected because its primary focus is on addressing real-world problems encountered in the field [14], particularly the challenges faced by the Regional BPBD of Minahasa in determining disaster logistics distribution priorities in a timely and accurate manner. The main objective of this applied research is to produce a practical solution. In this context, the proposed solution is a disaster logistics management information system that can be directly implemented and utilized by the relevant agency. To achieve this objective, the study adopts a mixed-method approach, integrating both qualitative and quantitative elements [15]. This approach is chosen due to the complexity of the research problem. The study requires not only an in-depth exploration of relevant concepts and criteria derived from the experience of field practitioners but also systematic mathematical calculations to ensure the objectivity of priority determination [16].

The qualitative phase focuses on the exploration and formulation of criteria that serve as the basis for determining logistics distribution priorities. The methods employed in this phase include interviews and Focus Group Discussions (FGDs) with BPBD Minahasa personnel and subject-matter experts. The collected data are analyzed descriptively to identify key criteria, such as the number of affected victims, the level of infrastructure damage, location accessibility, and the urgency of medical needs. Meanwhile, the quantitative phase utilizes two primary methods: the AHP and the TOPSIS [17]. AHP is used to determine the relative importance (weights) of each criterion based on expert judgment, with consistency ratio testing applied to ensure validity [18]. Subsequently, TOPSIS is employed to rank distribution alternatives based on the weights derived from AHP, resulting in an objective prioritization that aligns with actual field conditions.

Research Stages

The initial stage of the research begins with a literature review and problem identification. This phase is crucial as it involves a comprehensive theoretical review of disaster logistics, multi-criteria decision-making methods such as the AHP and the TOPSIS, as well as management information systems. Based on this theoretical foundation, a system requirements analysis is conducted at the Regional BPBD of Minahasa Regency. This analysis aims to ensure that the proposed system solution aligns with real-world conditions and operational needs in the field.

Following the identification of system requirements, the next stage is criteria identification and weighting, which is carried out using both qualitative and quantitative approaches. In the qualitative phase, interviews and FGDs are conducted with BPBD experts to identify the criteria for distribution priority. Commonly considered criteria include the number of affected victims, the level of damage, regional accessibility, medical urgency, and vulnerable populations. In the quantitative phase, the AHP is applied to determine the relative importance (weights) of the identified criteria based on expert judgments, accompanied by consistency ratio testing to ensure the validity of the weighting results.

The core stage of the research is the implementation and integration of methods, in which AHP is integrated with the TOPSIS. AHP generates the criterion weights, while TOPSIS is used to rank the logistics distribution alternatives based on these weights. This integration produces an objective and measurable priority ranking for logistics distribution. The purpose of the AHP–TOPSIS integration model is to design an accurate and implementable decision-making system that enhances the effectiveness of aid distribution at BPBD Minahasa. The final stage involves validation and sensitivity analysis. To ensure the reliability of the research findings, validation testing is conducted by comparing the ranking results generated by the system (AHP–TOPSIS model) with the manual decision-making approach commonly used by BPBD Minahasa. Additionally, sensitivity analysis is performed to evaluate the stability and robustness of the ranking outcomes, particularly in response to potential changes in the assigned criterion weights.

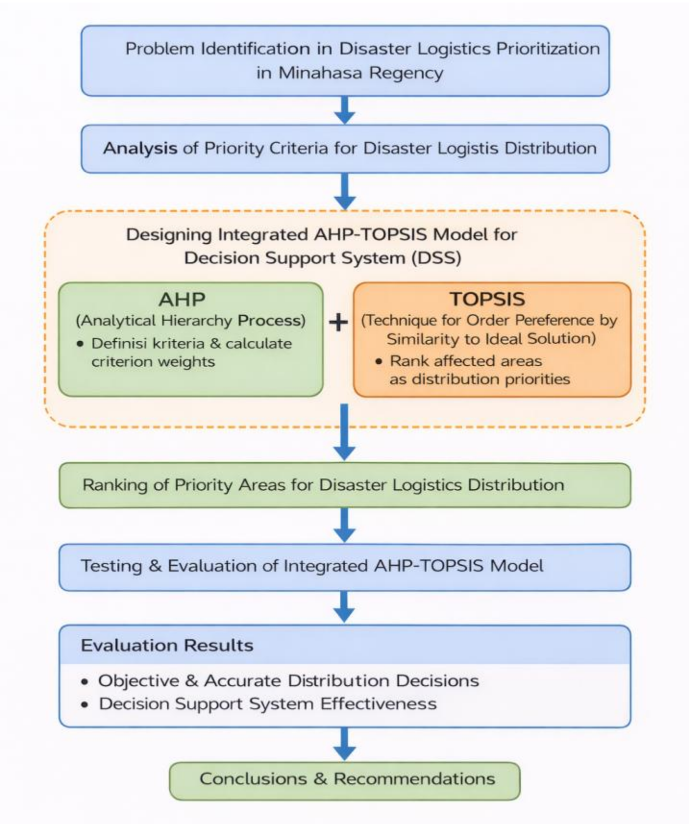

Figure 1. Flowchart

3. Results and Discussion

1. Analytical Hierarchy Process (AHP)

The AHP method was applied to determine the relative importance of each criterion based on expert judgments. The results show that the number of affected victims (C1) received the highest weight (0.32), followed by level of damage (0.25), urgency of needs (0.18), accessibility (0.15), and availability of logistics (0.10). The consistency ratio (CR) value obtained was 0.06, which is below the acceptable threshold of 0.10, indicating that the pairwise comparisons are consistent and reliable. AHP is employed in the initial stage of model design to determine the relative importanceof each criterion used as the basis for prioritizing disaster logistics distribution. The objectives of applying AHP are as follows:

- Establishing Criterion Weights, AHP ensures that the weights assigned to criteriasuch as the number of affected victims, the level of damage, regional accessibility, and the urgency of needs are proportional and well-balanced.
- Ensuring Consistent and Logical Judgments, the AHP process produces a robust weighting framework that is consistent, logical, and justifiable.
- Providing a Basis for Decision-Making, through AHP, logistics distribution decisions are grounded in measurable data and mathematical calculations, rather than subjective judgment.

2. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is applied after AHP to determine the priority ranking of logistics distribution. Once AHP provides standardized weights, TOPSIS performs the following functions:Generating Priority Rankings: TOPSIS ranks distribution alternatives (affected regions) based on their relative closeness to the positive ideal solution (best-case scenario) and their distance from the negative ideal solution (worst-case scenario). Supporting Fast and Measurable Decisions, this approach enables faster, more accurate, and quantitatively measurable decision-making, producing a final ranking that reflects the level of need in each affected area. Using the weights derived from AHP, the TOPSIS method was applied to rank six disaster-affected locations. The results indicate that:

Table 1. Rank Six Disaster

Rank	Location	Preference Value
1	Location A	0.82
2	Location B	0.76
3	Location C	0.64
4	Location D	0.55
5	Location E	0.47
6	Location F	0.39

The highest-ranked location (Location A) has the greatest priority for logistics distribution, as it is closest to the positive ideal solution and farthest from the negative ideal solution.

3. Integration Model (AHP–TOPSIS)

The integration of these two methods results in a decision-making approach that is: a) Objective and Transparent, the model minimizes subjective bias and ensures that aid distribution processes are conducted in an objective and transparent manner. b) Structured and Adaptive: AHP provides a structured weighting mechanism, while TOPSIS generates accurate final rankings, making the decision-making process more systematic and adaptable to field conditions. c) Effective in Addressing Manual Constraints: The implementation of this model overcomes the limitations of manual decision-making, which often leads to delays or misallocation, thereby enabling consistent and accountable aid allocation decisions.

To evaluate the effectiveness of the proposed model, the TOPSIS ranking results were compared with the manual prioritization approach currently used by BPBD Minahasa.

The comparison shows that: 1) 4 out of 6 locations (66.7%) have consistent ranking positions between the system and manual method. 2) 2 locations (33.3%) show differences in ranking, particularly in mid-level priorities. Further analysis reveals that the differences occur because the manual method tends to emphasize a single dominant factor (e.g., number of victims), whereas the AHP–TOPSIS model considers multiple criteria simultaneously.

To quantify the improvement in decision quality they are 1) The Spearman rank correlation coefficient between manual and system results is 0.83, indicating a strong positive relationship. 2) The model reduces subjective inconsistency by applying a structured weighting mechanism (validated by CR = 0.06). 3) The use of standardized scoring ensures uniform evaluation across all alternatives. These findings suggest that the proposed model provides more consistent and systematically derived rankings, particularly in cases where manual judgment may vary across decision-makers.

To improve transparency and demonstrate the computational process underlying the proposed model, one complete example of the AHP–TOPSIS calculation is presented using three representative alternatives (Location A, Location B, and Location C) and the five decision criteria. The criteria weights derived from the AHP analysis were as follows: number of affected victims (C1 = 0.32), level of damage (C2 = 0.25), urgency of needs (C3 = 0.18), accessibility (C4 = 0.15), and availability of logistics (C5 = 0.10), with a consistency ratio (CR) of 0.06, indicating acceptable consistency.

Table 2. Initial Decision Matrix for Three Sample Alternatives

Alternative	C1	C2	C3	C4	C5
Location A	5	4	5	3	4
Location B	4	5	4	4	3
Location C	3	3	4	5	4

The values in the decision matrix were normalized using vector normalization, and the normalized values were multiplied by the AHP weights to obtain the weighted normalized matrix.

Table 3. Weighted Normalized Matrix

Alternative	C1	C2	C3	C4	C5
Location A	0.214	0.123	0.108	0.064	0.058
Location B	0.171	0.154	0.086	0.085	0.044
Location C	0.128	0.092	0.086	0.106	0.058

Based on this matrix, the positive ideal solution (A+) and negative ideal solution (A−) were determined. The Euclidean distances of each alternative from the positive ideal (D+) and negative ideal (D−) were then calculated.

Table 4. Separation Measures and Preference Values

Alternative	D+	D−	Preference Value (V)	Rank
Location A	0.041	0.188	0.821	1
Location B	0.072	0.160	0.690	2
Location C	0.103	0.124	0.546	3

The preference value was calculated using the TOPSIS closeness coefficient:

$$V_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

where a higher preference value indicates that an alternative is closer to the positive ideal solution and farther from the negative ideal solution. Based on these calculations, Location A achieved the highest priority ranking, consistent with the full model results presented in Table 1. This example demonstrates how the integration of AHP weighting and TOPSIS ranking generates transparent, traceable, and reproducible prioritization outcomes.

Implementation and Application of the Model

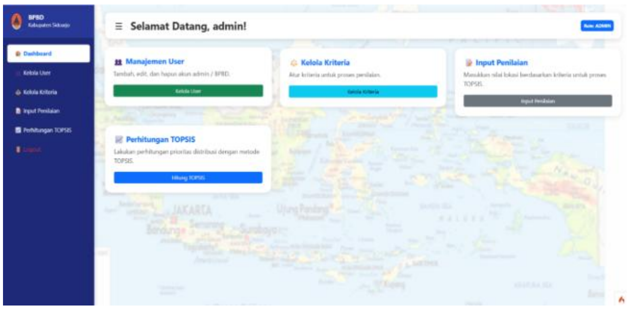

Figure 2. Admin Dashboard Page

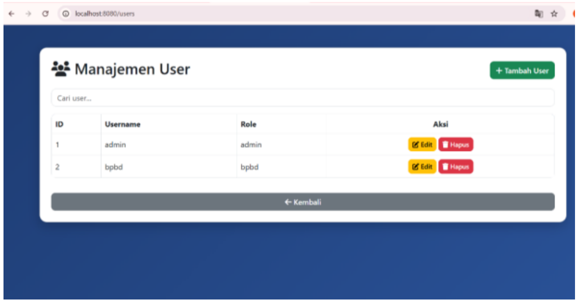

Figure 3. User Management Page

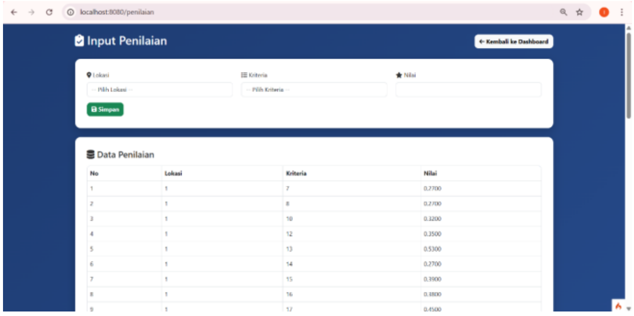

Figure 4. Assessment Input Page

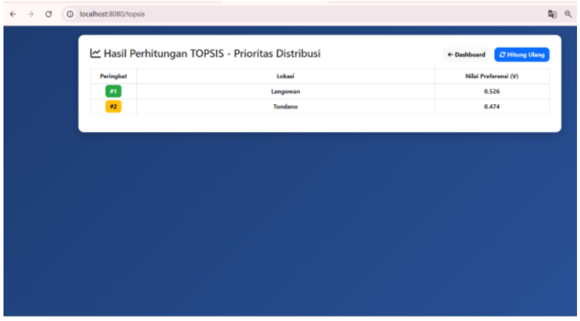

Figure 5. TOPSIS Calculation Page

Figures 2–5 illustrate the implementation of the BPBD Minahasa Regency logistics management information system through several integrated modules, including the login page, admin dashboard, user management, criteria and sub-criteria management, assessment input, and TOPSIS calculation results. The system is designed with a simple and functional interface that supports secure user authentication, structured navigation, efficient management of users and evaluation criteria, flexible input of assessment data based on disaster conditions, and systematic processing of decision-making data using AHP–TOPSIS methods. Each module contributes to supporting organized disaster logistics management, from data entry and criteria configuration to the generation of distribution priority recommendations based on TOPSIS calculations, thereby enhancing the effectiveness, transparency, and accuracy of logistics distribution decisions.

DISCUSSION

The findings indicate that the integration of AHP and TOPSIS provides a contextually appropriate decision-making model for disaster logistics distribution at BPBD Minahasa, particularly due to the complex operational characteristics of disaster response, which involve multiple criteria, limited resources, and high uncertainty. The suitability of this hybrid model lies in the complementary strengths of the two methods. AHP is effective in translating expert knowledge into structured criterion weights, which is highly relevant in BPBD Minahasa's context where logistics decisions often depend on practical judgments from field officers regarding affected victims, damage severity, accessibility, urgency of needs, and logistics availability. The consistency ratio result (CR = 0.06) confirms that expert judgments used in the weighting process are logically reliable. Meanwhile, TOPSIS is suitable for ranking affected locations because disaster logistics prioritization requires selecting alternatives that are closest to the ideal condition while minimizing exposure to worst-case conditions. This is particularly relevant for BPBD operations, where prioritization must balance urgency, feasibility, and resource constraints simultaneously.

The combination of AHP and TOPSIS is therefore advantageous compared with the use of a single method alone. AHP independently provides criterion weighting but does not optimally rank alternatives when multiple competing locations must be prioritized. Conversely, standalone TOPSIS requires externally determined weights and may produce unstable results if weighting is subjective or inconsistent. Their integration addresses these limitations by combining reliable weight determination with robust alternative ranking. This explains why the model demonstrates strong alignment with manual decisions (Spearman correlation = 0.83), while also reducing subjective inconsistency and improving transparency in decision-making.

Compared with alternative Multi-Criteria Decision-Making methods, the AHP–TOPSIS model also offers practical advantages for the institutional conditions of BPBD Minahasa. Methods such as ELECTRE and PROMETHEE provide strong outranking capabilities but often involve more complex parameter settings and are less intuitive for operational users with limited technical expertise. Fuzzy-AHP or Fuzzy-TOPSIS can better address uncertainty in linguistic judgments, but these methods require additional computational complexity and data handling that may exceed the current institutional and technological capacity of BPBD Minahasa. Similarly, methods such as VIKOR emphasize compromise solutions and conflict resolution among alternatives, which may be valuable in some disaster contexts, but are less straightforward for routine logistics prioritization compared to TOPSIS. In contrast, AHP–TOPSIS provides a balance between analytical rigor, computational simplicity, and practical implementability, making it suitable for local government disaster agencies operating under time-sensitive conditions.

Despite these advantages, several limitations must be acknowledged. First, the model depends heavily on expert-derived criteria weights, meaning changes in expert judgments may affect prioritization outcomes. Although sensitivity analysis supports model robustness, the results remain influenced by the assumptions embedded in the weighting process. Second, the model is based on a limited number of criteria and alternatives drawn from a specific case study, which may reduce generalizability to other regions with different hazard profiles or logistics infrastructures. Third, the current model assumes relatively static data during each decision cycle, whereas actual disaster environments are dynamic and may require real-time adaptation as field conditions change. Finally, the study evaluates effectiveness in terms of decision quality consistency, transparency, and structure rather than operational outcomes such as delivery speed, response time, or beneficiary satisfaction. As a result, claims regarding practical performance improvement should be interpreted cautiously. These limitations suggest opportunities for further development. Future research could compare AHP–TOPSIS directly with alternative MCDM models such as Fuzzy-TOPSIS, VIKOR, or PROMETHEE using the same disaster scenarios to assess comparative performance. In addition, integrating real-time data sources, geographic information systems (GIS), or adaptive hybrid approaches could improve responsiveness under dynamic disaster conditions. Such developments would strengthen the operational relevance of decision support systems for humanitarian logistics beyond the current model.

4. Conclusion

The development of an integrated model combining the AHP and TOPSIS has proven to be a strategic solution for improving the effectiveness, accuracy, and efficiency of disaster logistics distribution in Minahasa Regency. The model, implemented within a Decision Support System (DSS), enables BPBD Minahasa to determine aid distribution priorities in an objective, transparent, and measurable manner based on relevant criteria. By utilizing AHP to establish criteria weights and TOPSIS to generate priority rankings, logistics distribution decisions become more accountable, reduce delays, and ensure that assistance is delivered promptly and accurately to the communities most in need.

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