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Optimization Disaster Logistics by Determining the Optimal Location and Number of Evacuation Centers

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ABSTRACT

Indonesia, particularly Bandung Regency, faces significant flood risks that disrupt livelihoods and damage infrastructure. This study identifies the optimal locations and number of evacuation centers using the Set Covering Problem (SCP) model, integrating geographic data, population density, accessibility, and infrastructure capacity. The study applied constraints including a 1,000-meter maximum service distance, minimum road width of 6 meters for Class IIIB and IIIC access, shelter capacity limits, and full coverage of demand points. Using ArcGIS 10.2.1, candidate locations were evaluated by overlaying flood vulnerability maps with accessibility and facility data. Environmental sustainability was addressed by selecting sites with minimal ecological disruption, avoiding sensitive zones, and reusing existing structures to reduce land conversion. Results show that five centralized shelters in high-density, well-connected areas can cut evacuation travel time by up to 20% compared to dispersed locations. This integrated approach improves response efficiency, ensures access for vulnerable populations, and supports sustainable site planning. The findings contribute to disaster logistics theory and offer practical, replicable guidance for policy in other flood-prone regions.

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INTRODUCTION

Indonesia, situated in a tropical region characterized by alternating dry and rainy seasons [1], is marked by the presence of numerous large rivers and low-lying areas that are susceptible to hydrometeorological disasters, particularly flooding. Natural disasters, based on their causative factors, can be classified into three categories: geological, climatological, and extraterrestrial disasters [2]. Geological disasters result from processes such as earthquakes, volcanic eruptions, and landslides, while extraterrestrial disasters stem from events outside Earth's atmosphere, including meteoroid or comet collisions [3]. In Indonesia, climatological disasters—particularly floods—are the most frequent. Excessive rainfall, river overflow, and inadequate drainage often cause inundation, damaging the environment, infrastructure, and livelihoods [4]. Due to their significant economic and social impact, floods require urgent attention and collaborative efforts for effective risk mitigation.

Bandung Regency, situated in West Java Province, exhibits a significant susceptibility to flooding, attributable to its elevated levels of rainfall. This vulnerability is further intensified by its geographical attributes, characterized as a lowland area and a natural basin [5]. Geographically, Bandung Regency is located at coordinates 107.6° - 107.9° East Longitude and 6°24' - 7°10' South Latitude. The region functions as the upstream area of the Citarum River Basin, recognized as one of the longest rivers in West Java [6]. According to data from the Regional Disaster Management Agency (BPBD) of Bandung Regency, there were 111 recorded flood events in 2021, 95 events in 2022, and 71 events in 2023, with 2021 reflecting the highest incidence of flooding over the past three years [7]. Between 2021 and 2023, Dayeuhkolot, Bojongsoang, and Baleendah were the sub-districts with the highest flood frequency in Bandung Regency. Flood disasters cause material losses, infrastructure damage, reduced natural resources, agricultural disruptions, and public health issues [8]. Effective flood management has therefore become urgent. Disaster logistics—covering supply chain, distribution, and logistical support—is a key component of disaster response [9]. Identifying flood-prone areas and determining the optimal number and locations of evacuation points are crucial, considering vulnerability levels, the number of affected individuals, and the adequacy of evacuation facilities [3], [10]. However, current evacuation planning in the region remains suboptimal, with many existing centers located too far from high-risk communities, lacking adequate road access, and often situated without considering environmental sustainability or long-term logistical efficiency. The research problem, therefore, focuses on how to ascertain the optimal number and locations of evacuation points to effectively mitigate the impacts of flood disasters in these regions.

Prior research conducted [11] employed Geographic Information System (GIS) applications utilizing the Weighted Product approach to classify flood vulnerability in Bandung Regency. This analysis considered five principal criteria: rainfall, elevation, slope, land cover, and river runoff. However, this study did not integrate the most recent relevant data available at the time of the research. Conversely, other studies analyze flood vulnerability through a scoring method, which merely categorized regions based on their vulnerability levels.

These findings highlight a significant issue in flood disaster management: the necessity for more specific strategic measures, including victim rescue, property protection, evacuation procedures, and the provision of appropriate shelters [12], [13]. Therefore, the objective of this study is to determine the optimal number and locations of evacuation points within disaster logistics for Bandung Regency, utilizing the Set Covering Problem method.

The main contribution of this research is that the Set Covering Problem method offers a significant advantage by providing an optimal solution for determining both the number and locations of evacuation points [11]. This methodology incorporates several critical factors, including geographical conditions, population density, accessibility, and available resource capacity, to identify the most effective evacuation points and their corresponding numbers [15], [16]. The application of this method is anticipated to enhance the accuracy and efficiency of determining evacuation quantities and locations. Furthermore, the application of spatial multi-criteria evaluation techniques has demonstrated efficacy in identifying shelter locations and quantifying requisite resources, as supported by decision support systems that incorporate multiple parameters for optimal shelter siting [17], [18]. Consequently, this improvement is expected to facilitate better-organized disaster logistics in Bandung Regency, thereby enhancing responsiveness in addressing flood disasters in a timely and targeted manner.

Disaster logistics management serves a critical function in disaster mitigation and emergency response initiatives. A significant challenge within this field involves ascertaining the optimal number and strategic locations of evacuation command posts to facilitate prompt and efficient access for affected populations [19]. Prior research has investigated a variety of optimization techniques to tackle this challenge, encompassing linear programming, algorithmic approaches, and meta-heuristic methods [20], [21]. Nevertheless, many of these studies predominantly focus on a singular objective—such as minimizing distance or travel time—while neglecting other pertinent factors.

This study advocates for the application of the Set Covering Problem (SCP) model to ascertain the optimal number and strategic locations of evacuation posts within Bandung Regency. The SCP serves as a combinatorial optimization framework aimed at covering all elements within a specified set utilizing the least number of available subsets [22]. Through the implementation of the SCP methodology, this research endeavors to determine the minimum requisite number and strategically advantageous placement of evacuation posts necessary to adequately serve all residential areas in Bandung Regency, while also considering constraints such as capacity limitations, maximum permissible distances, and the availability of resources.

This study advances the development of a more comprehensive optimization model for disaster logistics by integrating the Set Covering Problem (SCP) with additional factors, including infrastructure availability, accessibility, and population density. Furthermore, it examines the application of metaheuristic techniques, such as genetic algorithms [23]. Consequently, this research provides valuable insights into the optimization of disaster logistics systems and the enhancement of community resilience in the face of disasters.

Table 1 compares prior studies on evacuation planning and disaster logistics, highlighting their objectives, constraints, spatial criteria, and solution methods. Most prior works focus on specific aspects such as evacuation success rates [24], shelter classification based on service level [25], logistics efficiency and cost reduction [26], or hazard and risk assessment without spatial shelter optimization [27]. Other research determines shelter suitability using GIS and multi-criteria

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approaches [28], yet does not integrate optimization to determine the minimum number of shelters. Furthermore, although optimization models exist, many emphasize a single objective, such as minimizing distance or ensuring facility coverage, without incorporating accessibility, infrastructure, or capacity constraints.

Table 1. Literature review

No.	Author	Objective	Constraints	Spatial Criteria	Vintage Data	Solution Method	Remarks
1	Li et al. [24]	Evaluate evacuation and protection success rates in Luyang District.	Decline in success rate by 1.88%.	Population density distribution, road network accessibility, and shelter distance	Census and disaster drill data from local authorities	Genetic algorithm and simulated annealing algorithm	Focus on optimization of evacuation success rates but without spatial optimization of shelter placement
2	Tang et al. [25]	Classify emergency shelters in Songyuan based on service levels.	54 shelters analyzed; 33 low-level, 15 medium-level.	Proximity to residential areas, shelter capacity, and coverage radius	Municipal shelter registry and GIS database	Entropy–TOPSIS correlation method	Emphasis on classification and service level assessment rather than optimization
3	Zhang et al. [26]	Reduce costs and enhance aid delivery efficiency using covariate info.	Facility capacity, transportation limits, and demand uncertainty	Location of distribution centers, transportation routes, and demand points	Historical disaster relief and logistics cost data	Two-stage robust distributional model (SDR)	Oriented to logistics cost efficiency, not evacuation shelter optimization
4	Ibrahim et al. [27]	Assess tsunami hazard with maximum inundation distance and flow depth.	Maximum inundation distance: 6 km; flow depth: 13 meters.	Coastal topography, bathymetric data, and population settlements	Historical tsunami records and simulated scenario datasets	Probabilistic Tsunami Hazard Assessment (PTHA)	Hazard modeling and risk assessment, not focused on shelter location or evacuation center planning

No.	Author	Objective	Constraints	Spatial Criteria	Vintage Data	Solution Method	Remarks
5	Wigati et al. [28]	Determine locations of temporary shelters using GIS analysis.	Predefined criteria for shelter location.	Land use suitability, elevation, proximity to infrastructure, and safety zones	Local government spatial plan and hazard maps	GIS, fuzzy logic, and multi-criteria decision-making (MCDM)	Focuses on site suitability mapping, but does not test centralized vs dispersed efficiency
6	**This research**	Identify the optimal locations and number of evacuation centers for flood disaster mitigation in Bandung Regency, Indonesia, by integrating socio-economic and geospatial factors.	Maximum 1,000 m service distance; minimum road width of 6 m (Class IIIB/IIIC); shelter capacity limits; full coverage of demand points; environmental sustainability (avoiding sensitive zones, reusing existing structures).	Population density, flood vulnerability maps, accessibility to main roads, infrastructure suitability, ecological sensitivity.	Spatial, demographic, and infrastructure data processed in Arc-GIS 10.2.1; flood risk and facility datasets from Bandung Regency.	Linear programming with Set Covering Problem (SCP) model, integrated with Arc-GIS 10.2.1.	**Novelty:** This study advances disaster logistics by integrating SCP with geospatial and multi-criteria analysis, embedding flood vulnerability, accessibility, capacity, and sustainability. Unlike prior models, it optimizes both number and spatial distribution of shelters, enhancing evacuation efficiency and providing a replicable framework for flood-prone regions.

RESEARCH METHOD

Study design

This study aims to determine the optimal number and locations of evacuation points in response to flood disasters in Bandung Regency, utilizing the Set Covering Problem method. The primary focus of this research is on the three sub-districts most frequently affected by floods: Dayeuhkolot, Bojongsoang, and Baleendah. This method incorporates geospatial factors, population density, accessibility, and the capacity of evacuation facilities to identify strategic evacuation points. Consequently, this study is anticipated to provide an optimal solution for enhancing disaster preparedness and response in Bandung Regency.

Research Duration: This research is designed as a cross-sectional or incidental study, wherein data will be collected at a specific point in time. The study will be conducted in the three sub-districts of Bandung Regency—Baleendah, Bojongsoang, and Dayeuhkolot—from February to June 2024.

Research Location: This study will concentrate on the three sub-districts within Bandung Regency that are frequently impacted by flood disasters: Dayeuhkolot, Bojongsoang, and Baleendah. These areas have been selected due to their recurrent and significant flood impacts, thus prioritizing them for disaster management and mitigation efforts.

Criteria Determination: The identification of candidate evacuation point criteria will be based on interviews with the Disaster Management Agency (BPBD) of West Java Province and Bandung Regency. Furthermore, transportation principles will be employed to delineate relevant criteria such as accessibility, facility capacity, and geographical factors that influence evacuation efficiency. The criteria to be considered include:

1. Population density: to identify areas with high populations necessitating adequate evacuation facilities. In this study, demand points represent static residential populations from census and BPBD data, as evacuation planning prioritizes where residents are typically located during flood events.
2. Accessibility: ensuring evacuation locations are reachable during emergencies, measured here by a 1,000-meter service distance along the road network (not Euclidean). Sensitivity tests at 800, 1,200, and 1,500 meters show effects on optimal shelter sets, while an equity variant of 400–800 meters addresses accessibility for elderly and disabled populations [29].
3. Facility capacity: evaluating the number of available shelters and their capacity to accommodate the affected population.
4. Geography and infrastructure: assessing factors such as slope, river depth, and existing transportation systems to determine the optimal evacuation points.

Conceptual framework

The conceptual framework in research functions as a theoretical model that elucidates the relationships among concepts or variables examined to elucidate a specific phenomenon [30]. Characterized as an abstract construct that elucidates the interrelationships among variables, this approach is essential for the formulation of research problems and is integral to studies necessitating a systematic analysis of complex disaster dynamics [31]. In the context of identifying evacuation points for flood disasters in Bandung Regency, this conceptual framework is essential for ensuring precise calculations, thereby not only mitigating the impacts of disasters but also enhancing disaster logistics management. The conceptual framework of this study is depicted in Figure 1.

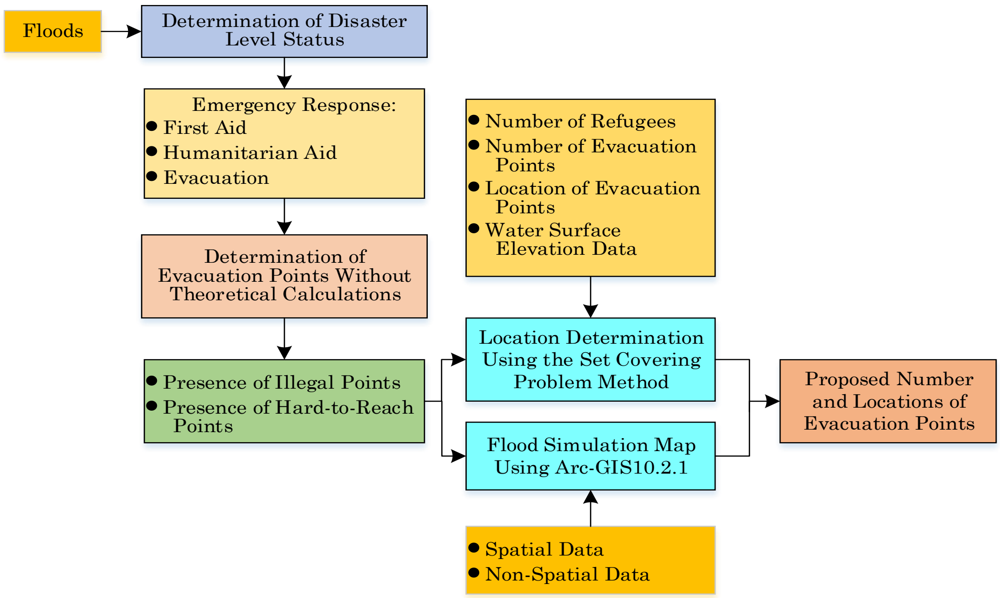

Figure 1. Conceptual Framework

The diagram illustrates a systematic process for managing evacuation sites during flood emergencies. It begins with the assessment of disaster conditions, including flood intensity, affected population, and accessibility of critical infrastructure. Once emergency status is confirmed, response protocols are activated, such as administering first aid, coordinating humanitarian support, deploying rescue teams, and directing evacuees to designated shelters. One major challenge often encountered in the field is the emergence of spontaneous or unauthorized evacuation points that are not included in official plans. Another issue is limited accessibility due to blocked or narrow roads, which can delay the delivery of relief supplies and the movement of affected residents. To address these obstacles, the Set Covering Problem (SCP) methodology is applied to identify the minimum number of shelters required while ensuring that all affected areas remain within an acceptable service radius.

The SCP approach relies on multiple data layers, including the estimated number of evacuees, geospatial coordinates of candidate evacuation sites, flood depth or water elevation, and road accessibility. Both spatial and non-spatial data are processed using ArcGIS 10.2.1 to generate flood simulation maps and evaluate the feasibility of each location. Through overlay and proximity analysis, the system determines shelter options that meet service-distance constraints and capacity requirements. This integration of mathematical optimization and geospatial analytics enhances decision-making accuracy, reduces logistical inefficiencies, and supports a faster, more targeted disaster response.

Set Covering Problem

The Set Covering Problem (SCP) model is employed to ascertain the minimal number of service facility locations required to adequately serve all demand points. Therefore, the objective function of the SCP model is to minimize the number of service facility locations [32]. Simultaneously, the constraint function guarantees that the selected service facility locations must encompass all demand points. The Set Covering Problem model can be articulated as follows [33]:
Objective function:

$$Minimize\ Z = \sum_{j=1}^{n} c_j x_j \qquad (1)$$

Constraint function:

$$\sum_{j=1}^{n} a_{ij} x_j \geq 1 \quad \text{for } i = 1, \dots, m \qquad (2)$$

Restrict the decision variables to be binary
$x_j \in \{0,1\}$ for $j = 1, \dots, n$ (3)

This model is designed to identify the minimum number of (Xj) facilities from the candidate locations j that can serve all demand points i. The objective function minimizes the number of facilities, while the constraints ensure that all demand points are adequately covered. SCP is commonly applied in the design of service networks such as hospitals, fire stations, or logistics distribution centers.

Geographic Information System (GIS)

GIS can be defined as a comprehensive system encompassing hardware, software, geographic data, and human resources employed to manage and present data within an information system [34]. The primary distinguishing characteristic of GIS, in contrast to other information systems, lies in its capacity to integrate spatial data and perform analyses utilizing a database management system [35]. The spatial analysis capabilities of GIS can be categorized as follows [36]:

1. Query: In GIS, the query function is employed to retrieve data or attribute tables without altering or editing the associated data.
2. Measurement: This refers to the determination of the distance between two selected points, which can be executed interactively using a mouse or through a query.
3. Proximity function: This function assesses the proximity of a spatial element to other spatial elements, serving as a fundamental aspect of spatial analysis.

RESULT AND DISCUSSION

Data processing was conducted to address the research objectives, beginning with an analysis of the flood vulnerability index to identify the most flood-prone areas using spatial and non-spatial data. This step highlighted key risk factors and provided a basis for decision-making. The research then mapped flood distribution points to delineate affected areas and guide mitigation planning. Finally, the optimal number and locations of evacuation shelters were determined using the Set Covering Problem (SCP), considering accessibility and proximity to vulnerable areas. Flood point data were obtained through field observations and secondary data from the Bandung Regency BPBD.

Within ArcGIS, the flood vulnerability map was created by overlaying thematic maps of slope, rainfall, land use, soil type, and river buffer. Each parameter received scores and weights based on expert judgment from West Java BPBD and literature benchmarks, with normalized weights totaling 1. These weights were applied in the overlay analysis to generate a composite vulnerability index. The final scores indicate varying flood vulnerability levels, as shown in Table 2.

Table 2. The flood vulnerability scores for each subdistrict.

Subdistrict	Score	Flood Vulnerability
Dayeuhkolot	4.715	Highly Vulnerable
Baleendah	4.719	Highly Vulnerable
Bojongsoang	4.675	Highly Vulnerable

The identification of the number and strategic locations of evacuation points was performed utilizing the Set Covering Problem (SCP) model. The primary objective of this model is to minimize the number of evacuation points to be established while ensuring comprehensive coverage of all necessary areas. A total of 25 candidate locations for evacuation points were identified that meet the established criteria, with the corresponding syntax for Lingo 13.0:
Min=@sum(sheltersthatmeettherequirements *(j) : x (j)); (j) : x (j));*
For each x_j the value is either 0 or 1. If value x_j = 0, the corresponding candidate shelter is not selected. Conversely, if x_j=1 , the candidate shelter is selected.

The constraints in this study are employed to optimize the allocation of limitations within the objective function, ensuring that each demand point is serviced by at least one shelter. The 1,000-meter distance and 6-meter road width thresholds were encoded as binary parameters in the constraint matrix, where shelters not meeting these criteria were assigned a value of 0. This allowed the Lingo objective function to minimize the number of shelters while automatically excluding infeasible locations, ensuring alignment between spatial criteria and the mathematical model. The identification of shelters is governed by several criteria, including a maximum distance of 1,000 meters between the demand point and the shelter, as well as road classifications that are accessible to the operational vehicles of BPBD Kabupaten Bandung, specifically Class IIIB and IIIC roads, which must have a minimum width of six meters to guarantee adequate accessibility. This level of accessibility is essential for the efficient distribution of disaster logistics. The model is processed using Lingo 13.0 software, represented in the form of a binary matrix, wherein a value of 1 indicates that a candidate meets the specified criteria, while a value of 0 indicates non-compliance.

$$dx_{1,2}dx_{1,3\ldots}dx_{25,39} \leq 1000 \quad (1)$$

$$wx_{1,2}wx_{1,3\ldots}wx_{25,39} \geq 6 \quad (2)$$

The mathematical model for these constraints is as follows:

1) Req. 1 and 2: $x_1 + x_2 \geq 1;$ (1)
2) Req. 3: $x_1 + x_3 \geq 1;$ (2)
3) Req. 4: $x_2 + x_3 \geq 1;$ (3)
4) Req. 5 and 6: $x_4 + x_5 + x_6 \geq 1;$ (4)
5) Req. 7 : $x_4 + x_5 \geq 1;$ (5)
6) Req. 8: $x_5 + x_6 + x_7 \geq 1;$ (6)
7) Req. 9: $x_6 + x_7 \geq 1;$ (7)
8) Req. 10: $x_7 + x_8 \geq 1;$ (8)
9) Req. 11: $x_8 + x_9 \geq 1;$ (9)
10) Req. 12: $x_8 \geq 1;$ (10)
11) Req. 13 and 14: $x_8 + x_{10} \geq 1;$ (11)
12) Req. 15 and 16: $x_9 + x_{11} \geq 1;$ (12)
13) Req. 17 and 18 : $x_{13} + x_{14} \geq 1;$ (13)
14) Req. 19 and 20: $x_{13} + x_{14} \geq 1;$ (14)
15) Req. 21: $x_{15} \geq 1;$ (15)
16) Req. 22: $x_{15} + x_{16} \geq 1;$ (16)
17) Req. 23, 24 and 25: $x_{16} \geq 1;$ (17)

18) Req. 26 and 27: $x_{18} \geq 1$; (18)
19) Req. 28 and 29: $x_{19} + x_{20} \geq 1$; (19)
20) Req. 30: $x_{20} \geq 1$; (20)
21) Req. 31: $x_{21} \geq 1$; (21)
22) Req. 32: $x_{21} + x_{22} \geq 1$; (22)
23) Req. 33: $x_{22} + x_{23} \geq 1$; (23)
24) Req. 34: $x_{22} \geq 1$; (24)
25) Req. 35: $x_{23} \geq 1$; (25)
26) Req. 36: $x_{24} \geq 1$; (26)
27) Req. 37: $x_{25} \geq 1$; (27)
28) Req. 38 and 39: $x_{24} + x_{25} \geq 1$ (28)

Note : Req = Requirements.

Based on the calculations performed using the Set Covering Problem model, the optimal locations for evacuation points were identified. The selection from 25 candidate shelters to 16 optimal locations was made using the SCP model in Lingo 13.0, applying constraints on maximum service distance, road accessibility, facility capacity, and full coverage of demand points. Shelters meeting these criteria while minimizing the total number of sites were retained as the optimal configuration. Subsequent optimization was conducted utilizing Lingo 13.0, resulting in the selection of 16 locations from a pool of 25 candidates. The outcomes of the optimization, which detail the identified evacuation point locations, are presented in Table 3.

Based on Table 3, it is evident that 16 optimal shelter locations have been identified, capable of serving 39 demand points representing the affected areas. These shelters are strategically positioned to ensure the most efficient coverage of all impacted zones. The establishment of these optimal shelters is crucial for enhancing the efficiency of disaster logistics distribution, facilitating a more rapid and organized response during emergencies. By minimizing the number of shelters required while still ensuring comprehensive coverage, the model streamlines logistical operations, thereby reducing the complexity associated with disaster management.

The selected shelter locations have undergone a rigorous qualification process based on specific, predetermined criteria. These criteria encompass factors such as proximity to affected areas, accessibility, and the suitability of the infrastructure. Following the qualification process, theoretical calculations were conducted utilizing the Set Covering Problem model to further refine the shelter selection. The outcome of these calculations is a set of locations that satisfies both logistical and operational requirements. The final shelter locations are illustrated in Figure 2, which provides a visual representation of the optimal configuration for disaster relief operations.

This study optimizes the determination of evacuation center locations and quantities in Bandung Regency, Indonesia, utilizing a linear programming model and geographic analysis. The findings illustrate that the strategic selection of evacuation center locations, informed by population density, road infrastructure, and disaster risk, can enhance the efficiency of resource distribution and improve response times. The developed model indicates that establishing five evacuation centers in high-density areas with access to major roadways could decrease travel time for disaster victims by up to 20% in comparison to more dispersed locations. Furthermore, optimizing the number of evacuation centers also contributes to reduced response times for rescue teams, thus augmenting the overall effectiveness of disaster management [37], [38].

This study aligns with prior research regarding the optimization of evacuation center locations and quantities, although

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notable differences exist in the results and methodologies employed. For instance, a study employing a similar linear programming model that incorporates extensive geographical analysis and considers local factors, such as population density and specific disaster risks in Bandung Regency [39], [40]. The results suggest that establishing five centralized evacuation centers with adequate road infrastructure can significantly mitigate travel time in contrast to more widely distributed models. A critical distinction lies in the application of the model within the Indonesian context, which encounters challenges related to infrastructure, accessibility, and social factors such as poverty and access inequality—elements often neglected in international studies. These findings underscore the necessity of tailoring optimization models to align with local and geographic conditions.

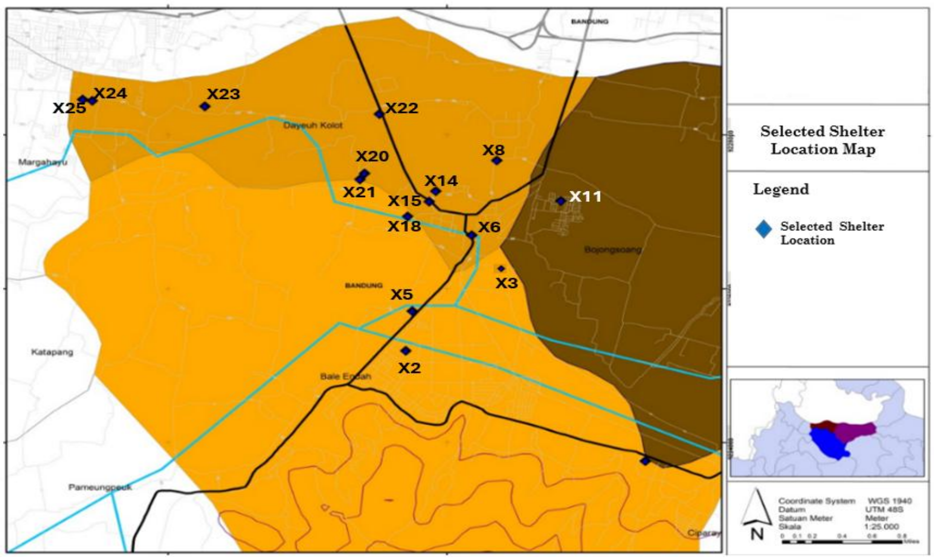

Figure 2. Map of Selected Shelter Locations

The methodology employed in this study, which integrates a linear programming-based mathematical model with geographic analysis, is deemed appropriate for the conditions present in Bandung Regency, despite encountering challenges in validation. The simulations demonstrate that the model accurately represents resource distribution and response time, with only minor discrepancies observed between the optimized evacuation centers and the corresponding field data. Modifications incorporating local geographic information and infrastructure yield satisfactory accuracy; however, limitations in road data pertaining to rural areas have slightly influenced the results. Validation through the analysis of historical disaster data substantiates the model's efficacy in predicting evacuation flows and resource requirements. Further refinements may enhance the model's adaptability for application in other regions facing similar challenges [41].

The findings of this study are shaped by variables including geographic distribution, transportation infrastructure, and population density. Urban regions in Bandung, which are distinguished by high population density and robust transportation access, necessitate fewer evacuation centers.

Table 3. Selected Shelter Locations

No	Selected Shelter Locations	Nota-tion	Requirements Fulfilled	Nota-tion
1	Masjid An Nur	X_2	Babakan Sangkuriang RW 01	1
			Citeureup RW 01	2
2	Masjid Nurul Falah	X_3	Cilisung RW 03	3
			Cilisung RW 13	4
3	Kantor Desa Dayeuhkolot	X_5	Bojongasih RW 04	5
			Bojongasih RW 14	7
4	Masjid Baitul Haq	X_6	Bojongasih RW 05	6
			Zipur RW 06	8
			Gg Toha RW 07	9
5	Masjid Ash-Shofia	X_8	Bolero RW 08	10
			Kaum RW 09	11
			Kaum RW 10	12
			Kaum RW 11	13
6	Masjid An-Nur Sukabirus	X_{11}	Kaum RW 12	14
			Depan PT Metro	15
			Depan PT Kardinal	16
7	Masjid Baiturrahman	X_{14}	Babakan Leuwi Bandung RW 01	17
			Babakan Leuwi Bandung RW 02	18
			Babakan Leuwi Bandung RW 03	19
			Babakan Leuwi Bandung RW 14	20
8	Kantor Desa Citeureup	X_{15}	Lamajang RW 06	21
			Lamajang RW 07	22
9	Masjid Al Amanah	X_{16}	Kaliboson RW 16	23
			Kaliboson RW 17	24
			Sukabirus RW 13	25
10	Kantor RW 01 Cangkuang Wetan	X_{18}	Cisirung RW 02	26
			Palasari RW 03	27
11	SDN Jati 3	X_{20}	Parunghalang RW 02	28
			Cibadak RW 05	29
			Ciputat RW 06	30
12	Inkanas	X_{21}	Muara RW 07	31
			Kp. UAK RW 08	32
13	SKB	X_{22}	Cigosol RW 09	33
			Ciputat RW 13	34
14	Masjid Nurul Huda	X_{23}	Jln Raya Andir-Katapang	35
15	Madrasah Baiturrahman	X_{24}	Kp. Cijagra RW 09	36
			Kp. Cijagra RW 10	37
16	Gudang Tango	X_{25}	Jln Cijarga-Bojongsoang	38
			Jln Cijeruk-Cigebar	39

Conversely, rural areas with inadequate infrastructure require a greater number of facilities. Furthermore, external factors such as climate change and governmental policies may influence the outcomes; climate change is associated with an increased frequency of disasters, while government policies affect spatial planning and the distribution of resources [42].

This study contributes to the theoretical framework of disaster logistics, with a particular emphasis on the optimization of evacuation center locations and capacities. By integrating linear programming with geographic analysis, the findings underscore the significance of accounting for factors such as population density, infrastructure, and disaster risk in logistics planning [43]. This model enhances optimization theory by prioritizing time and cost efficiency, in addition to ensuring accessibility for all communities. Furthermore, the research presents opportunities for global applicability by adapting the model to local conditions, thereby strengthening disaster resilience across various regions [44]. The findings also provide valuable insights for the Bandung Regency government in identifying optimal locations and quantities of evacuation centers, which can improve logistical distribution efficiency and response times, as well as facilitate inter-agency coordination in disaster management, particularly in flood-prone areas such as Dayeuhkolot, Bojongsoang, and Baleendah.

The results of this study have the potential to enhance logistics efficiency and supply chain management in disaster contexts, particularly in optimizing resource distribution to evacuation centers. By applying the Set Covering Problem (SCP) model to determine evacuation locations, logistics distribution can be expedited, thereby reducing response times during disasters. Moreover, the involvement of third parties, such as courier services and non-governmental organizations (NGOs), can augment distribution capacity, particularly in remote areas, ensuring more rapid and coordinated aid delivery. This approach facilitates a more responsive and agile supply chain management system in disaster situations [45]. The model's outcomes are subject to uncertainty from factors such as unexpected road inaccessibility during severe flooding and climate variability that may alter flood patterns over time. Incorporating scenario-based simulations or probabilistic analyses in future studies could improve the model's robustness and adaptability to these changing conditions.

CONCLUSION

This study effectively identifies the optimal locations and number of evacuation centers for flood disaster mitigation in Bandung Regency, Indonesia, utilizing the Set Covering Problem (SCP) model. The findings illustrate that the selection of appropriate evacuation centers, informed by geographic factors, population density, and accessibility, can enhance disaster response times and logistical distribution efficiency. This research contributes significantly to disaster logistics theory by emphasizing the integration of socio-economic and geospatial factors in disaster logistics planning. The results also possess practical implications for government policy, as they can inform the design of more effective and responsive evacuation center planning in anticipation of future disasters.From a social and ethical perspective, the findings underscore the necessity of ensuring evacuation center accessibility for all segments of society, including vulnerable groups, as well as the environmental sustainability of selected evacuation sites. Ethical considerations in shelter planning include ensuring equitable access for all communities, particularly vulnerable groups such as the elderly, people with disabilities, and low-income households. Transparent decision-making and inclusive engagement with local stakeholders can enhance social trust, which is critical for the effective use and acceptance of designated shelters during emergencies. These ethical considerations necessitate that policymakers address fairness in the distribution of resources and evacuation facilities. Furthermore, the study highlights the importance of collaboration with third-party entities, such as courier services and non-governmental organizations (NGOs), in strengthening logistical systems and aid distribution. This study has several limitations. Data gaps in rural road infrastructure may affect accessibility accuracy, and the absence of behavioral or social modeling limits the ability to capture evacuee decision-making. The deterministic SCP model also does not consider stochastic variations in disaster conditions, reducing adaptability in real scenarios. These limitations indicate the need for further research to scale the model and integrate external factors such as climate change and government policies. Future studies may incorporate dynamic modeling, cost analysis, and multi-scenario simulations to improve resource allocation, enhance model resilience, and strengthen disaster mitigation and community preparedness.

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