Determining the Location Scheme and Area of Logistics Centers to Optimize the Distribution of Disaster Cluster Areas in West Java

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Abstract— The West Java province, with an area of 35,377.76 km² and consisting of 27 districts/cities, frequently experiences earthquakes, floods, and volcanic eruptions. This study identifies five efficient logistics center points to reach all areas within the Golden Hour (3 hours) during disasters. Using Voronoi diagrams and the K-Means algorithm, each logistics center point has specific requirements for logistics packages, including minimum volume and warehouse area. This underscores the importance of technology in enhancing precise and efficient emergency responses in West Java.

Keywords: Humanitarian Logistics, West Java, Voronoi, K-Means, Logistics warehouse.

I. Introduction

Figure 1. West Java Province Region

West Java Province with the capital city of Bandung has an area of 35,377.76 km². Administratively West Java consists of 27 regencies/cities, which include 18 regencies, 9 cities, 627 sub-districts, and 5,957 villages. The natural conditions in West Java Province are very diverse and have a complex geological structure. Mountainous areas dominate the central and southern parts, while lowlands are distributed in the northern regions. This topographic diversity makes West Java vulnerable to various types of natural disasters.

West Java is often in the international spotlight because it is vulnerable to frequent natural disasters such as earthquakes, floods, and volcanic eruptions. Complex geographic and demographic conditions, including dense populations and fragile infrastructure, add to disaster management and mitigation challenges. Therefore, an efficient and responsive logistics system is important to ensure well-timed and targeted assistance to disaster victims.

National Disaster Management Agency (BNPB) Regulation Number 04 of 2018 is the main legal basis for regulating logistics and equipment management systems in disaster management in Indonesia. This regulation covers planning, procurement, warehousing, distribution, and disposal of logistical goods and equipment required for disaster emergency response. Proper implementation, of these regulations is crucial to increasing response capacity and reducing the negative impacts of disasters.

Figure 2. Map of Disaster Events from 2023-2024 (BARATA, 2024)

West Java is one of the provinces that frequently experiences natural disasters that require a fast and coordinated emergency response. Examples are the flash floods in Cianjur in 2021, the earthquake in Sukabumi in 2022, and the eruption of Mount Tangkuban Perahu in 2023. In each of these events, an efficient logistics system is needed to assist such as food, clean water, medical equipment, and shelter for affected victims.

From a series of disaster events recorded in West Java, the importance of having an efficient logistics warehouse cannot be underestimated. A well-organized warehouse can store logistics supplies safely and is available sufficiently for emergencies. This helps ensure fast, and timely aid distribution to disaster victims and supports coordination

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between agencies and volunteers in disaster management efforts.

The principles of first-in-first-out (FIFO) and first-expired-first-out (FEFO) are two approaches commonly applied in emergency logistics warehouse management. FIFO ensures that goods that arrive first (those in the warehouse longer) are distributed first, FEFO prioritizes goods with the closest expiry date to ensure the safety and quality of aid provided to disaster victims.

To support this, research will be designed to determine a logistics center point that is efficient and able to reach all areas in West Java in less than the Golden Hour for disaster management (3 hours). Determine package requirements, contents, and minimum warehouse area to support package storage.

II. LITERATURE REVIEW

A. *Logistics Management in Disaster Management*

Logistics management in the context of disaster management is an important aspect in ensuring an effective and rapid response to the urgent needs of disaster victims. In the acute phase of a disaster, aid distribution such as food, water, medical equipment, and other items must be carried out efficiently to minimize negative impacts on victims (Ahmed & Ahmed, 2020). Research shows that careful planning, good coordination between various related parties, and sophisticated information technology use greatly support the success of logistics operations in complex disaster situations (Kovacs et al., 2013).

B. *BNPB Regulations in the Context of Disaster Logistics in Indonesia*

BNPB has regulations governing disaster logistics management to ensure coordinated and efficient handling. BNPB Regulation No. 04 of 2018 is the legal basis for managing disaster logistics, covering the planning, procurement, and distribution of logistical items needed during emergencies (BNPB, 2018). The regulation implementation is important to ensure that all logistics processes run well and on time in an emergency.

C. *Technology and Innovation in Disaster Logistics Management*

Information technology and innovation use in disaster logistics management have a substantial impact increasing responsibility and efficiency. Geographic information systems (GIS) are used for real-time mapping and monitoring of field situations, enabling logistics coordinators to make more precise and faster decisions in resource allocation (Khaswani et al., 2020). Additionally, drone use and sensor technology help affected areas in a rapid survey, facilitating aid delivery more safely and efficiently.

D. *Voronoi diagram*

Voronoi diagrams are mathematical tools that divide an area into several cells or regions based on geographic proximity to certain points, called seed points or centroids (Okabe et al., 2000). Voronoi diagrams each cell, it consists of all points that are closer to a particular seed point compared to other seed points. This makes it very useful in determining the optimal service area of a logistics center for the surrounding area. The Voronoi diagram in this research maps the service area of each centroid (seed point) resulting from the K-Means algorithm.

E. *K-Means algorithm*

The K-Means algorithm is a popular data clustering method for grouping data into K groups based on measurable attributes. This algorithm works by grouping data into K groups where each data is combined into the group with the closest average value (centroid) to the data (MacQueen, 1967). The research will use the K-Means algorithm to group centroids or seed points that represent potential locations of logistics centers based on the shortest distance patterns from these points to the nearest centroid.

F. *Evaluation and Learning from Previous Disaster Experiences*

Systematic evaluation of responses to previous disasters is integral to capacity building in disaster logistics management. Analysis of successes and challenges faced in earlier disaster management provides valuable lessons for improving future responsibility plans (Kovacs et al., 2013).

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III. RESEARCH METHODOLOGY

This stage will discuss the framework of thinking and process stages and the results to be obtained from this research. The research stages that will be carried out can be seen in the flow diagram in Figure 3 below.

A. Research Flow Chart

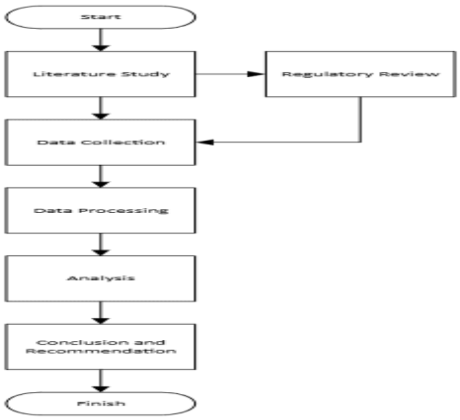

Figure 3. Research Flow Diagram

B. Research Flow

The research began with a literature study, then an assessment of regulations and laws regarding warehouses and disaster logistics packages. The next stage is data collection starting from the coordinates of cities/districts in West Java, the population of West Java, and disaster logistics package regulations. Then proceed with the data processing stage, namely dividing West Java into 5 clusters and determining the centroid of each cluster using integration between the Voronoi diagram and the K-Means algorithm and determining location access times.

After that, the number of packages needed in each city/district is calculated, the package contents are assumed, and the required size of the package box. Package requirements will be calculated using the formula below (PERKA No. 23, 2014).

Food Package Calculation Formula:

$$JP \times PR \times H = Minimum\ Total\ Package\ (Buffer\ Stock) \quad (1)$$

Clothing Package Calculation Formula:

$$JP \times PR \times H/4 = Minimum\ Total\ Package\ (Buffer\ Stock) \quad (2)$$

Board Package Calculation Formula:

$$JP \times PR \times H/4 = Minimum\ Total\ Package\ (Buffer\ Stock) \quad (3)$$

Information:

JP : Total population

PR : Percentage (1% Population)

H : Day

Then the total package volume is calculated for each centroid using the following formula:

$$Package\ Volume = Total\ Package \times Package\ Box\ Volume \quad (4)$$

After that, the required warehouse area is calculated using the following formula:

$$Warehouse\ Area = \frac{Total\ Package\ Volume}{height \times coef.\ utility \times coef.\ efficiency} \quad (5)$$

Information:

height : Warehouse height in meters.

coef. utility : A coefficient that describes how well the warehouse is used for storage (e.g., 0.8 for 80% efficiency).

coef. efficiency : Coefficient that shows how efficiently storage space is used in the warehouse (for example, 0.9 for 90% efficiency).

The final stage of this research involves drawing conclusions that provide a comprehensive and detailed overview of the findings, effectively summarizing the key insights and implications derived from the study.

IV. DISCUSSION

A. Data collection

1) City/Regency Center Coordinates in West Java:

Table 1. Central Coordinates and City/Regency Location Codes (GEOHACK, 2024)

No	*Code*	*Area*		*Coordinate*
1	L1	Regency	Garut	-7.204694, 107.88759
2	L2	Regency	Tasikmalaya	-7.3658, 108.1019
3	L3	Regency	Bandung	-7.021935, 107.528075
4	L4	Regency	Bogor	-6.32, 106.17
5	L5	Regency	Sukabumi	-6.987276, 106.551093
6	L6	Regency	Cianjur	-6.821222, 107.140101
7	L7	Regency	Majalengka	-6.835273, 108.227655
8	L8	Regency	Ciamis	-7.326664, 108.353107
9	L9	Regency	Karawang	-6.305085, 107.300258
10	L10	Regency	Cirebon	-6.757837, 108.480462
11	L11	Regency	Subang	-6.56985, 107.762831
12	L12	Regency	Kuningan	-6.976605, 108.484902
13	L13	Regency	Bekasi	-6.365909, 107.173086
14	L14	Regency	Purwakarta	-6.538564, 107.443557
15	L15	Regency	Sumedang	-6.85, 107.92
16	L16	Regency	Indramayu	-6.3269, 108.3222
17	L17	Regency	Bandung Barat	-6.841117, 107.512583
18	L18	City	Bogor	-6.597803, 106.799263
19	L19	City	Sukabumi	-6.932, 106.918564
20	L20	City	Bandung	-6.902186, 107.618756
21	L21	City	Banjar	-7.37, 108.53
22	L22	City	Tasikmalaya	-7.325802, 108.220181
23	L23	City	Depok	-6.405031, 106.817308
24	L24	City	Cimahi	-6.880038, 107.53852
25	L25	City	Bekasi	-6.2333, 107
26	L26	City	Cirebon	-6.73969, 108.552968
27	L27	Regency	Pangandaran	-7.701655, 108.49422

2) The population of each City/Regency in West Java:

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Table 2. The population of each City/Regency in West Java (BPS, 2024)

Code	*Population*	*Aid Packages for 3 Day*			
		Food	*Clothes*	*Other Logistics*	*Death*
L1	2636637	79.099	19.775	19.775	198
L2	1755710	52.671	13.168	13.168	132
L3	3831505	114.945	28.736	28.736	287
L4	6088233	182.647	45.662	45.662	457
L5	2470219	74.107	18.527	18.527	185
L6	2264328	67.930	16.982	16.982	170
L7	1210709	36.321	9.080	9.080	91
L8	1201685	36.051	9.013	9.013	90
L9	2370488	71.115	17.779	17.779	178
L10	2209633	66.289	16.572	16.572	166
L11	1612576	48.377	12.094	12.094	121
L12	1087105	32.613	8.153	8.153	82
L13	3899017	116.971	29.243	29.243	292
L14	971889	29.157	7.289	7.289	73
L15	1154428	34.633	8.658	8.658	87
L16	1737624	52.129	13.032	13.032	130
L17	1714982	51.449	12.862	12.862	129
L18	1126927	33.808	8.452	8.452	85
L19	330691	9.921	2.480	2.480	25
L20	2510103	75.303	18.826	18.826	188
L21	330691	9.921	2.480	2.480	25
L22	663986	19.920	4.980	4.980	50
L23	2484186	74.526	18.631	18.631	186
L24	620393	18.612	4.653	4.653	47
L25	3075690	92.271	23.068	23.068	231
L26	322322	9.670	2.417	2.417	24
L27	401493	12.045	3.011	3.011	30

3) Disaster Logistics Package Regulations:

Table 3. Categories of Disaster Logistics Packages (PERKA No. 18, 2009)

No	*Category Of Logistics Package*	*Description*
1	Food	yang termasuk dalam kategori ini adalah makanan pokok (beras/sagu/jagung/ubi, dll), lauk-pauk, air bersih, bahan makanan pokok tambahan seperti mi, susu, kopi, teh, perlengkapan makan (food ware) dan sebagainya.
2	Clothes	yang termasuk dalam kategori ini adalah perlengkapan pribadi berupa baju, kaos dan celana anak-anak sampai dewasa laki-laki dan perempuan, sarung, kain batik panjang, handuk, selimut, daster, perangkat lengkap pakaian dalam, seragam sekolah laki-laki dan perempuan (SD dan SMP), sepatu/alas kaki sekolah dan turunannya.
3	Other Logistics	termasuk dalam kategori ini adalah, obat dan alat kesehatan habis pakai, tenda gulung, tikar, matras, alat dapur keluarga, kantong tidur (sleeping bag) dan sebagainya.
4	Death	termasuk dalam kategori ini adalah, kantong mayat, kain kafan dan sebagainya.

B. Data processing

1) Determination of 5 Centroids for 5 Clusters:

Coordinate data processing was carried out using Voronoi diagrams and the K-Means algorithm using Python programming. Figure 4 shows the results of 5 centroids which will be used as the logistics center point for each cluster.

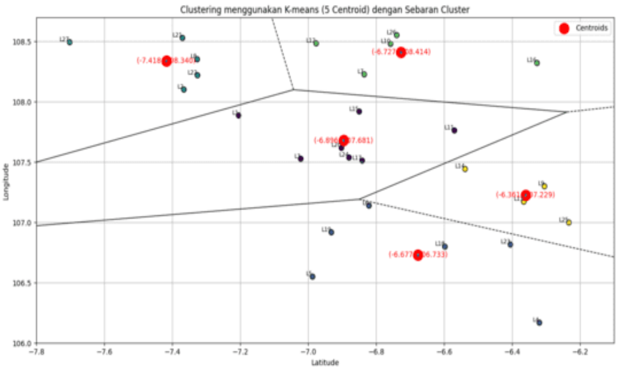

Figure 4. Centroid coordinates for 5 clusters

From the programming results, the coordinates of centroid 1 (-6.89569, 107.68119), centroid 2 (-6.67722, 106.73272), centroid 3 (-7.41798, 108.33988), centroid 4 (-6.72726, 108.41364), and centroid 5 (-6.36071, 107.22923). The location of the logistics center points for scenarios 1, 2, 3, 4, and 5 will be in Mandalajati sub-district (Bandung City), Tamansari sub-district (Bogor Regency), Cineam sub-district (Tasikmalaya Regency), Gempol sub-district (Cirebon Regency) and Telukjambe Barat sub-district (Karawang Regency).

Centroid 1 will serve Garut Regency, Bandung Regency, Bandung City, Subang Regency, Sumedang Regency, West Bandung Regency, Cimahi City. Centroid 2 will serve Bogor Regency, Sukabumi Regency, Cianjur Regency, Bogor City, Sukabumi City, Depok City. Centroid 3 will serve Tasikmalaya Regency, Tasikmalaya City, Ciamis Regency, Pangandaran Regency, Banjar Regency. Centroid 4 will serve Majalengka Regency, Cirebon Regency, Kuningan Regency, Indramayu Regency, Cirebon City. And Centroid 5 will serve Karawang Regency, Bekasi Regency, Purwakarta Regency and Bekasi City. With an average access time of 0,67 hours from each centroid to its respective service location. This access time was calculated using Python programming shown in Figure 5. The longest access time from the centroid to the service location was 1,14 hours. This access time meets the requirements of the Golden Hour for disaster management.

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Figure 5. Access time for each centroid to its service location

2) *Calculation of Logistics Packages Per Centroid:*

Processing data will calculate the package volume based on formula (1,2,3). Table 4 shows the results obtained from these calculations.

Table 4. Total Logistics Packages Per Centroid.

Centroid	Food	Clothing	Other Logistics	Death
1	360,144	90,036	90,036	902
2	443,939	110,734	110,734	1,108
3	130,608	32,652	32,652	327
4	197,022	49,254	49,254	493
5	309,514	77,379	77,379	774

3) *Calculation of Logistics Package Volume Per Centroid:*

Processing data will calculate the package volume based on formula (4). Table 5 shows the results obtained from these calculations.

Table 5. Total Volume Per Centroid

Centroid	Total Volume (cm³)
1	41,121,360,000
2	50,610,588,000
3	14,913,816,000
4	22,496,496,000
5	35,337,480,000

4) *Warehouse Area Per Centroid:*

This data process will use Python programming to simplify data calculations based on formula (5) to calculate the minimum warehouse area per Centroid.

Figure 6. Warehouse Area Data Processing with Python Programming

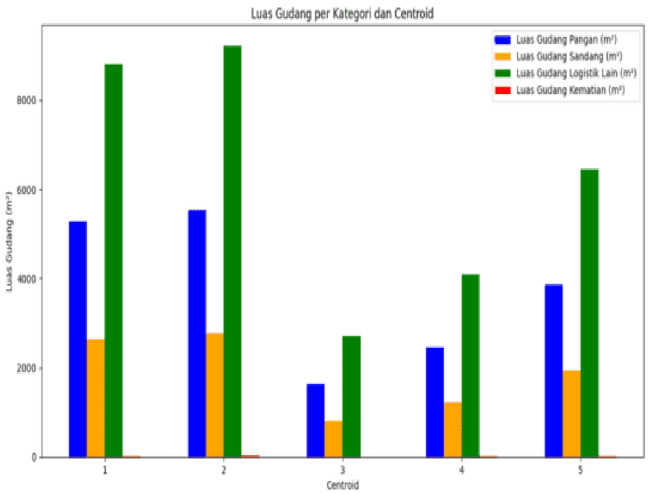

Figure 7. Calculation results of warehouse area per category and centroid

Based on the calculation results of the coding program, the minimum warehouse area for each centroid has been obtained. The minimum warehouse area needed for every Centroid is:

a. Centroid 1 minimum area is 16747 m^2
b. Centroid 2 minimum area is 17560 m^2
c. Centroid 3 minimum area is 5178 m^2
d. Centroid 4 minimum area is 7810 m^2
e. Centroid 5 minimum area is 12271 m^2

V. Conclusion

The determining process of five centroids for logistics clusters in the West Java region using Voronoi diagrams

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and the K-Means algorithm has been successfully carried out using Python programming. The centroid coordinates obtained are as follows: Centroid 1 is in Mandalajati District, Bandung City; Centroid 2 is in Tamansari District, Bogor Regency; Centroid 3 is in Cineam District, Tasikmalaya Regency; Centroid 4 is in Gempol District, Cirebon Regency; and Centroid 5 is in West Telukjambe District, Karawang Regency. This location determination is based on coordinate data analysis, ensuring that each centroid is located at a deliberate point to serve the surrounding area efficiently.

Each centroid is designed to serve several administrative regions. Centroid 1 will serve Garut Regency, Bandung Regency, Bandung City, Subang Regency, Sumedang Regency, West Bandung Regency, and Cimahi City. Centroid 2 will serve Bogor Regency, Sukabumi Regency, Cianjur Regency, Bogor City, Sukabumi City, and Depok City. Centroid 3 will serve Tasikmalaya Regency, Tasikmalaya City, Ciamis Regency, Pangandaran Regency, and Banjar City. Centroid 4 will serve Majalengka Regency, Cirebon Regency, Kuningan Regency, Indramayu Regency, and Cirebon City. Centroid 5 will serve Karawang Regency, Bekasi Regency, Purwakarta Regency, and Bekasi City. This regional division allows for a more even distribution of logistics and a faster response to aid needs. All centroids have an average access time of 0,67 hours to their service areas, with the longest being 1,14 hours. This access time meets the requirements of the Golden Hour for disaster management.

The calculation results show the total logistics packages needed for each centroid, with the following details: Centroid 1 requires 360.144 food packages, 90.036 clothing packages, 90.036 other logistics packages, and 902 death packages. Centroid 2 requires 443.939 food packages, 110.734 clothing packages, 110.734 other logistics packages, and 1.108 death packages. Centroid 3 requires 130.608 food packages, 32.652 clothing packages, 32.652 other logistics packages, and 327 death packages. Centroid 4 requires 197.022 food packages, 49.254 clothing packages, 49.254 other logistics packages, and 493 death packages. Centroid 5 requires 309.514 food packages, 77.379 clothing packages, 77.379 other logistics packages, and 774 death packages. This calculation ensures that each logistics center can meet aid needs efficiently.

Furthermore, the calculation of the total volume of logistics packages shows that Centroid 1 requires storage space for a volume of 41.121.360.000 cm³, Centroid 2 of 50.610.588.000 cm³, Centroid 3 of 14.913.816.000 cm³, Centroid 4 of 22.496.496.000 cm³, and Centroid 5 of 35.337.480.000 cm³. This calculation is important to determine the warehouse capacity required to store all logistics packages safely and efficiently.

The minimum warehouse area required for each centroid was also calculated. The result is that Centroid 1 requires a warehouse area of 16.747 m², Centroid 2 requires 17.560 m², Centroid 3 requires 5.178 m², Centroid 4 requires 7.810 m², and Centroid 5 requires 12.271 m². This warehouse space ensures adequate storage and readiness for use in emergencies.

Overall, this research underscores the technology's critical role in emergency logistics effective management. We can use Python and GIS to accommodate clustering for every area to maximize the determination of the logistics center so the package distribution can be faster in emergency cases. Logistics planning can be significantly enhanced by identifying strategic locations, logistics package requirements with precise calculating, and determining precise warehouse area needs. This approach facilitates a faster and more efficient response to community needs during disasters and ensures that aid can be distributed well-timed and targeted successfully.

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