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Design and Construction of Maternal and Infant Mortality Rate Mapping Using the K-Means Clustering Method Based on Geographic Information Systems (Case Study in Jember Regency)

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ABSTRACT

Indonesia's population continues to grow each year, including in Jember Regency, which reached 2,584,771 people in 2023. Population density contributes to various health issues, such as the high maternal mortality rate (MMR) and infant mortality rate (IMR), with 17 maternal deaths and 81 infant deaths recorded in 2023. The primary causes of MMR include pregnancy at too young or old an age, short birth spacing, and delays in referral, while IMR is mainly caused by asphyxia and low birth weight (LBW) due to premature birth. The government has implemented a midwife and traditional birth attendant partnership program to address this issue. However, information regarding high-risk areas remains inadequately conveyed. Therefore, this study develops a Geographic Information System (GIS)-based system using the K-Means Clustering method with a predefined number of clusters to classify high-risk maternal and infant mortality areas. The results show that the K-Means Clustering method with a fixed number of clusters (k = 5) successfully groups Jember Regency into five risk-level clusters, namely very high, high, medium, low, and very low. Visualization through GIS facilitates effective access to spatial information and supports the identification of priority areas for targeted health interventions, aiming to reduce maternal and infant mortality rates more effectively.

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1. INTRODUCTION

The Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR) are important indicators in assessing the degree of public health, particularly in terms of maternal and child health. The MMR is defined as the number of maternal deaths due to complications of pregnancy, childbirth, and the postpartum period per 100,000 live births, while the IMR is the number of infant deaths aged 0–12 months per 1,000 live births[1]. According to a report by the World Health Organization (WHO), in 2017 there were an average of 817 maternal deaths per day and around 2.5 million infant deaths worldwide. In Indonesia, population survey results show that the average MMR is still quite high, while the IMR also shows a value that needs serious attention, especially at the regional level[2].

Jember Regency is one of the most populous regions in the world, with a population of 2,584,771 in 2023. This situation contributes to the increasing complexity of health issues, including high maternal and infant mortality rates[3]. In 2023, there were 17 maternal deaths and 81 infant deaths in Jember Regency. The high maternal mortality rate is caused by several main factors, including too young or too late gestational age, too close birth spacing, and delays in medical referrals[4]. Meanwhile, the high maternal mortality rate is generally caused by asphyxia and low birth weight (LBW), which are often related to the mother's health conditions during pregnancy.

In an effort to reduce maternal and infant mortality rates, the government has developed various health programs, one of which is the midwife-traditional birth attendant partnership program[4]. This program aims to improve maternal and infant safety by positioning midwives as the primary providers [L2.1] of childbirth assistance, while traditional birth attendants act as partners in postpartum care. However, the success of this program depends heavily on the availability of accurate and easily understood information regarding areas with high maternal and infant mortality risk levels. Based on interviews with the Jember District Health Office, there is currently no system capable of comprehensively managing, analyzing, and visualizing maternal and infant mortality data. Information delivery is still limited, such as through direct communication between community health center midwives and pregnant women, resulting in relatively limited reach and ineffectiveness.

Several previous studies have discussed regional clustering based on maternal and infant mortality indicators. One related study used the K-Medoids method to cluster community health centers based on maternal and infant mortality indicators in Jember Regency[6]. While capable of producing clustering results, this method suffers from the higher complexity of distance calculations and the lack of integration of clustering results into Geographic Information System (GIS) visualizations. GIS plays a crucial role in presenting spatial information visually and interactively, making it easier for users to understand the distribution patterns of health phenomena[7].

Based on the identified problems and limitations of previous studies, this research proposes the application of the K-Means Clustering method integrated with a Geographic Information System (GIS) to map maternal and infant mortality rates in Jember Regency[8]. The K-Means method was selected due to its simpler computational process and efficiency in handling large datasets. In this study, the number of clusters was explicitly defined as k = 3 and k = 5 according to the analytical objectives and risk-level interpretation. The final analysis focuses on five clusters (k = 5), as this configuration provides a more detailed representation of maternal and infant mortality risk levels, namely very high, high, medium, low, and very low. The clustering results are then visualized through an interactive map with a specific color scheme, facilitating the identification of priority areas. This study is expected to provide added value in the form of an informative and structured information medium, as well as a decision-support tool for government authorities and related stakeholders in designing more targeted maternal and child health intervention strategies.

2. METHOD

The research method used in this study follows the Knowledge Discovery in Databases (KDD) stages, which consist of data collection, application of a clustering algorithm, evaluation of the clustering results, and visualization of the results using a Geographic Information System (GIS) [9]. This stage was chosen because it allows for systematic management of health data to produce meaningful and easily understood information.

2.1. Data Acquisition

The data used in this study is secondary data obtained from the Jember Regency Health Office. The data comprise the Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR) across all community health centers (Puskesmas) in Jember Regency. Each data point represents a single community health center area with two primary attributes: the number of maternal deaths and the number of infant deaths within a specific time period[10].

In addition to the numerical MMR and IMR data, this study also utilized spatial data in the form of geographic coordinates of the community health center areas, which were used in the mapping process in the Geographic Information System[11]. This spatial data serves as the basis for visualizing the clustering results in the form of a map of Jember Regency.

2.2. K-Means Clustering

The K-Means Clustering algorithm was used to group community health center areas in Jember Regency based on maternal and child mortality rates (MMR) and infant mortality rates (IMR)[12]. The clustering process was carried out in several stages, as follows:

1. Determine the number of clusters (K) to be used.

In this study, several K values were tested, namely K = 3, K = 4, and K = 5, to find the optimal number of clusters.
2. Determine the initial centroid randomly.
The initial centroid is the initial center point of each cluster, which will be updated iteratively.
3. Calculate the distance between each data point and each centroid using Euclidean distance.
The data will be placed in the cluster with the closest distance to the centroid.
4. Group the data into the closest clusters.
Each community health center area will be a member of one cluster based on the distance calculation.
5. Update the centroid value based on the average maternal mortality rate (MMR) and infant mortality rate (IMR) of all cluster members.
6. Repeat the distance calculation and centroid updating process until there are no changes in cluster members or until a certain iteration limit is reached.

This process produces groups of areas with relatively homogeneous maternal and infant mortality rates within a cluster and heterogeneous across clusters[13].

2.3. Evaluation of Clustering

To determine the quality of clustering results and select the best number of clusters[14]. this study used three evaluation methods:
1. Sum of Squared Error (SSE/Inertia)
SSE is used to measure the level of cluster compactness by calculating the total squared distance between each data point and its cluster centroid. The smaller the SSE value, the better the quality of the resulting cluster.
2. Silhouette Coefficient
Silhouette Coefficient is used to measure the level of fit of data to its cluster compared to other clusters. Silhouette values range from -1 to 1, with values closer to 1 indicating better clustering results.
3. Davies-Bouldin Index (DBI)
DBI is used to measure the ratio between intra-cluster distance and inter-cluster distance. A smaller DBI value indicates a more optimal cluster structure.

The results of these three evaluation methods are used as the basis for determining the most representative number of clusters for regional grouping.

2.4. Visualization Using Geographic Information System

The final stage of the research was the visualization of the clustering results
using a Geographic Information System (GIS)[15]. Each community health center area was mapped based on the cluster results obtained from the K-Means algorithm. Each cluster was represented by a different color to indicate the risk level of maternal and infant mortality: very high, high, moderate, low, and very low.

This map visualization aims to facilitate stakeholders in understanding the distribution patterns of maternal and infant mortality rates in Jember Regency and assist in determining priority areas for health care.

3. RESULTS AND DISCUSSION

3.1. Hasil Data Acquisition

Researchers conducted a search and collected data to support the research. The data was obtained from various sources, including the Central Statistics Agency (BPS), the Jember Regency BPS, and the Jember Regency Health Office. The following is data on maternal and infant mortality rates for each community health center in Jember Regency.

Tabel 1. Data AKB

No	Kecamatan	Tahun					Total
		2020	2021	2022	2023	2024	
1	Kencong	1	0	0	1	1	3
2	Cakru	1	3	0	2	0	6
3	Gumukmas	1	2	1	4	1	9
4	Tembokrejo	1	1	0	0	0	2
5	Puger	1	2	2	3	2	10
6	Kasiyan	0	1	1	3	1	6
7	Wuluhan	1	1	1	1	0	4
8	Lojejer	2	4	0	0	0	6
9	Ambulu	0	3	1	1	0	5
10	Sabrang	3	4	1	0	0	8
11	Andongsari	0	2	0	1	0	3
12	Tempurejo	1	5	2	1	0	9
13	Curahnongko	0	4	0	0	1	5
14	Silo 1	1	1	1	0	1	4
15	Silo 2	2	5	2	1	2	12
16	Mayang	0	1	3	0	2	6
17	Mumbulsari	2	4	2	1	2	11
18	Jenggawah	2	1	2	1	1	7
19	Kemuningsari Kidul	1	2	1	0	1	5
20	Ajung	6	4	0	1	4	15
21	Rambipuji	0	1	0	2	0	3
22	Nogosari	0	2	0	0	2	4
23	Balung	3	1	2	3	2	11
24	Karangduren	0	0	1	0	2	3
25	Umbulsari	0	2	2	0	0	4
26	Paleran	0	3	1	0	0	4
27	Semboro	0	1	1	0	0	2
28	Jombang	1	4	1	0	0	6
29	Sumberbaru	1	3	2	1	0	7
30	Rowotengah	2	5	0	1	0	8
31	Tanggul	1	2	2	2	1	8
32	Klatakan	0	2	0	0	0	2
33	Bangsalsari	2	1	1	1	1	6
34	Sukorejo	0	1	1	1	0	3
35	Panti	4	3	1	1	0	9
36	Sukorambi	2	0	4	0	0	6
37	Arjasa	1	1	4	0	2	8
38	Pakusari	2	2	1	2	2	9
39	Kalisat	1	1	3	0	3	8
40	Ledokombo	1	1	1	1	1	5
41	Sumberjambe	1	4	2	2	0	9
42	Sukowono	1	8	0	0	3	12
43	Jelbuk	1	1	1	0	1	4
44	Kaliwates	2	1	3	3	0	9
45	Mangli	0	1	0	2	1	4
46	Jember Kidul	0	0	0	0	0	0
47	Sumbersari	4	4	3	2	2	15

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No	Kecamatan	Tahun					Total
		2020	2021	2022	2023	2024	
48	Gladakpakem	2	4	0	0	0	6
49	Patrang	1	3	0	1	0	5
50	Banjarsengon	2	3	1	1	1	8
	Jumlah	**61**	**115**	**58**	**47**	**43**	**324**

Table 2 presents data on maternal mortality rates across 50 community health centers in Jember Regency. The table shows that the highest number of maternal deaths from 2020 to 2024 occurred at the Ajung and Sumbersari Community Health Centers, with 15 mothers..

Tabel 2. Data AKI

No	Kecamatan	Tahun					Total
		2020	2021	2022	2023	2024	
1	Kencong	4	2	7	3	2	18
2	Cakru	6	4	3	2	6	21
3	Gumukmas	5	4	1	5	10	25
4	Tembokrejo	2	1	0	0	4	7
5	Puger	3	1	0	7	8	19
6	Kasiyan	1	11	3	2	9	26
7	Wuluhan	11	8	8	4	10	41
8	Lojejer	2	14	12	2	3	33
9	Ambulu	7	5	7	8	2	29
10	Sabrang	4	6	5	2	8	25
11	Andongsari	5	9	4	3	0	21
12	Tempurejo	7	6	11	8	5	37
13	Curahnongko	7	5	5	2	1	20
14	Silo 1	8	3	5	4	11	31
15	Silo 2	20	9	8	11	9	57
16	Mayang	9	7	5	3	8	32
17	Mumbulsari	9	10	8	8	11	46
18	Jenggawah	7	10	10	3	4	34
19	Kemuningsari Kidul	3	5	2	4	7	21
20	Ajung	2	6	3	14	12	37
21	Rambipuji	1	1	1	4	5	12
22	Nogosari	6	7	4	5	6	28
23	Balung	4	3	6	5	8	26
24	Karangduren	8	5	4	2	4	23
25	Umbulsari	5	2	4	3	3	17
26	Paleran	5	7	7	0	1	20
27	Semboro	10	2	7	3	1	23
28	Jombang	3	1	5	1	4	14
29	Sumberbaru	9	3	7	11	9	39
30	Rowotengah	7	1	7	1	3	19
31	Tanggul	7	4	5	1	5	22
32	Klatakan	12	7	7	2	4	32
33	Bangsalsari	3	0	5	9	9	26
34	Sukorejo	3	1	1	6	5	16
35	Panti	12	8	16	4	7	47
36	Sukorambi	6	3	3	3	5	20
37	Arjasa	5	9	11	4	9	38

No	Kecamatan	Tahun					Total
		2020	2021	2022	2023	2024	
38	Pakusari	4	6	1	10	3	24
39	Kalisat	19	22	6	3	14	64
40	Ledokombo	18	15	12	9	10	64
41	Sumberjambe	6	10	11	9	16	52
42	Sukowono	14	8	10	9	6	47
43	Jelbuk	9	8	12	1	6	36
44	Kaliwates	1	2	3	10	8	24
45	Mangli	0	1	5	1	7	14
46	Jember Kidul	3	2	2	2	5	14
47	Sumbersari	8	14	9	10	9	50
48	Gladakpakem	3	1	2	2	2	10
49	Patrang	6	8	4	8	3	29
50	Banjarsengon	5	8	3	0	3	19
	Jumlah	**324**	**295**	**287**	**233**	**310**	**1449**

3.2. Hasil K-Means Clustering

The data processing process in this study is an implementation of the K-Means Clustering method on a normalized dataset. At this stage, data processing is carried out through a series of steps according to the K-Means Clustering procedure. The first stage is calculating the amount of data to be used in the analysis. Next, the number of clusters (k) is determined according to the research needs, in this case five clusters: very high, high, medium, low, and very low.

After that, an initial centroid point is randomly determined for each cluster. The next step is to calculate the distance between each data point in the dataset and the predetermined centroid using a specific formula, such as the Euclidean distance. After the distance is calculated, the data is grouped based on the closest centroid. Then, the calculation is repeated to determine the position of the new centroid based on the average of the data in each cluster. This process is repeated, calculating the distance between the data points and the new centroids until the centroid positions no longer change. The final result is a division of the dataset into five clusters according to the predetermined categorization level.

3.2.1. Perhitungan Jumlah Data

The first step is to calculate the amount of available data. This step aims to ensure that the data meets the requirements for implementing this method, particularly when determining the number of clusters. In this study, the dataset used consisted of 50 Community Health Center (Puskesmas) data and 31 Sub-district data in JemberRegency.

3.2.2. Penentuan Jumlah Klaster (k)

Once the total number of data in the dataset is known, the next step is to determine the number of K clusters. The number of K clusters must be less than or equal to the number of available data. In this case study, the data will be divided into 5 clusters: very high, high, medium, low, and very low. This division aims to group the data based on certain characteristic levels, so that each cluster clearly represents a different category. This number is balanced, not too little so that variation in the data remains visible, but also not too much so as not to cause excessive clustering.

3.2.3. Penentuan Titik Centroid Secara Acak

After the centroid point is randomly determined, the next step is to calculate the distance between the data and the centroid. To calculate the distance between the data, the author uses the following Euclidean equation.:

$$d(K_n, C_n) = \sqrt{(Kn - Cn)^2}$$

Keterangan :

$d(K_n, C_n)$: Jarak Euclidean / jarak antara data dengan centroid K_n

K_n : Kecamatan ke -n

C_n : Centroid ke -n

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In this case study, the author provides an example of calculation using Maternal Mortality Rate (MMR) data from Ajung District, with experiments conducted on centroids 1 to 5.

$d(K_1, C_1) = \sqrt{(15-2)^2} = 13$

$d(K_1, C_2) = \sqrt{(15-6)^2} = 9$

$d(K_1, C_3) = \sqrt{(15-9)^2} = 6$

$d(K_1, C_4) = \sqrt{(15-12)^2} = 3$

$d(K_1, C_5) = \sqrt{(15-16)^2} = 1$

Meanwhile, the process of calculating the Infant Mortality Rate data from Ajung sub-district, with experiments carried out on centroids 1 to 5, is as follows:

$d(K_1, C_1) = \sqrt{(37-14)^2} = 23$

$d(K_1, C_2) = \sqrt{(37-32)^2} = 5$

$d(K_1, C_3) = \sqrt{(37-40)^2} = 3$

$d(K_1, C_4) = \sqrt{(37-48)^2} = 11$

$d(K_1, C_5) = \sqrt{(37-75)^2} = 38$

This process is repeated using the same method until all data has been calculated for its distance to each cluster. Once all distances between the data and each centroid are obtained, the next step is to find the minimum value of that distance for each cluster. This minimum value is used to determine the data's membership in a particular cluster, in accordance with the principle of the K-Means Clustering method, which is to select the closest distance between the data and the centroid.

3.2.3. Pergitungan Jarak Antar Data dengan Centroid dan Menghitung Titik Centroid Baru

In this process, the selection of centroid points for the Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR) data was done randomly without following any specific rules, as this method allows for flexible centroid determination. The initial centroid points selected will serve as the center or reference for each cluster. Based on the data used, the initial centroid points for the MMR data are presented in the following table:

Tabel 3. Centroid Awal AKI

Centroid	Kecamatan	Jumlah
C1	Semboro	2
C2	Jombang	6
C3	Kencong	9
C4	Mumbulsari	11
C5	Ambulu	16

After determining the initial centroid points for the MMR data as shown in Table 4.3, the next step is to determine the initial centroid points for the IMR data. The initial centroid points for IMR were selected using the same method as for IMR, namely based on the number of cases in each sorted sub-district. The initial centroid points for the IMR data are presented in Table 4.4 below:

Tabel 4. Centroid Awal AKB

Centroid	Kecamatan	Jumlah
C1	Semboro	2

C2	Jombang	6
C3	Kencong	9
C4	Mumbulsari	11
C5	Ambulu	16

Based on the results of the AKB data clustering in the first iteration, the number of data in each cluster is as follows: C1 has 3 data, C2 has 5 data, C3 has 6 data, C4 has 10 data, and C5 has 7 data. To make it easier to read the clustering results, the clustering results table for the first iteration of AKI and AKB is presented in the following table:

Tabel 5. Tabel Hasil Clustering Iterasi ke-1 AKI

C1	C2	C3	C4	C5
Jelbuk	Jombang	Arjasa	Gumukmas	Ajung
Semboro	Ledokombo	Bangsalsari	Jenggawah	Ambulu
	Mayang	Kalisat	Kaliwates	Balung
	Rambipuji	Kencong	Mumbulsari	Puger
	Sukorambi	Pakusari	Patrang	Silo
		Panti	Sukowono	Sumberbaru
		Sumberjambe		Sumbersari
		Tanggul		Tempurejo
		Umbulsari		
		Wuluhan		

Table 5 shows the results of the Maternal Mortality Rate (MMR) clustering in the first iteration, where sub-districts were grouped into five clusters. C1 (Very Low) includes sub-districts with the lowest MMR. C2 (Low) has a slightly higher rate than C1. C3 (Medium) indicates areas with intermediate MMR. C4 (High) has a high mortality rate. C5 (Very High) includes areas with the highest MMR. These clustering results are subject to change in subsequent iterations.

Tabel 6. Tabel Hasil Clustering Iterasi ke-1 AKB

C1	C2	C3	C4	C5
Jombang	Gumukmas	Ajung	Balung	Ambulu
Semboro	Jelbuk	Arjasa	Jenggawah	Kalisat
Sukorambi	Mayang	Bangsalsari	Kaliwates	Ledokombo
	Pakusari	Kencong	Mumbulsari	Silo
		Rambipuji	Patrang	Wuluhan
		Umbulsari	Puger	
			Sukowono	
			Sumberbaru	
			Sumberjambe	
			Sumbersari	
			Tanggul	
			Tempurejo	

The clustering results in Table 5 and Table 6 will be the data that will be continued in the next iteration to determine the new centroid point.

3.2.4. Hasil Akhir

The final results of the AKI data clustering were obtained in the second iteration and the AKB data in the third iteration, where the cluster division remained unchanged compared to the previous iteration. This indicates that the iteration process has reached a stable condition, and each AKI data has been allocated to the appropriate cluster based on the minimum distance to the centroid. Thus, the clusters formed in the second iteration for the AKI data and the third iteration for the AKB data can be considered the final results of this clustering analysis. The final results of the most optimal AKI cluster division are presented in Table 7 below:

Tabel 7. Hasil Akhir Pembagian Cluster AKI

C1	C2	C3	C4	C5
Jelbuk	Jombang	Arjasa	Gumukmas	Ajung
Semboro	Ledokombo	Bangsalsari	Jenggawah	Ambulu
	Mayang	Kalisat	Kaliwates	Balung
	Rambipuji	Kencong	Mumbulsari	Puger
	Sukorambi	Pakusari	Patrang	Silo
		Panti	Sukowono	Sumberbaru
		Sumberjambe		Sumbersari
		Tanggul		Tempurejo
		Umbulsari		
		Wuluhan		

The final results of the AKI cluster division presented in Table 7 show that there was no change in the clustering results after the second iteration and the results were the same as the first iteration. This is evidenced by the final results remaining the same as the cluster division in the first iteration, indicating that the clustering process has reached a stable or convergent point.

Tabel 8.Hasil Akhir Pembagian Cluster AKB

C1	C2	C3	C4	C5
Jombang	Gumukmas	Ajung	Balung	Ambulu
Pakusari	Mayang	Arjasa	Jenggawah	Kalisat
Semboro		Bangsalsari	Kaliwates	Ledokombo
Sukorambi		Jelbuk	Mumbulsari	Silo
		Kencong	Panti	Wuluhan
		Puger	Patrang	
		Rambipuji	Sukowono	
		Umbulsari	Sumberbaru	
			Sumberjabe	
			Sumbersari	
			Tanggul	
			Tempurejo	

Based on the clustering results, the AKB data has changed compared to the clustering results in the first iteration. Several areas have moved clusters, indicating adjustments in the clustering process. These changes include Pakusari, which was previously in cluster C2, now moving to C1, and Semboro, which was previously in C3, now joining C1. In addition, Jelbuk, which was previously in C1, moved to C3, followed by Kencong, which also moved from C3 to the new C3. Panti, which was previously not included in the first iteration cluster division, is now included in C3, while Puger and Rambipuji, which were previously in C2, are now included in C3.

3.3. Hasil Evaluation of Clustering

After the implementation process is complete, the testing/verification phase continues. In the verification phase, the author conducted three stages of testing: data accuracy testing, blackbox testing, and user acceptance testing with users and the health department. Data accuracy testing was conducted by comparing the clustering results obtained from the system with those obtained from other methods, namely manual calculations and the Python programming language. Based on research by (Adzani, 2022), the level of data accuracy can be obtained using the following formula:

$$\text{Tingkat Akurasi} = \frac{Jumlah\ data\ yang\ sesuai}{Jumlah\ data\ keseluruhan} \text{x } 100\%$$

In testing the data accuracy level using the Python programming language, the Inertia Score (SSE), Silhouette Score, and Davies-Bouldin Index (DBI) values were also generated using the Python library, sklearn.

Blackbox testing was conducted by the author to ensure all website functionality was operational. User Acceptance Testing was conducted by distributing a Google Form questionnaire to a number of respondents. The sample size was determined using the Cochran formula as follows:

$$no = \frac{z^2 pq}{e^2}$$

Keterangan:
no = Ukuran sampel
z^2 = Tingkat kepercayaan 90% = 1.645
e = Tingkat ketepatan 10% = 0,1
p = Proporsi variabel dikehendaki (50%) = 0,5 , q = 1-p sebesar 0.5
Berdasarkan rumus diatas, maka diperoleh jumlah sampel sebagai berikut:

$$no = \frac{(1.645)^2 \times (0,5) \times (0,5)}{(0,1)^2}$$

$$no = \frac{2.706 \times 0,25}{0,01}$$

$$no = 67,65 \approx 68$$

After being calculated using the Cochran formula, the number of samples used for this study was 68 samples.

3.4. Hasil Visualization Using Geographic Information System

After the analysis and clustering were performed, a system was developed to visualize the clustering results. This web-based system was designed using Laravel as the backend and Tailwind CSS as the frontend framework. This system is equipped with various key features, including a Landing Page as the initial system display, an AKI Mapping Page and an AKB Mapping Page that display clustering results in the form of an interactive map, and a Chatbot Page designed to help users quickly obtain information. In addition, there is a Login Page and Dashboard Page as the main control center for users.

For data management, the system provides a Subdistrict Master Page, Add Subdistrict Page, Health Center Master Page, Edit Health Center Page, Year Master Page, and News Master Page that enable the management of information related to areas and health facilities. The analysis process is supported by the MMR Data Analysis Page, the Add MMR Data Page, and the IMR Data Analysis Page, which allow users to view trends and patterns based on clustering results. In addition, there is a Kadinkes Dashboard Page specifically designed to provide broader access to policymakers in monitoring data. The clustering results are displayed in a GIS-based interactive map to provide a visual representation of maternal and infant mortality rates in each subdistrict. This visualization uses a different color for each cluster, making it easier to identify areas based on risk levels. Red indicates areas with very high mortality rates, orange for high, yellow for medium, green for low, and blue for very low. The following is a display of the Geographic Information System for Mapping Maternal and Infant Mortality Rates in Jember: Jember Maternal Cluster (JMC):

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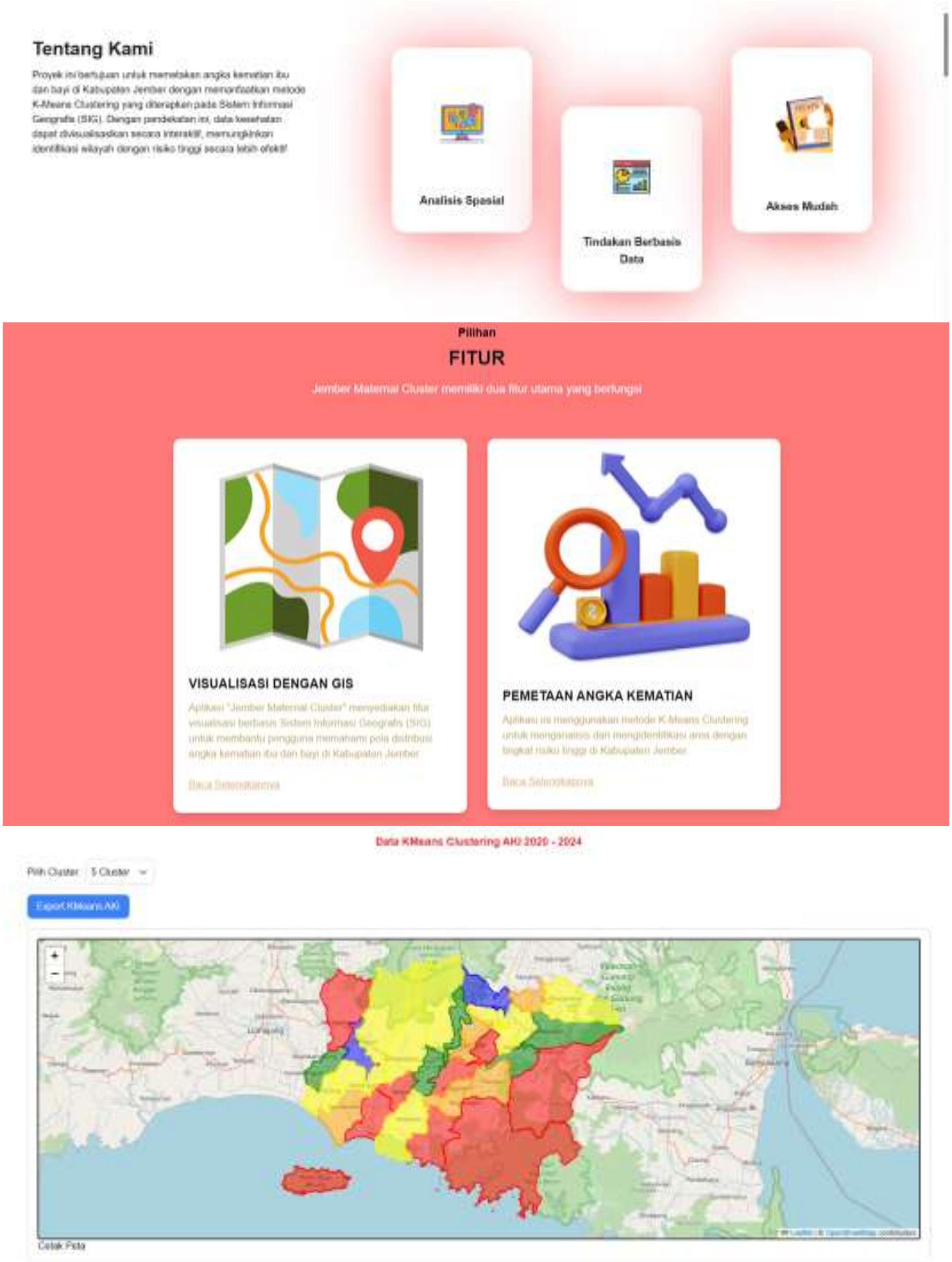

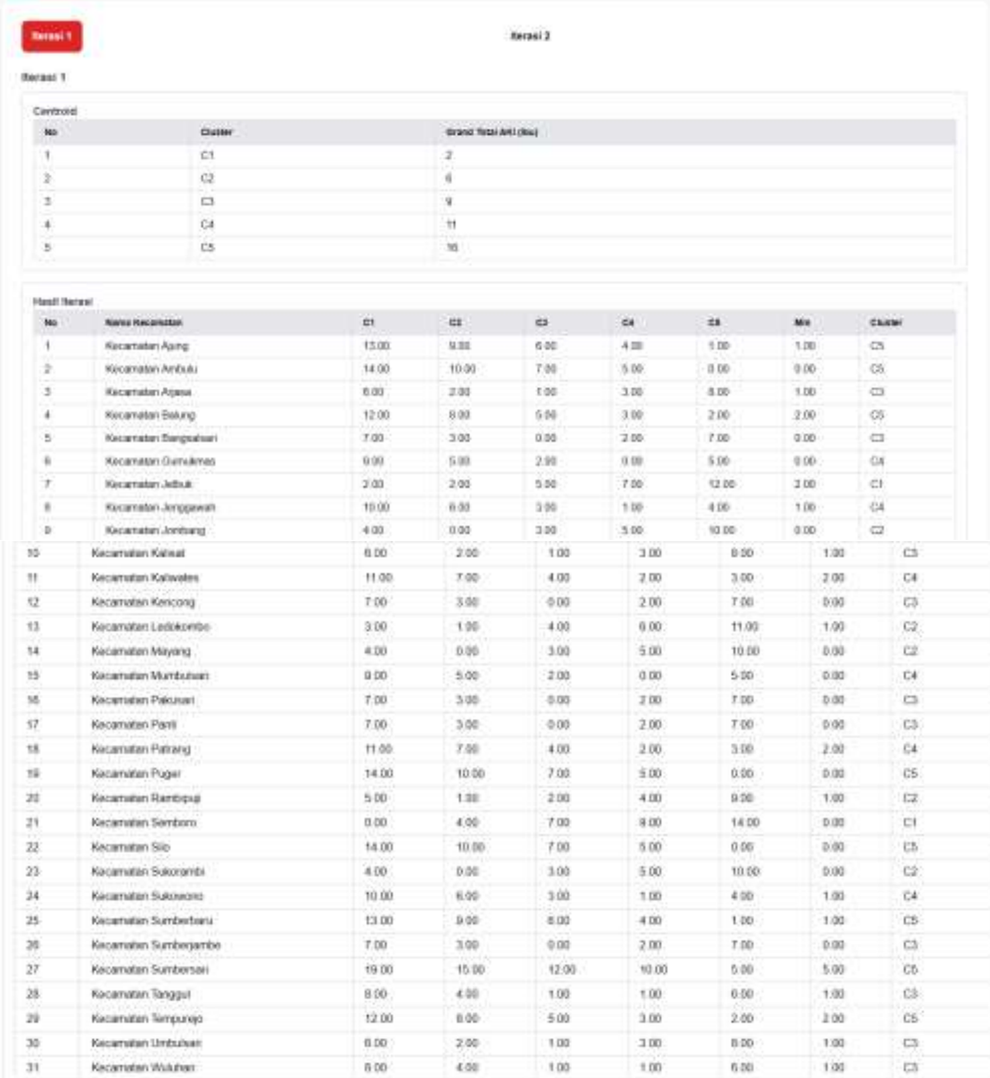

Iterasi 1

Centroid

No	Cluster	Grand Total AKI (Ibu)
1	C1	2
2	C2	6
3	C3	9
4	C4	11
5	C5	16

Hasil Iterasi

No	Nama Kecamatan	C1	C2	C3	C4	C5	Min	Cluster
1	Kecamatan Ajung	13.00	9.00	6.00	4.00	1.00	1.00	C5
2	Kecamatan Ambulu	14.00	10.00	7.00	5.00	0.00	0.00	C5
3	Kecamatan Arjasa	6.00	2.00	1.00	3.00	8.00	1.00	C3
4	Kecamatan Balung	12.00	8.00	5.00	3.00	2.00	2.00	C5
5	Kecamatan Bangsalsari	7.00	3.00	0.00	2.00	7.00	0.00	C3
6	Kecamatan Gumukmas	9.00	5.00	2.00	0.00	5.00	0.00	C4
7	Kecamatan Jelbuk	2.00	2.00	5.00	7.00	12.00	2.00	C1
8	Kecamatan Jenggawah	10.00	6.00	3.00	1.00	4.00	1.00	C4
9	Kecamatan Jombang	4.00	0.00	3.00	5.00	10.00	0.00	C2
10	Kecamatan Kalisat	6.00	2.00	1.00	3.00	8.00	1.00	C3
11	Kecamatan Kaliwates	11.00	7.00	4.00	2.00	3.00	2.00	C4
12	Kecamatan Kencong	7.00	3.00	0.00	2.00	7.00	0.00	C3
13	Kecamatan Ledokombo	3.00	1.00	4.00	6.00	11.00	1.00	C2
14	Kecamatan Mayang	4.00	0.00	3.00	5.00	10.00	0.00	C2
15	Kecamatan Mumbulsari	9.00	5.00	2.00	0.00	5.00	0.00	C4
16	Kecamatan Pakusari	7.00	3.00	0.00	2.00	7.00	0.00	C3
17	Kecamatan Panti	7.00	3.00	0.00	2.00	7.00	0.00	C3
18	Kecamatan Patrang	11.00	7.00	4.00	2.00	3.00	2.00	C4
19	Kecamatan Puger	14.00	10.00	7.00	5.00	0.00	0.00	C5
20	Kecamatan Rambipuji	5.00	1.00	2.00	4.00	9.00	1.00	C2
21	Kecamatan Semboro	0.00	4.00	7.00	9.00	14.00	0.00	C1
22	Kecamatan Silo	14.00	10.00	7.00	5.00	0.00	0.00	C5
23	Kecamatan Sukorambi	4.00	0.00	3.00	5.00	10.00	0.00	C2
24	Kecamatan Sukowono	10.00	6.00	3.00	1.00	4.00	1.00	C4
25	Kecamatan Sumberbaru	13.00	9.00	6.00	4.00	1.00	1.00	C5
26	Kecamatan Sumberjambe	7.00	3.00	0.00	2.00	7.00	0.00	C3
27	Kecamatan Sumbersari	19.00	15.00	12.00	10.00	5.00	5.00	C5
28	Kecamatan Tanggul	8.00	4.00	1.00	1.00	6.00	1.00	C3
29	Kecamatan Tempurejo	12.00	8.00	5.00	3.00	2.00	2.00	C5
30	Kecamatan Umbulsari	6.00	2.00	1.00	3.00	8.00	1.00	C3
31	Kecamatan Wuluhan	8.00	4.00	1.00	1.00	6.00	1.00	C3

Tabel Hasil Clustering

Sangat Rendah	Rendah	Sedang	Tinggi	Sangat Tinggi
Kecamatan Jelbuk	Kecamatan Jombang	Kecamatan Arjasa	Kecamatan Gumukmas	Kecamatan Ajung
Kecamatan Semboro	Kecamatan Ledokombo	Kecamatan Bangsalsari	Kecamatan Jenggawah	Kecamatan Ambulu
	Kecamatan Mayang	Kecamatan Kalisat	Kecamatan Kaliwates	Kecamatan Balung
	Kecamatan Rambipuji	Kecamatan Kencong	Kecamatan Mumbulsari	Kecamatan Puger
	Kecamatan Sukorambi	Kecamatan Pakusari	Kecamatan Patrang	Kecamatan Silo
		Kecamatan Panti	Kecamatan Sukowono	Kecamatan Sumberbaru
		Kecamatan Sumberjambe		Kecamatan Sumbersari
		Kecamatan Tanggul		Kecamatan Tempurejo
		Kecamatan Umbulsari		
		Kecamatan Wuluhan		

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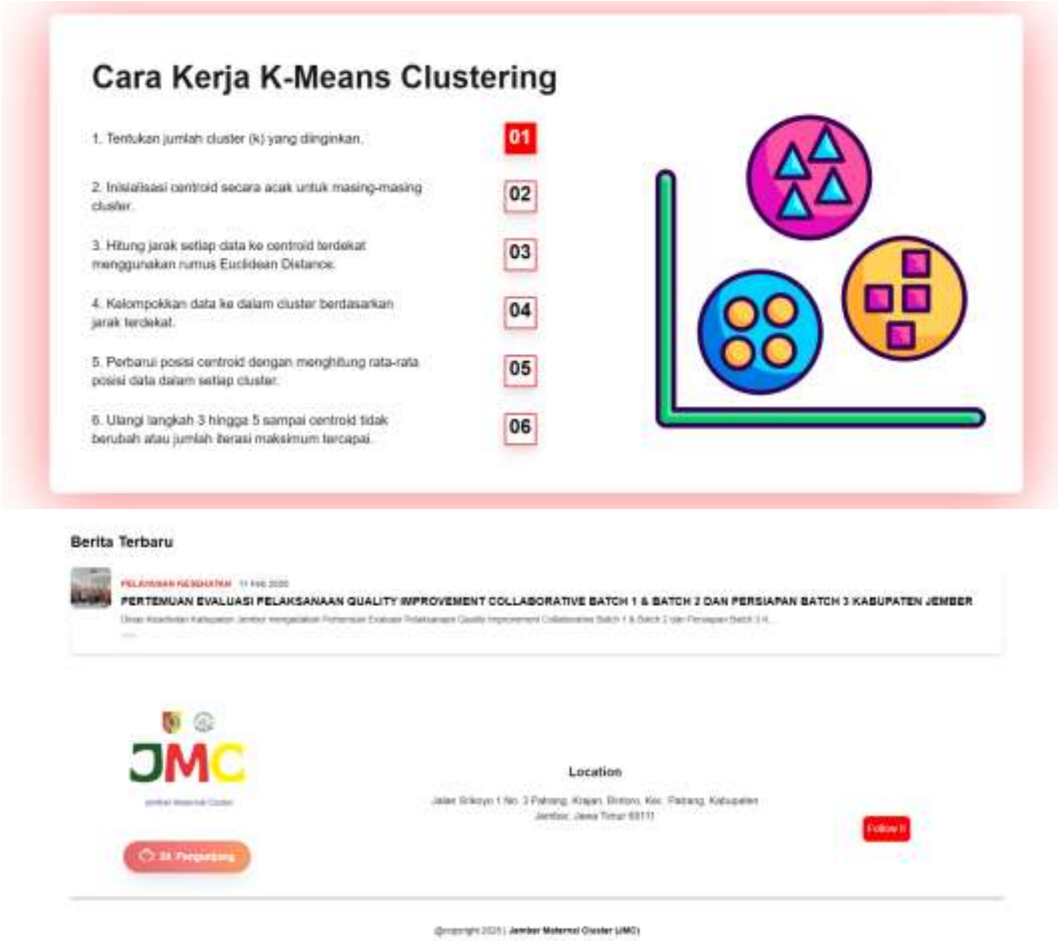

Gambar 1. Tampilan SIG Pemetaan Angka Kematian Ibu dan Bayi di Kabupaten Jember

4. CONCLUSION

Based on the discussion that has been discussed in the previous chapter, the final conclusion can be obtained in the research entitled "Design and Construction of Mapping of Maternal and Infant Mortality Rates Using the K-Means Clustering Method Based on Geographic Information Systems (Case Study in Jember Regency)" as follows: 1). Has analyzed and clustered areas with high maternal and infant mortality using the K-Means clustering method. The analysis was conducted using the K-Means Clustering method to group regions based on maternal and infant mortality rates (MMR & IMR) in Jember Regency. The data used in this analysis comes from the Jember Regency Health Office and covers the period 2020 to 2024. In the clustering process, the data is processed using several K values, namely 3 to 5 clusters, to group regions into very high, high, medium, low, and very low categories. In the data accuracy test, the data level is in the good category of AKI and AKB clustering, and the three evaluation metrics (Inertia, Silhouette Score, and Davies-Bouldin Index) show optimal results, especially in the division of 5 clusters because they show a decrease, namely in AKI data, inertia decreased drastically from 96.0064 in 3 clusters to 47.7750 in 5 clusters, while in AKB data, the decrease in inertia is even sharper, namely from 1869.0000 in 3 clusters to 765.1667 in 5 clusters. 2). Has built a clustering system for mapping areas with high maternal and infant mortality in Jember Regency. After analysis and clustering, a system was developed to visualize the clustering results. This web-based system was designed using Laravel as the backend and Tailwind CSS as the frontend framework. To ensure system reliability, blackbox testing was performed, which tests each function without viewing the internal code structure. The test results showed that all features performed as expected. 3). After analysis and clustering, a system was developed to visualize the clustering results. This web-based system was designed using Laravel as the backend and Tailwind CSS as the frontend framework. To ensure system reliability, blackbox testing was performed, which tests each function without viewing the internal code structure. The test results showed that all features performed as expected.

The clustering results are displayed in an interactive GIS-based map to provide a visual representation of maternal and infant mortality rates in each sub-district. This visualization uses a different color for each cluster, making it easier to identify areas based on risk level. Red indicates areas with very high mortality rates, orange for high, yellow for medium, green for low, and blue for very low.

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