Clustering of Cities/Regencies in East Java Province Based on the Number of Health Workers Using K-Means Clustering Analysis

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Abstract: This study aims to classify cities/regencies in East Java Province based on the availability of health workers using the K-Means clustering analysis method. Secondary data was obtained from BPS East Java for the year 2024, covering 12 variables of health worker types. The analysis process included data standardization, determination of the optimal number of clusters using the Silhouette method, and the application of the K-Means algorithm. The analysis results show that the optimal number of clusters is two. Cluster 1 exclusively consists of the City of Surabaya, characterized by a high concentration of modern and technical health workers but lower in community-based health workers. Cluster 2 includes the other 37 cities/regencies, showing a greater dependence on basic health workers such as midwives and nutritionists, with limited access to specialist medical personnel. This study recommends strengthening community health workers in Surabaya and increasing the availability of professional medical personnel in other regions to reduce health service disparities in East Java.
Keyword: Clustering Analysis, East Java, Health Workers, K-Means.

1. Introduction

Analysis of the clustering of cities and regencies in East Java based on health workers is a strategic effort to understand the distribution and availability of health services in this province. Given that health workers play a crucial role in improving the access and quality of health services, it is important to systematically map their distribution. Research indicates that areas outside the Java-Bali islands have fewer health resources and facilities compared to the Java-Bali region. This poses a challenge for the equitable distribution of public health in Indonesia, including East Java, which has a significant population and diverse health needs [1].

East Java was selected as the locus of this research because it is one of Indonesia's most populous provinces, with a diverse geographic, economic, and demographic structure that significantly influences health service disparities. Moreover, East Java serves as a regional health service hub in Eastern Indonesia, featuring major referral hospitals and medical education centers in cities such as Surabaya and Malang. Despite this, many regencies still face shortages of skilled health personnel, creating gaps in the quality and accessibility of healthcare services between urban and rural areas. These conditions make East Java an ideal case study for evaluating the spatial inequality of health resources.

In this context, clustering analysis using the K-Means method can be used to group regencies and cities based on indicators related to health workers, including the number of medical personnel, health facilities, and other health statistics. Previous studies have shown how the K-Means algorithm is effective in identifying patterns, such as in the case of poverty in various regions [2]. This methodology is not only limited to poverty analysis but is also relevant for examining health disparities in various regencies in East Java [3].

Therefore, the objective of this research is to identify and analyze clusters of cities/regencies in East Java Province based on the number and types of health workers and facilities. The results are expected to provide insights for policymakers in formulating more equitable health workforce distribution strategies.

2. Research Method

The research methods section provides a detailed narrative explaining the research design, along with information about the data sources, techniques used for data collection, and the methods of data analysis employed by the researcher.

2.1. Data

2.1.1. Data on the Number of Health Workers by Regency/City in East Java Province, 2024

The data used is a dataset on the Number of Health Workers by Regency/City in East Java Province, 2024. This is secondary data accessed from the BPS East Java Province website [15]. The variables used in this analysis are as follows:

Table 1. List of variable names for health worker data

No	Variable
1	Regency/City
2	Health Workers – Nurses
3	Health Workers – Midwives
4	Health Workers – Pharmacy Personnel
5	Health Workers – Public Health Personnel
6	Health Workers – Environmental Health Personnel
7	Health Workers – Nutritionists/Dietitians
8	Total Medical Personnel
9	Total Clinical Psychologists
10	Total Physical Therapy Personnel
11	Total Medical Technician Personnel
12	Total Biomedical Engineering Personnel
13	Total Traditional Health Practitioners

2.1.2. Data on the Number of Health Facilities by Regency/City in East Java Province, 2024

Facilities or infrastructure represent one of the essential elements supporting the achievement of organizational goals in delivering services to consumers [8]. The secondary data employed in this study were the number of health facilities in East Java Province, obtained from the BPS (Statistics Indonesia) of East Java. Furthermore, the distribution of health facilities in East Java demonstrates spatial heterogeneity; for instance, in Jember Regency, there are notable variations in accessibility [9]. In addition, the preparedness of community health centers (*puskesmas*) to undergo institutional transformation into Public Service Agencies (BLUD) has also become an important factor in strengthening service delivery [11]. The variables used in this study include:

Table 2. List of variable names for healthy facility data

No	Variable	Description
1	Village/Sub-district Has a Hospital	Number of villages/sub-districts having at least one hospital
2	Village/Sub-district Has Maternity Hospital	Number of villages/sub-districts with maternity hospitals
3	Village/Sub-district Has Polyclinic	Number of villages/sub-districts with polyclinics

4	Village/Sub-district Has a Community Health Center	Availability of public health centers
5	Villages/Sub-districts Have Assistant Health Centers	Number of assistant health centers (Pustu)
6	Village/Sub-district Has Pharmacy	Availability of pharmacies or drugstores

2.2. *Analysis Stages*

The data analysis process followed the statistical and computational procedures of K-Means clustering. The main stages were as follows:

2.2.1. Collecting datasets related to health workers and facilities.

This stage involved the collection of secondary datasets obtained from the Central Statistics Agency (BPS) of East Java Province (2024). Two types of datasets were collected:

- Health workers data, including nurses, midwives, pharmacists, nutritionists, clinical psychologists, medical technicians, and traditional health workers.
- Health facilities data, including the number of hospitals, maternity hospitals, polyclinics, community health centers (*puskesmas*), community health posts (*pustu*), and pharmacies for each district/city.

The aim was to provide comprehensive indicators reflecting the capacity and equity of health services in East Java Province.

2.2.2. Integrating and cleaning the data to ensure consistency across variables.

The data collected from the two sources were integrated based on the district/city names as the primary key. Data cleaning was then performed to ensure accuracy and consistency across variables through the following actions:

- Handling missing data (missing values)
- Unify writing formats (for example, regional names must be consistent)
- Eliminate anomalies or duplicate data.

This process was essential to ensure reliable and comparable statistical analysis between variables.

2.2.3. Standardizing the data using z-scores to equalize variable scales.

To ensure all variables were on a comparable scale, data were standardized using z-score transformation. This normalization allowed each variable to contribute equally in the clustering process and prevented bias due to differences in measurement units.

2.2.4. Determining the optimal number of clusters using the Silhouette Coefficient method.

After the data is standardized, the best number of clusters (k) is determined using the Silhouette Coefficient method. The Silhouette coefficient measures how well a data set fits within its cluster compared to other clusters.

- Higher Silhouette values indicate better and more clearly separated clusters
- In this study, the highest value occurred at k = 2, so two clusters were selected as the optimal result
- This result is also reconfirmed by the Elbow method, which gives the optimal point at the same k.

2.2.5. Applying the K-Means clustering algorithm to classify cities/regencies.

This stage applies the K-Means algorithm to group 38 regencies/cities in East Java based on similar characteristics of healthcare workers and facilities. Each city/regency is assigned to a cluster based on its Euclidean distance to the centroid. Iterations are carried out until the centroid position is stable and does not change significantly. Final results:

- Cluster 1: 37 regencies/cities (areas outside Surabaya).

- Cluster 2: only Surabaya City (with the largest number and types of healthcare workers and the most comprehensive and modern facilities).

2.2.6. Evaluating cluster validity and interpreting results based on variable averages.
After the clusters were formed, a validity evaluation was conducted using the average value of each variable in each cluster to assess the main characteristics of each group:

- Cluster 1: Dominated by primary health workers (midwives, nutritionists) and low-to-moderate numbers of health facilities, with the continued presence of traditional practices.
- Cluster 2 (Surabaya): Characterized by advanced healthcare facilities and a high concentration of professional medical personnel, yet a lower share of community-based workers.

This interpretation indicates an unequal distribution of health workers and facilities among regions in East Java Province.

2.2.7. Presenting the findings in the form of tables and visualizations.
The final stage involved the presentation of analytical results in both tabular and visual formats to enhance understanding and interpretability. Descriptive statistics of health workers and facilities were first presented in tables to summarize the range, mean, and standard deviation across regions. Subsequently, graphical visualizations were generated to illustrate the clustering outcomes and interregional disparities. The main presentation formats included:

- Descriptive Tables summarizing the distribution of health worker and facility variables.
- Silhouette Plot displaying the optimal number of clusters (k = 2) and the quality of separation between clusters.
- Cluster Membership Table showing the classification of each city/regency into Cluster 1 or Cluster 2.
- Cluster Profile Visualization using bar charts to compare average variable values between clusters (e.g., number of nurses, midwives, or hospitals).

These visualizations provided a clear depiction of the contrast between Surabaya (Cluster 2) and other regions (Cluster 1), emphasizing the disparities in professional health worker concentration and facility adequacy. The combination of numerical and graphical presentation aimed to support the validity of findings, facilitate comparative analysis, and improve policy relevance for health workforce planning in East Java Province.

3. Result and Discussion

Table 3. Descriptive statistics of health workers

Health Personnel Variables	Maks	Min	SD	Mean	Median
Health Workers – Nurses	7446	7446	1209.116	761.6579	442.5
Health Workers – Midwives	185	185	11.22133	5.026316	2
Health Workers – Pharmacy Personnel	69	69	1028.357	1488.5	1334
Health Workers – Public Health Personnel	0	0	438.0926	838.5	818
Health Workers – Environmental Health Personnel	4114	4114	570.0825	473.9211	356
Health Workers – Nutritionists/Dietitians	105	105	82.29591	96.63158	84.5
Total Medical Personnel	2047	2047	34.71469	48.15789	40.5
Total Clinical Psychologists	146	146	70.34526	93.36842	76.5
Total Physical Therapy Personnel	3482	3482	69.83358	43.97368	27.5
Total Medical Technician Personnel	107	107	194.3604	180.6316	136.5
Total Biomedical Engineering Personnel	532	532	125.7482	215.2368	173
Total Traditional Health Practitioners	26	26	10.98816	3.736842	0

Table 4. Descriptive statistics of health facilities

Health Facility Variables	Maks	Min	SD	Mean	Median
Village/Sub-district Has a Hospital	42	2	8.152224	8.973684	3
Village/Sub-district Has Maternity Hospital	20	0	3.638443	1.710526	9
Village/Sub-district Has Polyclinic	112	6	29.28461	34.92105	26
Village/Sub-district Has a Community Health Center	64	3	13.08556	25.89474	34
Villages/Sub-districts Have Assistant Health Centers	142	6	27.90081	58.36842	60
Village/Sub-district Has Pharmacy	171	16	42.19743	69.15789	63

Table 1 presents the condition of health workers in East Java Province. Nurses are the most dominant category, with an average of 761 and a maximum of 7,446 individuals in a single region. In contrast, the number of midwives varies widely from 0 to 69, with a relatively low average of only about 5 per region. Traditional health workers are also very limited, averaging only around 3–4 per region.

Meanwhile, Table 2 shows that the number of health facilities across regions exhibits considerable variation. Hospitals, for instance, range from only 2 to 42 units per region, with an average of around 8–9 units. Health centers (*puskesmas*) display the greatest variation, ranging from 16 to 171 units per region. This indicates significant disparities among regions in the availability of pharmacies. After conducting descriptive analysis, the data were standardized so that each variable had a comparable scale. The next step was to determine the optimal number of clusters using the silhouette method.

The descriptive results in the table of health facilities show considerable variation across regions. The number of hospitals remains relatively low, ranging from 2 to 42 units with an average of about 9 units per village/subdistrict. Maternity hospitals are even more limited, ranging from 0 to 20 units with an average of only 2 units, indicating uneven distribution. Clinics are relatively more available, ranging from 6 to 112 units with an average of 35 units, although the relatively high standard deviation (29.28) reflects substantial interregional differences. Health centers (*puskesmas*) range from 3 to 64 units with an average of about 26 units, suggesting that their availability is relatively adequate in most regions. Auxiliary health centers (*puskesmas pembantu*) are recorded as one of the most numerous facilities, ranging from 6 to 142 units with an average of 58 units. Pharmacies are the most abundant health facilities, ranging from 16 to 171 units with an average of 69 units, although variation remains relatively high with a standard deviation of 42.20. Overall, basic health facilities such as auxiliary health centers and pharmacies are relatively sufficient, whereas hospitals and maternity hospitals remain limited and unevenly distributed across regions.

3.1. *Determination of Optimal Number of Clusters*

After the data was standardized, the next step was to determine the optimal number of clusters using the Silhouette method. This method is used to assess how well an object is placed within a cluster. The highest Silhouette value indicates the most appropriate number of clusters [5].

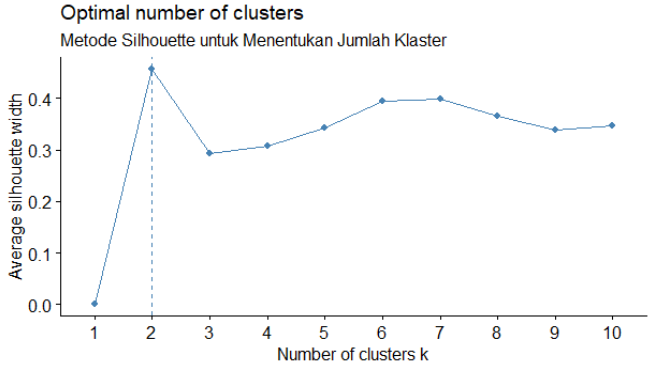

Figure 1. Silhouette method graph for determining the number of clusters

Based on the graphical output of the Silhouette method, the peak is at k=2. This means that the most optimal number of clusters for this data is 2. To further justify this finding, several alternative cluster numbers (k = 3, k = 4, k = 5, and k = 6) were also tested. However, these additional configurations produced lower average Silhouette scores and did not result in clearly distinguishable group patterns. In particular, intermediate values of k tended to create overlapping classifications between mid-sized regencies and urban areas, which reduced interpretability.

The k = 2 solution, in contrast, produced the most distinct separation, clearly isolating Surabaya's metropolitan health characteristics from those of other regions. Moreover, as a robustness check, the Elbow Method was applied and yielded a similar inflection point at k = 2, further supporting this configuration as the most stable and meaningful clustering structure for the dataset. Therefore, the choice of two clusters is statistically valid and conceptually interpretable, aligning with the demographic and health service distribution characteristics of East Java Province.

3.2. *Clustering Results*

Using 2 clusters, the clustering results of cities/regencies in East Java are shown in Table 1. From the table, it is evident that Cluster 1 consists of all other cities/regencies, while Cluster 2 includes only the City of Surabaya.

Table 5. Clustering Results of Cities/Regencies in East Java.

No	Regency/City	Cluster
1	Pacitan	1
2	Ponorogo	1
3	Trenggalek	1
4	Tulungagung	1
5	Blitar	1
6	Kediri	1
7	Malang	1
8	Lumajang	1
9	Jember	1
10	Banyuwangi	1
11	Bondowoso	1
12	Situbondo	1
13	Probolinggo	1
14	Pasuruan	1
15	Sidoarjo	1
16	Mojokerto	1
17	Jombang	1
18	Nganjuk	1
19	Madiun	1
20	Magetan	1
21	Ngawi	1
22	Bojonegoro	1
23	Tuban	1
24	Lamongan	1
25	Gresik	1
26	Bangkalan	1
27	Sampang	1

28	Pamekasan	1
29	Sumenep	1
30	Kota Kediri	1
31	Kota Blitar	1
32	Kota Malang	1
33	Kota Probolinggo	1
34	Kota Pasuruan	1
35	Kota Mojokerto	1
36	Kota Madiun	1
37	Kota Surabaya	2
38	Kota Batu	1

3.3. Cluster Profiles

The characteristic differences between the two clusters are very striking, especially when looking at the average number of each type of health worker.

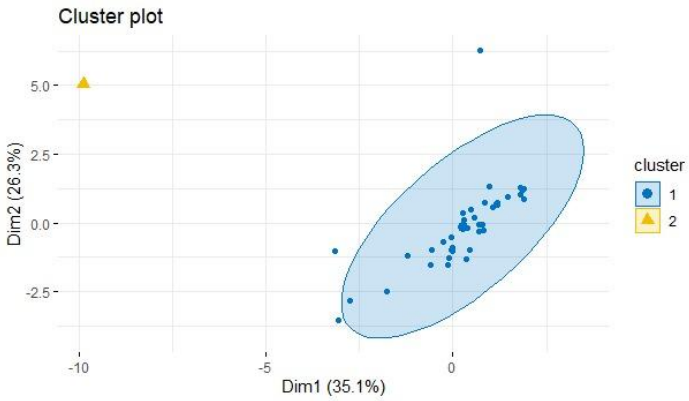

Figure 2. Visualization of clustering results

From the clustering results, it can be seen that cluster 1 all districts/cities except Surabaya, while cluster 2 only Surabaya. The following presents the average values of the variables in each cluster.

Table 6. Average values of variable in each cluster of K-Means analysis results

VARIABEL	Cluster	
	1	2
Health Workers – Nurses	7.446	390.866
Health Workers – Midwives	69	3.297
Health Workers – Pharmacy Personnel	11.570	142.143
Health Workers – Public Health Personnel	2.047	422.365
Health Workers – Environmental Health Personnel	3.482	354.092
Health Workers – Nutritionists/Dietitians	532	84.864
Total Medical Personnel	228	43.297
Total Clinical Psychologists	437	84.081
Total Physical Therapy Personnel	433	33.459
Total Medical Technician Personnel	1.209	152.837
Total Biomedical Engineering Personnel	2.280	214.891
Total Traditional Health Practitioners	64	2.108
Hospitals	42	8.081

Maternity Hospitals	20	1.216
Polyclinics	112	32.837
Community Health Centers	64	24.864
Auxiliary Health Centers	69	58.081
Pharmacies	138	67.297

3.3.1. Cluster 1 (37 Other Cities/Regencies)

The results of the cluster analysis indicate a striking difference between the two clusters, particularly in terms of the type and number of health personnel and facilities available. Areas outside Surabaya (Cluster 1) generally have a limited number of health workers. On average, there are only about 7 nurses, 11 pharmaceutical staff, and 2 public health workers. In terms of facilities, the number of general hospitals (42 units), maternity hospitals (20 units), and community health centers or *puskesmas* (64 units) is also relatively small. In addition, there are still around 64 traditional health practitioners, indicating that traditional medicine practices continue to persist in some regions.

This suggests that healthcare services outside Surabaya rely more on *puskesmas* or small-scale hospitals rather than large modern medical facilities. For example, in Malang City, the gap between supply and demand for *puskesmas* and auxiliary *puskesmas* remains quite noticeable [5]. Such disparities highlight the need for equal standards of public service delivery, as emphasized in a study evaluating healthcare services in Pacitan [13]. Moreover, the technical efficiency of local government health expenditures also influences the quality and equity of healthcare services [6].

Therefore, it is necessary to increase the number and distribution of professional health workers through training, placement incentives, and the utilization of technology such as telemedicine to strengthen healthcare services in these areas. In addition, mobile health service models can also serve as an alternative solution to reach regions with limited medical personnel and facilities [7]

3.3.2. Cluster 2 (City of Surabaya)

In contrast, Surabaya, which belongs to Cluster 2, has a much higher number of health workers and healthcare facilities. There are approximately 390 nurses, 142 pharmaceutical staff, and 422 public health workers. Medical personnel are also prominent, with more than 43 professionals, supported by modern facilities such as 32 polyclinics and 24 *puskesmas*. This illustrates that Surabaya has a greater concentration of professional health workers and more adequate medical infrastructure.

However, the number of personnel working directly within the community, such as midwives (3 people), public health workers (422 people), and environmental health workers (354 people), is relatively lower. This indicates that the healthcare system in Surabaya relies more heavily on large healthcare facilities than on health activities carried out directly within the community. Furthermore, the number of traditional health practitioners is also very small, only about 2 people, as urban residents tend to prefer modern medical services. This finding is consistent with research showing that community satisfaction with primary healthcare facilities, particularly those partnered with the National Health Insurance (BPJS Kesehatan) in East Surabaya, is still influenced by the availability and quality of basic services [12].

For Cluster 1 (areas outside Surabaya), increasing the number of medical personnel with specialized skills, such as nurses, pharmacists, and medical technicians, should be a priority to improve the quality of services in *puskesmas* and small hospitals, while also reducing disparities in healthcare access compared to big cities. Meanwhile, in Cluster 2 (Surabaya), which already has a large number of health workers and modern facilities, efforts should instead focus on strengthening community-based health personnel, such as midwives, public health officers, and environmental health workers, so that disease prevention and health education activities can be more balanced with hospital-based medical treatment.

4. Conclusion

The K-Means analysis successfully grouped 38 cities/regencies in East Java into two significantly different clusters based on the availability of health workers. Cluster 1 (areas outside Surabaya) is characterized by limited medical personnel and healthcare facilities, with services relying more on community health centers (*puskesmas*) and small hospitals. Meanwhile, Cluster 2 (City of Surabaya) serves as a center for modern healthcare services with a greater number of professional health workers and more comprehensive medical facilities. This disparity indicates an imbalance in the distribution of health resources across East Java Province. Based on these findings, it is recommended that the government increase the number and competence of specialized medical personnel in areas outside Surabaya, while strengthening community-based health workers in Surabaya to achieve more equitable and balanced healthcare services throughout the region.

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