JURNAL RISET INFORMATIKA **P-ISSN: 2656-1743 |E-ISSN: 2656-1735**
Vol. 5, No. 3. June 2023 DOI: https://doi.org/10.34288/jri.v5i3.219
Accredited rank 4 (SINTA 4), excerpts from the decision of the DITJEN DIKTIRISTEK No. 230/E/KPT/2023

K-Means Clustering Method for Determining Waste Transportation Routes to Landfill

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Abstrak

Waste is worsening in Magelang City, especially in urban areas. As a result of poorly managed waste disposal, a landfill is needed. Magelang City has a landfill called TPA Banyuurip, located in Plumbon Hamlet, Banyuurip Village, Tegalrejo Subdistrict, Magelang City. From this case, the application of the kmeans clustering method to determine the efficiency of the waste transportation route to the landfill is needed. The research began by conducting direct observations at the Banyuurip landfill by interviewing the drivers of waste vehicles to find out information such as waste sources, transportation schedules, etc. In this study, the data used are the name and address of the supplier, sub-district, coordinate point, and distance from the supplier's place to the landfill. After data collection, data preprocessing is done by dividing and selecting data based on sub-districts. Then the data is processed using the kmeans clustering algorithm to divide the route efficiency and the haversine formula algorithm to determine the closest distance between clusters. After the data has been successfully processed, the number of clusters is 4 for north Magelang, where each cluster will become a corridor with four routes. For central Magelang, 2 clusters with two routes, while for south Magelang, the results are 4 clusters with four routes. From these results, the evaluation results using silhouette score for data clustering of 3 sub-districts are 0.632560 for North Magelang, 0.640667 for Central Magelang, and 0.630186 for South Magelang. This method is expected to help in grouping routes and mapping supplier areas effectively and efficiently in the waste transportation process in Magelang City.

Keywords: Garbage, Transportation Route, TPA, K-Means Clustering, Haversine Formula

Abstrak

Permasalahan sampah menjadi isu yang semakin memburuk di kota Magelang, terutama di daerah perkotaan. Akibat dari pembuangan limbah yang tidak terkelola dengan baik, sehingga diperlukan Tempat Pembuangan Akhir (TPA). Kota Magelang memiliki TPA yang dikenal sebagai TPA Banyuurip yang terletak di Dusun Plumbon, Desa Banyuurip, Kecamatan Tegalrejo, Kota Magelang. Dari kasus tersebut penerapan metode kmeans clustering untuk penentuan efisiensi rute pengangkutan sampah ke tpa dibutuhkan. Penelitian dimulai dengan melakukan pengamatan secara langsung ke TPA di Banyuurip dengan melakukan wawancara kepada supir kendaraan pengangkut sampah untuk mengetahui informasi seperti sumber sampah, jadwal pengangkutan, dan lain sebagainya. Dalam penelitian ini, data yang digunakan adalah nama dan alamat supplier, kecamatan, titik koordinat, serta jarak dari tempat supplier ke TPA. Setelah pengumpulan data, dilakukan pre processing data dengan melakukan pembagian dan seleksi data berdasarkan kecamatan. Kemudian data diolah menggunakan algoritma kmeans klastering untuk membagi efisiensi rute dan algoritma haversine formula untuk menentukan jarak terdekat antar klaster, setelah data berhasil diolah memunculkan jumlah klaster sebanyak 4 untuk magelang utara yang di mana setiap klaster akan menjadi koridor dengan 4 rute, magelang tengah 2 klaster dengan 2 rute, sedangkan untuk magelang selatan mendapatkan hasil 4 klaster dengan 4 rute. Dari hasil tersebut dilakukan evaluasi hasil menggunakan silhouette score untuk pengelompokan data dari 3 kecamatan adalah 0.632560 untuk Magelang Utara, 0.640667 untuk Magelang Tengah, dan 0.630186 untuk Magelang Selatan. Metode ini diharapkan dapat membantu dalam pengelompokan rute dan pemetaan wilayah supplier secara efektif dan efisien dalam proses pengangkutan sampah di Kota Magelang.

Kata kunci: Sampah, Rute Pengangkutan, TPA, K-Means Clustering, Haversine Formula

INTRODUCTION

The cause of urban population growth does not only come from the increase in the birth rate but is also influenced by urbanization which affects the economic dynamics of the city (Wulakada & Mari, 2021). Waste is a worsening issue in Magelang City, especially in urban areas. Waste is the result of daily human activities. It has been a constant problem for many years in Indonesia (Ahmad & Sigarete, 2020), exacerbated by population growth and a lack of public awareness of the importance of protecting the (Hutabalian et al., 2021).

As a result of poorly managed waste disposal, the risk of water, soil, and air pollution and the spread of disease can occur, so a standardized landfill is needed to deal with this problem (Arifin et al., 2022). Magelang City has a landfill commonly known as TPA Banyuurip, located in Plumbon Hamlet, Banyuurip Village, Tegalrejo Subdistrict, Magelang City. From this case, the application of the kmeans clustering method to determine the efficiency of waste transportation routes to the landfill is needed. The efficiency of the waste transportation route is analyzed using the KMeans clustering method, which is accompanied by a GIS-based geographic information system as a simulation of its implementation.

The k-Means algorithm is one of the non-hierarchical cluster algorithms used to group data with similar characteristics into one or more clusters. Data in one cluster has a small level of variation (Irawan et al., 2022). IEEE recognizes it as one of the top ten data mining algorithms (Gustientiedina et al., 2019). A Geographic Information System (GIS) comprises hardware, software, human resources, and data that work together effectively. Its primary function is to input, store, manage, and display data in geographic-based information (Annugerah et al., 2016).

Researchers used a PHP framework called Codeigniter and added Leaflet and Routing Machine libraries to make GIS. EllisLab developed CodeIgniter as an open-source PHP framework that supports the Model View Controller (MVC) concept (Sentosa, 2018). CodeIgniter has also provided various ready-to-use libraries to speed up the process of creating web applications and can also add third-party libraries. For example, Leaflet and Routing Machine libraries can be used (Annugerah et al., 2016).

The leaflet is an open-source JavaScript library that allows the creation of interactive maps (Sakti et al., 2021). Using LeafletJs, users can display maps from various sources in their application . The Leaflet Routing Machine is a crucial feature widely used in developing online maps because it can easily control location route finding and visualize location directions and alternative routes (Hanifah et al., 2020).

Several articles that discuss topics that support and help in this research are already available, one of which is the literature on "Management Information System for Solid Waste Collection and Transportation with Route Efficiency Using K-Means Clustering and Traveling Salesman Problem" (Hanafi et al., 2022). Utilization of Geographic Information System for Waste Collection Truck Route Analysis in Bogor City (Apriyanti et al., 2017). and Geographic Information System Mapping of Temporary Waste Sites in Pekanbaru City by Finding the Nearest Route Using A Star Algorithm (A.

The study is used as a reference by the author of this study to determine the efficiency of the waste transportation route. This study uses the haversine formula algorithm to determine the shortest route for transporting waste to landfills. Therefore, this study aims to determine the optimal route for waste vehicles and divide the efficiency of route points based on the closest area between suppliers in Magelang City using the kmeans clustering method and the haversine formula. This method is expected to help group routes and map supplier areas effectively and efficiently transport waste in Magelang City.

RESEARCH METHODS

In conducting research, data is needed as the material used to support research. The methodology used in this research is carried out through a series of steps listed in Figure 1.

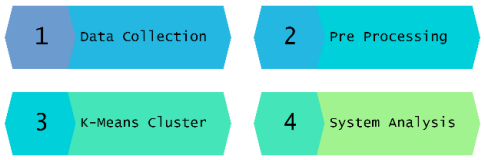

Figure 1. The flow of Research Stages

Data Collection

The data collection process has a vital role in this research (Hermanto et al., 2021) because the data collection method will determine the quality and accuracy of the data to be collected (Sugianto et al., 2020). The data used in this study results from direct observation at the Banyuurip landfill to collect data needed to obtain information and understand the waste management situation in Magelang City. In this case, the researcher needs information is the supplier's name and address, sub-

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district, coordinate point, and distance from the supplier's place to the landfill. The data collected amounted to 55 on waste supplier information in Magelang City.

Pre Processing

Preprocessing is critical in analyzing data. This stage includes identifying missing values in the data to find out if there is incomplete data, selecting data to determine which data will be used in the clustering process, deleting irrelevant data, and then performing the data normalization stage.

Data normalization plays an essential role in the data preprocessing stage because it can reduce the difference in scale values between variables which can cause some variables to be too dominant or disproportionate to the analysis results (Riza et al., 2018). In addition, data normalization can also improve the accuracy of a cluster. The formula for calculating data normalization using Min-Max Normalization is as follows.

$$x_{scaled} = \frac{x - x_{min}}{x_{max} - x_{min}} \quad \text{..... (1)}$$

Description:
x = data to be normalized
x_min = minimum data x
x_max = maximum data x
x_scaled = normalized data

K-means Clustering

This method partitions data into clusters/groups so that data with the same characteristics are grouped into the same cluster and data with different characteristics into other groups (Triyansyah & Fitrianah, 2018). The first stage in performing kmeans cluster by determining the optimal k value using the elbow method to determine the optimal number of clusters in cluster analysis. After the optimal k value is determined, the clustering process can be done by calculating the distance between each data point and the cluster center. Then, the data points will be grouped into clusters closest to the center. The results of this clustering process will produce output in the form of cluster division containing supplier route points in Magelang city based on the closest sub-district between suppliers.

The results of the division of routes are based on clusters in each sub-district area in Magelang City to find the shortest route from each cluster with the Haversine formula. Haversine Formula (Rohmatulloh et al., 2022). Haversine Formula is an essential equation in the navigation system used to calculate the shortest distance between two points, using longitude and latitude. The Haversine Formula algorithm in this study is used to determine the closest distance between the supplier point and the landfill based on the route formed through the clustering process using the K-Means method in clustering.

System Analysis

System analysis is critical to evaluate the results of a clustering process to determine whether data clustering is optimal or still needs improvement. One evaluation method that is often used is the silhouette score, which measures how close each data point is to the specified cluster and how far the data point is from the nearest another cluster . The higher the silhouette score value, the better the quality of the resulting cluster. The formula for calculating evaluation with silhouette score is as follows.

$$Si = \frac{bi-ai}{max(ai - bi)} \quad \text{..... (2)}$$

Description:
ai: average cluster point n distance to all cluster n data.
bi: minimum average distance from cluster point n to another cluster point different from cluster n (Drl et al., 2023)

RESULTS AND DISCUSSION

The collected data will be used as the basis for creating a web-based Geographic Information System that can display the nearest waste transportation route and determine service requirements (features) (Hanafi et al., 2022), as well as system objectives , as listed in Table 1 below are the results of the final data recap.

Table 1. Recap of Waste Supplier Data

ID	Supplier	Sub-district	Latitude	Longitude	Distance
1	Kel. Gelangan	Magelang Tengah	-7.474427	110.224408	3.9
2	Dlh Kota Magelang	Magelang Utara	-7.444415	110.230218	8
3	Disperindag Magelang	Magelang Selatan	-7.498371	110.223580	5.3
		.....			
53	SMK N 3 Magelang	Magelang Tengah	-7.468206	110.218839	5.5
54	Kebon Semilir Magelang	Magelang Utara	-7.453331	110.219162	6.5
55	Kel. Cacaban	Magelang Tengah	-7.478665	110.215013	7.4

After the data collection process, data preprocessing is carried out by dividing and selecting data based on sub-districts, such as examples in Figure 2, Figure 3, and Figure 4 below, where the data has been selected according to the needs of transportation route clustering. There are 22 data for North Magelang, 13 for Central Magelang, and 20 for South Magelang.

```
utara.head(4)
```

	latitude	longitude	jarak
1	-7.444415	110.230218	8.0
3	-7.453075	110.215089	6.9
4	-7.445096	110.227643	8.0
8	-7.465744	110.223117	4.9

Figure 2. North Magelang data

```
tengah.head(4)
```

	latitude	longitude	jarak
0	-7.474427	110.224408	3.9
5	-7.480971	110.220413	4.9
7	-7.479942	110.213983	7.4
13	-7.484405	110.215406	6.2

Figure 3. Central Magelang data

```
selatan.head(4)
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	latitude	longitude	jarak
2	-7.498371	110.223580	5.3
6	-7.488235	110.209844	7.0
11	-7.494285	110.231931	3.9
15	-7.489852	110.219541	6.4

Figure 4. South Magelang data

After dividing the data, the data will be normalized using MinMax Scaller on each data, as shown in Tables 2, 3, and 4, which are the normalized data. Normalization aims to scale the values of variables where the data is transformed into a uniform scale, thus allowing a fairer comparison between features or variables.

Table 2. North Magelang Normalization Result Data

X1	X2	Y
-0.99655431	1	8
-0.99771367	0.99986275	6.9
	.....	
-0.99948845	0.99992225	5.2
-0.99774785	0.9998997	6.5

Table 3. Central Magelang Normalization Result Data

X1	X2	Y
-0.99843348	1	3.9
-0.99930759	0.99996376	4.9
.....		
-0.99760242	0.99994948	5.5
-0.99899965	0.99991476	7.4

Table 4. South Magelang Normalization Result Data

X1	X2	Y
-0.99938307	0.99991591	5.3
-0.99803217	0.9997913	7
.....		
-0.99928602	0.99977357	7.7
-0.99847572	0.99990081	6.1

The purpose of clustering in this research is to divide the supplier points close to each other to produce an optimal route for transporting waste in Magelang City. However, in this case, the researcher divided the data into three groups based on the sub-districts in Magelang City. After using the Elbow method, it was found that the optimal number of clusters for each sub-district in this study is 3.

The K-means clustering process was carried out in the North Magelang sub-district using 4 clusters. The number of members in each cluster is as follows, Cluster 1 has eight suppliers, Cluster 2 has six suppliers, Cluster 3 has six suppliers, and Cluster 4 has two suppliers. The results of K-means clustering for waste suppliers in the North Magelang sub-district can be found in Table 5.

Table 5. Results of K-means clustering in North Magelang sub-district

Cluster	Total Suppliers	Supplier
1	8	DLH KOTA MAGELANG, Depo Sidotopo, Kel. Kramat Utara, Sumberjaya, RSJ Magelang, Ngembik, Depo Sanden Kuncen, Perum Depkes Magelang
2	6	Depo Maluku, RSUD Budi Rahayu, PLN Magelang, Pasar GR Bonpolo, UD. Rasyid Jaya, Kodim Magelang
3	6	Gor Samapta, Kel. Potrobangsan, Untidar, Kel. Kramat Selatan, Kel. Kedungsari, Kebon Semilir Magelang
4	2	Kel. Wates, RST Magelang

Meanwhile, the Central Magelang sub-district uses 2 clusters, with five suppliers in Cluster 1 and 8 suppliers in Cluster 2. Information regarding the results of K-means clustering for waste suppliers in the Central Magelang sub-district can be found in Table 6.

Table 6. Results of K-means clustering in Central Magelang sub-district

Cluster	Total Suppliers	Supplier
1	5	Kel. Gelangan, Pecinan (Khusus Taman), Kel. Panjang, Depo Tarumanegara, SMK N 3 Magelang
2	8	Depo Cacaban, Kel. Kemirirejo, Kel. Magelang, Taman Kyai Langgeng, Telkom Magelang, Oxalis Hotel, Dinas Pertanian Magelang, Kel. Cacaban

In the South Magelang sub-district, K-means clustering was conducted with 4 clusters. The number of members in each cluster is as follows: Cluster 1 has six suppliers, Cluster 2 has six suppliers, Cluster 3 has four suppliers, and Cluster 4 has four suppliers. The results of K-means clustering for waste suppliers in the South Magelang sub-district can be found in Table 7.

Table 7. Results of K-means clustering in South Magelang sub-district

Cluster	Total Suppliers	Supplier
1	6	DISPERINDAG MAGELANG, Pasar Rejowinangun, Lidah Buaya, Hotel Trio Magelang, Armada Finance Magelang, DISHUB Magelang
2	6	Kel. Jurangombo Selatan, Depo Giriloyo Nambangan, Catering Sari, SMK N 1 Magelang, Akmil Magelang, TPST Jurangombo
3	4	Depo Tidar, TPST Tidar Campur, Cengkeh 55 Magelang, Kel. Tidar Selatan
4	4	Depo Jurangombo, Kel. Magersari, Kel. Jurangombo Utara, Satpol PP Magelang

The K-Means Cluster process is completed, and the closest route from the supplier point to the final processing site (TPA) in each sub-district cluster will be found using the Haversine Formula algorithm. North Magelang sub-district uses 4 clusters, where each cluster will be a corridor with four routes. Complete information about the results of using the Haversine Formula to determine the route with the closest distance to the landfill in clusters in the North Magelang sub-district is contained in Table 8 below.

Table 8. Nearest Route Search Results in North Magelang

Cluster	Route
1	TPA→Perum Depkes Magelang→Ngembik→Kel. Kramat Utara→Sumberjaya→RSJ Magelang→Depo Sanden Kuncen→Depo Sidotopo→DLH Kota Magelang→TPA
2	TPA→Kodim Magelang→UD. Rosyid Jaya→Depo Maluku→Pasar GR Bonpolo→PLN Magelang→RSUD Budi Rahayu→TPA
3	TPA→Gor Samapta→Kebon Semilir Magelang→Untidar→Kel. Kramat Selatan→Kel. Kedungsari→Kel. Potrobangsan→TPA
4	TPA→RST Magelang→Kel. Wates→TPA

In the Central Magelang sub-district, data were grouped using 2 clusters, where each cluster resulted in a corridor trajectory with two routes. The details of the Haversine Formula solution to determine the route with the closest distance to the landfill (TPA) in clusters in the Central Magelang sub-district are documented in Table 9 below.

Table 9. Nearest Route Search Results in Central Magelang

Cluster	Route
1	TPA→Pecinan (Taman) →SMK N 3 Magelang→Depo Tarumanegara→Kel. Panjang→Kel. Gelangan→TPA
2	TPA→Oxalis Hotel→Taman Kyai Langgeng→Kel. Kemirirejo→Depo Cacaban→Kel. Cacaban→Dinas Pertanian Magelang→Kel. Magelang→Telkom Magelang→TPA

Meanwhile, in the South Magelang sub-district, the data grouping is done using 4 clusters, and each cluster also produces corridor trajectories with four routes, similar to North Magelang. The details of the Haversine Formula solution to determine the route with the closest distance to the landfill for the clusters in the South Magelang sub-district are documented in Table 10 below.

Table 10 Nearest Route Search Results in South Magelang

Cluster	Rute
1	TPA→Hotel Trio Magelang→DISHUB Magelang→Armada Finance Magelang→DISPERINDAG Magelang→Lidah Buaya→Pasar Rejowinagun→TPA
2	TPA→SMK N 1 Magelang→AKMIL Magelang→Depo Giriloyo Nambangan→Akmil Magelang→TPST Jurangombo→Kel. Jurangombo Selatan→Catering Sari→TPA
3	TPA→TPST Tidar Campur→Kel. Tidar Selatan→Depo Tidar→Cengkeh 55 Magelang→TPA
4	TPA→Depo Jurangombo→Kel. Jurangombo Utara→Kel. Magersari→Satpol PP Magelang→TPA

P-ISSN: 2656-1743 | E-ISSN: 2656-1735
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JURNAL RISET INFORMATIKA
Vol. 5, No. 3 June 2023
Accredited rank 4 (SINTA 4), excerpts from the decision of the DITJEN DIKTIRISTEK No. 230/E/KPT/2023

After completing data processing with data mining using the K-Means algorithm and Haversine Formula, then the implementation is carried out to the geographic information system in Figure 5, which is the prominent display of the web gis dashboard of the Magelang city garbage transportation route, which includes several menus such as route map, master data, cluster data, and settings.

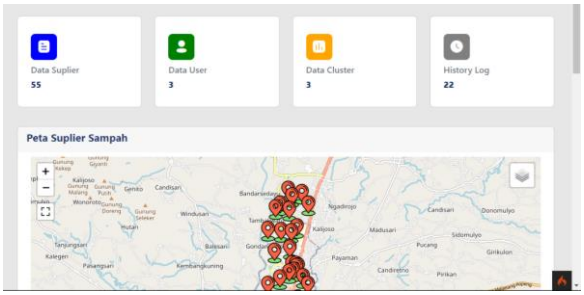

Figure 5. Dashboard Main Page

In the dashboard menu, there is a display card in the form of information on the amount of data in the database, such as displaying the amount of supplier data in the database. There is also a map display of waste suppliers and waste supplier data, which can be seen in detail in the master data menu as in Figure 6, which displays the distribution of waste supplier points in Magelang City.

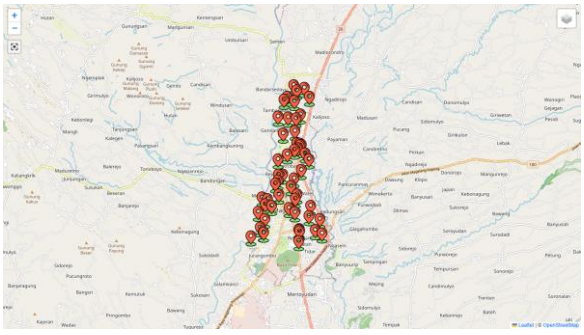

Figure 6. Waste Supplier Map of Magelang City

After that, there is a route map menu where this menu is for implementing a simulation of the route or path taken by a garbage truck from 1 supplier to tpa banyuurip. Features on this menu can run when the user selects input in the name of the existing supplier and selects the destination tpa, then presses the route search button as in Figure 7 below.

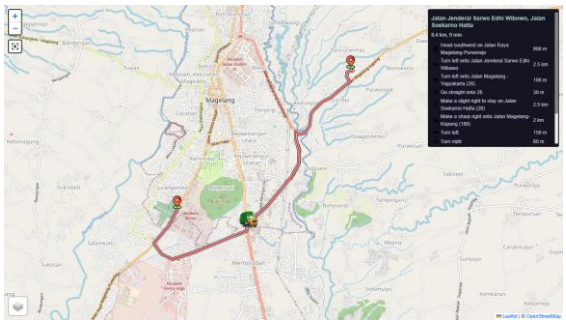

Figure 7. Route Map Menu

The Cluster Menu page displays the results of data clustering with the K-means Clustering method, in which, in this menu, there are more sub-menus in the form of north, central, and south Magelang cluster menus. Figure 8 below is an example of the display of the cluster sub-menu in the North Magelang sub-district. In addition to the North Magelang cluster data, there is a view map feature of the distribution of waste supplier points that have been clustered and a feature that displays the distribution of k-means cluster transportation routes and the determination of the closest distance that has been processed with the Haversine Formula.

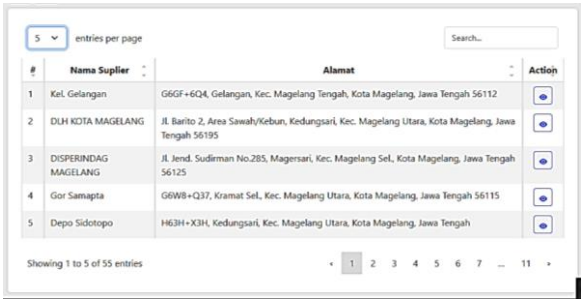

Figure 8. North Magelang Cluster Data Menu

For other sub-menus, such as central and south Magelang, it is more or less the same as the previous picture. Then is the display of the view map feature of the distribution of waste suppliers from the cluster results in the north Magelang sub-district such as to distinguish the supplier points between clusters with different marker colors in each cluster, where for cluster 1 red marker, cluster 2 blue color, cluster 3 yellow, and the last for cluster 4 the marker color is black. Can be seen in Figure 9 below.

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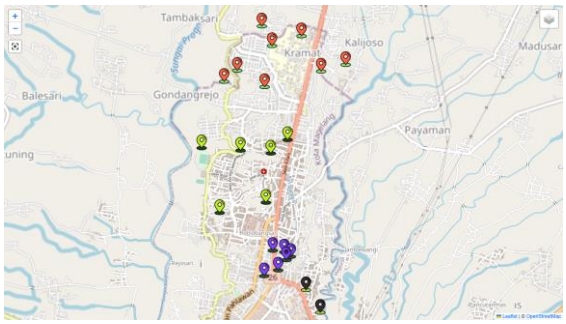

Figure 9. North Magelang Cluster Map

Moreover, the last is an example of a feature display that displays the distribution of waste transportation routes in cluster 3 in North Magelang, which in this feature display in addition to simulating which routes are passed for waste transportation, there is also information on which roads are passed, the total mileage in the transportation process and users can also see which suppliers are included in the cluster 3 route in North Magelang. The implementation of the feature display is in Figure 10 below.

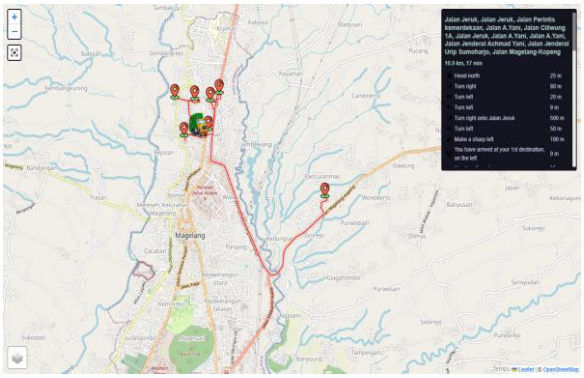

Figure 10. North Magelang Fear Cluster Route

After the K-Means Clustering stage and the determination of the shortest route, the process of analyzing or evaluating the results of the optimal route distribution cluster is carried out. For the evaluation result of accuracy score using silhouette score for clustering data from 3 sub-districts are 0.632560 for North Magelang, 0.640667 for Central Magelang, and 0.630186 for South Magelang.
It can be concluded that applying the k-means method in determining waste transportation routes is quite good because if the silhouette score value is close to 1, it indicates that the resulting cluster is perfect. If the silhouette score value is close to 0, it indicates an overlap between clusters, and further evaluation is needed, and finally, if the silhouette score value is close to -1, it indicates a significant overlap between clusters, and the clustering process may not fit the data.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on this study's results, the k-means cluster method is applied to distribute optimal waste transportation routes in Magelang City by dividing it into three sub-districts, namely the north, central, and south Magelang sub-districts. The results of route division using k-means cluster include, in north Magelang getting 4 clusters or arguably there are four waste transportation routes from suppliers to tpa, for central Magelang there are 2 clusters with two routes, and the last for south Magelang there are 4 clusters with four route divisions. It is hoped that waste hauliers in Magelang City can improve efficiency in terms of time and transportation equipment. In addition, the use of efficient routes also has a positive impact on the use of transportation equipment. With well-organized routes, waste hauliers can utilize transportation equipment optimally, reduce fuel use, and extend the vehicle's life.

Suggestion

From the results of this study, it is necessary to evaluate so that further research can further develop this method so that the results of route division can be even better to display a higher silhouette score value so that data clustering can be more accurate.

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