Design of Employee Bus Routes for Madiun City Government Based on Home Locations and Presence Location History

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Abstract. Madiun City is strategically positioned as the center of regional activities in the western part of East Java Province. Based on the data presented for the City of Madiun in Figures for 2022, the number of residents and private vehicle units is almost the same. Hence, road congestion is likely to occur. The solution that can be given to reduce the use of personal vehicles is to provide public transportation facilities, such as buses. This bus is specifically for segments of society that have the same daily mobility. Before providing employee buses, it is necessary to plan bus routes. Route planning certainly requires accurate location point data. During the pandemic, Regional Apparatus Organization (OPD) employees in Madiun City were location-based. This study uses the data point locations of 3066 employees in Madiun City obtained from location presence history data. This location point is used as data for designing employee bus routes. Problems in determining employee bus routes can be solved with the Vehicle Routing Problem (VRP) using its variation, namely the Multi-Depot Vehicle Routing Problem (MDVRP). This study looks at the movement patterns of employees from the point of location of the home address, which is analyzed using QGIS. The stages of this research started with collecting point location data and visualization using a heatmap to determine high-intensity areas. Then, the route is formed by selecting the depot and calculating its capacity to determine the number of employees who can meet it. Then data processing is carried out using QGIS software by grouping each employee into the nearest depot. Finally, sort the route to get the closest mileage. The result is that there are two recommended routes assuming departure from the bus station, namely the east bus line (Gajah Mada Road - Yos Sudarso Road - Jawa Road - Dr. Sutomo Road - Mastrip Road) and the west bus (Letkol Suwarno Road - Panglima Besar Sudirman Road - Mastrip Road - Heroes Road - Jawa Road).

Keywords: Bus Route, Multi-Depot Vehicle Routing Problem, GIS.

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1 Introduction

Madiun City is strategically positioned as the center of regional activities in the western part of East Java Province. This position makes Madiun City a center for government services, trade, services, industry, education, and health in the western part of East Java Province. The 2019-2024 City of Madiun RPJMD document explains GRDP growth. There are three sectors with the highest average growth during the 2013–2018 period. One is the transportation and warehousing sector, at 7.70% per year. Based on an analysis of the City of Madiun in the 2021 Figures published by BPS, the number of private vehicles is 123,077 units [1]. This figure continues to rise every year. Meanwhile, the population of the City of Madiun in 2021 is 196,917 people [1]. When compared between the number of residents and private vehicle units, the number is almost the same. The solution that can be given to reduce the use of personal vehicles is to provide public transportation facilities such as bus for 196,917 people. The aim is to reduce the use of private vehicles.

Public transportation brings many benefits to society when providing mobility and access opportunities for people [2]. Based on the Smart Living Roadmap in the Madiun City Smart City Master Plan, 2020-2024 has one program, namely the Collaboration Program for the Provision of Affordable and Environmentally Friendly Transportation. This is the basis for the implementation of this research that there is a need for a transportation concept to support Madiun City as a smart city, especially in terms of smart mobility indicators. However, the provision of public transportation for all levels of society will undoubtedly be challenging to implement given the different mobility of people, making it difficult to determine the most effective route. The mobility of one of the elements of society that have the same rhythm, namely government employees, who have definite working hours and days. There is research which explains that the congestion point in Madiun City is on Jalan Jawa because it connects 4 main roads, namely Jl. MT. Haryono – Jl. Salak – Jl. Major General De Panjaitan – Jl. Panoramic Raya [3]. This road will become one of the bus lanes that will be passed so that there will be less private vehicles.

Based on data obtained from the Employee Performance Targets (SKP) application managed by the Madiun City Government Communication and Information Service, the number of Madiun City government employees is 3,066 people. Determining the route, of course, requires accurate location point data. During the pandemic, the presence of Regional Apparatus Organization (OPD) employees in Madiun City was location-based. So that there is data on the location of each employee's house. This data can be used to determine bus routes for OPD employees in Madiun City to support Madiun City as a smart city, especially in terms of smart mobility indicators. However, the provision of public transportation for all levels of society will undoubtedly be challenging to implement given the different mobility of people, making it difficult to determine the most effective route. The mobility of one of the elements of society that has the same rhythm, namely government employees, who have definite working hours and days.

Route determination using the minimum mileage has been suggested by [4] in his research entitled "Truck Dispatching Problem". This research models how a homoge-

neous truck fleet can serve oil demand from several gas stations from a central hub. These problems are known as vehicle routing problems or Vehicle Routing Problems (VRP) [5]. Other studies have examined bus routes with the highest acceptable distance for students to travel from their homes to the bus lane. Since the research location is in a tropical zone and the subjects are pre-adolescent children, the distance has been reduced from 400 to 300 meters [6].

VRP has many variants as research develops, as analyzed by [7] based on literature studies discussing VRP. Multi-depot vehicle routing problem (MDVRP) is the VRP variant appropriate for this research because it involves multiple depots [8]. The multi-depot vehicle routing problem (MDVRP) is a variant of the vehicle routing problem (VRP) in which vehicles depart and return to one of several depot locations [9]. In addition to designating vehicle routes, selecting the depot from which customers will be visited is necessary. MDVRP simultaneously establishes the closest vehicle route and defines the service area of each depot [10]. MDVRP is proven to solve vehicle routing problems by recommending the shortest route [11]. With MDVRP, logistics distribution management tasks such as shipment routing and scheduling can result in reduced delivery distances or times [12].

This research focuses on the Madiun City area, multi-depot vehicle routing models combined with GIS will facilitate decision support for problems with complex path restrictions and many vehicles, to obtain optimal delivery route planning with minimum travel distance [13]–[17]. The goal is to find employee bus routes that can find the shortest distance to shorten the time. Multi-depot vehicle routing problem (MDVRP) analysis is mostly done with Quantum GIS (QGIS) software [18], [19]. QGIS is a classic desktop geographic information system (GIS), a highly customizable, open-source geospatial environment that can create effective visualizations [20]. Therefore, this study uses QGIS software to analyze employee and office location data using MDVRP. Distance is utilized in the processing and analysis of the data for this study. Distance refers to the utmost acceptable distance between employees' homes and offices and the bus stop. MDVRP's primary objective is to determine the optimal route for each vehicle by minimizing the total distance or travel time traveled.

2 Research Methodology

This research focuses on the location of employees' houses based on the presence of Madiun City employees to design employee bus routes in the Madiun City Government. The research process is divided into five stages: identification of existing location data, location data visualization, location data processing, route assessment, and route selection **(Figure 1).**

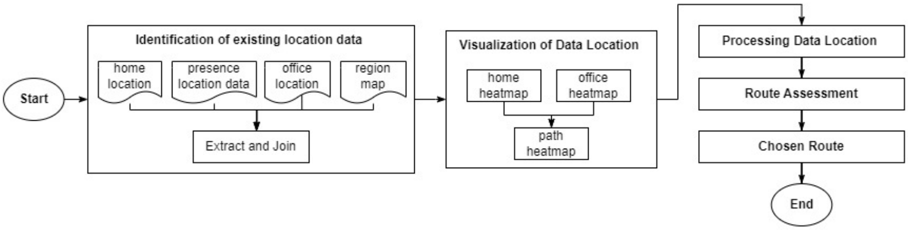

Fig. 1. Research Methodology

2.1 Identification of existing location data

The initial data was identified by collecting data on the number of employees and the location of the house obtained from the history of attendance locations in the City of Madiun. Data were collected at the Office of Communication and Informatics, which is responsible for the application of employee presence in all Regional Apparatus Organizations (OPD) of the Madiun City Government. Obviously, data collection is conducted legally, with permission and sanction from the appropriate Office. Employee home location data and selfie absence location data were used to identify location data.

Data collection was carried out from the beginning of 2022 to August 25, 2022. The data was collected from the employee records of Madiun City, which included 2653 ASN, 2140 Non-ASN, and 1462 Teachers. At this initial stage, it generates location data for employee homes and location data for selfie attendance that has been mapped into QGIS **(Figure 2 and Figure 3)**

- **Data on employee's house location**

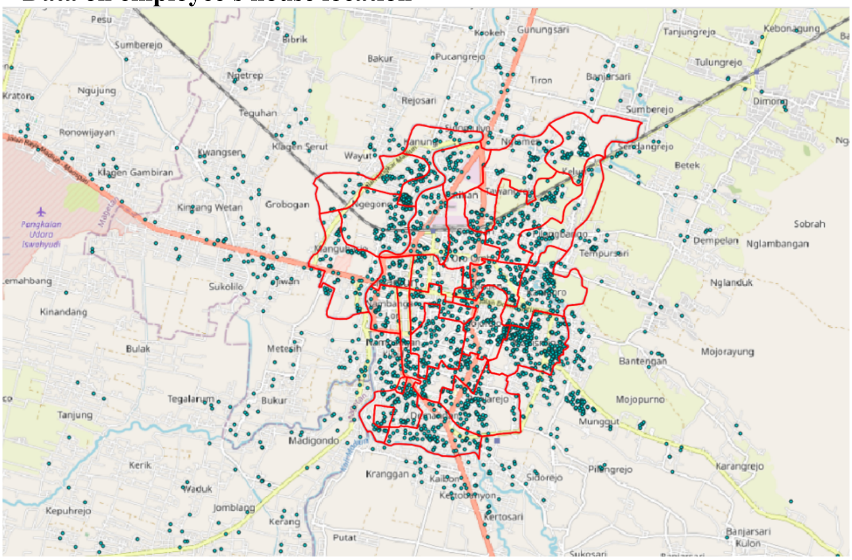

Fig. 2. Point Location of employee's house in Madiun City

The mapped location data is spread throughout the Madiun City area but has the most points in the city center. The green-colored points residential houses of the madiun city employee. The red line shows the boundaries of the Sub-districts in Madiun City. The attendance location mapping is carried out after all employees' homes are mapped.

- **Selfie presence location data**

Data on the presence of selfies were collected from 859 locations. The number differs from the number of employees because selfies are primarily taken at workplaces. The selfie presence location is indicated by a green dot **(Figure 3).** The location point for selfie presence is carried out at the Office in the Madiun City Region so that the variations in location points are spread only in the city center.

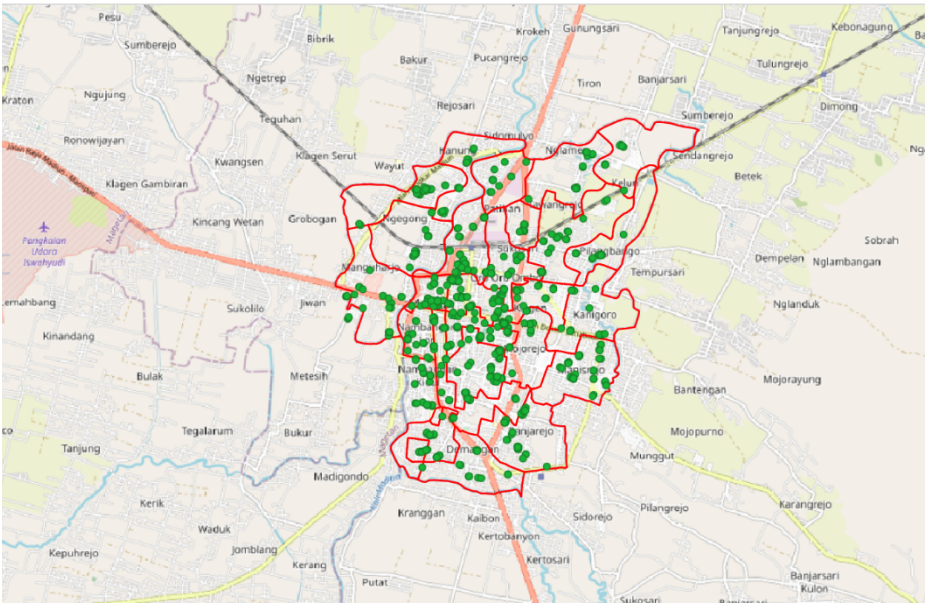

Fig. 3. Location Points of Employee Selfie Presence in Maidun City

2.2 Data Location Visualization

QGIS is used to generate heatmaps for use in data visualization. The purpose of data processing is to generate patterns. Visualizing the density of the analyzed location markers is used to process data. One is using the Kernel Density Estimation (KDE) method to generate a Heatmap. This technique generates a continuous map based on the data points distribution.

Heatmap is used to find out which locations have high intensity. Three intensities will be made, namely:

- House intensity: The greater the intensity value, it will show the density of the house's occupants at that point.

- Office intensity: The greater the intensity value, it will show the office density at that point.
- Path intensity: The greater the intensity value, the more frequently the path is traversed.

Therefore, the optimal employee shuttle route will pass through a high-intensity home, then a high-intensity line, and finally a high-intensity office. A 500-meter-radius heatmap is generated to visualize the concentration of employee residences, office locations, and frequently traveled routes. The following is the result of a residential and office heatmap visualization **(Figure 4 and Figure 5).**

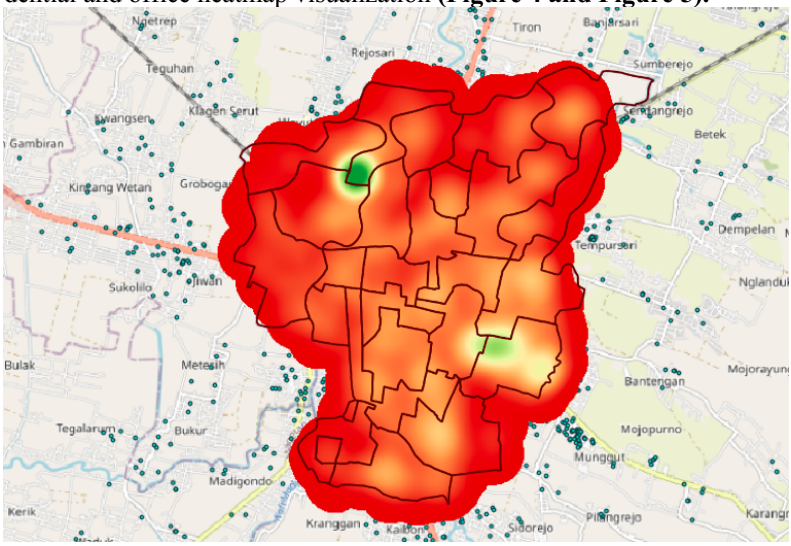

Fig. 4. Home location Heatmap

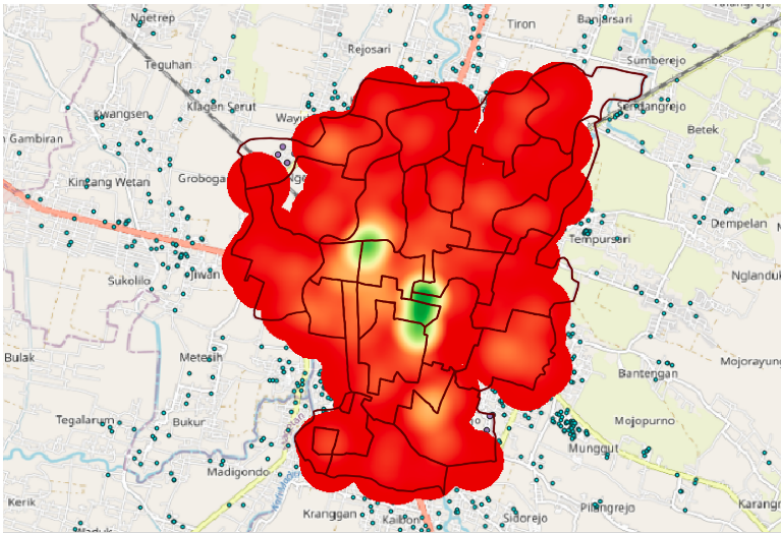

Fig. 5. Office Location Heatmap

The results of the visualization of the home and office heatmaps will serve as the foundation for the creation of pathway heatmaps. To achieve this, a home-office relationship must be established, followed by the reduction of the high-value area on the office heatmap so that data does not accumulate at the destination location but rather at locations in between.

2.3 Processing Data Location

At this stage, a line is made from the home point to the office. Draw Location Point Lines Using location point data, draw a line connecting the points. The home-office path data used is 429,921 records. Draw a line for one day and one month **(Figure 6 and Figure 7)**, the goal is to be able to see the density of home-office paths to be visualized into a path heatmap.

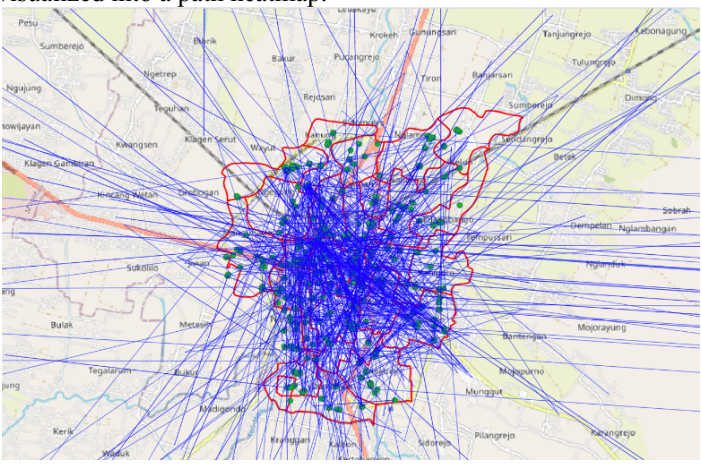

Fig. 6. Home-Office line in one day

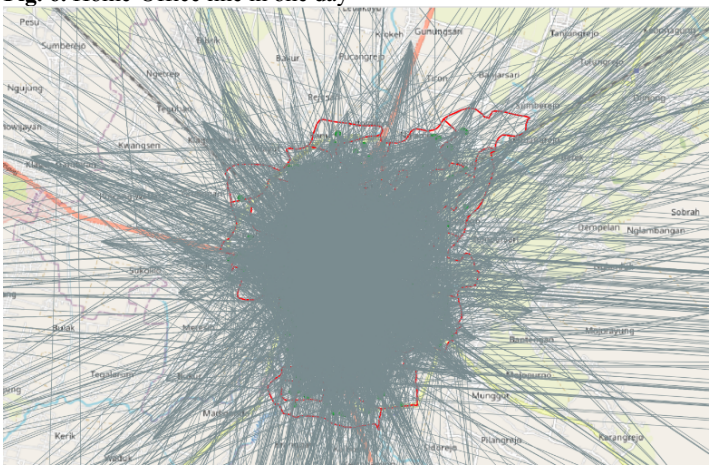

Fig. 7. Home-Office line in one month

Based on these results, intermediate points are generated for each line **(Figure 8)** so that they can be used for path heatmaps. Then subtract the high-value locations on the office heatmap **(Figure 9).** So it will generate a path heatmap **(Figure 10).**

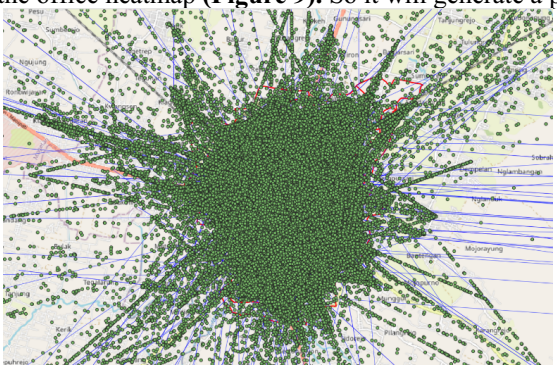

Fig. 8. Generate Point from Line

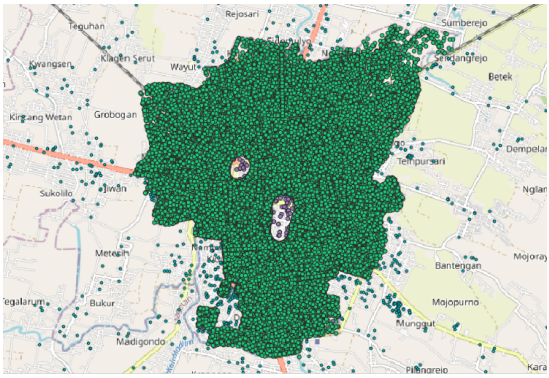

Fig. 9. The result of reducing the line with the office heatmap

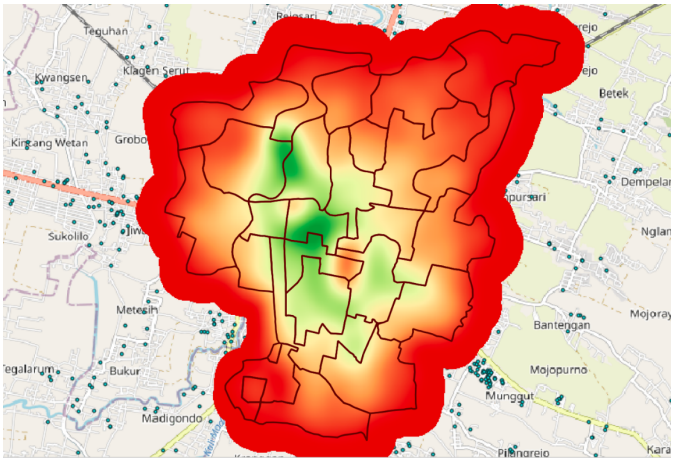

Fig.10. Path Heatmaps

Based on the results of the path heatmap, the next step is to convert the Heatmap to Vector and identify the paths with the highest heatmap values. Heatmap analysis was carried out to see the population density or the location of the Madiun City employee's home address. The red color indicates areas with low values to be used as bus lanes. While the green color indicates areas with high scores as bus route recommendations.

2.4 Route assessment

QGIS is utilized to conduct network analysis for route formation. This analysis is conducted by accumulating relational data arranged in the form of a matrix as opposed to conducting surveys pertaining to the social characteristics of a sample of the larger population [21]. Network analysis can be used to model infrastructure and networks such as water distribution, electricity networks, roads, and telephones. After the route has been determined, it will be sorted to determine the optimal route.

Using the MDVRP settlement method, the formation of vehicle routes is conducted independently for each depot. This phase analyzes, using QGIS software, the movement patterns of employees from the location of their residential addresses. First, ascertain the depot's capacity and location. Second, determine how many employees are necessary to satisfy the depot's capacity. This will determine how many employees with the minimum distance to the depot can be classified and how many employees with the greatest distance to the depot can be classified.

2.5 Chosen Route

Route sequencing is a step in executing the order of employee pick-up routes computed with QGIS so that employees in the queue or next visit are at the most convenient location. The nearest point from one employee to the next will continue to be determined so that all employees who have not been selected remain in the sorting queue up to a predetermined capacity limit. MDVRP recommends the most efficient solution or quickest route at this sorting stage. This phase will generate optimal route suggestions for every employee.

3 Result and Discussion

Based on attendance results, the initial data analysis stage has been completed to ascertain the location of the employee's residence and place of business. The MDVRP routing stages have been completed, which included determining the optimal route for each vehicle deposited at the depots. The primary objective is to minimize total travel distance or travel time while adhering to all restrictions. This routing stage helps determine the optimal route for a vehicle in MDVRP by considering existing constraints and criteria. The location of high-intensity residences and workplaces has been selected by employing heatmap visualization. Then the relationship between the home-office has also been connected with a line for data in a day and a month. The results

will be converted to points and then subtracted by the location with the highest value on the office heatmap. The path heatmap will then be created.

The path heatmap is then converted to a vector to show the roads with high heatmap values. Areas with high values are shown in green on the heatmap analysis (Figure 10). The area will be the recommended bus route. As a result, buses will pass through Jawa Road and Mastrip Road **(Figure 11)** for areas with high office intensity. Then, the location of the high-intensity house passes Gajah Mada Road and Letkol Suwarno Road **(Figure 12).**

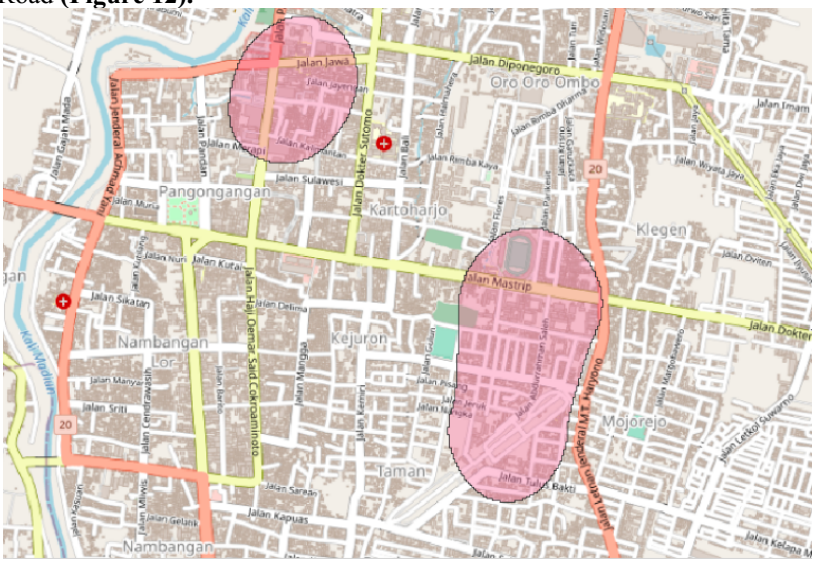

Fig. 11. Area with High-intensity Office

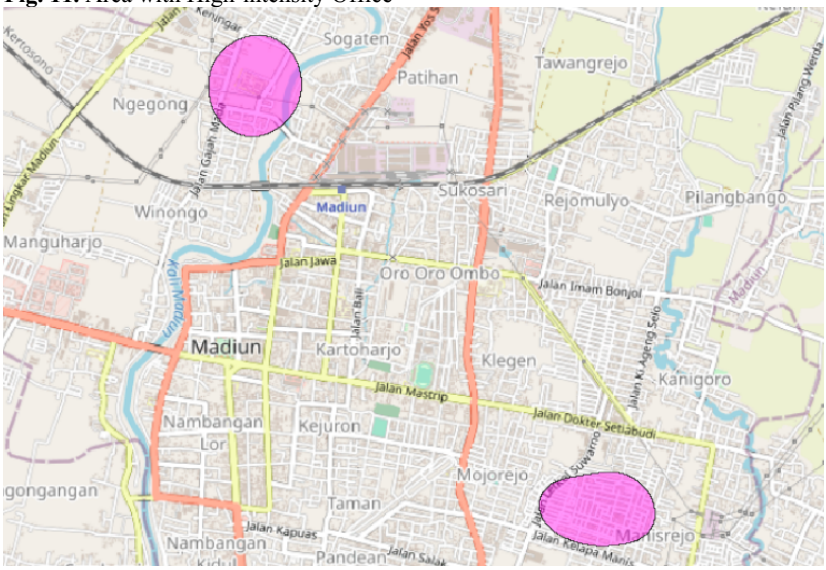

Fig. 12. Area with High-intensity house

Because the two regions are far apart and the destination location is between them, it is necessary to make two bus routes: the eastern bus for passing Letkol Suwarno Road and the western bus for passing Gajah Mada Road. These two bus lines will go to 2 roads with high office intensity **(Figure 13).**

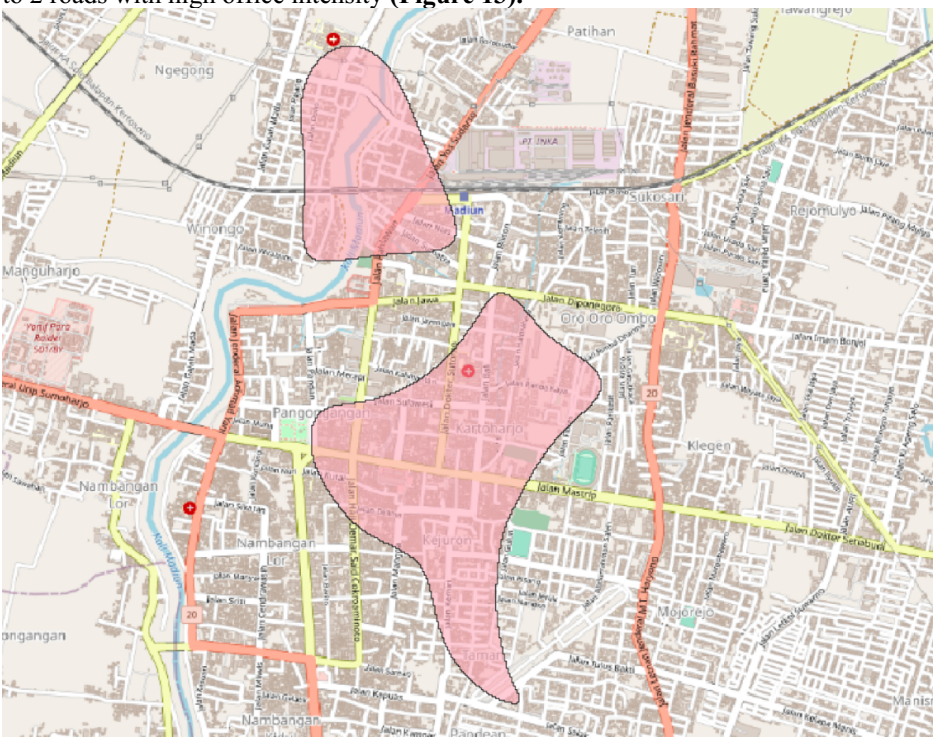

Fig. 13. Density Strip Intensity

The intensity of the congested lanes can be seen at the top, passing Yos Sudarso and Pahlawan roads. The lower portion then traverses Mastrip Road and Panglima Sulaiman Road. According to the results of the analysis, the West Bus Line and the East Bus Line are proposed as the two optimal bus lanes for Madiun City employee buses.

Assuming the bus departs from the bus station, for West Bus departure to the office in the morning, it will go through the route, namely Bus station -> Gajah Mada Road (house of high-intensity employees) -> Yos Sudarso Road (busy line of employee travel) -> Jawa Road (high-intensity office) -> Dr. Sutomo Road (busy line of employee travel) -> Mastrip Road (high-intensity office) **(Figure 14).**

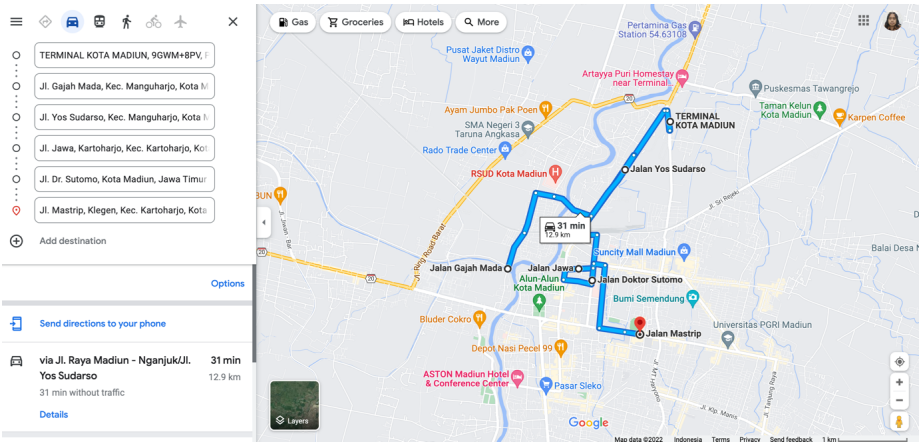

Fig. 14. East Bus Route Recommended Line

Then, the West Bus route to the office will take the following route: Bus station -> Letkol Suwarno Road (high-intensity employee's house) -> Panglima Besar Sudirman Road (the congested route for employee travel) -> Mastrip Road (high-intensity office) -> Pahlawan Road (the congested route for employee travel) -> Jawa Road (high-intensity office) **(Figure 15).**

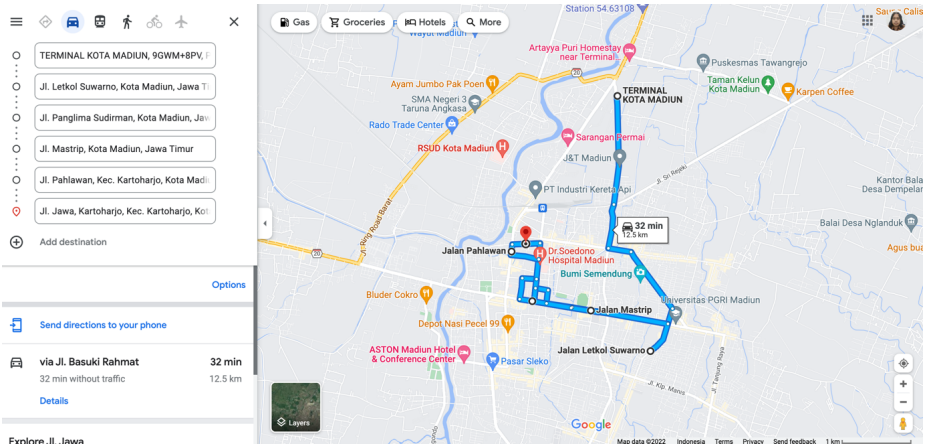

Fig. 15. West Bus Route Recommended Line

Another study conducted a traffic jam analysis, the level of congestion in Madiun city often occurs at the Java intersection that connects Jl. MT. Haryono – Jl. Salak – Jl. Major General De Panjaitan – Jl. Panoramic Raya [3]. The results of the analysis of bus routes pass through major roads in Madiun City, one of which is the Java road

and will reduce congestion because the presence of buses can reduce the use of private vehicles.

4 Conclusion

Utilizing employee presence data in the City of Madiun that has not been optimally used thus far, this study aids in providing a solution for recommending employee transportation routes. This research employed the Multi-depot vehicle routing problem (MDVRP), which was analyzed using QGIS software. The analysis uses a heatmap to visualize the level of intensity, home, and office data. Afterward, a path heatmap is constructed using 429,921 home-office data points. The data is depicted as lines for a 1-day and 1-month line. Then points are generated based on the existing line and subtracted from the office heatmap's high-intensity locations. It will then create a path heatmap, which will be converted to a vector so that the routes with the highest heatmap can be identified. The bus will proceed through Jawa Road and Mastrip Road for high-density office areas and Gajah Mada and Lt. Col. Suwarno Road for high-density residential areas. This study concludes with two recommendations for bus routes leaving the bus station each morning: the east bus line (Gajah Mada Road - Yos Sudarso Road - Jawa Road - Dr. Sutomo Road - Mastrip Road) and the west bus line (Letkol Suwarno Road - Panglima Besar Sudirman Road - Mastrip Road - Pahlawan Road - Jawa Road).

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