Evaluation of Waste Collection with Route Optimization Using ArcGIS PRO

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1. Introduction

With an accelerated urbanization and rising population, managing solid waste has become both important and difficult, if waste is not managed and collected in a timely manner, the environment will become polluted. Optimization of waste collection helps reduce the garbage trucks travel distance, the time required for collecting the waste, fuel consumption, also CO_2 emissions. There are many studies related to the improvement of waste collection, such as the use of waste collection vehicle navigation by simulating collection in a small city with smart bins [1], however it is also possible to apply geographical and spatial software to aid in this type of analysis, Arc GIS is one of the software that allows this type of analysis, and there are many research addressing this method specifically [2][3].

The objective of this study is to perform a route optimization for waste collection route, based on actual waste collection data, with the vehicle routing problem network analyst of the ArcGIS Pro software, and evaluate the differences between the original routes and the optimized routes. An evaluation for optimal location for charging stations, within the analyzed area, for the introduction of electric vehicles it is also considered.

2. Methodology

With the data provided from waste collection, it was analyzed the possible areas for optimizing the waste collection route with a Geographic Information System (GIS) analysis, which is a potent tool to combine spatial information with economic, social, and technical elements. From the maps information within the data, it was inputted in the Vehicle Routing Problem (VRP) network analysis of the ArcGIS the location of each collection point of the chosen routes, the number of vehicles operating in each area, the capacity of the garbage truck, the location of the starting point of operation and the location of the disposal site after the collection of waste was accomplished and then it was performed simulation for the original route, according to the information for the daily reports and collection maps provided, and simulation for an optimized route for each area. An evaluation of optimal location for charging stations was accomplished with the Location-Allocation tool, in this evaluation it was considered facilities of parking areas as candidates for charging stations.

The ArcGIS Pro provides detailed information about the streets and geographic information that are essential for this type of analysis. In figure 1 and figure 2 it is displayed an overview map of the selected area for this study.

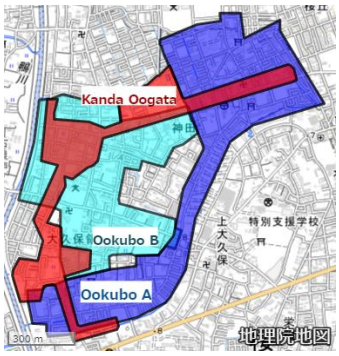

Figure 1. Overview Map of the selected area of Okubo

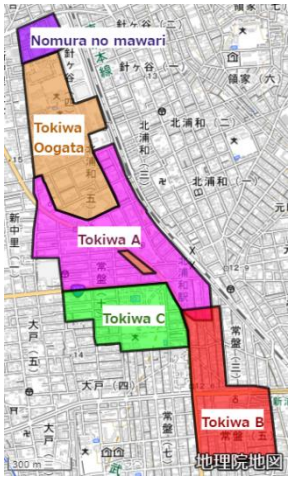

Figure 2. Overview Map of the selected area of Okubo

3. ArcGIS PRO Analysis

From the original data, it was decided to analyze the areas corresponding to “Tokiwa A” and “Tokiwa C” together, due to the proximity of their location, for this area there was a total of 132 collection points divided between 4 routes, for the operation one different truck managed each route, making a total of 4 trucks, the area includes residencies and commercial locations. In this area it was considered a service time of 3 minutes for each collection point, an estimated value to simulate the

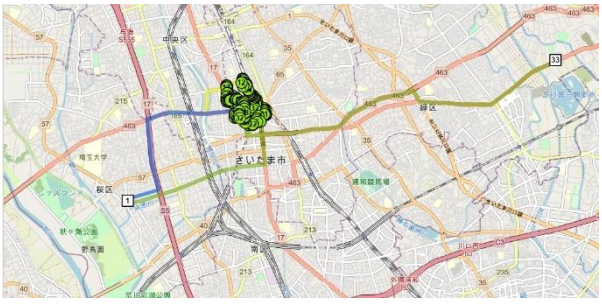

Figure 3. Overviewmap of the entire route

real operation of service time. For the route operation time, it was set for starting at 8AM and end to 6PM, and for the travel settings it was set for the truck only perform U-turns in dead-ends and intersections where it is allowed, since the software also consider this type of data.

In figure 3 it is shown the overview of the simulated area with the starting point and end point for the disposal site, and table 1 indicates the information for the original routes, the time elapsed to complete the route and the distance elapsed by each truck and number of collection points. By using the VRP network analyst, the order of the collection points for the original route is displayed, as in figure 4.

Figure 4 . Simulation of route optimization for the route in Tokiwa area.

Table 1. Reduction ratio for all the areas

Area	Time reduction ratio	Distance reduction ratio
Okubo A+ Kanda Ogata	-12.9%	-13.3%
Okubo B	-7.21%	-7.49%
Tokiwa A+C	-2.76%	-7.44%
Tokiwa B	-10.1%	-10.8%
Okubo Complete	-11.30%	-11.20%
Tokiwa Complete	-9.59%	-9.10%

4.Results and Discussion

With the VRP network analysis, it was calculated the reduction ratio for time and distance for all of the evaluated areas, displayed in table 1. The highest reduction ratio for both time and distance correspond to the areas of “Okubo A” and “Kanda Ogata”, with reduction of 12.9% considering the time for collection of the waste and reduction of 13.3% for the necessary distance to complete all of the collection points, this reduction represents 59 minutes and 9.20 km less to complete the route. The “Okubo B” area presented reduction ratio of 7.21% for time and 7.49% for distance, which represents 17 minutes and 2.5 km. For the areas of “Tokiwa A” and “Tokiwa C”, the distance presented a considerable reduction ratio of 7.49% which represents 5.4km of mileage reduction, however the time reduction ratio from the original route to the optimized route was of 2.76%, representing about 13.8 minutes of saved time for collection of the waste.

For the “Tokiwa B” the total reduction was 10.8% of the mileage, which represents 3.9 kms of reduction in the mileage, the time reduction ration was of 10.1%, corresponding to 26.3 min of time reduction in the operation. All the reduction ratios are also displayed in figure 4. For the whole area of “Tokiwa” the total reduction ratio for time and distance presented 9.59% and 9.19%, respectively. The simulation for the complete area of “Okubo” had reduction of 11.30% for time and 11.20% regarding the distance.

5. Conclusion

By applying the vehicle routing problem network analyst of the ArcGIS combined with data from real operations of waste collections in the Saitama city in Japan, the results indicates it is possible to improve the real operations due the reduction in time required to complete the waste collection and reduction in the mileage, the optimizing results indicates distance reduction ratio of 13.3% and 11.20% in the best cases, which can represent a significant cost reduction in the real operation of waste collection, by doing so, the CO_2 emissions can be reduced as well. A better waste management strategy can contribute to a neighborhood’s improvement and the general wellbeing of a community.

REFERENCES

[1] Baras N., Ziouzios D., Waste collection vehicle navigation in modern cities, 6th *South-East Europe Design Automation, Computer Engineering, Computer Network and Social Media Conference (SEEDA-CECNSM)*, 2021.

[2] Lan Vu, H., Bolinbroke D., Wai Ng K. T.,Fallah B., Assessment of waste characteristics and their impact on GIS vehicle collection route optimization using ANN waste forecasts, *Waste Management*, vol. 88, pp. 118-130, 2018.

[3] Lan Vu H, Wai Ng, K., Richter A., Interactions of residential waste composition and collection truck compartment design on GIS route optimization, *Waste Management*, vol. 102, pp. 613-623, 2019.

Research Achievements

(1) MAZULLO JUNIOR Da C. Antonio B. and FUJITA Goro. Assessment of a garbage collection data for electric vehicle introduction. Student Forum 2021 - Sustainable Energy. Pg453-456. IBN:978-604-316-339-1. January9-9,2022.

(2) MAZULLO JUNIOR Da C. Antonio B. and FUJITA Goro Electric vehicle introduction with evaluation of waste collection data. The 40th National Conference of the Institute of Electrical Installation Engineers of Japan, September 1-2, 2022.

(3) MAZULLO JUNIOR Da C. Antonio B. and FUJITA Goro Evaluation of waste collection with route optimization using ArcGIS Pro: A case study in Saitama. The 17th South East Asian Technical University Consortium Symposium (SEATUC), non-reviewed (In progress).