Optimization of Municipal Solid Waste Transporter in Batam City using Genetic Algorithm

A R Purnajaya and F D Hanggara
1Department of Software Engineering, Faculty of Computer, Universal University, Indonesia
2Department of Industrial Engineering, Faculty of Engineering, Universal University, Indonesia

Email: rezkipurnajaya@gmail.com, samfu.31@gmail.com

Abstract. Municipal Solid Waste is an endless problem because as long as life is still running, waste will always be produced. Batam city shows that there is poor scheduling of transportation of garbage from community settlements to temporary collection points (TPS) to the final disposal site (TPA) of Batam City. The study aims to optimize the number of waste transporters by applying a genetic algorithm. In this study, genetic algorithm can optimize the number of Batam City TPS transporters based on the number of TPS per district, the volume of TPS, and the distance between TPS to TPA. The number of waste transporters available in Batam City in dump trucks, arm rolls, pickups, and motorized pedicabs are 54, 44, 100, and 40 respectively. The result determines the optimization number of waste transporters with a genetic algorithm succeeded in making the volume gap as small as possible, particularly 15.96% with the target volume of waste transportation and reducing 26.38% of the average gap in the actual volume of waste transportation. In addition, the non-transportable waste volume optimally by using dump trucks, arm rolls, pickups, and motorized pedicabs is 58.92, 120.21, 346.31, and 380.74 ton respectively.

1. Introduction
The rapid development of industry in Batam City was followed by an increase in the movement of some people from other cities to Batam with hopes of a better life. Increased population and community income and all activities that are feared will exceed support and environment capacity. Mismatch or excess environmental power will have a negative impact that can pollute the environment. One of the environmental pollutants that arise is a municipal solid waste [1].

The problem of determining the transport route is closely related to determining the route of travel from one point to another until returning to the point of origin in a transport route. The results of the experiments in the study of Fahmi [2], many factors influence the process of transporting waste from the starting point in this case temporary collection points (TPS) to the final disposal site (TPA). These factors are the volume of waste in each TPS, transporter capacity, and transportation distance.

Optimization means the process of optimizing or the process of making perfect, making the highest, making the most profitable [3]. The application of optimization is by maximizing container filling by focused on the weight capacity and volume of the container [4-6]. The genetic algorithm can be used to solve problems with a lot of solution space, but it will take much time if done manually, and the resulting solution is less than optimal [7-8]. In previous studies, the genetic algorithm used to optimize the
problem in finding the shortest route with the number of points that must be passed by 20 cities [9]. The study by Mahmudy and Muljadi [10,11] overcome lecture schedules that often experience constraints related to space and lecture schedules who often collide with teaching hours in other classes on the same day and time. Then, a study by Hasibuan et al. [12], the search for the best route on the TSP (Traveling Salesman Problem) using genetic algorithm at the Dinas Kebersihan dan Pertamanan in Pekanbaru City.

In this study, we analyzed the waste transportation system using genetic algorithm to provide recommendations for optimizing the distribution of the municipal solid waste transportation scheduling trucks in the city of Batam. The genetic algorithm optimizes the distribution of 184 waste transporters with 54 dump trucks, 44 roll arms, 100 pickups, and 40 becak motors in serving nine districts with 67 total TPS. Parameters affecting the process of transporting waste from the TPS to the TPA point are the volume of waste in each TPS, transporter capacity, and the distance of the transportation. From the three parameters, we can optimize the distribution of transporters in each district and minimize municipal solid waste that is not transported.

2. Materials and Methods

2.1. Materials
The dataset used in this study is data from the DinasPekerjaanUmumdanPerumahan in Batam City [13]. The type of transporters used to transport municipal solid waste every TPS to TP4in Batam City is dump truck, arm roll, pickup, and motorized pedicab. The volume capacity of each type of transporter is 8 tons of dump truck, 3 tons of arm roll, 1.7 tons of pickup, and 0.6 tons of motorized pedicab. Each transporter is prepared differently for each district as can be seen on table 2. The number of dump trucks, arm rolls, pickups, and motorized pedicabs needed in Batam City are 54, 44, 100, and 400 respectively. The number of these transporters will be optimized in each district with variable volumeTPS, nTPS, and distanceTPS.

The volumeTPSis the target waste volume that must be transported, nTPSis the number of TPS, and distanceTPSis the distance of TPS to the TPA. These three parameters are factors in determining the optimal number of transporters in each district. Initial numbers and parameters of waste transporter per district can be shown in table below:

Table 1. Initial numbers and parameters of transporter per district.

| District     | Waste Transporter | Parameter          |
|--------------|-------------------|--------------------|
|              | Dump Truck | Arm Roll | Pickup | Motorized Pedicab | volumeTPS (Ton) | nTPS | distanceTPS (Km) |
| Batam Kota   | 10        | 7        | 15      | 3         | 125          | 8    | 12.2             |
| SeiBeduk     | 4         | 6        | 14      | 6         | 58           | 3    | 26               |
| Nongsa       | 7         | 4        | 12      | 5         | 72           | 2    | 21.5             |
| Lubuk Baja   | 3         | 2        | 4       | 3         | 95           | 1    | 21.3             |
| BatuAmpar    | 3         | 2        | 8       | 3         | 60           | 3    | 24.7             |
| Bengkong     | 2         | 2        | 4       | 1         | 72           | 2    | 16               |
| Sekupang     | 7         | 6        | 14      | 5         | 75           | 18   | 24.1             |
| BatuAji      | 9         | 7        | 15      | 6         | 66           | 10   | 33.2             |
| Sagulung     | 9         | 8        | 14      | 8         | 80           | 20   | 30.3             |
| Total        | 54        | 44       | 100     | 40        | 703          | 67   | 209.3            |
2.2. Methods

2.2.1. Genetic Algorithm

The genetic algorithm is heuristic and random search process therefore the election operators used define the success genetic algorithm in finding the optimum solution of a problem given. Things to watch out for is avoiding premature convergence, namely achieving an optimum solution that have not the time, in the sense that the solution obtained is the result of a local optimum. Genetic operators used after the first stage of the evaluation process forming a new population of the current generation. Here is the stages of the optimization transporter with genetic algorithm in pseudocode can be shown in table below:

**Table 2. Algorithm developed for the research.**

| Genetic Algorithm |
|-------------------|
| (Initialization) |
| Optimization_Genetic Algorithm(Population, Fitness) |
| Population {Population formed by individual\textit{\textit{nTransporter}} and individual \textit{volumeTPS}} |
| Fitness {fitness function formed by \textit{volumeTPS}, \textit{nTransporter}, and distanceTPS} |
| (Declaration) |
| \textit{i, nTransporter, volumeTPS} : Integer; |
| (Algorithm) |
| \textbf{Repeat} |
| \textit{new\_population} \leftarrow 0; |
| \textbf{For} \textit{i} = 1 to size(\textit{nPop}) \textbf{do} |
| \textit{nTransporter} \leftarrow random selection (Population, Fitness); |
| \textit{volumeTPS} \leftarrow random selection (Population, Fitness); |
| \textit{child} \leftarrow Reproduction by crossover (\textit{nTruck}, \textit{volumeTPS}) as big as \textit{pc} and \textit{beta}; |
| \textbf{if} (RouletteWheelSelection) \textbf{then} |
| \textit{child} \leftarrow Mutation (\textit{child}) as big as \textit{pm}; |
| add \textit{child} to \textit{new\_population}; |
| \textbf{until} |
| all individuals makes fitness 1 or \textit{maxIteration}; |
| \textbf{return} |
| Input best individuals into population (based on Fitness value); |

2.2.2. Set Parameter

The next step is to initialize some parameters of the genetic algorithm. The initial parameters of the genetic algorithm can be seen on table 3.

**Table 3. Initial parameters of genetic algorithm.**

| Parameter                        | Value |
|----------------------------------|-------|
| Maximum number of iterations (\textit{maxIteration}) | 20    |
| Population Size (\textit{nPop})  | 600   |
| Crossover Percentage (\textit{pc}) | 0.5   |
| Mutation Percentage (\textit{pm}) | 0.02  |
| Selection Pressure (\textit{beta}) | 8     |

3. Result and Discussion
3.1. Optimal Non-Transportable Waste Volumes per Iteration

By using the genetic algorithm shown in Figure 1, the optimum non-transportable waste volume using dump trucks, arm rolls, pickups, and motorized pedicabs is 58.92, 120.21, 346.31, and 380.74 ton respectively. The optimal volume is obtained from the fitness function based on the variables $volume_{TPS}$, $n_{TPS}$, and $distance_{TPS}$. The total volume of trash that is not transported per transporter per iteration can be seen in the figure below:

![Figure 1. Optimal non-transportable waste volumes per iteration on dump truck (a), arm roll (b), pickup (c), and motorized pedicab (d).](image)

3.2. Comparison of Actual and Optimized Transporter Tonnage with Target Tonnage per District

The algorithm also produces an optimal number of transporters per district. The number of dump truck, arm roll, pickup, and motorized pedicab distribute in Batam City is optimized for each district with variable $volume_{TPS}$, $n_{TPS}$, and $distance_{TPS}$. Following are the results of the optimization of the number of transporters produced can be seen in the table below:

| District   | Dump Truck | Arm Roll | Pickup | Motorized Pedicab |
|------------|------------|----------|--------|-------------------|
| Batam Kota | 8          | 8        | 30     | 10                |
| SeiBeduk   | 5          | 3        | 1      | 1                 |
| Nongsa     | 5          | 3        | 5      | 1                 |
| Lubuk Baja | 6          | 6        | 11     | 6                 |
| BatuAmpar  | 6          | 3        | 4      | 1                 |
| Bengkong   | 7          | 3        | 3      | 1                 |
| Sekupang   | 7          | 7        | 17     | 8                 |
| BatuAji    | 5          | 5        | 13     | 4                 |
| Sagulung   | 5          | 6        | 16     | 8                 |
| Total      | 54         | 44       | 100    | 40                |

The results of the optimization of the number of transporters per district are compared with the number of actual transporters to determine the gap between the $TPS$ volume or target waste tonnage.
The tonnage of waste transporter is generated by multiplying the number of transporters by the transporter volume capacity. In table 5 below proves that the target tonnage gap with the optimized transport tonnage is 112.2 ton less than the gap in the actual transporter tonnage that is 282.2 ton.

**Table 5.** Comparison of actual and optimized transporter tonnage with target tonnage per district.

| District    | Target Tonnage | Actual |              | Optimized |
|-------------|----------------|--------|--------------|-----------|
|             |                | Total  | Tonnage (Ton)| Gap (Ton) | Total  | Tonnage (Ton)| Gap (Ton) |
| Batam Kota  | 125            | 25     | 128.3        | 3.3       | 45     | 145           | 20        |
| SeiBeduk    | 58             | 26     | 77.4         | 19.4      | 4      | 51.3          | 6.7       |
| Nongsa      | 72             | 21     | 91.4         | 19.4      | 8      | 58.1          | 13.9      |
| Lubuk Baja  | 95             | 9      | 38.6         | 56.4      | 24     | 88.3          | 6.7       |
| BatuAmpar   | 60             | 13     | 45.4         | 14.6      | 12     | 64.4          | 4.4       |
| Bengkong    | 72             | 7      | 29.4         | 42.6      | 8      | 70.7          | 1.3       |
| Sekupang    | 75             | 25     | 100.8        | 25.8      | 26     | 110.7         | 35.7      |
| BatuAji     | 66             | 28     | 122.1        | 56.1      | 19     | 79.5          | 13.5      |
| Sagulung    | 80             | 30     | 124.6        | 44.6      | 38     | 90            | 10        |
| **Total**   | **703**        | **184**| **758**      | **282.2** | **184**| **758**       | **112.2** |

**Table 6.** Comparison percentage of gap in actual and optimized tonnage with target tonnage.

| District    | Percentage of Gap in Actual Tonnage (%) | Percentage of Gap in Optimized Tonnage (%) | Average Percentage of Gap in Actual Tonnage and Target Tonnage (%) | Average Percentage of Gap in Optimized Tonnage and Target Tonnage (%) | Percentage Decrease Gap in Actual Tonnage and Optimized Tonnage (%) |
|-------------|----------------------------------------|-------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------------|
| Batam Kota  | 2.64                                   | 16.00                                     | 42.34                                                            | 15.96                                                               | 26.38                                                             |
| SeiBeduk    | 33.45                                  | 11.55                                     |                                                                  |                                                                     |                                                                   |
| Nongsa      | 26.94                                  | 19.31                                     |                                                                  |                                                                     |                                                                   |
| Lubuk Baja  | 59.37                                  | 7.05                                      |                                                                  |                                                                     |                                                                   |
| BatuAmpar   | 24.33                                  | 7.33                                      |                                                                  |                                                                     |                                                                   |
| Bengkong    | 59.17                                  | 1.81                                      |                                                                  |                                                                     |                                                                   |
| Sekupang    | 34.40                                  | 47.60                                     |                                                                  |                                                                     |                                                                   |
| BatuAji     | 85.00                                  | 20.45                                     |                                                                  |                                                                     |                                                                   |
| Sagulung    | 55.75                                  | 12.50                                     |                                                                  |                                                                     |                                                                   |

The volume gap that has been obtained in each district can be calculated in percentage. In table 6 above shows the percentage of the actual volume gap and optimization volume gap for each district. So it can also be concluded the average actual volume gap of 42.34% and the average optimized volume gap of 15.96%. The results of optimized transporter with genetic algorithm succeeded in making the volume gap as small as possible, which is 15.96% and lowering the 26.38% of the average actual volume gap.

4. Conclusion
The genetic algorithm can be used to optimize the distribution of transporters in serving the municipal solid waste in Batam City with the determining variables are volumeTPS, nTPS, and distanceTPS. The results of transporter optimization with genetic algorithm succeeded in making the volume gap as small as possible, which is 15.96% and lowering the 26.38% of the average actual volume gap. It shows that optimized transported can reduce the distance between the target tonnage and the tonnage transporter. Besides, the optimal number of transporters can finalize the remaining volume of waste that is not transported using dump trucks, arm rolls, pickups, and motorized pedicabs are 58.92, 120.21, 346.31, and 380.74 ton respectively.

In the future, there is a potential that genetic algorithm can not only be applied for Batam City, but it can also be used for other cities, which also has a waste transportation problem. This algorithm can optimize the transporter required for each district in another city with three variables namely target waste volume that must be transported each TPS, number of Transporter each TPS, and transportation Distance each TPS.

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