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Waste transportation management information system using web-based integrated "Simpaskot".

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Abstract: Waste management is a major challenge in urban areas, including in Lhokseumawe. The main problem is that the route still needs to be optimal for operating waste transportation or Vehicle Routing Problems (VRP). Metter this is because there are still obstacles in the field, including the need for more resources, the number of waste trucks, the increase in the amount of waste produced, the lack of temporary collecting points, as well as the long distances to the landfill. The proposed solution to this problem is creating a management information system integrated with web-based waste transportation in Lhokseumawe. Through this system, waste transportation can be optimized as well as provide waste management information to the public. Algorithm Simulated Annealing (SA) is an algorithm that can solve this problem VRP problem very well. Previous research has proven this algorithm better when compared to the GA algorithm in determining the optimal route, so it is hoped that it will also produce better routes determining the optimal route for transporting waste in this research. The data used in this research were taken from the Environmental Service Lhokseumawe City, Indonesia, including total waste transportation trucks, old temporary collecting points, total daily waste generation, waste volume transported per day, current transportation routes, and landfill locations. The initial condition was there are 15 temporary collecting points, 20 large trucks, and 7 small trucks in Lhokseumawe city. The results show that, it was required 17 large and 7 small waste transportation trucks. The SA calculation is carried out using parameters that have been tested to produce optimal values. The parameters used are To = 5000, α= 0,55, and T1=1. The result is that costs and travel time can be reduced by 30%, and travel distance can be reduced by 17% if compared to initial conditions.

Keywords: *Information system, Urban Areas, Waste management, Waste transportation, Web-based.*

1. Introduction

Waste is one of the main problems faced by urban communities. In addition to health problems, flooding, odour pollution, waste is also a scourge for the community because it causes many negative impacts, especially environmental pollution. Waste management problems are currently also a major problem faced by the city of Lhokseumawe. As one of the industrial cities and also a student city, Lhokseumawe has a fairly high population growth every year, both local residents and migrants who study at several higher education institutions in the city of Lhokseumawe, one of which is Universitas Malikussaleh. This makes the amount of waste produced also increases every year. Based on data from the Central Statistics Agency of Lhokseumawe City, the waste generated reaches 280 m3 per day, this makes waste management important to do so that there is no landfill. One of the obstacles faced by the Lhokseumawe City Environmental Service as the waste manager of Lhokseumawe city is the management of the waste transportation system. these problems include: (1) the lack of waste collection trucks (currently there are 13 truck units to transport 85 tonnes of waste per day in 4 sub-districts and 68 villages); (2) the increasing amount of waste generated per day; (3) the lack of temporary disposal

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sites (TPS), so that people throw garbage carelessly at several points in Lhokseumawe city; (4) the small size of the garbage bins at temporary landfills at several points so that they cannot contain all the garbage disposed of and cause garbage to scatter around the garbage bins; (5) the far location of the Final Disposal Site (TPA) so that it takes time for garbage trucks to reach the TPA. One solution that can be done to overcome the above problems is to create an integrated waste transport management system that can be accessed by all parties.

1.1. Information System

According to (*Cegielski, 2015*) Information systems are the process of collecting, processing, analysing, and disseminating information for specific purposes, while (*O'Brien, 2011*) states that information systems are an orderly combination of people, hardware, software, and databases that collect, convert, and disseminate information in an organisational form. In essence, information systems are a combination of people, hardware, software, and databases that are widely used to improve the performance of an organisation to be more effective, integrated, so that it has consistent data, and can be used more optimally.

1.2. Transportation

Transportation is the process of moving passengers or goods from one place to another that arises because of the process of fulfilling needs. Waste transportation is a waste transportation sub-system that aims to carry waste from the transfer location or from the waste source directly to the final processing site, or landfill (*Aminuddin et al., 2020*). Sub-system optimisation is carried out so that the transportation and management of waste becomes optimal, easy, fast, and relatively low cost. The transport system is made so that workers and equipment can be used effectively, where waste transport transport management is made based on the potential volume of waste collected at the TPS by balancing vehicle capacity (*Ambariski, 2016*).

1.3. VRP (Vehicle Routing Problem)

VRP (*Vehicle Routing Problem*) is a classic problem that is currently faced, both in industry and in government. With the aim of reducing transportation costs, determining the optimal route is a basic requirement that must be achieved (*Darina et al., 2021*). The route created must meet the needs by looking at the existing constraints and the available supporting factors, so that to achieve optimal results, a suitable road network is needed so that transportation costs can be minimised. The objectives of the vehicle routing problem according to (*Darina et al., 2021*) are as follows: (a). Minimise global transportation costs, depending on global mileage and for fixed costs associated with vehicle usage; (b). Minimising the number of vehicles used to serve all customers; (c). Balancing the route between journey time and vehicle load. In modelling the Vehicle Routing Problem, there are several variants that are extensions or developments of the previous ones, such as VRP with backhauls (VRPB), VRP with multiple trips (VRPMT), and VRP with time windows, all of which have different characteristics. The three variants can also be combined or combined into one, such as VRP with Backhauls and Time Windows (VRPBTW) and VRP with Backhauls, Multi Trips, and Time Windows (VRPBMTTW).

1.4. Simulated Annealing

Simulated Annealing (SA) is one of the optimisation algorithms that can be used for scheduling and finding the optimum route. One of the advantages of this algorithm is that it can solve the Vehicle Routing Problem (VRP), which is how to plan vehicle routes with minimum cost (Prana, 2007). Some previous research on the SA algorithm proves that this algorithm can provide solutions that are close to the global optimum in a short computation time (*Noviardianto et al., 2019*), (*Darsono and Stefani, 2022*), (*Adam et al., 2021*) and (*Nugracia, 2020*). Here are the steps of solving the SA algorithm (*Panggabean, 2005*):

a. Generate an initial solution called the current solution, symbolised by (s) and a high initial temperature T;
b. Generate a new solution s from this current solution using neighborhood search;

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c. Calculate the objective function against the current solution $f(s)$ and the new solution $f(s')$;
d. If $f(s') < f(s)$ then Update the current solution $s = s'$
e. If $f(s') > f(s)$ then s is accepted as the current solution if it satisfies the following conditions:
   1. Find the value of the Botzman probability factor $p = exp(|f(s') - f(s)|)/T)$;
   2. Generate a random value $z \in [0,1]$;
   3. If $p < z$ then update $s = s'$;
   4. Reduce the temperature;
   5. Repeat Steps 2 - 6 based on the cooling schedule, $T_{i+1} = \alpha T_i$ where $\alpha \in [0,1]$

2. Methodology

2.1. Figure Style and Format

The research framework of this activity starts from the research preparation stage, up to the production of documentation. The preparation stage includes literature study and field study to identify problems. The data collection stage is carried out through literature study and interviews with the Lhoksemawe city environmental office. The next stage is to determine the solution to the problems found. At this stage the research team discussed to find the right solution in solving the problems found. The next stage is system design using the waterfall method and system design using UML. In the final stage, the system will be built using the Simulated Annealing (SA) algorithm and PHP programming language. The following is a description of the research framework that will be carried out:

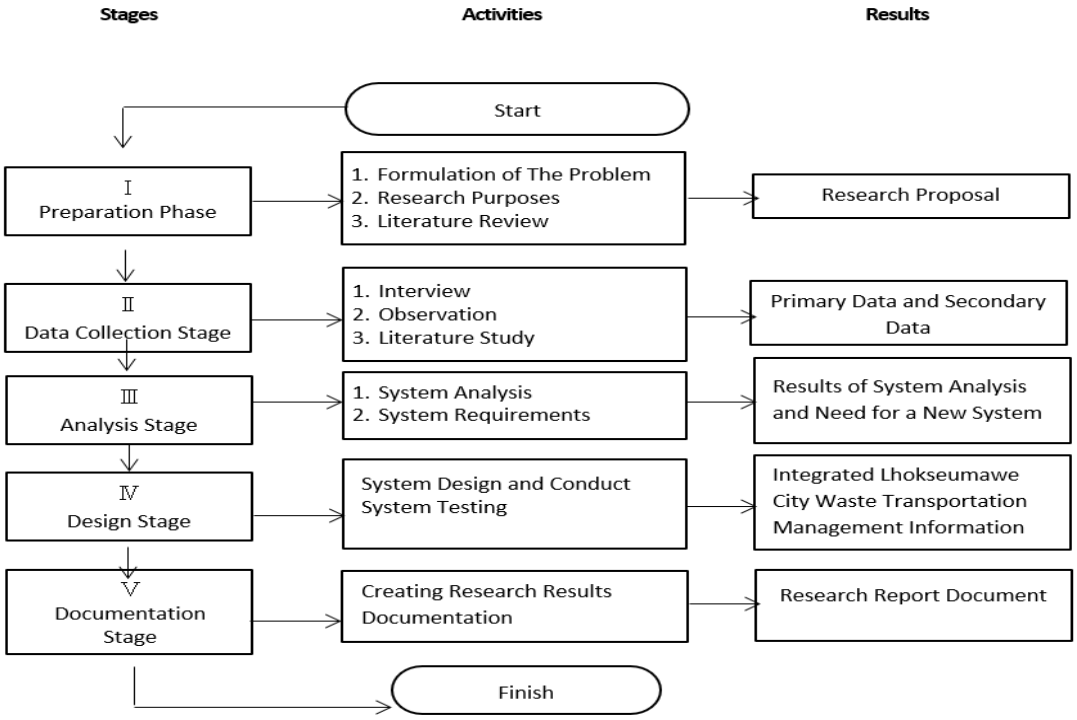

Figure 1.
Research Framework flowchart.

2.2. System Development Methodology

2.2.1. Data Collection and Preprocessing

Data collection is done through interviews and requests for data directly to the Lhokseumawe city environmental service. The data needed includes the amount of waste generated per day, the number of waste collection points, the number of waste collection fleets, the amount of waste transported per day, the initial route of the waste collection route, the location of the landfill, and other supporting data. The

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data collected starts from 2021 - 2023. The preprocessing stage has three stages, namely calculating the distance travelled between locations starting from the initial point of departure to the landfill, calculating the time taken by the transport vehicle from one point to another, and calculating the costs used during the transportation process with the price of fuel for each truck that transports waste.

2.2.2. Processing

The processing stages carried out are calculating the shortest distance with the SA algorithm and solving VRP by optimising the route. The initial step taken in the SA algorithm is to determine the initial route and several route options as alternative solutions to be tested. Then the route is calculated using the SA algorithm. The parameters used are initial temperature($\boldsymbol{T^0}$), final temperature ($\boldsymbol{T^1}$), temperature drop $^{\Delta}\boldsymbol{T}$ and temperature drop factor or Alpha (α). What is meant by the parameter $\boldsymbol{T^0}$ is the initial cost, $\boldsymbol{T^1}$is the limit for calculating costs, $^{\Delta}\boldsymbol{T}$ T is the determinant of cost reduction and α is the factor determining the cost reduction. The formula equation used in the SA algorithm is:

$$\boldsymbol{P_i(T) = k\, exp(-E_i|T)} \quad (1)$$

Where:

$\boldsymbol{P_i}$: Condition to be achieved
$\boldsymbol{exp}$: Exponent
$\boldsymbol{T}$: Temperature
$\boldsymbol{k}$: Constant
$\boldsymbol{-E_i}$: Energy Required

The route obtained in the SA algorithm calculation results will be processed into VRP to get the closest route that has the lowest cost, optimization of truck luggage and transportation time. The formula equation in VRP work is as follows:

$$minimum\ value\ f = \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{N} d_{ij}\ x_{ijk} \quad (2)$$

With the following decision variables:

$$\boldsymbol{x_{ijk}} \begin{cases} \boldsymbol{1, \text{if vehicle k serves } j \text{ after serving } i} \\ \boldsymbol{0, \text{otherwise}} \end{cases}$$

2.3. Testing and Evaluation of Results

The last stage is testing and evaluating the results that have been done at the processing stage. There are 2 stages of testing which are explained as follows:

1. SA algorithm parameter sensitivity testing This test aims to determine the impact of parameter changes on the decision variable and find out the parameters that affect the SA algorithm. The parameters tested are the initial temperature $\boldsymbol{T^0}$) and the temperature drop factor or Alpha (α). These parameters are adjusted to obtain maximum results.
2. Effectiveness of SA algorithms with initial conditions The use of SA algorithms to solve VRP is applied to problem solving. The effectiveness compared is cost, travelling time and distance travelled. Data is compared for effectiveness before and after applying the SA algorithm.

3. Results

In this section we will explain how to determine the optimal lhokseumawe city garbage collection route using the Simulated Annealing Algorithm. Some of the constraints contained in this study are:

a. The initial route of each vehicle starts from the waste truck storage warehouse (depot) and ends at the landfill.
b. The onward route of each vehicle starts and ends at the landfill site
c. Each route is only allowed one waste collection at each point.
d. Vehicle load must not exceed capacity during the waste delivery and collection process.

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e. Garbage truck vehicles only pick up garbage at authorised temporary disposal sites (TPS) and do not pick up garbage scattered along the route.

3.1. Completion Steps

The first step of the research is to determine the coordinates of TPS in lhokseumawe city using Google maps, in this study there were 21 TPS located in 19 different locations, the following table of TPS found:

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Table 1.

No.	Name TPS	Location TPS	Total	Coordinate		Waste load volume (m^3)	Waste load weight (Ton)
				Latitude	Longitude		
1	TP-01	City fish market	1	51.743.300.465.385	97.151.824.604.081	3	2,1
2	TP-02	Cunda bridge	1	5.177.609.224.689	97.130.966.438.378	3	2,1
3	TP-03	Prison	1	51.797.211.948.054	97.149.192.296.048	3	2,1
4	TP-04	Pasar Impress	2	51.836.980.248.889	97.142.149.096.048	6	4,2
5	TP-05	Cunda	1	51.750.212.578.548	97.130.529.418.679	3	2,1
6	TP-06	Brimob Company	1	51.360.689.732.979	97.107.415.589.353	3	2,1
7	TP-07	Lhok Mon Puteh Islamic Boarding School	1	51.612.177.166.281	97.129.517.397.292	3	2,1
8	TP-08	Politeknik	1	5.120.614.308.847	97.158.366.296.048	3	2,1
9	TP-09	General Hospital	1	51.221.308.850.208	97.156.367.699.476	3	2,1
10	TP-10	Paloh boarding school	1	52.101.562.314.618	97.084.714.788.057	3	2,1
11	TP-11	Punteut	1	51.160.453.588.676	97.168.242.087.696	3	2,1
12	TP-12	Blang Rayeuk	2	51.945.017.596.566	9.713.469.391.932	6	4,2
13	TP-13	Abu Bakar boarding school	1	51.153.571.741.178	97.172.158.280.235	3	2,1
14	TP-14	Kesrem	1	51.824.297.190.881	97.150.219.540.007	3	2,1
15	TP-15	BI Field	1	52.062.485.514.116	97.073.040.111.749	3	2,1
16	TP-16	Behind the Sub-district Office	1	51.157.968.479.427.400	9.717.340.129.009.140	3	2,1
17	TP-17	Abu Him boarding school	1	5.189.441.329.694.680	971.435.196.527.073	3	2,1
18	TP-18	Batuphat market	1	5.218.099.968.895.380	9.705.355.259.054.720	3	2,1
19	TP-19	Meunasah Mesjid	1	5.176.958.161.617.480	9.712.480.102.259.730	3	2,1

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The next step is to determine the number of garbage trucks available and the volume of waste that can be transported in a single collection. Here are the data:

Table 2.

No.	Transportation type	Total	Waste load volume (m^3)	Garbage load weight (Ton)
1	Medium dump truck	17	6	4.2
2	Pick Up	2	2	1.33

Next, determine the initial route travelled, starting from a predetermined starting point, namely the Waste Truck Storage Warehouse (depot). Next, the vehicle will visit the TPSs that have been determined according to its coordinates until it reaches the landfill through a route optimisation process with the following stages:

1. Randomly swap two polling stations on the route. The resulting new route is evaluated based on its travelling distance.
2. If the new route is shorter, it is accepted. Otherwise, the new route is accepted with a certain probability to avoid the local optimum.
3. Repeat this process until it reaches the minimum temperature or reaches the maximum number of iterations, with initialisation Parameters used in this study are:

Table 3.

Parameter SA	Nilai
T beginning	5000
T finale	1
Cooling Factor ($\propto$)	0,55
Iteration Each Temperature	100
Maximum Iteration	1000

4. Display the optimised schedule based on the coordinates of polling stations and also the distance travelled between polling stations.

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Table 4.

No.	Time range	Vehicle	Route	Cost	Distance	Time
1.	08:00 - 09:26	BL 123 ABC (Driver A)	POOL (Lhokseumawe City DLH Office) - TP-01 (city fish market) - TPAS (TPAS Alue Lim) - TP-02 (Cunda Bridge) - TP-03 (prison) - TPAS (TPAS Alue Lim)	Rp 75.913,27	21.69 km	86 minutes 2 seconds
2.	09:26 - 11:00	BL 234 BCD (Driver B)	POOL (Lhokseumawe City DLH Office) - TP-04 (impress market) - TP-05 (Cunda) - TPAS (TPAS Alue Lim) - TP-06 (Kompi Brimob) - TP-07 (Lhok Mon Puteh) - TPAS (TPAS Alue Lim)	Rp 55.604,11	15.89 km	94 minutes 4 seconds
3.	11:00 - 12:57	BL 345 CDE (Driver C)	POOL (Lhokseumawe City DLH Office) - TP-13 (Abu Bakar Boarding school) - TP-11 (Punteut) - TPAS (TPAS Alue Lim) - TP-19 (Meunasah Mesjid) - TP-10 (Paloh Boarding school) - TPAS (TPAS Alue Lim)	Rp 123.461,53	35.27 km	117 minutes 20 seconds
4.	12:57 - 14:28	BL 456 DEF (Driver D)	POOL (Lhokseumawe City DLH Office) - TP-08 (Politeknik) - TP-09 (General Hospital) - TPAS (TPAS Alue Lim) - TP-12 (Blang Rayeuk) - TPAS (TPAS Alue Lim)	Rp 93.117,91	26.61 km	91 minutes 56 seconds
5.	14:28 - 16:23	BL 567 EFG (Driver E)	POOL (Lhokseumawe City DLH Office) - TP-14 (Kesrem) - TP-17 (Abu Him boarding school) - TPAS (TPAS Alue Lim) - TP-15 (BI Field) - TP-18 (Batuphat market) - TPAS (TPAS Alue Lim)	Rp 118.851,86	33.96 km	115 minutes 45 seconds
6.	16:23 - 17:10	BL 678 FGH (Driver F)	POOL (Lhokseumawe City DLH Office) - TP-16 (Behind the Sub-district Office) - TPAS (TPAS Alue Lim)	Rp 50.948,71	14.56 km	47 minutes 28 seconds

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Here is a view of the SImpaskot application created:

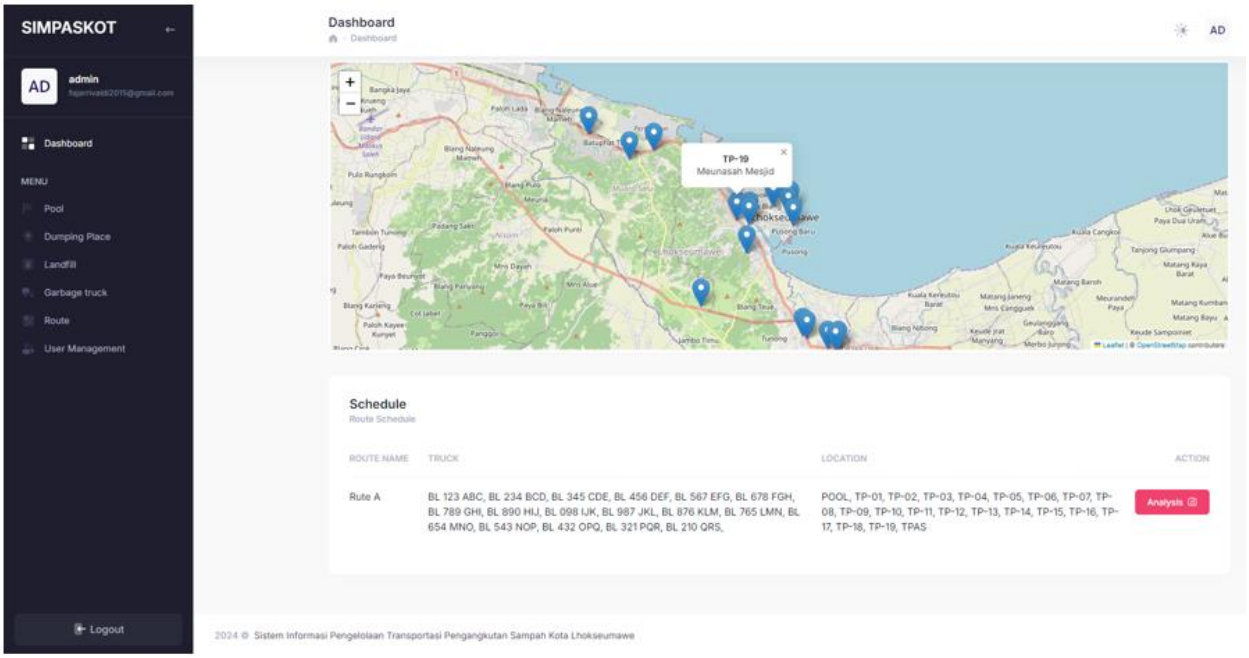

Figure 2.
Lhokseumawe city waste transportation management information system (SIMPASKOT) dashboard page.

In the picture above is the dashboard page of the Lhokseumawe City Waste Transportation Management Information System (SIMPASKOT). This dashboard displays an interactive map that shows the locations of Waste Disposal Sites (TPS) and transportation routes that will be optimised and travelled by garbage trucks.

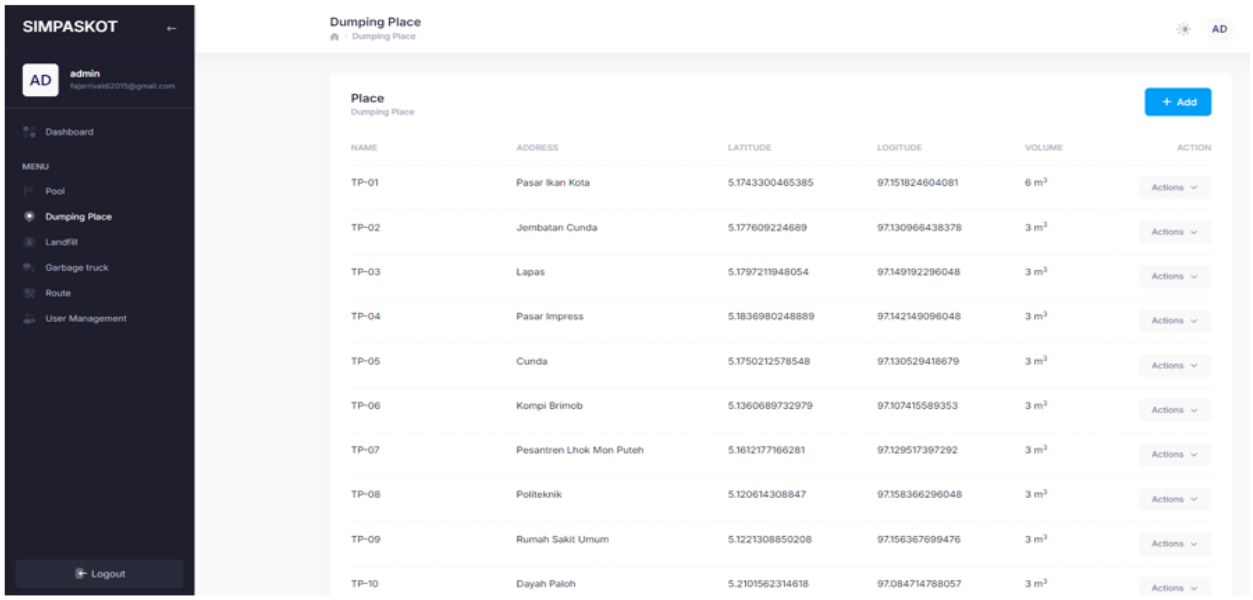

Figure 3.
Dumping place.

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In the picture above is the 'Waste Disposal Sites' page of the Lhokseumawe City Waste Management Information System (SIMPASKOT). This page displays a list of Waste Disposal Sites (TPS) locations in Lhokseumawe City.

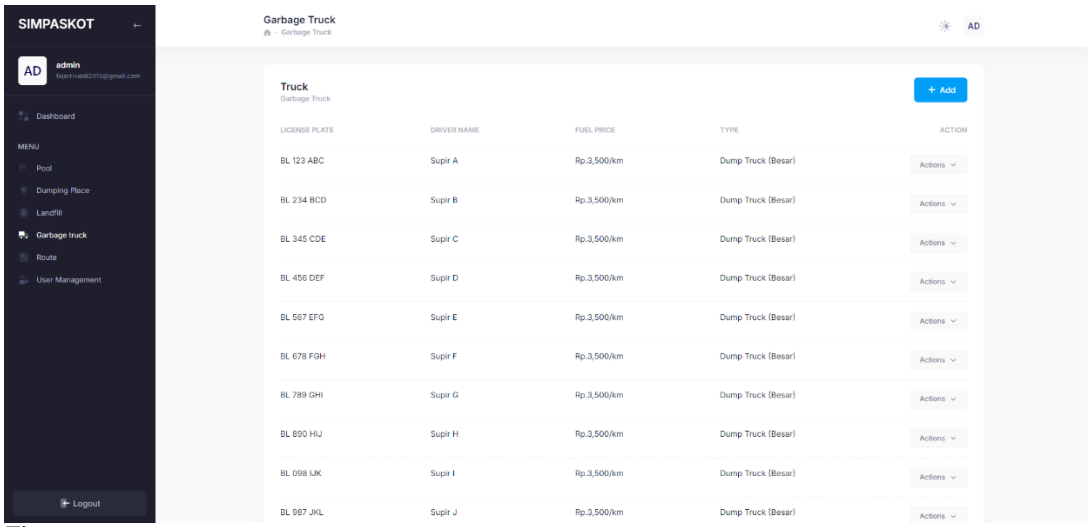

Figure 4.
Garbage truck.

In the picture above is the 'Garbage Truck' page of the Lhokseumawe City Waste Transportation Management Information System (SIMPASKOT). This page displays a list of garbage trucks used in the waste transportation system in Lhokseumawe city.

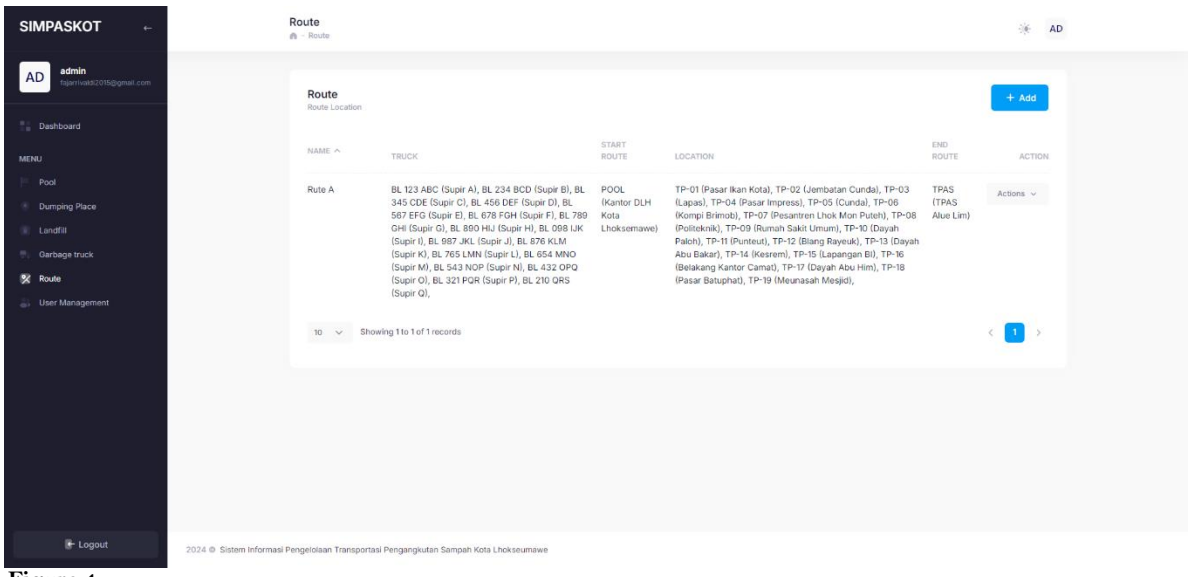

Figure 4.
Route.

In the picture above is the 'Route' page of the Lhokseumawe City Waste Transportation Management Information System (SIMPASKOT). This page displays a list of initial routes travelled by garbage trucks in the waste transportation system in Lhokseumawe city.

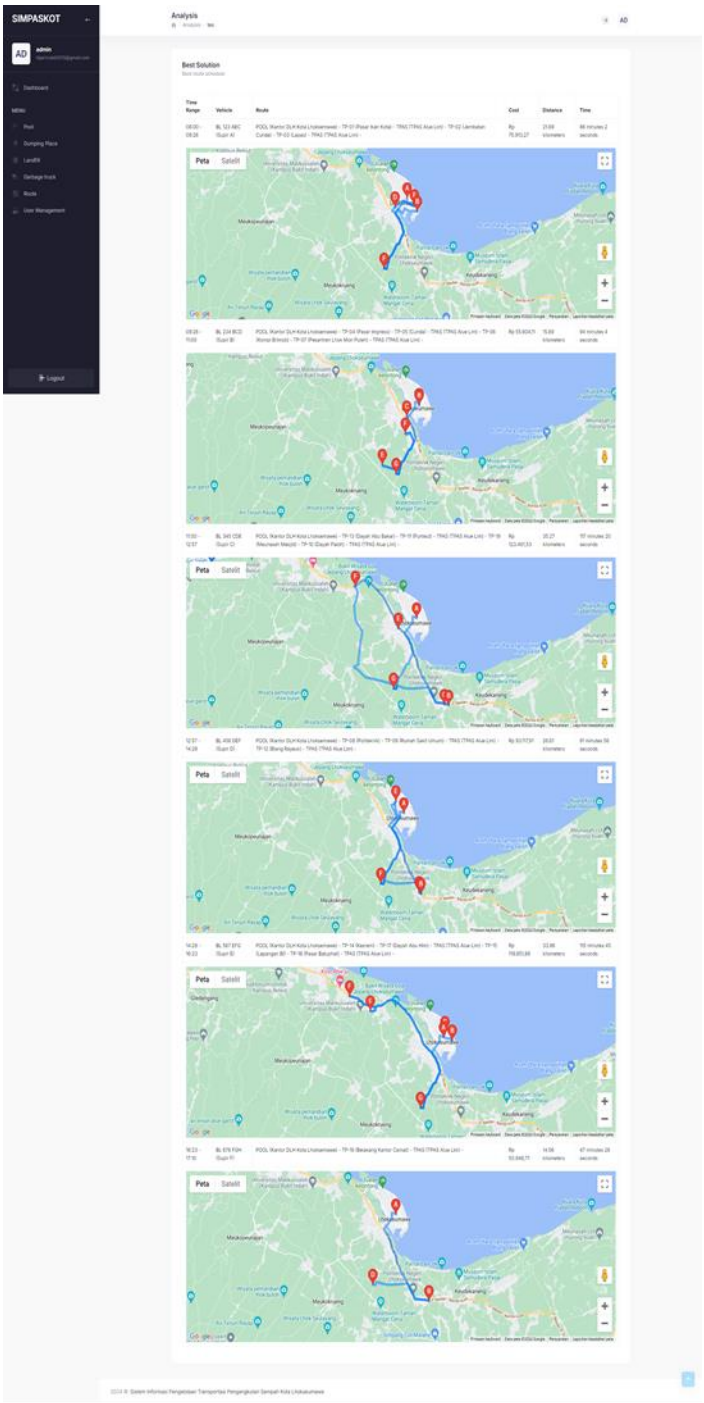

Figure 5.
Best solution view for waste transportation route schedule.

The figure above shows the best solution for the waste collection route schedule. This result was obtained through optimisation using the Simulated Annealing Algorithm.

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4. Conclusions

The results of this study indicate that the application of the Simulated Annealing Algorithm in the optimisation of waste collection routes in the city of Lhokseumawe provides various significant advantages over the current waste collection routes. The following are the results of testing the application of the SA method in scheduling garbage trucks in Lhokseumawe city conducted in this study:

Table 5.

Parameter	Before	After
Number of trucks	19 trucks	After
Operating costs / Day	> Rp. 1.000.000	Rp. 518.000
Transportation schedule	Each route is served by 3 trucks together at the beginning. The next truck picks up the waste that was not collected by the previous truck.	The transportation route is well scheduled, each truck has its own route without overlapping with other trucks.
Average travel time	Unpredictable due to overlapping routes and repeated waste collection	More consistent and predictive, with an average travel time reduction of 20%

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