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Decision Support System for Optimizing Rastra Distribution Routes Using Genetic Algorithm

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Abstract

Vehicle Routing Problem (VRP) is an optimal route design from a group of vehicles that deliver goods to a set of customers with a certain demand. VRP was widely studied as part of solving the distribution efficiency which minimizes the cost of traveled vehicle. Bulog Subdivre South Surabaya distribute Rastra to every village which has constraint of Multi depot and Split delivery (MDSDVRP). This study aims to minimize the traveled distance of MDSDVRP (Rastra distribution) using Genetic Algorithm (GA) and to find out the efficiency of the route solution. The research covers the steps to solve MDSDVRP using GA to generate feasible and efficient solution route. Then development of a Decision Support System (DSS) that applies the algorithm is implemented on web platform and the result of route solution is presented on the mobile platform. The system testing is carried out to test the user satisfaction (83.8%) which found that overall users were considered very agree, good, like for each component of user satisfaction. The traveled distance is compared between GA route and routes of the original data from 2013-2017. The efficiency of GA was evaluated and found that the traveled distance from the previous route is reduced by 3.7% (444 km) and in 2017 is reduced the distance traveled by 9.5 % (1,093 km). The GA can generate a better solution and optimize the distance than the original route.

Keywords: Decision Support System; Genetic Algorithm; Rastra Distribution; MDSDVRP

1 Introduction

In Vehicle Routing Problem (VRP) is an optimal route design from a group of vehicles that deliver goods to a set of customers with a certain demand. This notion of solving VRP was first proposed by Dantzig & Ramser (Dantzig & Ramser, 1959). There are many VRP variants, one of the VRP variants is the Multi Depot Split Delivery Vehicle Routing Problem (MDSDVRP). MDSDVRP is a VRP that has several depots (multi depots) as a constraint and in the process of sending goods to customers, it can be carried out in multiple deliveries (split delivery) by several vehicles. VRP has so far been widely studied with solutions through various approaches. One of the approaches applied is Genetic Algorithm (GA), a metaheuristic algorithm based on the mechanism of biological evolution. The diversity in biological evolution is the variation of chromosomes between individuals. GA was discovered by John Holland in 1975 as a search algorithm method based on the mechanism of natural selection and natural genetics. The conducted research by Karakatiˇc & Podgorelec (2014) stated that based on a survey to several paper provider sites, the number of GA used for solving VRP each year has increased, means that GA is still seen as capable method to solve VRP (Karakatič & Podgorelec, 2015).

Rastra is a support program in the form of rice for underprivileged families in the economic field which was previously called Raskin. Bulog Subdivre South Surabaya distribute Rastra have business process which involve Multi depot and Split delivery (MDSDVRP) constraint. GA will

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produce a solution in the form of a Rastra distribution route from each warehouse as a depot to each sub-district as a customer by optimizing the traveled distance by vehicles according to the constraints on the distribution of Bulog Subdivre South Surabaya. This study aims to find the optimization solution of MDSDVRP (Rastra distribution) using Genetic Algorithm (GA) and to find out the efficiency of the resulting route solution. The route solution will be presented to users in the form of a DSS as decision support for determining Rastra distribution routes.

2 Related Works

MDSDVRP is a VRP variant with multiple depot constraint, which also allows one customer to be served several times by several vehicles. MDSDVRP is a combination of VRP variants with multi-depot problems (MDVRP) with split delivery (SDVRP). Many studies on MDVRP have been carried out such as research paper of "A Decision Support System for Supply Chain Management based on PSO and GIS" which discusses the completion of MDVRP with the addition of limited vehicle constraint through the Modified Genetic Particle Swarm Optimization Method (MGPSO) algorithm (Lei & Li, 2009), as well as research on MDVRP with time constraints in a paper "New Assignment Algorithms for The Multi-depot Vehicle Routing Problem" (Giosa et al., 2002). The studies on SDVRP in the research of Archetti et al. (2008) about "An Optimization-Based Heuristic for the Split Delivery Vehicle Routing Problem" which discusses SDVRP with the Integer Programming algorithm (Archetti et al., 2008) and research on SDVRP with the addition of the minimum number of delivery constraint in a paper of "The split delivery vehicle routing problem with minimum delivery amounts" (Gulczynski et al., 2010) and the MDSDVRP in the study of determining depot locations and efficient routes in MDSDVRP (Ray et al., 2014) and solving MDSDVRP with Integer Programming-based Heuristics in his paper "The Multi Depot Split Delivery Vehicle Routing Problem: An Integer Programming Based Heuristic" (Gulczynski et al., 2011). Depot is the place of origin where the factory/warehouse stores goods to be delivered to the customer. MDVRP requires delivery of goods to customers from one of the depots with a fleet of vehicles based at each depot. Each vehicle originates from one depot, serves customers who are sent goods from that depot, and returns to the same depot. The goal of this problem is to serve all customers while minimizing the mileage required to serve customer requests. Meanwhile, the addition of the split delivery problem lies in the MDVRP constraint where previously one customer could only be served in one delivery route by one vehicle to be served in several delivery routes by several vehicles.

3 Research Method

This research covers the collecting data needed for solving MDSDVRP process using GA. Then the system development of Decision Support System (DSS) that applies the GA implementation inside. The data collection carried out includes four stages, namely:

1) Interview to find out the Rastra distribution business process for developing DSS system requirements and the MDSDVRP constraint model on Rastra distribution.
2) Retrieval of secondary data to determine data on the number of rice shipments per village, warehouse capacity data, capacity data and the number of vehicles for each warehouse, coordinate data for the location of the village and warehouse (Google Maps).
3) Retrieval of primary data to find out the coordinates of the location of the village and warehouses that have not been found from the secondary data collection stage by visiting the location directly.

Furthermore, GA is analyzed to find the right parameters then implementing GA in solving the MDSDVRP on the Rastra distribution according to the constraints and parameters. The final stage, implementing the algorithm in the DSS and comparing the efficiency of the resulting route solution with the route from the original data. Besides, system testing was also carried out through Blackbox testing, user satisfaction testing with questionnaires and validity testing of the GA route output.

As for the results of the process business interviews conducted, we obtained the constraints and objective functions in the MDSDVRP on the Rastra distribution. The following is the objective function and combined constraints of MDSDVRP by (Gulczynski et al., 2011) and the constraints

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found (fourth to sixth constraints) on Rastra distribution at Bulog Subdivre, South Surabaya.

Objective Function:
Minimize $\sum_{r \in R} \sum_{e \in E(r)} Ce$

Constraints:

1) Route r starts and ends at wk, for k ϵ {1,2, …, M} and for all r ϵ R (a route departs and returns to the same depot).
2) For all r ϵ R (vehicle load limitation)
$$\sum_{i \in V(r)} dir \leq Q$$
3) For all i ϵ V (all customer’s demands must be delivered)
$$\sum_{r \in R} dir = Di$$
4) Total demand fulfilled does not exceed the capacity of rice available in the warehouse.
$$\sum_{i \in V} Di \leq \sum_{j \in W} Gj$$
5) The cumulative load from customer i which is a highland village to the last customer on the subroute does not exceed the limit K, with i in bi, bi ϵ V(r), and m is the last customer in V(r).
$$\sum_{i}^{m} dir \leq K$$
6) The capacity of one warehouse must fulfill the rice demand to be sent, if it cannot fulfill it, another warehouse will fulfill it.
$$\sum_{riw \in R} dir \leq Gw$$

Meanwhile, V(v1, v2, ..., vn) is a collection of customers (village). A collection of warehouses (depots) is represented by W(w1, w2, …, wm) and B(b1, b2, ..., bn) in the form of a collection of customers or village in the highlands, where B ϵ V. Di is customer demand i while Gw is the capacity of the warehouse to w. The capacity of a vehicle is represented by Q. K is the load limit of a vehicle for delivery to district at highlands ce or cij is the distance between pairs of nodes e = (i, j) (customer-customer or customer-depot). The subroute, r ϵ R is represented in r and riw as the i-th subroute in the w-th warehouse. V(r) is a collection of nodes on a sub route and E(r) is a collection of edges or lines between 2 nodes on r. dir represents the amount of payload delivered to the customer.

4 Result and Discussion

Conclusions The process of developing GA to solve MDSDVRP based on the defined constraints. Process of solving MDSDVRP using GA in the distribution of Rastra in the South Surabaya Subdivre is illustrated in Figure 1.

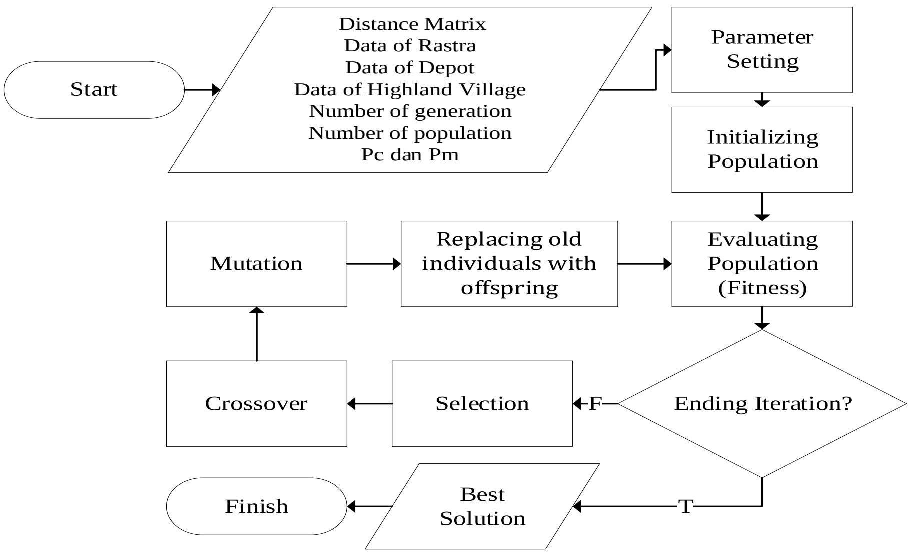

Figure 1. Workflow of Genetic Algorithm

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1) Parameter Setting

Table 1 presents the results of the GA parameter combination test. Based on the results in the table it is known that the tenth combination has the smallest average value of the other combinations, which is equal to 11,485 Km in 25 minutes of execution time. The table consist of the combination of NoP (Number of Population), NoG (Number of Generation), PC (Crossover Probability), PM (Mutation Probability)

Table 1. Parameter Combination

No	NoP	NoG	PC	PM	Distance Avg.	Time Avg.
1	50	100	0.75	0.001	11.494	23
2	50	100	0.75	0.0025	11.491	23
3	50	100	0.75	0.005	11.492	24
4	50	100	0.75	0.0075	11.488	23
5	50	100	0.75	0.01	11.495	22
6	50	100	0.60	0.001	11.496	25
7	50	100	0.60	0.0025	11.487	30
8	50	100	0.60	0.005	11.492	23
9	50	100	0.60	0.0075	11.491	21
10	50	100	0.60	0.01	11.485	25

2) Initializing Population

In the MDSDVRP representation in the route solution, a representation with multiple arrays is used and illustrated in Figure 2. The route solution contains a sequence of customers, each row contains a sub-route, which a collection of sub-routes forms a route solution. Each chromosome of individual has information about the route solution, namely the order of villages delivered on the sub-route, the origin depot (depot that serves sub-route), the total load (amount of demand load in a sub-route), the status of the highlands (status of sub-route if contains highland villages). Each generated individual must be feasible that satisfies each constraint.

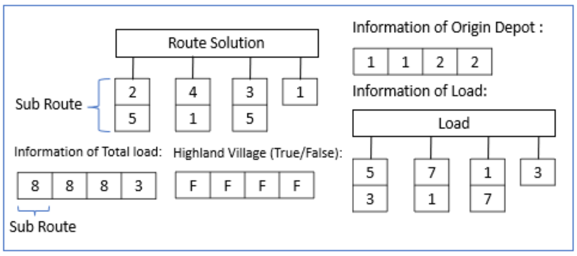

Figure 2. Illustration of MDSDVRP Representation with Multiple Arrays

Meanwhile, the initializing population process is based on the research of Surekha & Sumathi (2011) begins with village grouping that group the villages into warehouses based on the smallest distance from the village to the warehouse (Surekha, 2011). the route creation process by creating a sub-route with villages that have a demand that exceeds vehicle capacity (Generate Routes for Single Villages). The creation of sub-route based on the parallel version of the Clark and Wright Savings method (routing) which is made from a collection of villages in each warehouse (Wallace, 2012). In the routing process, sub-routes are formed without violating constraints (feasible). The final process is scheduling, sort the villages on each sub-route by finding the village closest to the warehouse, then looking for the next village that is closest to the previous village and so on. The Initial Population process is simply presented in Figure 3.

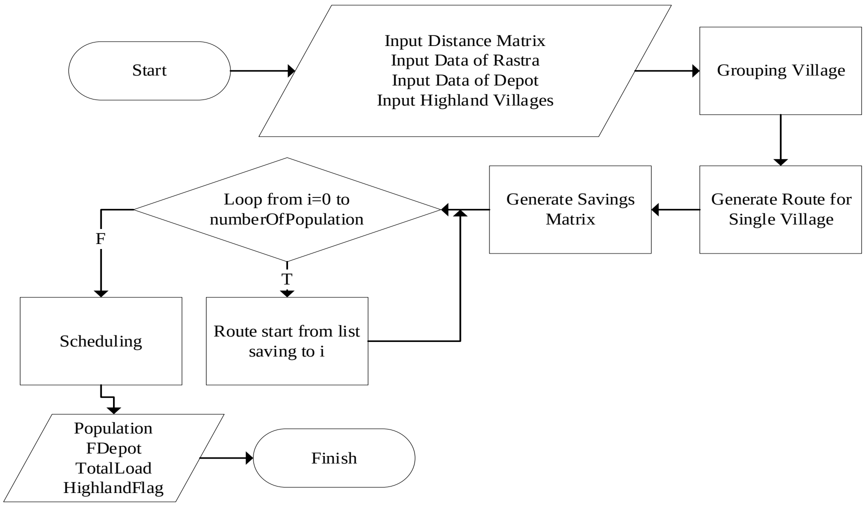

Figure 3. Flowchart of Initializing Population Evaluating Population

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Population evaluation is done by calculating the fitness of each individual. Fitness is total distance traveled by all individuals in the population divided by the total distance traveled in each route solution. The objective function is to minimize the distance traveled so that. The number of vehicles used is not considered. Individuals who have the best or greatest fitness will be stored as elites, the best solution.

3) Selection

selection process is selecting individuals as parents used in the recombination process which involves crossover and mutation using a Roulette Wheel (Ge, 1997). The details of the Selection process are explained through the flowchart in Figure 4.

	Fitness	Cumulative Fitness	P
Individual 2	3,612903226	3,612903226	0,232142857
Individual 4	3,862068966	7,474972191	0,464562239
Individual 1	4,307692308	11,7826645	0,741071429
Individual 3	4,307692308	16,09035681	1

Area in Roulette Wheel	
0 ≤ Random Numb. < 0,23214286	Individual 1
0,232142857 ≤ Random Numb. < 0,46456224	Individual 3
0,464562239 ≤ Random Numb. < 0,74107143	Individual 4
0,741071429 ≤ Random Numb. ≤ 1	Individual 2

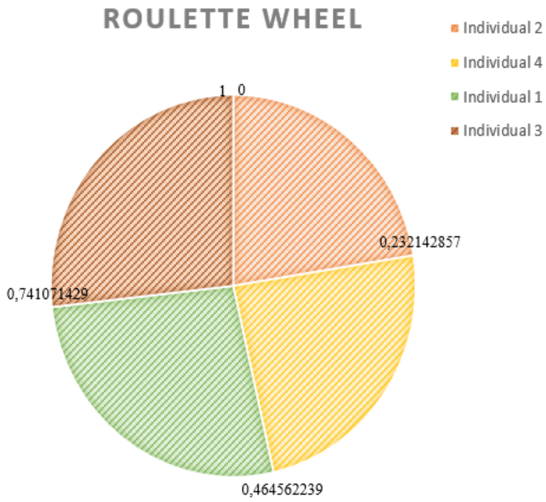

Figure 4. Flowchart of Selection Process

4) Crossover

Crossover is part of the process to produce offspring. Crossover only happens to the individual who is chosen based on Crossover Probability. The crossover process was carried out using the Improved Best Cost Route Crossover (BCRC) (Ombuki-berman & Hanshar, 2009). In the applied BCRC to this case, producing offspring is applied by producing a child from deleting chosen sub-route from one of the parents and re-insert the sub-route to the child while modifying it to be feasible. Figure 5 illustrates the way of producing child 1 by copying chromosome from parent 1. Then choose a sub-route from parent 2 randomly and delete the village of the chosen sub-route from parent 2 on child 1. In the illustration, the chosen sub-route contains village 3 and village 4, the child 1 (copy of parent 1) will delete this village from its chromosome. Next, return customers 3 and 4 to child 1 by searching for the ordered cost insertion and the feasibility status of the insertion (Figure 6). This return process is modified so that the process produces individuals who are still feasible. And vice versa to produce child 2. If in BCRC by Ombuki & Hanshar (2009), customer returns can cause individuals to become infeasible, then in this application this is eliminated so that customer returns based on cost insertion are only at feasible insertion locations. Then at this stage two parents and two children in the crossover process will be selected based on the smallest route distance so that only one individual from either parent or child becomes the offspring.

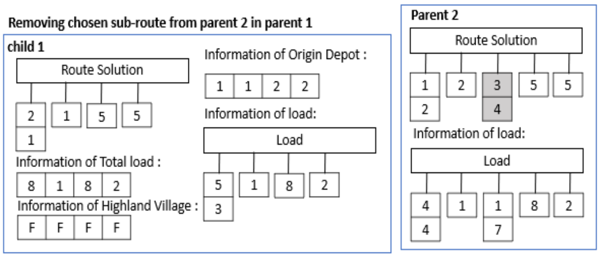

Figure 5. Deleting the chosen sub-routes process

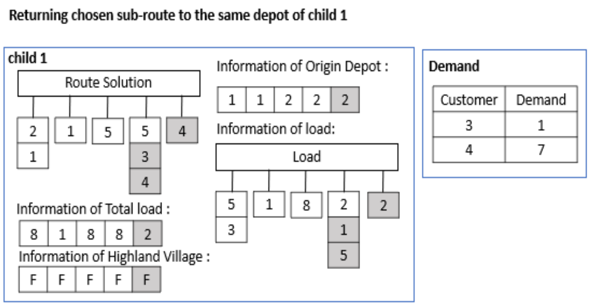

Figure 6. Returning the village back process

5) Mutation

Mutation is also a process of producing offspring. The random numbers is the deciding factor of the mutation. If the random number is less than the mutation probability, then the offspring will be mutated. Mutations are only performed on sub-routes in the same warehouse and non-highland sub-routes. The process begins by randomizing the warehouse affected by the mutation. Then search for non-highland sub-routes from the selected warehouse. From this search, you will get a collection of sub-routes that will be mutated. Next, find the beginning and end of the sub-routes to be mutated randomly. This random number find the cut point on the first selected sub-route and the cut point on the last selected sub-route. Mutations are carried out by Inversion Mutation (Ombuki-berman & Hanshar, 2009; Surekha, 2011), namely mutations carried out by inverting the gene sequence at two selected cut points. For example, if there is a customer at the chosen cut point is 5-3-4-4 will be reversed to 4-4-3-5 (Figure 7). If customer 4-4-3 is on a sub-route and customer 5 is on a new route because the previous sub-route is fully loaded. Then on a sub-route that has the same customer, it will be combined with customer 4 twice so that customer 4 is written once with the total load of the two load customers 4. This fixing sub-route is illustrated in Figure 8.

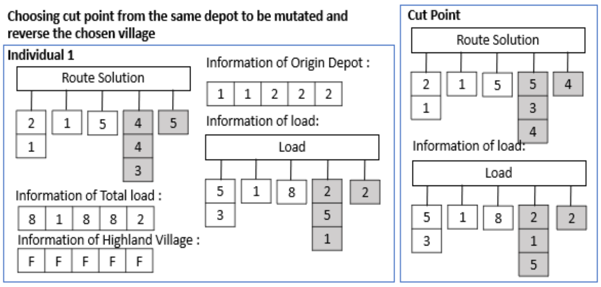

Figure 7. Inversion mutation process

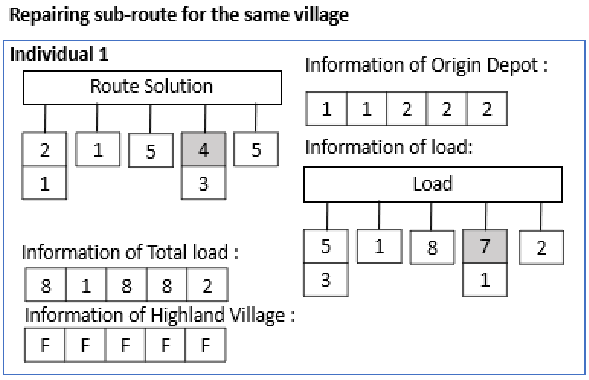

Figure 8. Fixing sub-route process

6) Replacing old individuals with offspring

Children or offspring is the new chromosomes produced in the crossover and mutation process, then replace the individuals in the old population. The new individual then becomes the next generation in a population.

7) Criteria for Ending Iteration

The end of the iteration is done when the generation has reached the number of generations that has been set.

The Developed GA is implemented with other supporting features as part of DSS. This DSS is developed in two platforms. The web platform using Angular framework for processing the data and generate the route solution of GA and route solution is displayed on the mobile platform using Ionic framework. The web platform will generate Rastra delivery routes, and these routes will be displayed on a map on the mobile platform to provide delivery route information to the driver (Satker). On the web platform, users at the Bulog Office can enter data of distributed Rastra for each sub-district or village. Users can manage constraints of rice stocks in warehouses and villages that are in the highlands. Next, after the data and constraints are set, the route results can be generated. Figure 9 presents the interface display of the DSS developed on the web platform. As for the mobile platform, users can view the routes generated by the GA (web platform) which are displayed on the map so that they can provide village location information to the driver. The user can also input the delivery status of the village as 'has been delivered' on the sub-route for the delivered village to provide information on the sub-

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route that has been and has not been delivered. Figure 10 presents the interface display of the system developed on the mobile platform.

From previous section, the right combination of parameters is obtained, namely a combination of parameters with a number of populations of 50, a number of generations of 100, a crossover probability of 0.6 and a mutation probability of 0.01 which generate the best result during the parameter test. The method used in each stage of the GA are the initial population process with grouping-routing (the parallel version of Clark and Wright Savings method-Scheduling), the selection process with the Roulette Wheel, the crossover process with Improved BCRC and the mutation with Inversion Mutation. The developed DSS is tested to determine system functionality using Blackbox testing. Test cases are generated based on the user scenario of each feature in the developed system. Based on testing on the web and mobile platforms, it shows that each test case can be passed successfully (PASS) which means functionally the system has been tested and is free from bugs. To test user acceptance, a test was carried out using a questionnaire which was distributed to the Operations and Public Services division of five respondents. Assessment of user satisfaction is carried out through a questionnaire that is built based on the question items (Doll & Torkzadeh, 1988). According to Doll & Torkzadeh (1988), the components of user satisfaction include content, accuracy, format, ease of use, timeliness which are then measured through twelve question instruments on the questionnaire. For each component of user satisfaction, it is calculated using the percentage index formula to find out the interpretation of the user's answer to each of these components. Calculations on the content component obtained a percentage index value of 91% which can be considered as a user who strongly agrees, well, likes the content on the system. In the accuracy component, a percentage index value of 84% is obtained which can be considered as a user who strongly agrees, well, likes the accuracy of the system. The format component obtained a percentage index value of 80% which can be considered as a user who strongly agrees, well, likes the format on the system. In the ease-of-use component, a percentage index value of 84% is obtained which can be considered as a user who strongly agrees, well, likes the ease of use (user friendly) of the system. In the Timeliness component, a percentage index value of 80% is obtained which can be considered as a user who strongly agrees, well, likes the timeliness of the system. The average percentage index value of all components that affect user satisfaction (content, accuracy, format, ease of use, timeliness) is 83.8% which can be considered as a user who strongly agrees, favors, or likes system satisfaction.

Then to calculate the efficiency of the route solution generated by the GA, the route solution is compared with the route in the original data. It was found that the GA route produced a smaller distance than the previous route in the original data. In data for 2013-2016 the routes produced by GA can reduce the distance traveled by 3.7% (444 Km) and in 2017 data by 9.5% (1,093 Km) that depicted in Figure 11. Testing the output validity of the Rastra distribution route is carried out by comparing the output generated by the program with the output from manual calculations. The test uses sample data with five villages, one of which is a highland village. The parameters used are a number of populations of 5, a number of generations of 1, a crossover probability of 0.8 and a mutation probability of 0.2. This validity test returns with the same produced outputs which can be concluded that the route results from the program are valid.

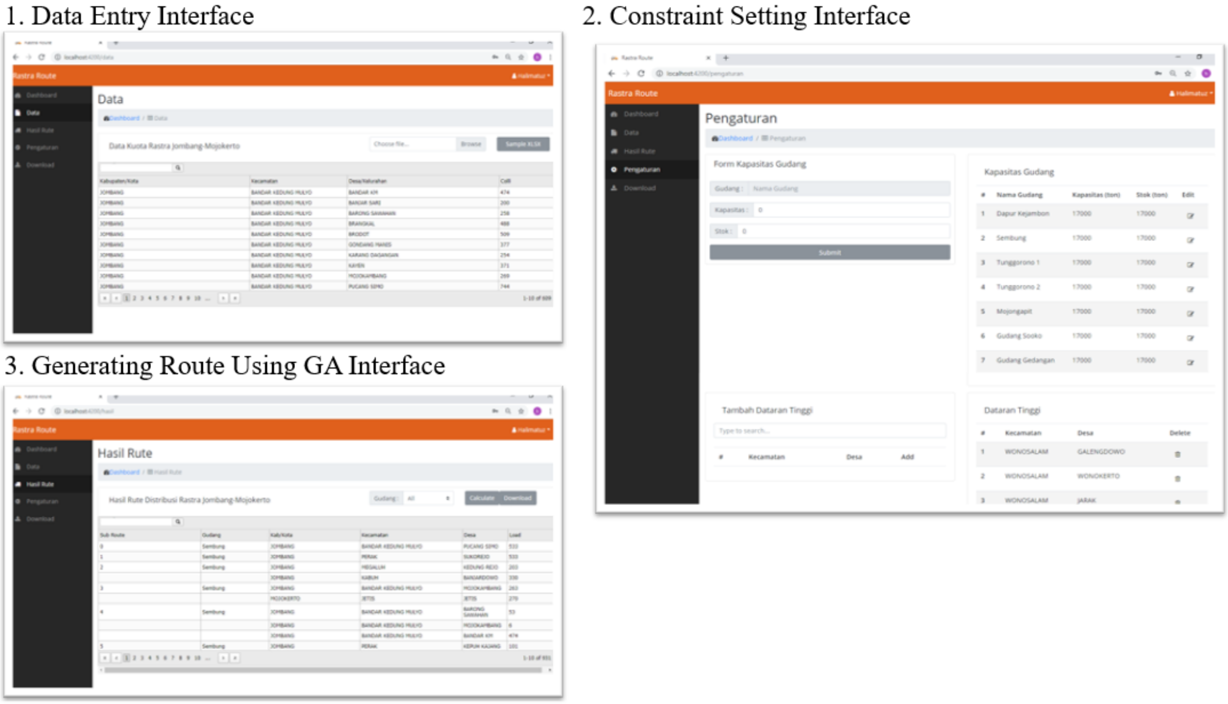

Figure 9. User Interface of DSS in Web Platform

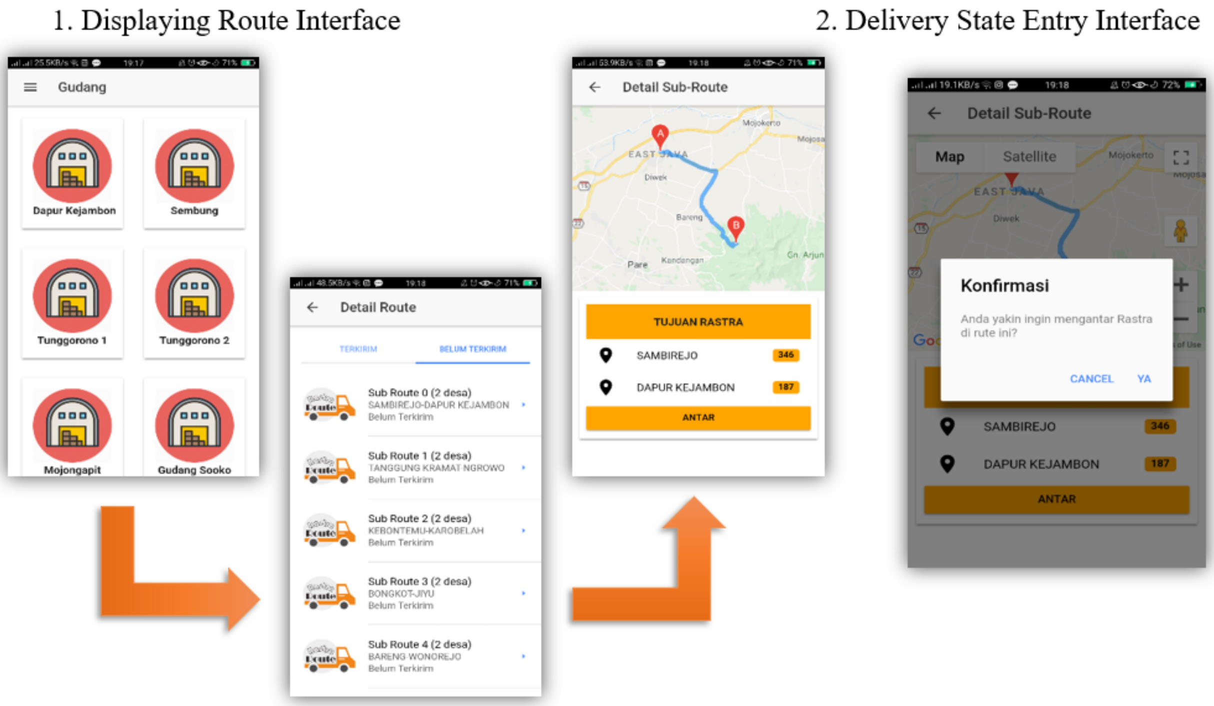

Figure 10. User Interface of DSS result in Mobile Platform

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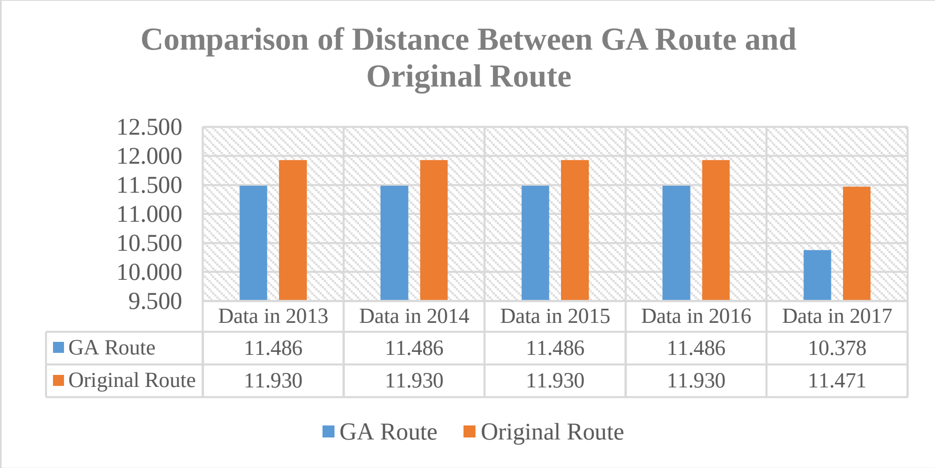

Figure 11. Efficiency of generated route GA

5 Conclusion

Solving MDSDVRP with homogeneous vehicles using GA produces feasible route solutions (fulfills all constraints) with initial population (Grouping-Routing-Scheduling) process using Clark and Wright Savings method, selection process with Roulette Wheel, Crossover with Improved BCRC and Mutation with Inversion Mutation. The parameters found to be the best combination were the number of populations of 50, the number of generations of 100, the crossover probability of 0.6 and the probability of mutation of 0.01 with an average execution time of 25 minutes and an average distance of 11,485 km. The results of the solving of MDSDVRP are used as a decision support for determining the Rastra distribution route which is implemented in the DSS Rastra Route with a web platform for generating routes with GA and a mobile platform for displaying routes interactively on a map. System testing is carried out through black box testing to test system functionality which obtained 100% passed for each test case. As for testing user satisfaction result 83.8% of overall users. This result can be interpreted as very agree, good, like each component of user satisfaction which cover content, accuracy, format, ease of use, timeliness. The traveled distance is compared between GA route and routes of the original data from 2013-2017. The efficiency of GA was evaluated and found that the traveled distance from the previous route is reduced by 3.7% (444 km) and in 2017 is reduced the distance traveled by 9.5 % (1,093 km). The validity testing is compared between output from manual calculations and produced route by GA. This validity test returns with the same produced outputs which can be concluded that the route results from the program are valid.

6 Future Work

The DSS system and MDSDVRP solution with the developed GA still have deficiencies which it is hoped that these deficiencies can be overcome in further research. So, the researchers suggest research using other method approaches in the process of population initialization, selection, crossover and mutation so that it is expected to produce even better solutions. As well as the use of methods other than GA in solving MDSDVRP such as the Tabu Search method, PSO or other methods so that they can produce better solutions.

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