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Application of Genetic Algorithms for Multiple Traveling Salesman Problems: A Case Study of Distribution of Sacrificial Animal Meat at the Islamic Center in Mataram City

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ABSTRACT

Islamic Center of Mataram is the center of Islamic religious activities. On Eid al-Adha and Tasyrik Day, animals are slaughtered. The average amount of animal meat that will be distributed annually is 7500 Kg of raw meat where will be distributed to 9 (nine) urban villages in Mataram City. In distributing the meat of the sacrificial animal, they only have limited time and staff, which is only done on 3 days of Tasyrik or sometimes only 2 days because the slaughtering is not carried out immediately after Eid prayer. Distribution starts from 12.00 - 16.00 every day. To help the problem of the distribution process, known as the Multiple Traveling Salesman Problem, the author uses a genetic algorithm to solve the problem. To build a software to implement Genetic Algorithm on the M-TSP problem in the distribution of sacrificial animal meat, several stages are carried out, starting from collecting data used to apply genetic algorithms, designing display prototypes and features to be able to process the data that has been collected, stages of system coding become a web-based system and finally testing the system that has been made. By implementing officer data and distribution locations which will then be tested using one of algorithms, namely the Genetic Algorithm. The accuracy and efficiency of the total distance that will be taken in making a distribution route using this algorithm where calculation is carried out by finding the largest fitness value from several kromosomal populations that are generated after going through crossover process and gene mutations on each kromosome. The result from this system tests with different method are 100% from using a black box, and 81.7 from using SUS testing which is classified as good. The best average fitness value resulting from testing the distribution system of sacrificial animal meat using the number of chromosomes 9 as many as 5 experiments using the number of generations 3, and the crossover parameter = 40% and mutation = 40% which is 0.045 with a total distance of 22.33 km. The design of this system is very useful for the administrators Islamic Center of Mataram ta'mir as a reference in determining optimal route in process of distributing sacrificial animal meat as well as for authors in applying the scientific theory they have.

1. Introduction

The Islamic Center in Mataram city is a center of Islamic religious activities. On Eid al-Adha and Tasyrik Day, animal slaughter is carried out. The amount of animal meat to be distributed each year averages 7,500kg of raw meat. Of course, sacrificial meat is less durable. The distribution of sacrificial animal meat at the Islamic Center in Mataram city still uses a manual process. A problem that often occurs in the distribution of sacrificial animal meat is that the route to the destination location is not known correctly by each committee on duty, which results in less efficient distribution in terms of time, energy, and fuel to find or pass inappropriate routes. Sacrificial animal meat will be distributed to 9 villages in Mataram City. Distribution is also limited to a time of only 3 days or sometimes only 2 days because slaughter is not carried out directly after Ied prayers. Distribution starts from 12.00 - 16.00 every day. Therefore, an optimization program is needed to speed up the process of distributing the meat of these sacrificial animals. In this Islamic Center, there is more than one committee member who is required to distribute meat to each village, of which more than one area passes. For this reason, the process of dividing distribution routes must be carried out optimally. This study aims to determine the shortest distance that will be passed by several distribution committees to several destination locations. This distribution problem is known as the Multiple Travelling Salesman Problem (M-TSP). M-TSP is the process of distributing goods to several places, where in this case the Islamic Center of Mataram City has more than one distribution committee. M-TSP is a development of the TSP (Travelling Salesman Problem) model where the salesman consists of more than one person and several salesmen will visit a number of points then return to the starting point with a note that each point can only be visited exactly once [1] [2]. In general M-TSP is a complex optimization problem, as the search for the order of all locations (e.g. cities) to visit, how to determine the shortest distance on the way past certain points. This problem is very important because the M-TSP model aims to determine the path of each salesman visit to get a minimum route and a smaller cost. Every salesman must visit exactly once every place and return to the starting place. Thus the M-TSP case is included in the NP-Complete category because this distribution or M-TSP case can reduce the problems previously mentioned. M-TSP problem solving can use heuristic methods that are able to solve problems close to or achieve optimum global solutions, one that can be used is the Genetic Algorithm [3].

In solving this M-TSP problem, the author applies the genetic algorithm method which is a search method that utilizes the mechanism of genetic surgery and natural selection. Unlike other conventional search methods, genetic algorithms work with a set of candidates for n (chromosomes) solutions known as populations. The end result of this genetic algorithm is a collection of chromosomes that have the highest fitness value of all generations [4].

2. Research Method

2.1. Stage of Research

First, confirm that you have the correct template for your paper size. This template has been tailored for output on the A4 paper size. If you are using US letter-sized paper, please close this file and download the file “MSW_USltr_format”.

This study is generally a study that aims to implement the Genetic Algorithm on the M-TSP problem in the distribution of sacrificial animal meat at the Islamic Center in Mataram City. Where the data obtained is in the form of committee data along with data on the locations of animal meat distribution that have been running at this time. The object of research is the most important thing in a study because all the variable data needed as input will be obtained from here to implement a method [5].

In this study, several equipment is divided into 2 (two) parts, namely software and hardware. The software needed includes the operating system and software or applications to build a system in implementing the algorithms used in M-TSP problems and hardware including a set of computers or laptops used. a. The hardware used in this study is a laptop with the following specifications:

a. CPU Intel Core i3 M 380 2.53 GHz
b. Memory RAM 4 Gb
c. Hard Disk 500 Gb

d. Graphic Card Intel(R) HD Graphics 3000.

The software used in this study is software or applications including:

a. Microsoft Windows 10 Pro

b. Visual Studio Code 1.55

c. Apache 2.4.46

d. Code Igniter 3 e. PHP 7.4.25 f. MySQL 8.0.

2.2. Maintaining the Integrity of the Specifications

This research requires data and information as a basis for conducting research activities. The data collection process in this study was carried out in the following ways:

1. Observation In making observations, the researcher selects the things observed and records everything related to the research topic. The observation made in this study is to examine the process of distribution activities for sacrificial animal meat distribution that has been carried out so far. In this study, data was obtained in the form of data from the committee in charge of distributing animal meat as many as 4 (four) people along with data on distribution locations, namely the district office as many as 9 (nine) places spread across the Mataram district of Mataram City [6].
2. Literature Study The use of document sources in the form of reading literature and journals obtained according to the same method is used to test and interpret the technique of the method used and relevant data related to the problem under study [7].

3. Result and Discussion

The system built is a web-based system in solving the problem of M-TSP distribution of sacrificial animal meat at the Islamic Center Mataram. The purpose of building this system is to assist the committee in dividing the route of each distribution in distributing sacrificial animal meat. Users can easily determine routes and minimize the distance for each committee that is available systemically. The discussion in this chapter includes the study stage of identifying systems used for related research objects and developing systems using prototype methods (Collection, Needs, Design, and Evaluation) [8-10].

3.1. Needs Analysis

The initial data needed to build the system is an analysis of user needs. In this study, some data relevant to the algorithm to be implemented was obtained by the researcher when conducting interview observations with one of the takmir administrators, namely Mr. Moh Soleh, such as data from the village head office in Mataram district as a distribution location.

Table 1. Distribution locations

No	Name	Address	Mileage (Km)
1	Mataram East	Flute Street No.9	2.4
2	Pagesangan	Jl. Guru Bangkol	3.2
3	Western Pagesangan	Jl. Meninting Raya No.54	3.7
4	East Pagesangan	Jl. Bangil IV No.7	4.1
5	Pagutan	Jl. Karno	5.1
6	West Pagutan	Jl. Batu Bolong No.46 RT.01	5.7
7	East Pagutan	Jl. Raden Mas Panji Anom	6.1
8	Pejanggik	Kebyar Street No.20	1.7
9	Punia	Purworejo Street No.7	1.9

3.1.1. Functional Requirements

a. The system can manage existing committee data, either adding changes or deleting data.

b. The system can manage existing location data, either adding changes or deleting data.

c. The system can create, determine, and divide routes for all committees to locations where animal meat is distributed systemically.

3.1.2. Non Functional Requirements

a. The system can be accessed via computer or mobile devices by users

b. The system can provide route information that is displayed in text along with visuals

3.1.3. Hardware Requirements

The hardware used in running this system is a laptop with the following specifications:

a. CPU Intel Core i3 M 380 2.53 GHz

b. Memory RAM 4 Gb V-Gen

c. Hard Disk 500 Gb Western Digital

d. Graphic Card Intel(R) HD Graphics 3000

3.1.4. Software Requirements

The software used in this study is software or applications including:

a. Microsoft Windows 10 Pro

b. Visual Studio Code 1.55

c. Apache 2.4.46

d. Code Igniter 3

e. PHP 7.4.25

f. MySQL 8.0

3.1.5. User Requirements

User needs are analyzed to find out what is expected of the developed system which can be seen in the Table 2.

Table 2. User requirements

No	User Requirements	Description
1	Input	User enters data of the sacrificial animal dividing committee User enters all distribution location data
2	Output	The system can display route recommendations along with locations for each committee
3	Process	The system can create and define routes with the calculation algorithm used

3.1.6. Use Case Diagram

It is an overview of the functional diagram of the actor in the system being built. Here's the use case diagram as shown in Fig. 1.

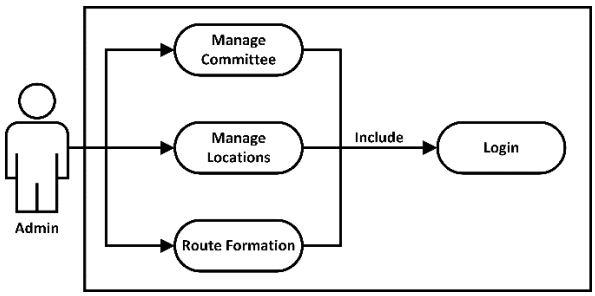

Fig. 1. Use case diagram

Fig. 1 explains that actors have tasks, among others, which are to add changes to delete committee data, locations, and carry out the route formation process.

3.2. Activity Diagram

3.2.1. Activity Diagram Login

Describes the flow of work activities when performing the process of authenticating users to log into the system environment and further manage data as shown in Fig. 2.

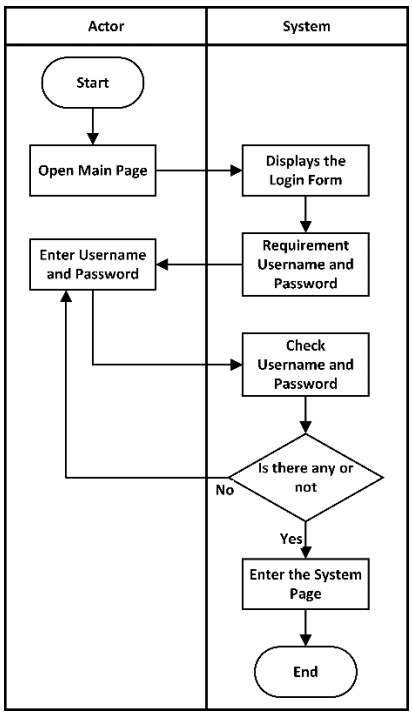

Fig. 2. Login diagram activity

3.2.2. Activity Diagram Manage Committee

Describes the flow of work activities while carrying out the process of managing committee data on the built system as shown in Fig. 3.

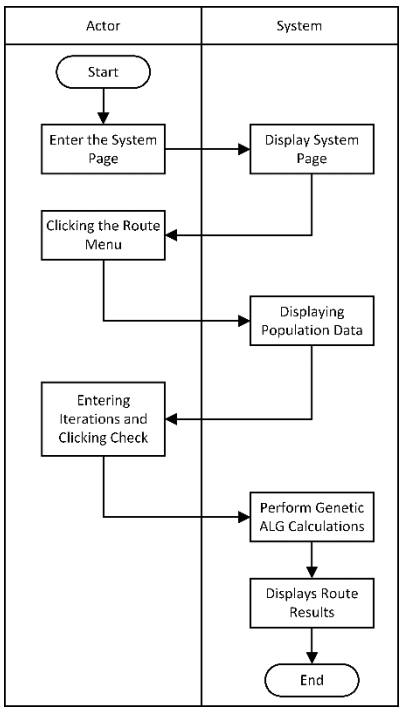

Fig. 3. Route formation diagram activity

3.3. System Design Results

At this stage, system development is carried out based on interface design that has been designed using Visual Studio Code software with PHP programming language.

1. Login Page

   Page where as a facility to authenticate users who act as admins before entering the system to be able to process the next data shown in Fig. 4.

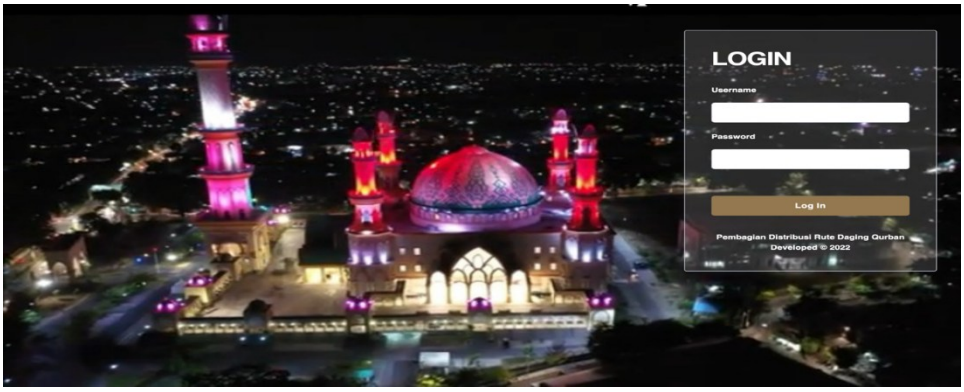

Fig. 4. Login page

   In Fig. 4. These 4 login pages are required to first enter the user's username and password to be able to carry out further data processing.

2. Committee Page

   In Fig 5, this page functions to process and process committee data, either adding, changing, or deleting data. To enter new committee data, click the Add button. There is a Change icon which is used to change committee data that has been entered, and a Delete icon which is used to delete data.

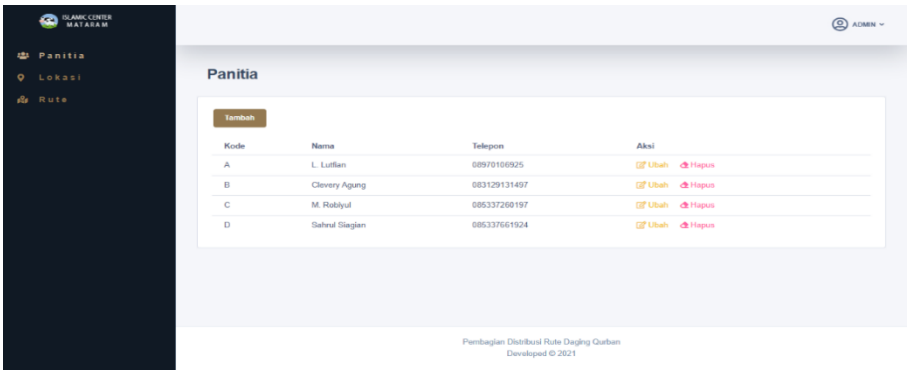

Fig. 5. Committee Page

   In Fig. 6, the added committee page explains how to add new data. Start by completing all the existing columns, then proceed by clicking the Save button to save data and the Cancel button to cancel adding data.

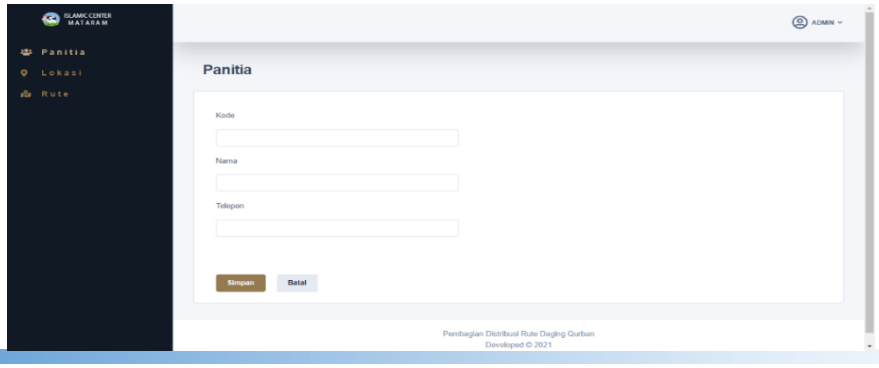

Fig. 6. Add Committee page

In Fig. 7, the change committee page explains how to change committee data. Start by completing all the existing columns, then proceed by clicking the Update button to update and save the data.

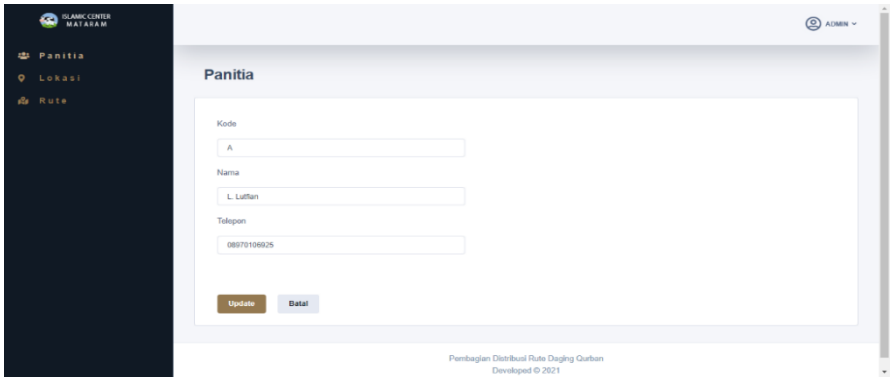

Fig. 7. Change committee page

In Fig. 8, the delete committee page explains how to delete data which is done by clicking the Delete icon then the system will display a message box confirming the deletion of committee data, if you agree to delete data, proceed by clicking the OK button and if canceling data deletion, continue by clicking click the Cancel button.

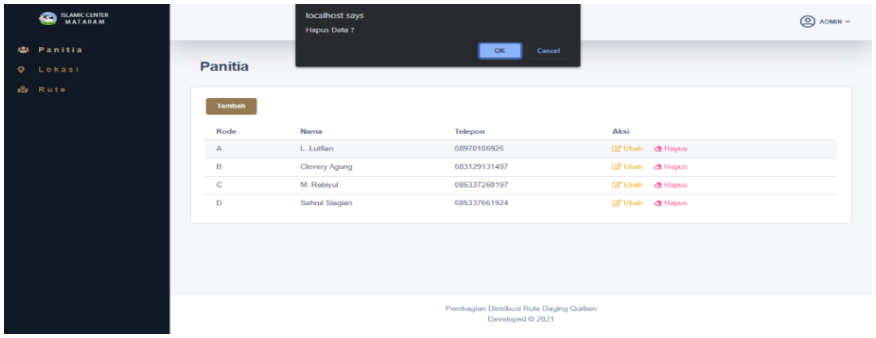

Fig. 8. Delete committee page

3. Location Page

In Fig. 9, this page functions to process and process location data, either adding, changing, or deleting data. To enter new location data, click the Add button. There is a Change icon which is used to change location data that has been entered, and a Delete icon which is used to delete data. There is also a search facility to find the name of the intended location.

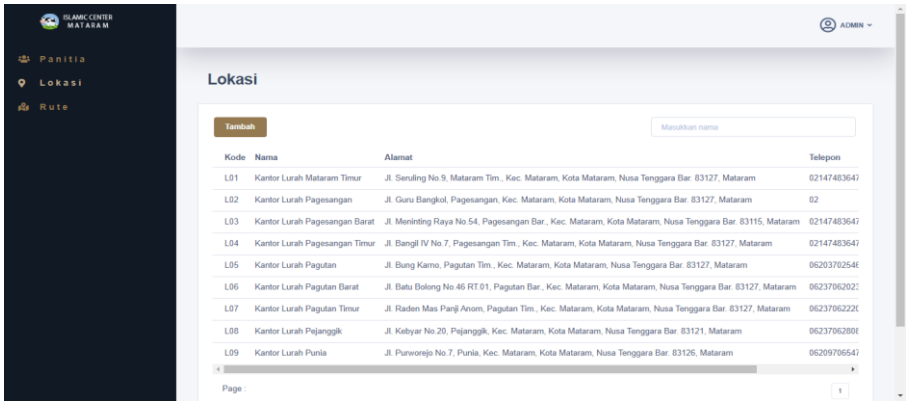

Fig. 9. Location page

In Fig. 10, the add location page explains how to add new data. Start by completing all the existing columns, then proceed by clicking the Save button to save data and the Cancel button to cancel adding data.

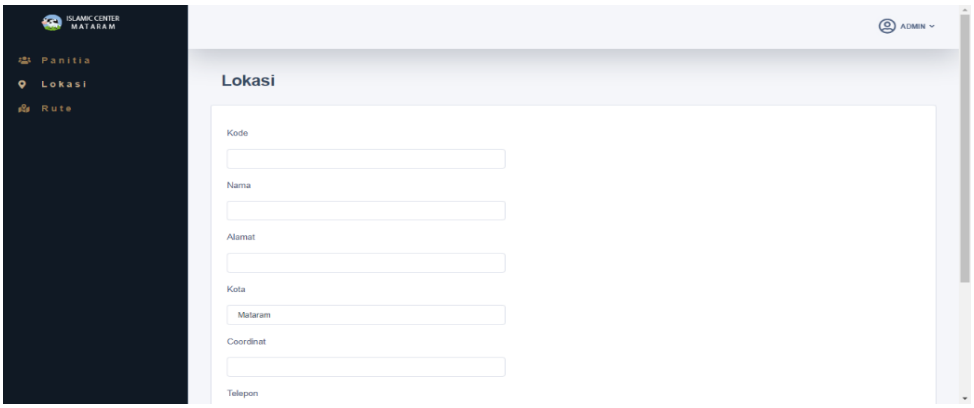

Fig. 10. Add location page

In Fig. 11, the change location page explains how to change location data. Start by completing all the existing columns, then proceed by clicking the Update button to update and save the data.

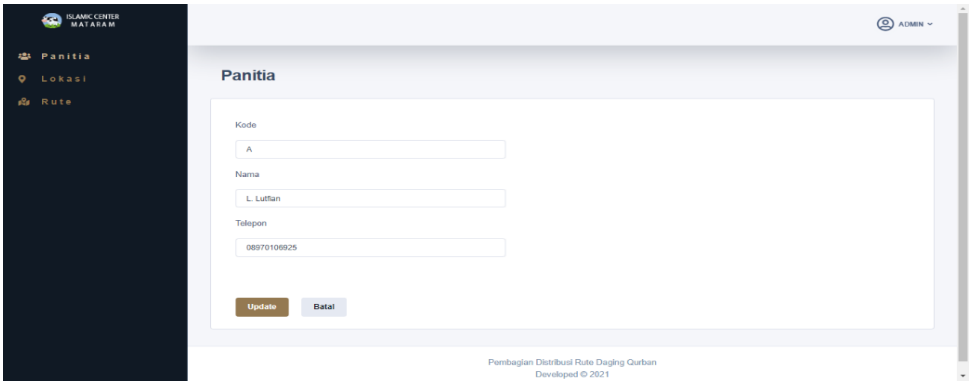

Fig. 11. Change location page

In Fig. 12, the delete location page explains how to delete data which is done by clicking the Delete icon then the system will display a message box confirming the deletion of location data, if you agree to delete data proceed by clicking the OK button and if canceling data deletion continue by clicking -click the Cancel button.

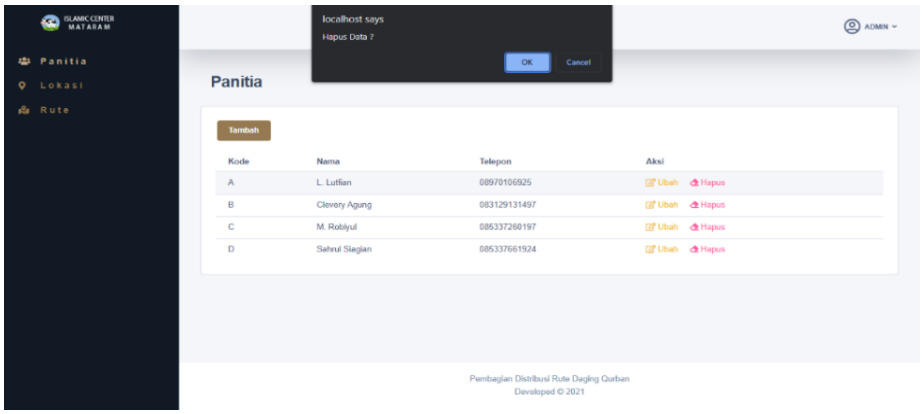

Fig. 12. Delete Location page

4. Route Formation Page

The page in Fig. 13 functions to create and determine the location of the distribution of each committee based on the calculation algorithm used. Start by completing all the parameter columns used, then proceed by clicking the Process button to start route formation.

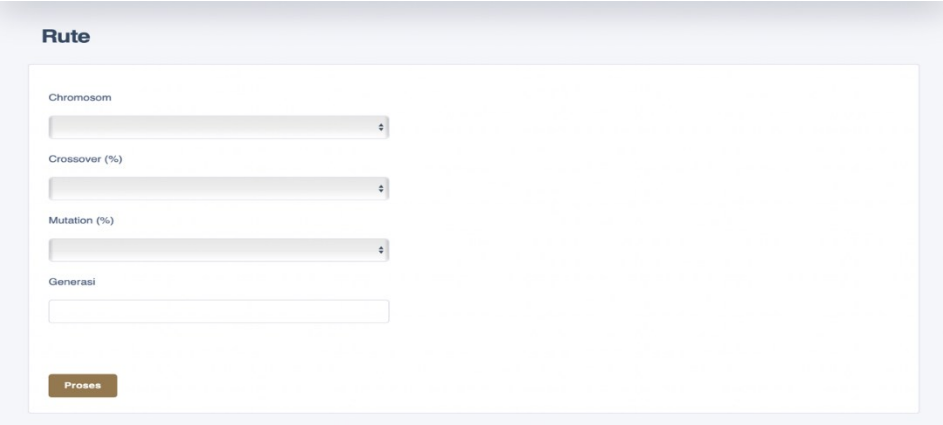

Fig. 13. Route parameter page

Furthermore, in Fig. 14 the system will form several chromosomes with a number of input parameters that have been determined by the user where each chromosome consists of several genes that are formed randomly, then the route formation process can be continued by clicking the Continue button.

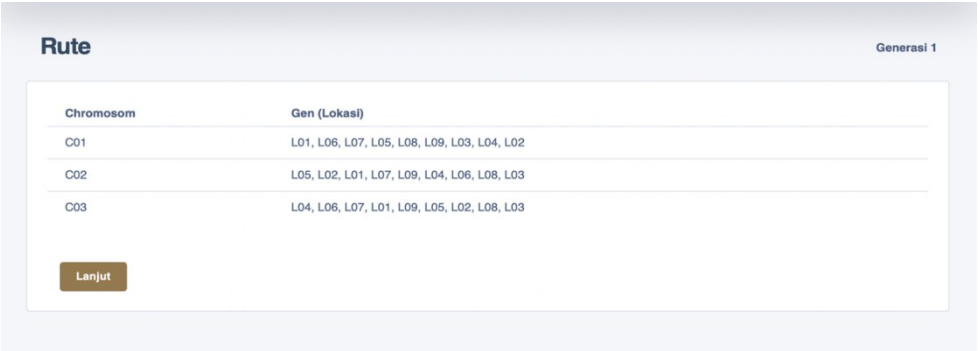

Fig. 14. Page of chromosome formation

Furthermore, in Fig. 15 the system takes 2 (two) chromosomes from the previous stage to carry out the crossover process to form new chromosomes as many input parameters as have been determined by the user for all existing chromosomes. Chromosome C01 will be crossover with Chromosome C02, C01 with C03, and C02 and C03, the selected crossover parameter is 40% so to determine the crossover results between C01 and C02, Chromosome C01 is taken 40% of the entire generation, namely L01-L06-L07-L05, then to fill in the next index, look at starting from Chromosome C02 index The 4th one is L-09, because L-09 was not in the previous index on the crossover result chromosome, L-09 enters the 4th index crossover chromosome, and so on in the existing chromosome crossover process. Then the route formation process can be continued by clicking the Continue button.

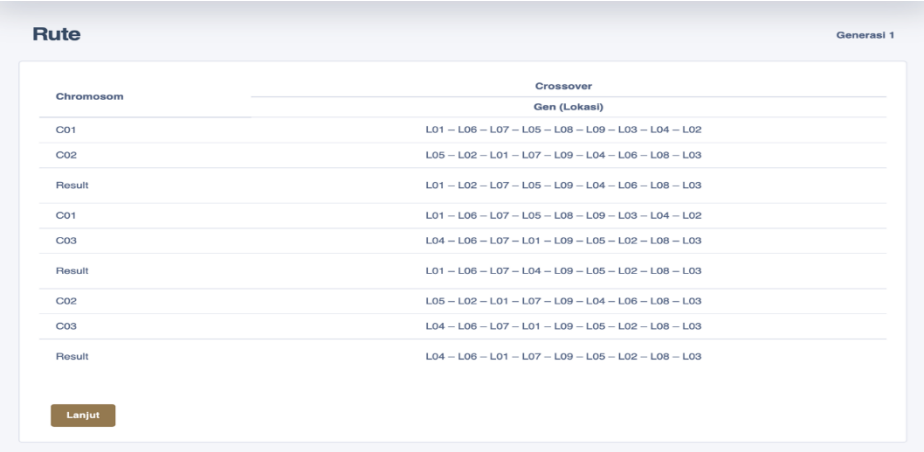

Fig. 15. Page crossover process

Furthermore, in Fig. 16, the system carries out the gene mutation process as many input parameters as have been determined by the user for each new chromosome obtained from the previous crossover process. Chromosomes C0102, C0103, and C0203 will be mutated. The selected mutation parameter was 40%, so to determine the result of the mutation between C0102, 40% of the gene was taken and then exchanged at the next index. 40% of the C0102 mutation process is L01-L02-L07-L05, exchanged its position with the next index in the amount of 40% of the index taken, then the rest remains at the last index, so that the result of mutation C0102 becomes L09-L04-L06-L08-L01 -L02-L07-L05-L03, and so on for other chromosomes, then the route formation process can be continued by clicking the Continue button.

Fig. 16. Page mutation process

Furthermore, in Fig. 17 the system will calculate the total fitness of each existing chromosome based on the total distance (Km) produced by each chromosome, according to the input parameter the number of chromosomes taken at the initial stage, then 3 Chromosomes with the highest fitness value will be taken for processing crossover iteration and mutation of route formation according to the input generation parameters that have been set by clicking the Next button.

Fig. 17. Fitness Calculation Page

5. Results of Route Formation

The results of the algorithm calculations that have been carried out to form the distribution route for each committee's location are depicted in Fig. 18.

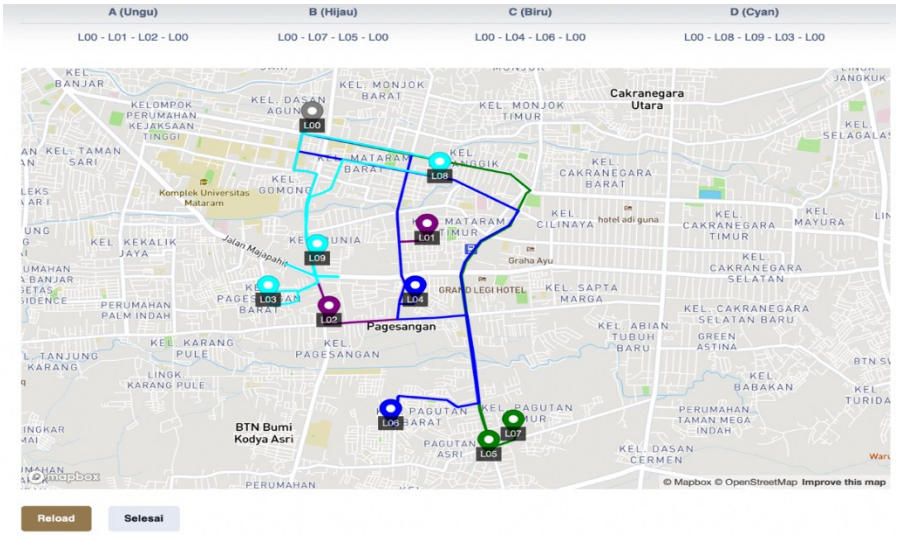

Fig. 18. Route Formation Results Page

3.4. System Evaluation

3.4.1. Black Box Testing

This test is carried out with the aim of checking that all functionality on the system has been running properly and according to what is shown in Table 3.

Table 3. Black Box evaluation test results

No	Scenario	Expected steps	Expected results	Conclusion
1	User Login	Users can enter the system	The system can forward user entry into the system	Valid
2	User Logout	Users can exit from within the system	The system can forward the user out from within the system	Valid
3	View Location Data	Users can view location data stored in the database	The system can display location data stored in the database	Valid
4	Add Location Data	Users can add new location data	The system can add new location data and save to in the database	Valid
5	Change Location Data	User can change location data	The system can change the location data and save it into database	Valid
6	Clear Location Data	User can delete location data	The system can delete location data from within the database	Valid
7	View Committee Data	Users can view committee data stored in the database	The system can display data committees stored in the database	Valid
8	Add Committee Data	Users can add new committee data	The system can add new committee data and save to in the database	Valid
9	Change Committee Data	Users can change committee data	The system can transform committee data and save it into a database	Valid
10	Delete Committee Data	User can delete committee data	The system can delete committee data from within the database	Valid

3.4.2. SUS Testing

The testing process is carried out by measuring the level of user satisfaction with the system created which affects the advantages and disadvantages of the system. The factors to be tested are factors that have been previously determined in the test design. The purpose of using a questionnaire is to obtain the data needed to determine the advantages and disadvantages of the system being created. It can be

seen in Table 4 that there are 10 questions in which there are 15 respondents with different answers so that the next process is calculating to find out the score results from the SUS.

Table 4. SUS test results

		Question									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
User	**1**	3	2	4	1	5	1	3	2	4	1
	2	5	1	4	2	4	2	5	2	4	4
	3	4	2	4	3	4	2	5	2	5	4
	4	5	2	5	1	4	1	5	2	4	3
	5	4	1	5	1	4	3	4	2	4	3
	6	5	1	5	1	4	1	5	1	5	2
	7	4	2	4	2	5	2	5	2	5	2
	8	4	1	5	2	4	1	5	2	4	1
	9	5	1	5	3	5	2	4	2	4	1
	10	5	1	5	2	5	1	5	1	5	3
	11	4	2	4	1	4	3	4	2	4	2
	12	4	2	4	4	4	3	4	2	4	4
	13	4	1	5	2	4	2	4	2	5	3
	14	4	2	5	2	5	2	5	2	5	2
	15	4	1	5	1	5	1	5	1	1	1

From the data from Table 4 it can be calculated by calculating for each odd numbered question, subtract 1 from the score (X-1) and for each even numbered question, subtract the value from 5 (5-X) then add the values of the even numbered statements and odd numbered. Then the sum result is multiplied by 2.5 and that is the result of the SUS Score for a feature or product, with that the SUS Score result can be one of the benchmarks for how good the usability of a product or feature is, so calculate it using a table.

Table 5. Calculation of SUS

		Question										**Total Shoes**	**Shoes THEIR**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
		X-1	5-x	X-1	5-x	X-1	5-x	X-1	5-x	X-1	5-x		
User	**1**	2	3	3	4	4	4	2	3	3	4	32	80
	2	4	4	3	3	3	3	4	3	3	1	31	77.5
	3	3	3	3	2	3	3	4	3	4	1	29	72.5
	4	4	3	4	4	3	4	4	3	3	2	34	85
	5	3	4	4	4	3	2	3	3	3	2	31	77.5
	6	4	4	4	4	3	4	4	4	4	3	38	95
	7	3	3	3	3	4	3	4	3	4	3	33	82.5
	8	3	4	4	3	3	4	4	3	3	4	35	87.5
	9	4	4	4	2	4	3	3	3	3	4	34	85
	10	4	4	4	3	4	4	4	4	4	2	37	92.5
	11	3	3	3	4	3	2	3	3	3	3	30	75
	12	3	3	3	1	3	2	3	3	3	1	25	62.5
	13	3	4	4	3	3	3	3	3	4	2	32	80
	14	3	3	4	3	4	3	4	3	4	3	34	85
	15	3	4	4	4	4	4	4	4	0	4	35	87.5
		SUS Score Results											**81.7**

From the results of Table 5, the SUS score was **81.7**, where the results of the interpretation of the SUS score stated that **81.7** was categorized as **GOOD**.

3.4.3. Population Size (Chromosome) Testing

In measuring population size (chromosomes) the right test aims to produce an optimal solution for the distribution system of sacrificial animal meat at the Islamic Center of Mataram City in terms of the best average fitness value and the resulting average shortest distance. The size of the chromosomes to be tested are 2, 3, 4, 5, 6, 7, 8, 9, and 10 chromosomes for 5 trials each using the number of generations 3, and the crossover parameter = 40% and the mutation parameter = 40%.

Based on the results of testing the size of the chromosomes regarding the distribution system of sacrificial animal meat at the Mataram City Islamic Center using a genetic algorithm, it was found that the greater the number of chromosomes, the resulting fitness value also tends to increase and the resulting distance also tends to be shorter.

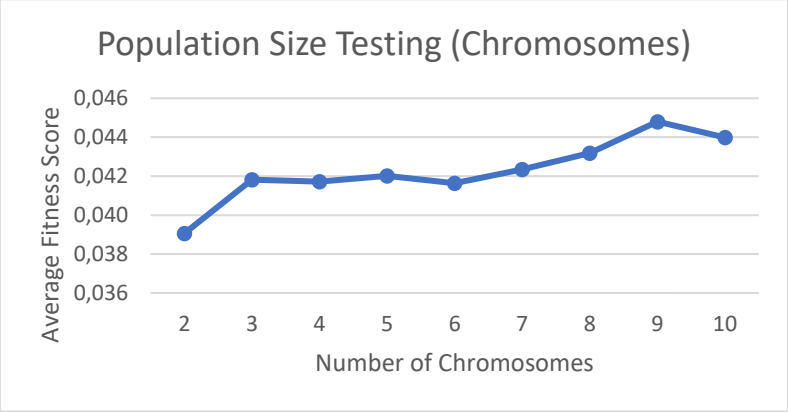

Fig. 19. Graph of the average fitness test

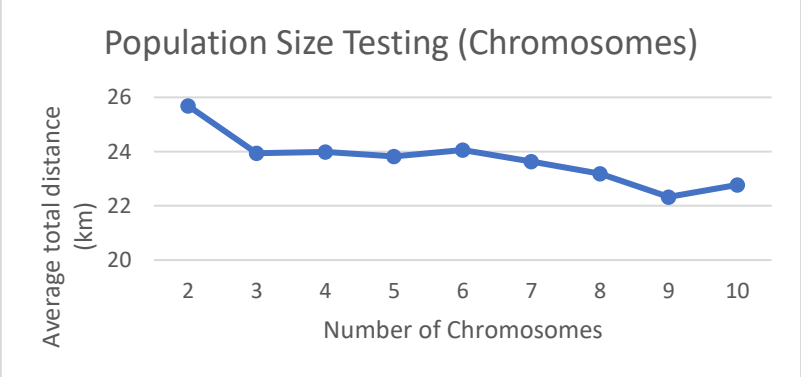

Fig. 20. Graph of testing the average total distance

It can be seen that the test results in Fig. 3.19 and Fig. 3.20, the number of chromosomes 2 to 5 experienced an increase in the average fitness value or a decrease in the total shortest distance. However, the number of chromosome 6 decreased and increased again on the number of chromosomes 7 to 9, but decreased again on the number of chromosome 10. Tests with a number of chromosomes that are too large require longer computational time and do not necessarily get a fitness value higher. Increasing the number of chromosomes also does not guarantee an increase in the fitness value obtained because the search area is getting bigger. The smaller the population size also does not guarantee a decrease in the fitness value obtained due to the random concept in the genetic algorithm. In testing the number of chromosomes with the most optimal fitness value is the number of 9 chromosomes with an average fitness value of 0.045 and an average total distance of 22.33 km.

4. Conclusion

The system that was built succeeded in determining and making routes for delivery locations for each existing committee effectively by implementing the algorithm used. With the design of this system, it can be used to store and manage committee data and distribution locations properly which are useful for dividing routes to make them more efficient. Black box testing on this system has a

score of 100% and an SUS score of 81.7 which is relatively good. The best average fitness value resulting from testing the distribution system of sacrificial animal meat using the number of chromosomes 9 for 5 trials using the number of generations 3, and crossover parameters = 40% and mutations = 40%, namely 0.045 with a total distance of 22.33 km. The number of each parameter in each experiment has an effect on the results, especially on the genetic algorithm population size variable.

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