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Case Study

An Application of Genetic Algorithm in Determining Salesmen's Routes: A Case Study

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A B S T R A C T

This paper presents a case study of determining vehicles' routes. The case is taken from a pharmaceutical products distribution problem faced by a distribution company located in the city of Padang, Indonesia. The objective of this paper is to reduce the total distribution time required by the salesmen of the company. Since the company uses more than one salesman, then the problem is modeled as a multi travelling salesman problem (*m*-TSP). The problem is solved by employing genetic algorithm (GA) and a Matlab® based computer program is developed to run the algorithm. It is found that, by employing two salesmen only, the routes produced by GA results in a 30% savings in total distribution time compared to the current routes used by the company (currently the company employs three salesmen). This paper determines distances based on the latitude and longitude of the locations visited by the salesmen. Therefore, the distances calculated in this paper are approximations. It is suggested that actual distances are used for future research.

INTRODUCTION

Distribution is an activity of transporting products from the location where the products are produced to other locations where the products are used by the consumers [1]. This activity is one of the key components in a logistic business [2]. The objective of a distribution activity is to transport products from the supply locations to the locations of the consumers such that the distribution cost is minimized [3]. A distribution company located in Padang, Indonesia (identity of the company is classified due to privacy consideration) has to deal with transporting pharmaceutical products to pharmacies (outlets) located in the city of Padang. In running its business, the company uses 3 units of 4-wheel truck and there are 324 outlets partnering with the company. Currently, the company does not have a policy, plan, or a structured method in determining routes that must be followed by the salesmen. Routes are only decided based on the experiences of the salesmen. Historical data show that outlets frequently experienced delays in receiving products that they had previously ordered from the company.

According to the historical data, see Table 1, the number of products that experienced delays from December 2016 to February 2017 were 143, 254, and 288 boxes, respectively. This was equivalent to 7% of total boxes that must be distributed by the company. On average, the duration of delay time was almost 27 hours. Moreover, some orders experienced delay for 2 days. This indicates that there is inefficiency in the current distribution policy of the company. This problem can be reduced if a structured methodology is applied by the company in determining routes that must be followed by its salesmen. The above routes determination problems can be classified as a multi traveling salesman problem (*m*-TSP) and can also be expressed as a linear programming problem [4]. Considering the number of outlets that must be served by the company, the solution space of the problem (routes combination) would be very large. Therefore a fast and accurate enough methodology needs to be applied.

Genetic algorithm (GA) is a very suitable method to solve the above problem [5,6]. GA can deal with linear and nonlinear optimization problems that have a large solution space [4]. Moreover, GA does not need a complex mathematical computation to find a better solution. Since GA is a heuristic method, there is no guarantee that the solution produced by GA is an optimal solution. GA can only guarantee a solution that is close to optimal.

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Table 1. Quantity Distributed by the Company from December 2016 to February 2017

Month	Quantity distributed (boxes)								%-Delayed	Average delay duration
	Week 1		Week 2		Week 3		Week 4			
	On schedule	Delayed	On schedule	Delayed	On schedule	Delayed	On schedule	Delayed		
12/2016	162	14	221	16	238	19	293	19	6.70%	26 hours 20 Minutes
1/2017	168	7	239	19	227	14	270	19		
2/2017	172	12	212	13	191	11	187	11		

This paper aims to reduce delays experienced by the aforementioned company in distributing its products to the outlets. This is done by modeling the problem as an *m*-TSP problem and employing GA to find better routes. A Matlab® based computer program is also developed to run GA. A sensitivity analysis is also presented in order to see the effect of changes in the number of salesmen available and capacity of the truck to the current solution provided by GA.

Supply Chain Management

Supply chain is all stages which are directly and indirectly included in fulfilling the requirements of plants, suppliers, transporters, warehouses, and customers [2]. Supply chain does not only include the movement of products from the factories to the consumers but also the movement of information and money in the supply network. In a business, supply chain includes all aspects of customers' needs fulfillment (product development, marketing, operations, distribution, finance, customer service). Figure 1 [2] depicts all processes involves in a supply chain.

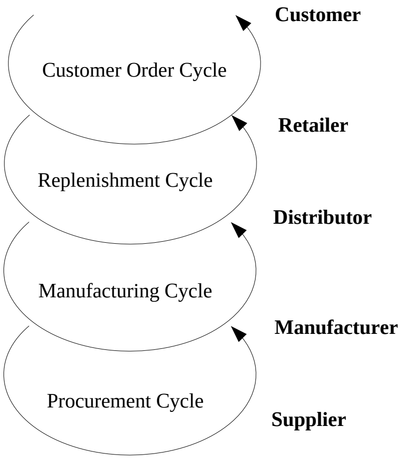

Figure 1. Supply chain processes [2]

There are three types of flows in a supply chain [1]: (1) Material flows – materials, parts, and products; (2) Financial flows – money including payment and invoices; (3) Information flows – available capacity and shipment status.

Traveling Salesman and Multi Travelling Salesman Problems

Traveling salesman problem (TSP) is known as one of the classical optimization problems. TSP involves a salesman who must visit cities and returns to his original location (depot) [7]. TSP is classified as a combinatorial optimization problem and falls into the category of an NP-hard problem. NP-hard problem is a kind of problem for which there is no known polynomial algorithm to solve the problem and the amount of time required to solve the problem grows exponentially as the size of the problem increases [8]. Some examples of TSP application in the real world are product distribution, garbage man route determination, and school bus route determination [7]. Mathematically TSP can be expressed as the following [9]:

$$Z = \text{Min} \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} x_{ij} = 1, \quad j = 1,2,3,\cdots,n-1 \text{ and } i \neq j \tag{1}$$

$$\sum_{j=1}^{n} x_{ij} = 1, \quad i = 1,2,3,\cdots,n-1 \text{ and } i \neq j$$

$$x_{ij} = \begin{cases} 1 & \text{, if there is a journey from } i \text{ to } j \\ 0 & \text{, if there is no a journey from } i \text{ to } j \end{cases}$$

where c_{ij} denotes traveling cost or distance from *i* to *j*.

In problem (1), the first set of equalities guarantees that a salesman arrives to a location from exactly one other location. The second set of equalities requires a salesman to depart to exactly one location after visiting a location. The last set of equalities is the binary constraint.

Multi traveling salesman problem (*m*-TSP) is the generalization of TSP [10]. In *m*-TSP there are $m \geq 2$ salesmen visiting *n* locations. A city will only be visited by a salesman. All salesmen may start from different locations or from the same location. An example of *m*-TSP is depicted in Figure 2 [10]. In the figure, there are 3 salesmen and node 1 represents the depot (origin). The resulting routes are $1 \to 3 \to 7 \to 1$ (salesman 1), $1 \to 2 \to 6 \to 1$ (salesman 2), and $1 \to 5 \to 4 \to 1$ (salesman 3) [10].

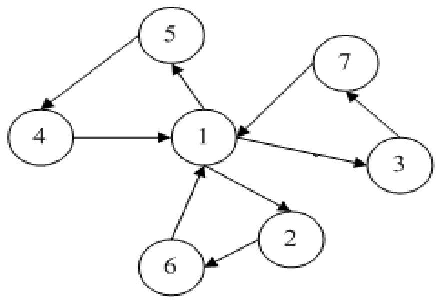

Figure 2. An example of *m*-TSP solution [10]

Mathematically *m*-TSP can be expressed as the following [11]:

$$
\begin{aligned}
& Z = \text{Min} \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \\
\text{s.t.} \quad & \sum_{i=1}^{n} x_{ij} = 1, \quad j = 1, 2, 3, \cdots, n-1 \text{ and } i \neq j \\
& \sum_{j=1}^{n} x_{ij} = 1, \quad i = 1, 2, 3, \cdots, n-1 \text{ and } i \neq j \\
& \sum_{i=1}^{n} x_{i1} = m \\
& \sum_{i=1}^{n} x_{1j} = m
\end{aligned}
\qquad (2)
$$

where,

Z = total distance
x_{ij} = 1, if there is a journey from i to j and 0, if there is no a journey from i to j
c_{ij} = traveling cost or distance from i to j

TSP and *m*-TSP are well established optimization problems. Abundant research regarding TSP and *m*-TSP can be found in the literature. Dhammpal *et al*. [12] employed ant colony optimization algorithm to find the shortest path in a problem consisting 10 cities that must be visited by up to 10 salesmen. Study conducted by Serna *et al*. [13] proposed a hybrid metaheuristic algorithm (a combination of GA and 2-opt algorithm) to solve a vehicle routing problem. The advantage of the proposed method is that the computational duration is short. Utamima *et al*. [14] also used a hybrid metaheuristic algorithm to solve a vehicle routing problem. The authors combined GA and Tabu Search, applied the algorithm to a gallon water distribution case study, and found that the methodology is capable in avoiding looping over the same solution. Other study, conducted by Razali [6], used GA to solve a large scale vehicle routing problem and observed that the offspring introduced during GA computation are not trapped in a local optimum.

Genetic Algorithm

Genetic algorithm (GA) was first developed by John Holland from the University of Michigan in 1975. GA is a metaheuristic search algorithm which simulates the evolution process and performs genetic operations [4]. GA modifies a population of individuals (solution candidates) through selection, crossover, mutation, and evaluation [15]. The selection is done randomly and the selected individuals are used as parents. Those parents produce offspring. After several generations, the population will lead to a near optimal or an optimal solution. In general, the structure of GA is presented in Figure 3 [4]. nThe general procedure of a GA is as follows [4]:

Begin
 $t \leftarrow 0$;
 initialize *P(t)*;
 evaluate *P(t)*;
 while (not termination condition) **do**
  recombine *P(t)* to yield *C(t)*;
  evaluate *C(t)*;
  select *P*(*t*+1) from *P(t)* and *C(t)*;
  $t \leftarrow t + 1$;
 end
End

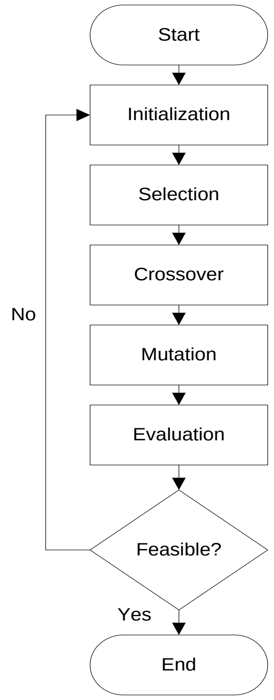

Figure 3. General structure of GA [4]

The characteristics of a problem that can be solved using GA are the following [16]: (1) The problem has a linear or nonlinear objective function and constraints; (2) The problem possibly has an infinite number of solutions; (3) The solution needs to be found quickly; (4) The problem has more than one objective.

GA is a heuristic searching method that is widely used in solving optimization problems. Liu *et al*. [17] developed a multi-objective optimization model in order to minimize electricity consumption in a job shop manufacturing system. GA is employed by the authors in order to find the solutions to the model. Based on the solution produced by GA, this study found that electricity consumption was significantly reduced. De *et al.* [18] applied GA in searching a solution to a multi-objective optimization. The model was employed to obtain optimal process parameters of a nickel-cobalt-phosphorus coating process. This research indicated that the implementation of GA results in a set of optimal combination of process parameters that maximizes the weight percentages of nickel, cobalt, and phosphorous yielded from the process.

In the area of sustainability, Spinnraker *et al.* [19] utilized GA in order to determine retrofit order of old buildings such that their total life cycle cost is minimized. Similar to [18], Zhang *et al*. [20] used GA to determine optimal operation parameters for a micro-turbine such that energy saving rate and exergy efficiency are maximized. Sangwan and Kant [21] used response surface methodology and GA to decide optimal

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process parameters such that energy consumption is minimized.

METHOD

In order to aid the aforementioned company in order to obtain routes that must be followed by the salesmen, GA is used. The procedure presented in Mayuliana *et al*. [5] is followed in this paper. The procedure is as follows.

Step 1: Determine initial chromosome and population

In this step, an initial population with the size of N_{pop} = 50 is used. Each individual in the population is represented by a two-part chromosome. Figure 4 illustrates the two-part chromosome.

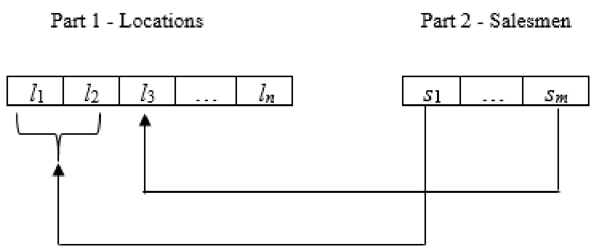

Figure 4. Structure of the two-part chromosome [5]

As it can be seen from the figure, a chromosome consists of two parts, part 1 represents the locations to be visited and part 2 represents the salesmen. The arrows indicate the number of locations visited by a salesmen. Now, let's define that n is the total number of locations to be visited, m is the number of salesmen, and s_i be the number of locations to be visited by the ith salesman. Then, a chromosome is said to be valid if it fulfills the following expression.

$$s_1 + s_2 + \cdots + s_m = n, \text{ where } s_i > 0 \text{ and } i = 1, 2, \ldots, m. \quad (3)$$

Step 2: Generate distance matrix **D**

In this paper, the distance between two locations is approximated using Euclidean distance method. First, latitude and longitude of the locations are identified (this can be determined using Google Maps®). The latitude and longitude are then converted into degree minutes and second (DMS) format. Finally, the DMS format of the latitude and longitude is converted into a distance unit, in this case in kilometer (km). The Euclidean distance between two locations is obtained using the following equation.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (4)$$

where,

x_i and x_j = latitude locations (in km) of the ith and jth locations.
y_i and y_j = longitude locations (in km) of the ith and jth locations.

By utilizing d_{ij}, a distance matrix **D** is generated. The diagonal of **D** are zeros. The distance matrix **D** is illustrated below.

$$\mathbf{D} = \begin{pmatrix} 0 & d_{01} & \cdots & d_{0n} \\ d_{10} & 0 & \cdots & d_{1n} \\ \cdots & \cdots & 0 & \cdots \\ d_{n0} & d_{n1} & \cdots & 0 \end{pmatrix} \quad (5)$$

In the above matrix, subscript 0 means the origin. Therefore d_{01} means the distance in km between the origin and location 1. By using roulette wheel method, routes visited by salesmen are then determined. For example, in the chromosome depicted in Figure 5 [5], it is assigned that salesman 1 visits locations 1, 2, and 3; salesman 2 visits locations 4 and 5, and salesman 3 visits locations 6, 7, 8, 9. In the example s_1 = 3, s_2 = 2, and s_3 = 4.

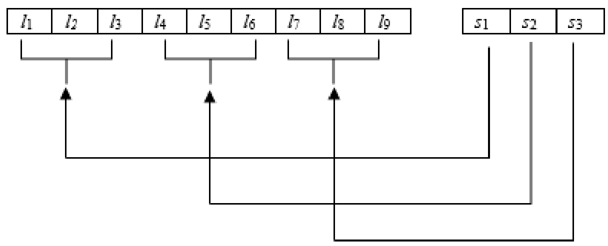

Figure 5. Example of a two-part chromosome [5]

The routes can be represented by an attendance matrix **X**. The size of **X** is the same as the size of **D** that is a ((n + 1) × (n + 1)) matrix. For the example depicted in Figure 5, the size of **X** is 10 by 10 and is presented below.

In the matrix **X**, x_{ij} = 1 means that a salesman travels from the ith location to the jth location, otherwise x_{ij} = 0. Therefore total distance travelled by the salesmen represented by the ith chromosome can be computed using equation (6).

$$\mathbf{X} = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$h_p = \sum_{i=0}^{n} \sum_{j=0}^{n} x_{ij} d_{ij} \quad (6)$$

Step 3: Calculate fitness value

Fitness value is used to evaluate the eligibility of a chromosome. Fitness value of the ith chromosome, f_p, p = 1, 2, …, N_{pop}, is calculated using the following equation.

$$f_p = \frac{1}{h_p} \quad (7)$$

f_p is calculated for all chromosomes from the initial population N_{pop}. Then, the cumulative probability of the pth chromosome $Pcum_p$ is computed using equation (6).

$$Pcum_p = \frac{\sum_{i=1}^{p} f_p}{\sum_{i=1}^{N_{pop}} f_p} \qquad (8)$$

Step 4: Select elite chromosomes

To select elite chromosomes the roulette wheel method is used. The first step is to generate a series of uniformly distributed random numbers between 0 and 1, $R_p \sim U[0,1]$, $p = 1, 2, \ldots, N_{pop}$. If $Pcum_p \leq R_p$ then the pth chromosome is selected as an elite chromosome. The number of elite chromosomes that are selected is denoted as N_{elite}. N_{elite} is an even number and, in this paper, its value is set equal to N_{pop}.

Step 5: Crossover

The members of elite chromosomes are then selected for crossover. The method of crossover used in this paper is the *Order I Crossover* (OXI). The number of chromosomes that will be used for crossover must satisfy $2 \leq N_{cross} \leq N_{elite}$ and N_{cross} must be an even number. Each pair for crossover will result in one offspring chromosome. In order to do the crossover process, first the crossover probability $P_c = 0.5$ is utilized and then a series of random numbers $R_p \sim U[0,1]$ is generated. If $R_p \leq P_c$ then the pth member of elite chromosomes is selected for crossover. This process is done until all elite chromosomes have a mate. Figure 6 illustrates how the crossover process used in this paper [5]. In the figure, for part 1 of the chromosome, the underlined consecutive genes from Parent 1 are randomly selected. This random selection is done by generating 2 random numbers, R_1 and R_2, where $R_1, R_2 \sim U[1,9]$ and $R_1 < R_2$. In the example depicted in Figure 4, $R_1 = 4$ and $R_2 = 8$.This means that the 4[th] until the 8[th] genes of the part 1 chromosome of parent 1 are underlined. Then drop those underlined genes to the offspring and strikethrough those genes in Parent 2. Starting from the right side, insert genes without strikethrough from part 1 chromosome of Parent 2 to the offspring. For part 2 of the chromosome, drop all genes from Parent 1 to the offspring.

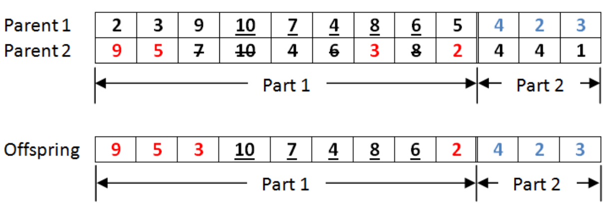

Figure 6. Illustration of the crossover process [5]

Step 6: Mutation

The pth offspring will mutate if the generated random number $R_p \sim U[0,1]$ is less than the mutation probability P_{mut}. In this paper P_{mut} is set to be 0.3. In order to select genes that will mutate, 2 integer random numbers R_1 and R_2, where $R_1, R_2 \sim U[1,9]$ and $R_1 \leq R_2$, are generated. Then, genes in the position of R_1 and R_2 change positions. Figure 7 illustrates the mutation process, $R_1 = 4$ and $R_2 = 8$ [5].

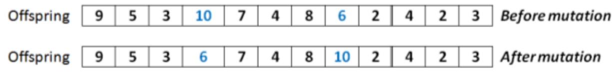

Figure 7. Illustration of the mutation process [5]

Step 7: Evaluation

Calculate total distance travelled from each offspring, select the best chromosome from the current generation (the best chromosome gives the shortest distance), and then repeat crossover and mutation process. In this study the algorithm terminates when number of generations produced by the algorithm equals 200. The distance is then converted into travel time by using the relationship between distance s, time t, and speed v, $t = s/v$. In this paper v is assumed to be constant.

RESULTS AND DISCUSSION

New Routes Produced by GA

The above methodology is then applied to schedule the distribution of pharmaceutical products that must be done by the aforementioned company located in Padang, Indonesia. On a particular day there are 31 outlets that have placed their orders to the company. The company needs to fulfill those orders in a day. The distribution activities (including loading and unloading) starts at 8AM and needs to be completed before or at 5PM. A 1-hour lunch break is also provided. Therefore, the salesmen have 8 hours to complete the distribution.

Note that the following assumptions are used in the case study,

1. Trucks used for distributing the products are in good condition.
2. There is no traffic jam.
3. Products are always available and enough to fulfill the demand.
4. Type of products does not have any effects to the distribution process.

Table 2 lists those outlets, their location, and the quantity of their orders. The latitude and longitude locations are then converted into coordinate locations expressed in kilometer. Illustration on how the conversion is done is as follows. From Table 2, it is known that:
XYZ latitude = -0.9465
XYZ longitude = 100.3695.

Latitude,
Degree = -0”
Minute = 0.9465 × 60 = 56.7906 = 56 minutes
Second = 0.7906 × 60 = 47.4360 = 47 seconds
DMS = -0”56’47

Longitude,
Degree = 100”
Minute = 0.3695 × 60 = 22.1714 = 22 minutes
Seconds = 0.1714 × 60 = 10.2864 = 10 seconds
DMS = 100”22’10.

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Table 2. Outlets' Locations and Demands

Outlet	Location		Order	Outlet	Location		Order
	Latitude	Longitude	(box)		Latitude	Longitude	(box)
XYZ	-0.9465	100.3695	-	SAD	-0.8611	100.3365	3
IRL	-0.9466	100.3700	1	CSA	-0.8383	100.3285	4
BMA	-0.9510	100.3694	1	ART	-0.8328	100.3271	2
TFA	-0.9508	100.3701	5	UME	-0.8328	100.3276	3
RIL	-0.9468	100.3797	3	TTK	-0.8271	100.3155	3
CAN	-0.9376	100.3878	3	BS	-0.9456	100.3674	2
RLM	-0.9375	100.3879	6	KFA	-0.9433	100.3690	5
RLS	-0.9284	100.3988	5	OOT	-0.9500	100.3615	3
SHT	-0.9490	100.4375	4	AAP	-0.9498	100.3592	4
BSS	-0.8969	100.3669	5	BCT	-0.9479	100.3581	3
OMM	-0.8991	100.3726	2	NDS	-0.9465	100.3590	4
LIN	-0.8832	100.3640	4	MVM	-0.9566	100.3608	2
YD	-0.8895	100.3584	1	YOK	-0.9595	100.3627	3
MDM	-0.8913	100.3545	2	AMA	-0.9415	100.3662	5
X	-0.8908	100.3520	1	ASR	-0.8832	100.3637	2
TI	-0.8665	100.3426	2	YUL	-0.8328	100.3276	2

* XYZ is the distribution company

Convert the DMS format into kilometer,

Latitude expressed in km = -0 × 110.57 + 56 × 1.84 + 47 × (30.72/1000) = 104.4838 km

Longitude expressed in km = 100 × 111.32 + 56 × 1.86 + 47 × (30.92/1000) = 11173.2292 km

In order to calculate distances, equation (4) is utilized. By using the same procedure as above, it is found that the location of IRL in terms of coordinate location expressed in kilometer is (104.5146, 11173.2300). Therefore the distance between XYZ and IRL is,

$$d_{\text{XYZ-IRL}} = \sqrt{(104.48-104.52)^2+(11173.23-11173.23)^2}\ .$$
$$= 0.38\ \text{ km}$$

The company uses three salesmen (trucks) to distribute the products to the outlets. Each truck is operated by a salesman. The trucks can carry up to 600 boxes. It is assumed that, on average, the speed of the trucks is 35 km/hour. The durations of the loading and unloading activities are also measured. Note that unloading time consists of handling the box and product inspection done by the customer. On average, the durations of the loading and unloading activities are 100.17 minutes and 8.75 minutes, respectively. Total distribution time is defined as the sum of travel time, loading time, and unloading time.

By converting the procedure presented in the methodology into a computer program (MATLAB® R2008b is used) and using the data presented above, the resulting routes of the distribution are presented in Table 3. To run the program, a personal computer with Windows 10 operating systems, an Intel core *i*3 processor and a 4 GB RAM was utilized. However, a personal computer or laptop that meets MATLAB® R2008 system requirements will be enough. Figure 8 presents the animated routes.

Based on Table 3, it is found that GA results in a total of 14.86 hours distribution time (salesman 1 needs 5.10 hours, salesman 2 needs 5.08 hours, and salesman 3 needs 4.68 hours to fulfill the orders). If it is compared to the actual distribution schedule applied by the company (the company determines the distribution routes just based on the experiences of the salesmen), GA produces a 20% reduction to the total distribution time. According to the schedule applied by the company, salesman 1 needs 4.6 hours, salesman 2 needs 7.5 hours, and salesman 3 needs 6.5 hours to fulfill the orders.

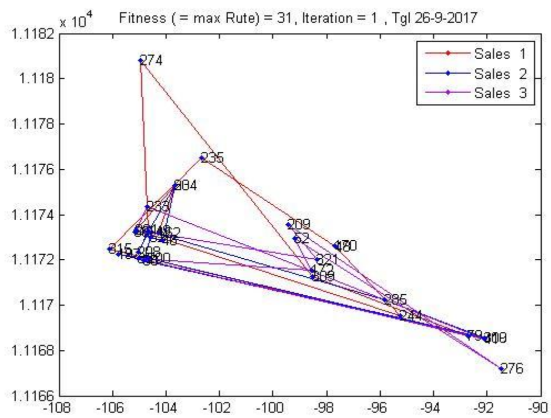

Figure 8. Animated distribution routes (Base case, 3 salesmen)

Sensitivity Analysis

In this study, a sensitivity analysis is also conducted. Two scenarios are designed: (1) What if the number of salesmen (trucks) is varied into 2 and 4; (2) What if the company uses trucks that have a capacity of up to 200 boxes. Note that, for both scenarios, outlets and the quantities of their orders stay the same. Table 4 summarizes the comparison of total distribution time when the number of salesmen is varied. Table 5 and 6 present the distribution routes when 2 and 4 salesmen are used. The animated routes, when 2 and 4 salesmen are used, are shown by Figure 9 and 10.

Table 3. Distribution Routes (Base case, 3 salesmen)

Salesman	Outlet	Cumulative Time (hour)	Cumulative Order (box)	Salesman	Outlet	Cumulative Time (hour)	Cumulative Order (box)
1	KFA	1.810	5	2	MVM	3.510	17
1	RLM	2.023	11	2	NDS	3.692	21
1	TFA	2.244	16	2	UME	4.215	24
1	SAD	2.696	19	2	TI	4.481	26
1	LIN	2.958	23	2	IRL	4.899	27
1	ASR	3.109	25	2	OOT	5.078	30
1	RLS	3.440	30	3	BMA	1.814	1
1	YOK	3.741	33	3	RIL	2.000	4
1	CSA	4.289	37	3	ART	2.546	6
1	X	4.621	38	3	AAP	3.079	10
1	SHT	5.100	42	3	MDM	3.414	12
2	CAN	1.865	3	3	BSS	3.608	17
2	AMA	2.085	8	3	TTK	4.032	20
2	BS	2.248	10	3	OMM	4.473	22
2	BCT	2.429	13	3	YD	4.678	23
2	YUL	2.955	15	-	-	-	-

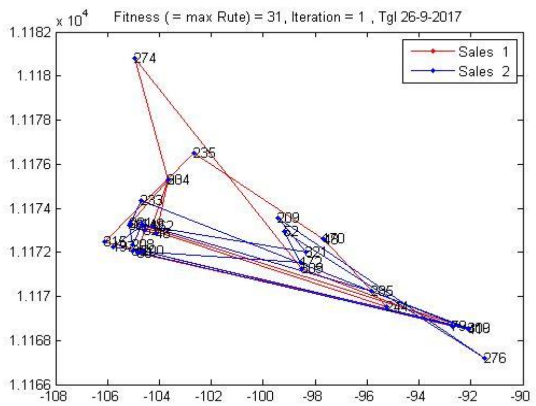

Figure 9. Animated distribution routes (2 salesmen)

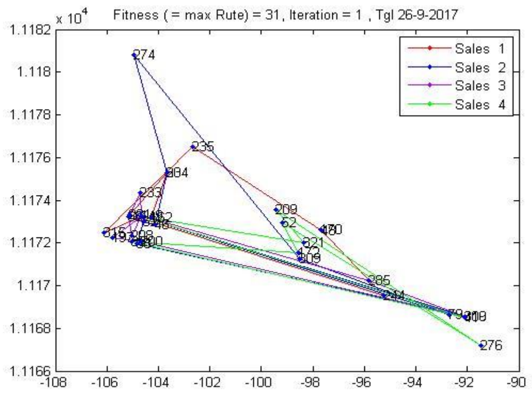

Figure 10. Animated distribution routes (4 salesmen)

In terms of total distribution time, Table 4 implies that performing the distribution using 2 salesmen is a better option. The company is still able to complete the distribution in 8 hours with 2 salesmen. It gives a 30% savings, if compared to the current distribution schedule used by the company (uses 3 salesmen and requires 18.60 hours). Moreover, using two salesmen also means reducing operation costs. However, if the company prefers to avoid the risk of delaying order shipment, using three or four salesmen is a better option.

Table 4. Number of salesmen and total distribution time

Number of salesmen	Distribution time (hour)				
	Sales-man 1	Sales-man 2	Sales-man 3	Sales-man 4	Total
2		6.45	-		12.95
3	5.10	5.08	4.68	-	14.86
4	3.74	4.38	3.77	4.32	16.21

When the capacity of the trucks used by the salesmen is reduced to 200 boxes, it is found that the routes stay the same as what has been found when 3 salesmen are employed. This is because the trucks (after the capacity is reduced) are still able to transport all boxes ordered by the customers.

Effects to the Distribution Policy of the Company

The results have shown that the suggested routes have a better performance compared to the routes currently applied by the company. If the company decides to use the resulting routes, there will be some changes need to be done by the company. The company needs to get rid of the current policy that consumers having a higher quantity of orders will get their products prior to the consumers having a lower quantity of orders. This change is expected to reduce the number of orders getting delayed. As a consequence, the salesmen must strict to the routes produced by GA.

In terms of the number of salesmen, the results of this study also prove that using 2 salesmen is sufficient. However, this can be done if the company optimizes the utility of the vehicles used by the salesmen. Furthermore, the results of this study also suggest the company not to depend on the experiences of the salesmen but on the routes produced by the computer program running the GA.

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Table 5. Distribution routes (2 salesmen)

Salesman	Outlet	Cumulative Time (minute)	Cumulative Order (box)	Salesman	Outlet	Cumulative Time (minute)	Cumulative Order (box)
1	KFA	1.810	5	2	MVM	1.842	2
1	RLM	2.023	11	2	NDS	2.024	6
1	TFA	2.244	16	2	UME	2.547	9
1	SAD	2.696	19	2	TI	2.813	11
1	LIN	2.958	23	2	IRL	3.231	12
1	ASR	3.108	25	2	OOT	3.410	15
1	RLS	3.440	30	2	BMA	3.586	16
1	YOK	3.741	33	2	RIL	3.771	19
1	CSA	4.289	37	2	ART	4.318	21
1	X	4.621	38	2	AAP	4.851	25
1	SHT	5.099	42	2	MDM	5.186	27
1	CAN	5.412	45	2	BSS	5.379	32
1	AMA	5.632	50	2	TTK	5.804	35
1	BS	5.795	52	2	OMM	6.245	37
1	BCT	5.976	55	2	YD	6.449	38
1	YUL	6.502	57	-	-	-	-

Table 6. Distribution routes (4 salesmen)

Salesman	Outlet	Cumulative Time (minute)	Cumulative Order (box)	Salesman	Outlet	Cumulative Time (minute)	Cumulative Order (box)
1	KFA	1.810	5	3	MVM	1.842	2
1	RLM	2.023	11	3	NDS	2.024	6
1	TFA	2.244	16	3	UME	2.547	9
1	SAD	2.696	19	3	TI	2.813	11
1	LIN	2.958	23	3	IRL	3.231	12
1	ASR	3.108	25	3	OOT	3.410	15
1	RLS	3.440	30	3	BMA	3.586	16
1	YOK	3.741	33	3	RIL	3.771	19
2	CSA	2.165	4	4	ART	2.183	2
2	X	2.497	5	4	AAP	2.716	6
2	SHT	2.976	9	4	MDM	3.051	8
2	CAN	3.288	12	4	BSS	3.244	13
2	AMA	3.508	17	4	TTK	3.669	16
2	BS	3.672	19	4	OMM	4.110	18
2	BCT	3.852	22	4	YD	4.314	19
2	YUL	4.378	24	-	-	-	-

CONCLUSIONS

This paper has successfully applied GA in determining better routes for salesmen in distributing pharmaceutical products for a company located in Padang, Indonesia. The case study shows that the resulting routes are better than the actual routes (designed based on experience) used by the company. The routes presents in this paper results in a 20% savings compared to the actual routes used by the company. Those two routes, the proposed and actual routes, use three salesmen. However, according to the sensitivity analysis, using two salesmen is still feasible and turns out to be the best option in terms of total distribution time. The analysis shows that using 2 salesmen results in a 30% savings compared to the actual distribution routes currently used by the company.

In this study, the distances among outlets are determined by using the latitude and longitude locations of the outlets. Those locations are then converted into kilometer using Euclidean method. Therefore, the resulting distances are just an approximate. For future research, it is suggested that the distances used in determining better routes are the actual distances. Google Maps® may also be used to determine the actual distances.

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