# A Study on Network Design for the Shortest Path in Expedition Company

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***Abstract*—It is common for pick-up and delivery service to encounter problems to satisfy customers on the punctuality and efficiency of the delivery service. The delivery service industry consists of small package for shipments and it tends to change dramatically over the time. The changes include the location of the marketplace, the technology and the transportation system on how goods are transported. This study proposes a decision support system model to find a way to get the shortest path to send the goods to the customer by considering the distance in the kilometer and time in minutes. This model is aimed to achieve a profitable tour design based on the lowest price of pickup and delivery in different areas to make an efficient pickup and delivery system for all customers by considering the distance. The solution procedure aims at minimizing the total cost of the system by using heuristic based on the genetic algorithm. Its applicability and performance are demonstrated through a numerical example problem.**

***Index Terms*— About; Delivery; Genetic Algorithm; Simulations; Traveling Salesman Problem.**

## I. INTRODUCTION

This study proposes a realistic model that creates an efficient pick-up and delivery system to determine the best route to minimize delivery cost. Pick-up and delivery is the most important service provided by a company that engages in the field of logistics. This type of company provides delivery services of goods in the form of packages or documents to someone in a city or all over the world. In Indonesia, there are several companies that provide domestic and international pick-up and delivery services such as the JNE, Tiki, and *Pos* Indonesia. The growth of these delivery services companies has a significant impact to the community as well as the corporate world. It allows the community to experience the ease of delivering goods and provide companies with an efficient distribution to their customers.

These companies have a set of features for the pick up and delivery service to support good quality service. This feature can facilitate the customer in determining the process of shipping. Although it is a good service to the customer, the formulation of the items needs to be carefully identified to ensure customers satisfaction of the services. The process of delivery still obstacles as there are a number of factors such as determining the path of the delivery, the distance and the density and frequency of traffic jams during the process of delivery. This study proposes a decision support system model to find a way to get the shortest path to send the goods to the customer by considering the distance in the kilometer and the calculated time to deliver the goods in minutes. The purpose of this study is to minimize the total cost of the system by considering the pick-up and delivery points, which are located at different areas. It is suggested that the result must be included in minutes because of the bad traffic jam in Indonesia.

## II. LITERATURE REVIEW

There are many related papers to the design of service networks for express delivery service. The network design for the profitable tour problem with pickup and delivery services is further investigated in [1]. Ferdinand et al. [2, 3] extended the study of Chung et al. [4] by considering the survival of multiple service centers in merging regions. Recently, Ferdinand et al. [5] proposed a non-linear integer programming models by considering maximizing the minimum expected profit for each participating company using four types of strategic alliances in express delivery services. There are also several studies related to the profitable tour problem with pick-up and delivery visits which represented by Lee et al. [6] configured an express delivery service network that maximizes revenue for PDPs. Kim et al. [7,8] proposed an optimization model for a profitable tour design with pick-up and delivery based on a multi-objective formulation involving single and multiple companies allied for resource sharing. Recently, Ferdinand et al. [9] developed a network design for the profitable tour problem with pick-up and delivery for multiple tours with the objective to maximize the incremental profit, which belongs to the PTP (Profitable Tour Problem) class. The differentiating feature of the study is its objective to minimize the total cost by proposing a decision support system model that finds a way to get the shortest path to send the goods to the customer by considering the distance in kilometer and calculated in minutes.

## III. PROBLEM DEFINITION AND ALGORITHM DEVELOPMENT

This study investigates the problem to maximize the profit of a tour company by considering a collaboration among several companies that provide pick-up and delivery services. It aims is to get the shortest path to send the goods to the customer by considering the distance in kilometer and calculate the time in minutes. This research uses genetic algorithms to get the results based on the steps that need to be followed. The model is developed based on the following assumptions: (i) Pick-up and delivery points are located in different areas; (ii) There are two terminals in this case, first terminal is to pick-up and the second terminal is reach the delivery point. The following steps should be done:

1. Forming beginning chromosomes used as route for

delivery of goods
2. Fitness value is calculated on each chromosome in the population.
3. Genetics operator used for selection is Tournament Selection. Selection is used to choose the best fitness value of each chromosome. In this case, the fitness value is the distance.
4. Genetics operator used for a crossover is PMX stands for Partial-Mapped Crossover.
5. Crossover rate used for crossover in the genetic algorithm is 0.7.
6. Genetics operator used for mutation is the reciprocal mutation.
7. Mutation rate used for mutation in the genetic algorithm is 0.0015.

The solution procedure is implemented using genetic algorithm (GA), which is a stochastic solution search procedure proven to be useful for solving combinatorial problem by adopting the concept of evolution [10]. The initial step in applying a GA is to design a suitable chromosome. This step is the key issue to the successful implementation of GA since it applies probabilistic transition rule on each chromosome to create a population of chromosomes and representing a good candidate generation. The chromosome representation in this study is illustrated in Figure 1. Looking for the best and fastest track involves several stages with the genetic algorithms:

1. Formation of the chromosome formation of the chromosomal genes requires using the binary number in the process of genetic algorithms.

2. Initialization the genes given a value on each of the chromosome correspond to the variables used.

The problem is to maximize the profit by minimizing cost of each participating company by selecting one service center in each region. It can be represented as the multi-objective in the non-linear integer programming model [2,4,5,9]. The following notations are introduced for developing the mathematical model to address the problem to minimize the total cost of the system:

Definitions:

1. $k$ : Number of customer
2. $J$ : Set of Customer such that$|J| = k$
3. $T_{j^*}$ : Shortest distance between Terminal and customer's location
4. $T_j$ : Distance between Terminal and $j^{th}$ customer in km
5. $l_{start}$ : Starting point for each iteration
6. $j^*$ : Chosen customer whose distance to terminal is the shortest
7. $Start$ : Vectors that stores order of route
8. $x$ : $x^{th}$ place that visited on route
9. $Start_x$ : Customer that being visited on x$^{th}$ order
10. $i, j \in J$ : such that $\max(i) = k \wedge \max(j) = k$
11. $a_{ij}$ : distance between customer *i* and customer *j* in km
12. $l$ : chosen customer on iteration such that customer l is the nearest customer from its previous place
13. $c$ : is cost per km

Modelling

1. $T_{j^*} = \min(T_j), \forall_j$
2. $l_{start} = j^*$
3. $Start_x = l_{start}$
4. $\forall_{i,j}, i = l_{start} \Rightarrow a_{ji} = 0$
5. $\forall_{i,j} | a_{ij} > 0,\ a_{ij^*} = \min(a_{ij}) \Rightarrow j^* = l$
6. $\forall_{i,j}, i = l, j \neq l_{start} \rightarrow a_{ji} = 0,$
7. $x = x + 1; Start_x = l$

Repeat Step 5 with substituting $l_{start}$with $l$ Profit:

$$\sum_{l=1}^{i} \sum_{m=1}^{j} a_{ij} * c \quad (1)$$

The objective function is shown in equation 1, which is to find a way to get the shortest path to send the goods to the customer by considering the distance in kilometer and calculate the time in minutes in order to minimize the total cost of the system by considering the pick-up and delivery points, located in different areas.

Design chromosomes is the most important part of the genetic algorithm because it determines the place to be passed to make the pick-up and delivery process. An initial chromosome is described in Figure 1. The number of service centers in each region and the chromosomes converted into binary is shown in Table 1. In this study, one vehicle with 5 service centers is assumed with the number of pick-up and delivery for each service center. The delivery addresses are represented into binary and the final chromosome will contain 33 genes. The first and the last genes shows the depot and the 30 genes represent the number of service centers that can be supported by one vehicle. The chromosome can be expanded depending on the number of service centers.

A few of genetic operators are used in this study: parent selection, crossover and mutation. In the parent selection, the roulette wheel selection is used. The one point of crossover for permutation representation is applied to these chromosomes with two chosen random values between 1 and 33 to build the range of the length of crossover points and the points can be in any position in the parents. Based on the crossover points, the position between parent can be changed. The reciprocal mutation is adopted as mutation operator in this study.

| P | Pick-up | | | | | | | | | | D | Delivery | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | 1 | | 2 | | 3 | | 4 | | 5 | |
| 5 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 5 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |

Figure 1: Chromosome representation

Table 1
Numbers to binary

| Regions | Binary Number |
|---|---|
| Service Center 1 | 001 |
| Service Center 2 | 010 |
| Service Center 3 | 011 |
| Service Center 4 | 100 |
| Service Center 5 | 101 |

The crossover method used in this study is PMX, and it stands for Partial-Mapped Crossover that performs the crossover between 2 parents and produces a new child chromosome, which is shown in Figure 2. The process is mapped from a portion of one parent onto a portion of the other parent, while the remaining values are exchanged.

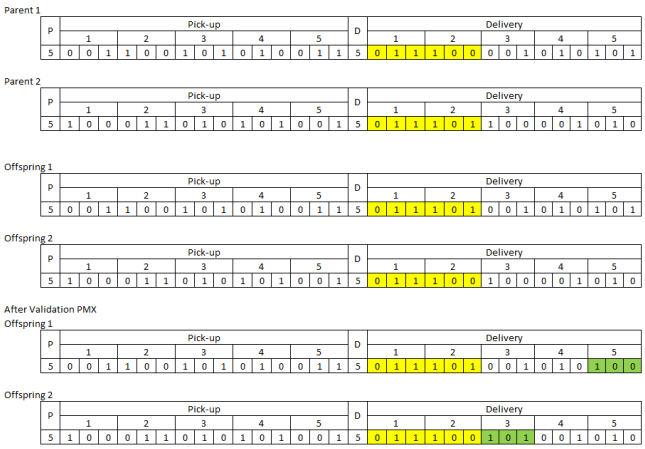


Figure 2: PMX (Partial-mapped crossover)

The mutation method is described in Figure 3 and the reciprocal exchange mutation is adopted as a mutation operator. The decoded chromosome generates a candidate solution and the fitness value is based on the fitness function. A fitness value of each chromosome can be obtained by assigning destinations to all service centers in the Pick-up and Delivery process to find a way to get the shortest path by considering the distance in kilometer and the time in minutes.

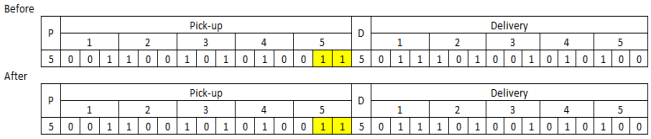


Figure 3: Reciprocal exchange mutation

## IV. Numerical Example, Implementation, and Result

An example of problem involving express courier company is described below in detail to verify the appropriateness of suggested optimization model and evaluate the performance of the genetic algorithm (GA). Suppose there are five addresses in each region, and in this study, two scenarios were observed: (i) Pick-up and (ii) Delivery in two different areas: Area I (Delivery process in Grogol) and Area II (Pick-up process in Serpong) as our numerical example. It should be noted that the locations of each service center are not identical for the two scenarios. In order to calculate in Java, the distance between terminal and locations need to be converted into coordinates by using the MATLAB image viewer. Table 2 shows the coordinates of addresses in two different areas. Table 3 and Table 4 shows the distance in kilometer length between the depot and each address in area I and area II respectively. The distance in time is described in Table 5 and 6 which shows the needed time between each address and also a depot in the area I and area II area. After All data have been obtained, the research can be continued by running a program that has been created using Java with NetBeans 8.0.2 IDE.

Table 2
Addresses coordinates (area I and area II)

| | Area I | | Area II | |
|---|---|---|---|---|
| **Address** | **X** | **Y** | **X** | **Y** |
| JNE | 646 | 71 | 629 | 635 |
| 1 | 439 | 323 | 607 | 580 |
| 2 | 644 | 360 | 600 | 531 |
| 3 | 303 | 697 | 335 | 292 |
| 4 | 381 | 490 | 459 | 530 |
| 5 | 677 | 710 | 357 | 635 |

Table 3
Distance between addresses in area I in length (delivery process)

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **JNE** | 2.8 | 1.9 | 6 | 4.1 | 4 |
| **1** | - | 6 | 8 | 7 | 10 |
| **2** | | - | 7 | 6 | 8 |
| **3** | | | - | 8 | 11 |
| **4** | | | | - | 9 |
| **5** | | | | | - |

Table 4
Distance between addresses in area II in length (pick-up process)

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **JNE** | 2.8 | 1.9 | 6 | 4.1 | 4 |
| **1** | - | 1.9 | 4.1 | 2.8 | 3.7 |
| **2** | | - | 4.1 | 2.6 | 2.7 |
| **3** | | | - | 2.6 | 3.4 |
| **4** | | | | - | 3 |
| **5** | | | | | - |

Table 5
Distance between addresses in area I in minutes

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **JNE** | | | | | |
| **1** | - | 2.3 | 1.9 | 2.7 | 4.2 |
| **2** | | - | 2.8 | 1.8 | 2.9 |
| **3** | | | - | 1.7 | 4.3 |
| **4** | | | | - | 3.1 |
| **5** | | | | | - |

Table 6
Distance between addresses in area II in minutes

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **JNE** | 46 | 34 | 101 | 69 | 68 |
| **1** | - | 32 | 71 | 48 | 62 |
| **2** | | - | 69 | 46 | 46 |
| **3** | | | - | 45 | 57 |
| **4** | | | | - | 50 |
| **5** | | | | | - |

The objective of this study is to develop decision support system model to find the shortest path for the pick-up and delivery process in an expedition company in Indonesia .It is

conducted by considering time in minutes and distance in kilometer. Figure 4 shows the optimal solution developed using Java and based on the GA. The parameter values for the GA algorithm are population size equals to 500, maximum number of generations is 100, cloning rate is set at 1%, crossover rate and mutation rate are 50% and 2% respectively. Based on the genetic algorithm method, the results of the total conducted based on one hundred times the simulation in two different areas were obtained. There are two results: (i) Area I: Delivery route Terminal – 1 – 4 – 3 – 5 – 2 – Terminal, this route has resulted in an average of distance as far as 14.4 Kilometers, and time delivery of an average of 242 minutes to make the delivery of the goods to the customer's place. (ii) Area II: The route taking the freight is through Terminal – 2 – 4 – 5 – 1 – 3 - Terminal. This route has resulted in an average of 3.9 kilometers with time taken on average 10 minutes to do the pick-up of the goods to the customer's place. The result of this route will be transformed into the final chromosome, which is represented in Figure 5 obtained from the program based on the GA. Based on these results, we observe that the total travel time can be reduced with this decision model system, as shown in Figure 6.

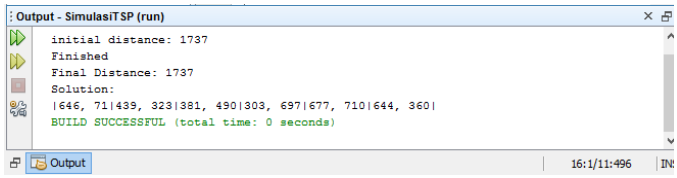


Figure 4: Java program output

| P | Pick-up | | | | | | | | | | D | Delivery | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | | 1 | | 2 | | 3 | | 4 | | 5 | |
| 5 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 5 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |

Figure 5: Binary chromosomes of the best route in Serpong

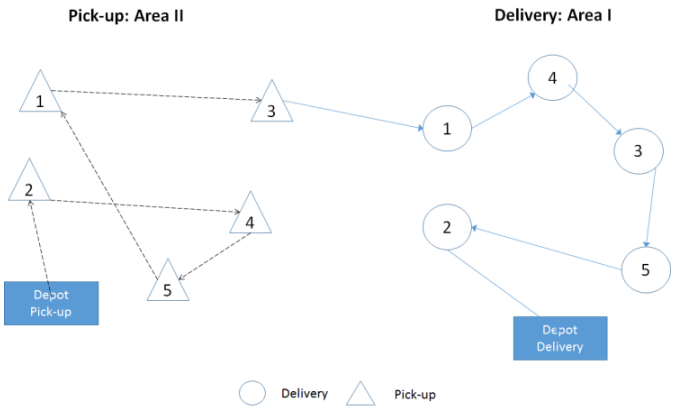


Figure 6: Tour sequence resulting from genetic algorithm for Grogol and Serpong

## V. CONCLUSION

The genetic algorithm was applied in this study to solve the problem and the simulations based on Java was developed. It can be concluded that in the process of delivery of goods which can be assisted with finding the shortest path, the goods are delivered to the customers by courier can be quicker. With this model, the process of pick-up and delivery of the goods will be quicker and can better facilitate the distribution of goods. It also helps to reduce travel costs in distributing the goods. The program is expected to help companies and couriers delivering goods in large quantities with faster delivery times and provide a good service to customers. Furthermore, other problems in the expedition company can be solved and a better solution procedure for traveling salesman problem will be studied in future research.

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