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Optimization of Goods Delivery in Supply Chain using Genetic Algorithm

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ABSTRACT

The growing competition between business organizations had been challenging for the owner to push the business process become more innovative and advance in supply chain such as, goods delivery. There are many methods and algorithms use to solve optimization problem, but Genetic Algorithm will be explored in this paper. Genetic algorithm is meta heuristic method which able to answer goods delivery problems. Using correct fitness function formula, it can provide correct chromosomes value which enhance the delivery process. In this paper genetic algorithm is proposed to optimizing goods delivery in supply chain. It is found GA method able to answer this problem.

Key words : supply chain, genetic algorithm, goods delivery, optimization

1. INTRODUCTION

Improving the supply chain quality, profitability and efficiency in highly competitive global market force many enterprises to redirect their business strategies from independent and conventional operations to integrated and strategic partnership with other businesses [1]. Solving inefficient supply chain network problems become more important nowadays than before due to market globalization and competition year after year [2]. In current situation, the integration in logistics service providers becomes one of the main methods in supply chain [3]. However, most of the provider only focused on the functional logistic providers which produce average or low service quality as it is cheaper compared to the providers who target the better service quality [3]. The approach that improve service quality will cost a large amount of time and space when solving big and complex problem as it directs on managerial and mathematical approach. It can be costly to the business [4].

In recent years, meta-heuristic method like genetic algorithm (GA) are powerful algorithm to deal with many optimization problems [5]. Using GA in supply chain delivery goods to be efficient as ideal method, which is simple to implement, for finding optimal solution. GA not only suitable to optimize supply chain problems, there are several problems were solved by GA like improve logistic network [4], increasing clothes production profit margin [6] and creating schedule learning activities for lecturer in university [7].

Instead using mathematical method like linier regression, the author will use GA to solve optimization goods delivery problem in supply chain. In this paper, the dataset will be operating Kalganova and Dzalbs's dataset that made for public [8], the dataset is real supply chain data from global microchip manufacture [9].

Therefore, this paper will explore the genetic algorithm in resolving this issue.

2. LITERATURE REVIEW

2.1 Related Work

This chapter is summary of result from previous researchers work to solve optimization problem using GA method.

The first paper compared how fast and accurate to process optimization problem between GA and Ant Colony to optimize scheduling problem in logistics process [5]. The result showed that both methods perform equally well, but in general GA was faster compare to the Ant Colony. However, the problem that occur is GA only manage small number of data and information. Whereas, Ant Colony could undertake more data and information about the solution which provide some advantages in to solve some optimizations problems. Moreover, the author stated before that performing GA in this condition are more suitable as it solve the problem quickly and more accurate in finding the result.

In paper [1], the author used GA to solve optimization problem in supply chain logistics network. They found out that GA contributed on the less computation time than traditional and analytical method. When the author defined initial population with good individual, the results were better than using random initial population. However, if the mutation probability rate were increased it did not present optimal solution and even worse compare to lower mutation probability rate.

Another study to optimize operation of 3PL logistic networks they created basic model for optimizing logistics operation [4]. They created three optimization models named Logistics Network Optimization Model with Time Windows, Logistics Network Optimization Model with Price Discount and Logistics Network Optimization Model with Multi-transport Mode. However, the result in this study is unclear as is shown some problem on mathematic experiment. Moreover, the author believed that using this method will have direct impact to solve optimization problems of 3PL logistics network. Therefore, further research is needed to prove this finding.

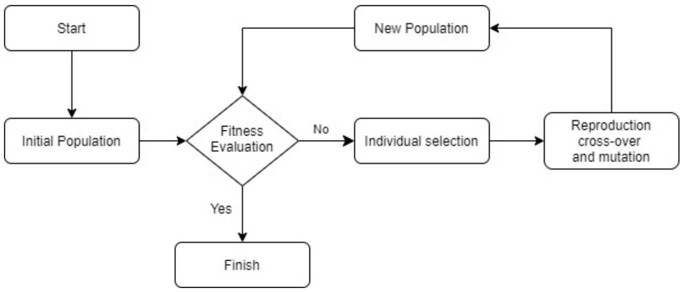

Figure 1: Genetic Algorithm Process

One study is written by [10] would optimize base level of stock and minimize storage cost in entire supply chain using GA. They used simulation to evaluate stock base level generated by GA. The proposed method, GA, was evaluated many supply chain settings to test its performance across different supply chain scenarios. The results generated by GA did not differ from the optimal solution obtained from various supply chain settings thus showing the effectiveness of GA method.

2.2 Genetic Algorithm

GA first introduced by John Holland at the Michigan University in 1975 [11]. The research was using adaptive process of natural system and designing artificial system that will retain superior mechanisms of natural systems. GA is based on Charles Darwin evolution theory "Survival of the Fittest" and become one of many popular techniques to solve optimization problem [2]. Fitness function is used to choose which individual in the current population to be used to have offspring, the better the fitness function value the higher chance for individual to use for reproduced offspring [3]. Too reduce chromosome similarity, each chromosome prone to mutate [13].

In Figure 1, it will describe the flowchart of GA. The evolutionary stage begins with the formation of a randomly generated initial population and then every individual generated were evaluated by the fitness. If the individual does not provide optimal solution, a new individual will be formed by selecting an individual that deemed suitable to be re-iterated on the next generation by cross-over and mutation. Then new formed individual is re-evaluated until maximum iteration completed or get the optimal solution to solve the problem [12].

2.3 Supply Chain

Supply chain is a network system to integrated material and service procurement, converting materials into finish product, then distribute or send the finish product into customers hands [13]. All these processes include buying and outsourcing activities, with other additional functions that essential to the relationship between suppliers, distributors and manufactures. The main purpose of supply chain is to fulfill customer demand and maximize overall added value [13].

Figure 2 is the entire process in supply chain that explained by [14]. The writer described supply chain is a management both upstream and downstream relationship between suppliers and customer to provide highest added value service possible with product at the most inexpensive cost.

3. PORPOSED MODELLING

3.1 Data Preparation

The dataset used in this paper consists of seven tables such as OrderList, FreightRates, WhCosts, WhCapacities, ProductsPerPlant, VmiCustomers, and PlantPorts. The main function of OrderList table is saving all the data related to the delivery route for every order in daily basis. Moreover, the other six additional table explain about the restrictions and problems in delivery route [8].

There are more than 9000 orders that need to be routed by their supply chain network of 19 warehouses, 11 origin ports, 11 couriers and one destination port. Figure 3 is describing how the supply chain network operate [9]. Warehouse are bound to serve only from specific origin ports, but all origin port will send to single destination port. There are three service level customers can choose DTD (Door to Door), DTP (Door to Port) and CRF (Customer Referred Freight). In CRF level, the customer will organize the freight and company only charge for warehouse cost and transportation cost is zero. Service level DTD and DTP cost are available in the dataset, thus it will use cost stated in the dataset. Most of the delivery used air transport by airplane some orders are shipped via ground using trucks.

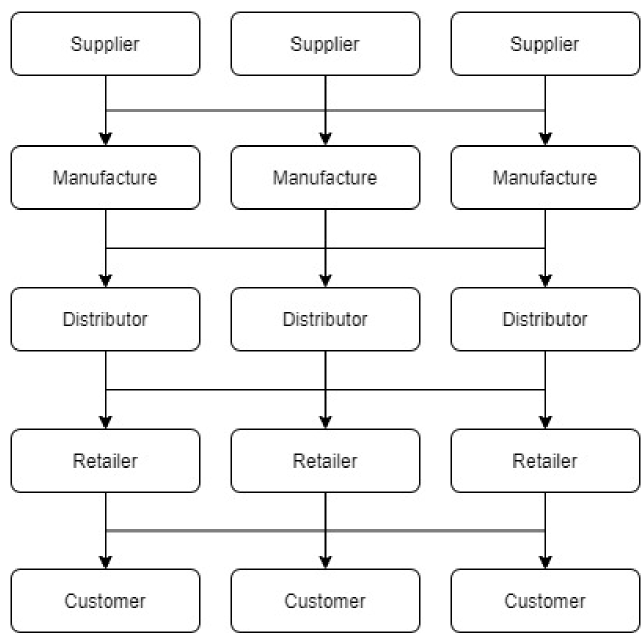

Figure 2: Supply Chain Process

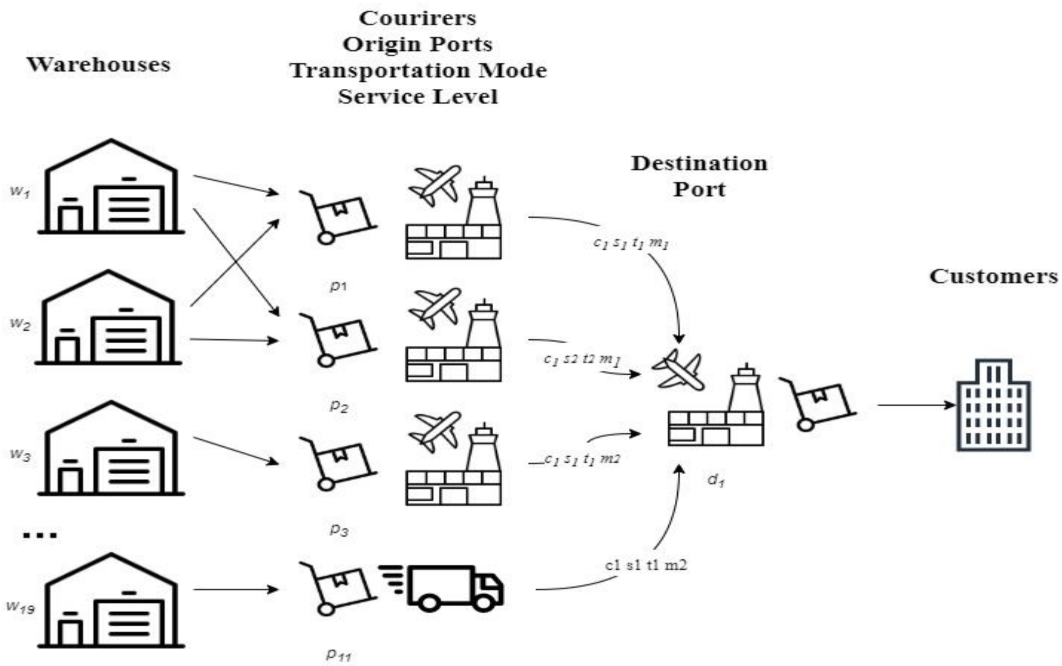

Figure 3: Dataset Outbound Supply Chain Network Model

Most of delivery courier offer discount rates based on weight of the goods, even though the minimum rates for delivery still applied. Faster shipping is more expensive, however it popular among the customer as increase the satisfaction level.

Table 1: Data use for research

Field	Description
Plant Code	Where the goods stored from Table WhCost
Origin Port	Goods sent from port from Table PlantPorts
Mode	Ground and Air from Table FreightRates
Service Level	DTD, DTP and CRF from Table FreightRates
Weight	Goods weight from Table FreightRates
Courier	Courier delivery from Table FreightRates

Simplified version of sample supply chain model is shown in Figure 3. Plant w_1 and w_2 can supply to origin port p_1 or p_2. In other hand plant w_3 only can supply to port p_3 and w_{19} can deliver to port p_{11}. In sample model shipping lane, p_1 d_1 c_1 s_1 m_1 can be referred to port origin (p_1), destination port (d_1), courier (c_1), service level (s_1) and transportation mode (m_1).

This paper does not use all data and table in the dataset, but it uses data that described in Table 1. Other data that do not include in the table 1 will exclude from this research.

3.2 Fitness Function

Main objective of this optimization is to find a set of warehouses, shipping routes, and couriers in order to reduce supply chain cost significantly. The fitness functions are combination of two main components: warehouse cost (WC_i) and transportation cost (TC_{ipd}). It is described in equation (1).

$$min \sum_{i=1}^{n}(WC_{iw} + TC_{ipd}) \quad (1)$$

Where WC_{iw} = warehouse cost w of order i

TC_{ipd} = transportation cost of order i between origin port p and customer port d

N = total order i

$$WC_{iw} = q_i \, x \, r_w \quad (2)$$

Equation (2) is how to calculate warehouse cost q_i number of unit order and r_w warehouse storage rate (WhCosts table).

Table 2: Data Index, Parameter and Data Range

Data Index	Parameter	Data Range
0	Plant Code	1 - 19
1	Origin Port	1 - 11
2	Mode	1 - 2
3	Service Level	1 - 3
4	Weight	0 – 99.999
5	Courier	1 - 10

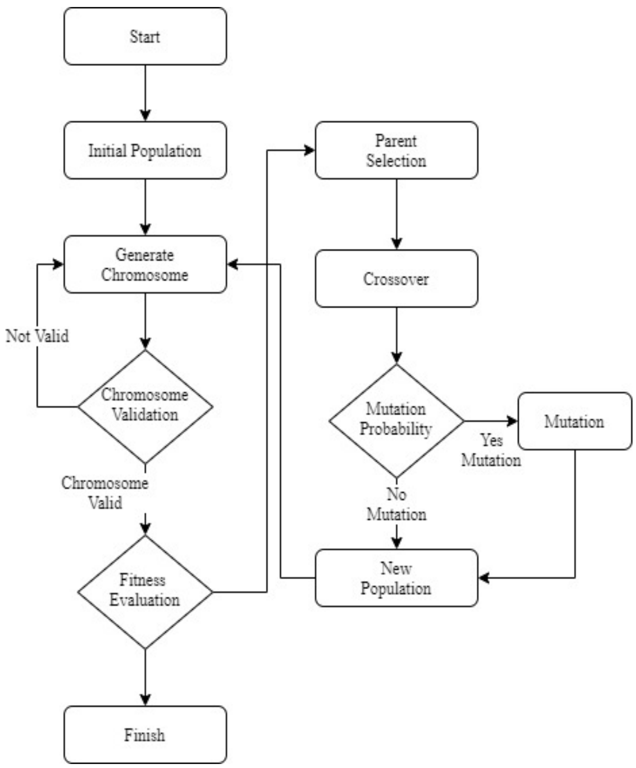

Figure 4: Experiment Process Flow

4. EXPERIMENT & RESULTS

There are certain rules that have been addressed in this experiment, like range of chromosome and dataset validation on every chromosome to ensure the experiment work fast, smooth, and accurate. Table 2 is the list of data index, parameters, and data range that operate in this paper. Even though, the nature of GA is random, the data range on every gene will generate the solution with less iteration.

In this experiment, 100 populations will be generated with 20 chromosomes in each population. Six best chromosomes will be chosen as parents and mutation probability rate is 40%. The experiment flow in this paper is shown in Figure 4. It starts with creating initial population, filled with 20 random chromosomes. Each chromosome then validated with dataset, if chromosome is not valid then it will be deleted. The new chromosome will be created until we get 20 valid chromosomes.

We determined validation chromosome based on data in table PlantPorts and FreightRates, if the chromosome combination not available in the two tables it means the chromosome is not valid, moreover it will get destroyed and created new chromosome.

When all chromosomes are valid it goes to next step which calculate fitness of each chromosome. After all fitness are calculated, fitness score then sorted as process to select best parent of current population. Selected parents then goes to process crossover that is resulting in new set of chromosomes. Then chromosomes go to mutation probability, when it is chance to mutation it will select random chromosome then randomly change the gene of the chromosome. After that, it will create new population and generate new chromosome. The cycle continues until reach the number of populations which is 100 or the fitness score is optimal.

Figure 5 present the sample chromosome generated by the algorithm. The chromosome consists of 6 genes, each gene represents different column as shown in Table 2.

```
Chromosome-1 :[  10    2    1    1  243    2]
Chromosome-2 :[  15    8    1    1  112    2]
Chromosome-3 :[  17   10    1    1  554    2]
Chromosome-4 :[   1    2    1    1  508    2]
Chromosome-5 :[   5    6    1    1 1038    4]
```

Figure 5: Sample Chromosome

Figure 6 shown sample parents is chosen by GA. GA chooses parents by their fitness score, this experiment chooses six parents to be process in next step.

```
Parent-1: [   10     2     1     1 15308     4]
Parent-2: [    6     6     1     1 15513     1]
Parent-3: [    5     6     1     1 18079     5]
Parent-4: [    5     6     1     1 21513     4]
Parent-5: [    3     4     1     1 22077     8]
Parent-6: [    4     5     1     1 25511     4]
```

Figure 6: Sample Chosen Parent

Figure 7 shown sample offspring after crossover by GA. Author use multi-point crossover in this paper in index [0 , 1] and [4 , 5] in Parent-1 and Parent-2.

```
Offspring-1: [    6     6     1     1 15513     1]
Offspring-2: [   10     2     1     1 15308     4]
Offspring-3: [    5     6     1     1 21513     4]
Offspring-4: [    5     6     1     1 18079     5]
Offspring-5: [    4     5     1     1 25511     4]
Offspring-6: [    3     4     1     1 22077     8]
```

Figure 7: Sample Offspring after Crossover

Mutation is not developing in every iteration as it depends on mutation probability rate. When the mutation occurs, it will choose random chromosome from offspring, and randomly change gene value in the chromosome. Figure 8 shown sample of mutation. In the Figure 8 it chooses Offspring-1 and gene index [1] mutated with random number, then created new chromosome Mutation-1.

```
Offspring-1:    [    6     6     1     1 15513     1]
Mutation-1:     [    6     9     1     1 15513     1]
```

Figure 8: Sample Mutation from Crossover Offspring

Figure 9 shown result after running the GA with above configuration. It clearly shown that fitness score was better in every iteration and after 10 iteration fitness score was up and down for many times. Then fitness score at most optimal value in iteration 50 to 90 and goes up again until iteration 100.

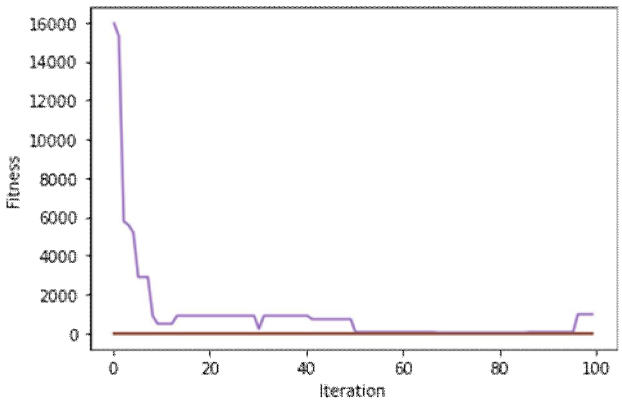

Figure 9: Experiment Result

The mutation probability rate has major impact in the fitness score, because it is more likely to generate invalid chromosomes after the mutation. It is quite hard to find any literature or resources that explained about this factor because the random nature in GA method itself that made difficulty to achieve any conclusion. Therefore, further research is needed to prove this theory.

5. CONCLUSION

This study provide evidence that the GA can solve the supply chain optimization problems. After running the experiments, the finding indicates that fitness score is most likely to get better after 10 iteration as shown in Figure 9. Although, there is some drawback in fitness score as shown in Figure 9. In addition, same solution less likely to occur when the GA method rebooted

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