Simulation of product distribution at PT Anugrah Citra Boga by using capacitated vehicle routing problem method

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Abstract. PT Anugrah Citra Boga is a food processing industry that produces meatballs as their main product. The distribution system of the products must be considered, because it needs to be more efficient in order to reduce the shipment cost. The purpose of this research is to optimize the distribution time by simulating the distribution channels with capacitated vehicle routing problem method. Firstly, the distribution route is observed in order to calculate the average speed, time capacity and shipping costs. Then build the model using AIMMS software. A few things that are required to simulate the model are customer locations, distances, and the process time. Finally, compare the total distribution cost obtained by the simulation and the historical data. It concludes that the company can reduce the shipping cost around 4.1% or Rp 529,800 per month. By using this model, the utilization rate can be more optimal. The current value for the first vehicle is 104.6% and after the simulation it becomes 88.6%. Meanwhile, the utilization rate of the second vehicle is increase from 59.8% to 74.1%. The simulation model is able to produce the optimal shipping route with time restriction, vehicle capacity, and amount of vehicle.

1. Introduction

Transportation of goods is an important task in running a business of today. The amounts of daily expenses on fuel, equipment, maintenance of equipment and wages are noteworthy to be concerned. It is therefore obvious to attempt to reduce the amount of money spent on transportation as even small improvements can lead to huge improvements in absolute terms. Several approaches are taken by the company to minimize the cost, one could improve the infrastructure and other could look at the operation research techniques. Toth and Vigo claim that the use of computerize planning of the distribution process often leads to savings in the area of transportation costs [1]. Operation research has been quite successful in the transportation area [2]. OR techniques are applied within the airline, trucking, shipping industries and other optimization matter. Consequently, the optimization within transportation is a subject that is used and sought-after in the real industry and not just a topic studied in academia. The real industry need solution methods that are fast, easy to apply to variety of problem characteristics, precise, and more robust.

One problem in the field of transportation related OR that has been given a lot of attention in the scientific literature is the method of vehicle routing problem (VRP). The VRP is a widely studied combinatorial optimization problem that was introduced in 1959 by G B Dantzig and J H Ramser [3] The VRP is defined as the problem of serving a number of customers with a fleet of vehicles, minimizing the cost of distributing the goods. The cost of travelling between each pair of customers and the depot is given. The task is to find a route for each vehicle that have the less total cost. Typically, the solution

has to obey several other restrictions, such as capacity of the vehicles or desired visit times at customers. In which a quantity d_i of a single commodity is to be delivered to each customer $i \in N = \{1, \cdots, n\}$ from a central depot $\{0\}$ using k independent delivery vehicles of identical capacity C. Delivery is to be accomplished at minimum cost, with $C_{ij} \geq 0$ denoting the transit cost from i to j, for $0 \leq i, j \leq n$. The matrix cost and distance is assumed symmetric, i.e., $C_{ij} = C_{ji}$ and $C_{ii} = 0$. Therefore, the solution for this problem consists of a partition of N into k routes $\{R_1, \ldots, R_k\}$, each satisfying $\sum_{j \in R,} d_j \leq C$, and a corresponding permutation of each route specifying the service ordering. This problem is naturally associated with the complete undirected graph consisting of nodes $N \cup \{0\}$, edges E, and edge-traversal costs $C_{ij,} \{i, j\} \in E$ [4]. By associating a binary variable with each edge in the graph, we obtain the following integer programming formula. In this thesis the term of vehicle routing problem is used for the method of Anugrah Citra Boga company to determine the route for each vehicle.

2. Research Method

The research within an area like vehicle routing problem start with visiting Anugrah Citra Boga Company for observation and interview to supervisor and distribution manager. After doing a quick glance of the company activity, the next step is identifying problem of Anugrah Citra Boga. The main problem of the company is lack of efficiency in distribution routing that cause a high shipping cost. Afterward start with studying some literature that connected to optimization and distribution topic.
The purpose of this thesis is creating a simulation model for the distribution of goods at Anugrah Citra Boga company for the area of Jakarta, Depok, Bekasi, and Cikarang. Collecting data is needed to calculate the distribution cost of each vehicle.

Distribution route per day, service time in each customer, distance and, shipping costs are collected as data. Then build the model using AIMMS software with the capacitated vehicle routing problem method, based on figure 2.1 the transportation model start from a depot which is the factory and then distribute the goods to each customer by using vehicles as their transporter. Each vehicle has their own schedule route according to the optimal time in every customer. After obtaining the simulation result of each day, compare the shipping time of simulation model and historical data. Analyse the result of comparison and create a sample of graph between simulation model and historical data. So it can conclude whether the simulation model work well or not.

In building a model a vehicle scheduling is needed to optimize the distribution and minimize the cost. Anugrah Citra Boga use their own transportation system to distribute their goods to the customer, the company should deliver the goods from their home base to several locations in different direction. This problem could add some problem for the distribution system start with amount of vehicle that need for the shipping, vehicle capacity and the best routing for optimize the shipping cost. Although there are problems that may occur in the distribution system, vehicle scheduling could help on fixing this problem. Some rule that help on making a scheduling is start with appoint the farthest point from the depot. Next step is find a location that have the fastest time service (travel time + service time). Then continue finding the best location for the optimal distribution route. Use this method for several vehicles to find out the best distribution route.

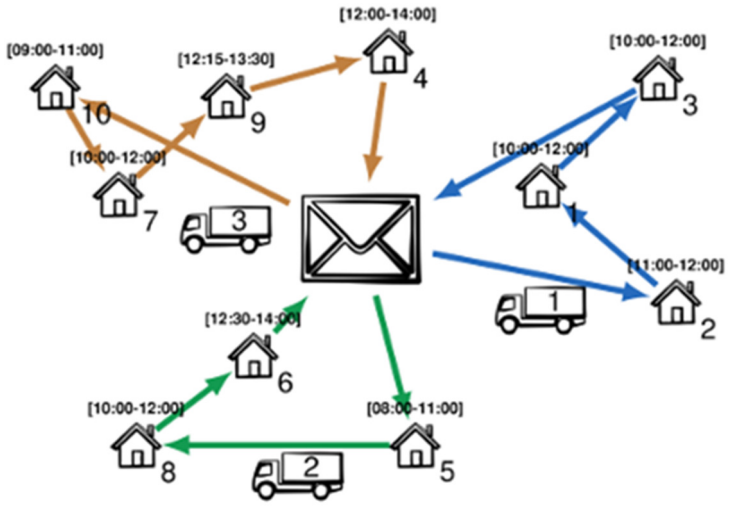

Figure 2.1 VRP scheduling

3. Modelling and Solution Methods

The art and science of modelling can be divided into two disciplines. The first one is concerned with modelling a problem occurring in real life. The point that should be considered are the description of the real life problem given to the modeller may be ambiguous, so a good model should be expressed such that there are no ambiguities (the model should be written in mathematical notation, but textual can be sufficient as well). Next, the model must represent the real life problem reasonably well and last the model should not be unnecessarily complicated.

The second discipline in modelling is transforming a model into an equivalent model that in some way is easier to solve using existing techniques. The new model should have the same solution as the original model given the same input. **[5]**

The set of feasible solutions is so large that require computer to calculate the model simulation and evaluate the cost of a trillion solutions in a blink of an eye. There are several type of solution methods that are typically employed to solve these types of problem heuristics, approximation algorithms, and exact methods. However, in this thesis the model simulation use heuristics method as their type of solution methods.

- **Heuristics**. A solution that quite fast on finding a feasible solution with reasonable quality. The heuristics method is tested empirically and based on the experiment of data history, this are the best solution on solving real life problem because of the speed and the ability to handle large amount of data in instances. There is a special class of heuristics which is metaheuristics that could provide a general framework for heuristics that can be applied to many problems, also a high solution quality is often obtained using this method. **[6]**

  The vehicle routing problem use heuristics method as their base on solving the distribution model. Step that are required on building the model are; 1.) simulate the distribution channel by using the current vehicle from depots to customer that unserved (with time and vehicle restrictions). 2.) Deliver the goods to nearest customers (customer needs ≤ vehicle capacity). 3.) Continue delivering item until all customers are well served and at last send the vehicle to depots (notes each route that the vehicle travel during the distribution). 4.) Repeat the simulation model for all vehicle to accomplish the distribution of goods.

The simulation program that used in the thesis is software simulation AIMMS. AIMMS is a software system design to create optimization model who focus on the shortest total time in each vehicle. So it assumes that by optimizing the total time it can create an optimal cost. Total time are the calculation of service time add by travel time for each customer. In capacitated vehicle routing problem there are restriction that require to be added to perform as the real life problem. The restriction that needed are vehicle capacity over 200 box for each vehicle, time capacity for 1 vehicle over 480 minutes / 8 hours.

4. Building The Model

In creating a model distribution an index is needed to set the main data of model such as customer (*i* & *j*) and vehicle (*k*). Model simulation require identifier to proceed the calculation of route those identifiers are index, parameter, variable and constraints. Step of building the model are shown in the flow chart of figure 4.1. To build the model some data are require to extend the model to present as the real life problem. The declaration for the model start with customers with the index code of *i* and *j,* the different between index *i* and *j* are the declaration of from and too nodes. *i* is refer to from customer *i* and next *j* is referring to too customer. Those identifiers for index domain parameter and variables. The parameter that need to be added to fill the model simulation are number of customers, vehicle speed, customer demand, number of vehicles, and customer selection. Some data that need to determine to show the customers location are the X coordinate and Y coordinate for each location. Then creating matrix of distance between each location for the routing model. Parameter service time of each customer receive from one-month observation over distribution of PT Anugrah Citra Boga. Next input require for vehicle are the load capacity and time available in each day. Next for the formula of Travel Time = (Distance(*i*,*j*)/VehicleSpeed*60)+ServiceTime(*i*). Next for the variables there are 6 variable which is variable X(*i,j,k*) for the model to determine customer need to be access with the vehicle. Next the binary data for second variable with the name Y(*i,k*) to determine which vehicle will handle the distribution route. Next for the variable total time to calculate each vehicle travel time. For the constraint of the model to create the simulation as the problem real life. First for the constraint customer assignment to create restriction for each vehicle to only deliver one time per customer. Next constraint for time restriction and capacity restriction in each shipping. For calculating the model simulation, a mathematical programming is needed so to optimize the cost, model distribution uses total time as their objective on optimizing the model with the type of calculation is mixed integer programming. For the appearance, creating a new section for the route colour can help people to determine which vehicle deliver the customer goods. At last for the execution in solving the problem, creating main execution is needed to proceed the model simulation to work as the simulation of the real life problem. [7]

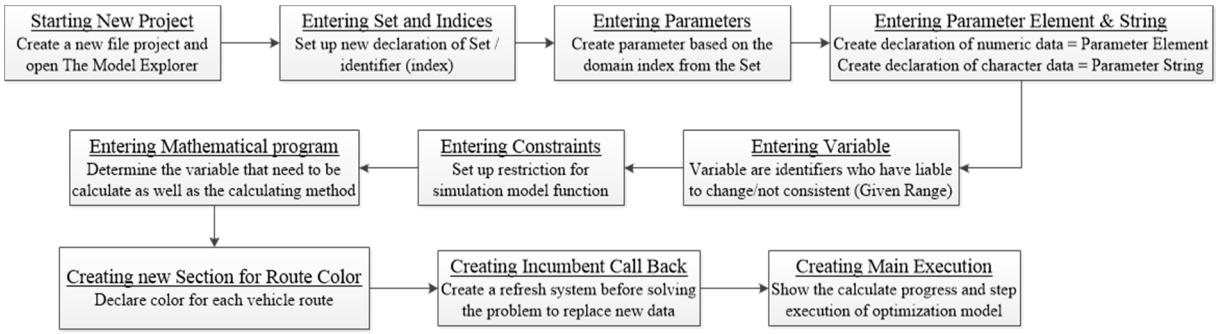

Figure 4.1 Flow chart building simulation model

5. Result and Discussion

The distribution system in PT Anugrah Citra Boga have a number of customers that have a daily routine of shipment in each day. The comparison between the model simulation and real life data is based on the total time for each vehicle. Provided that, in this paper to analyse between real life data and simulation data it takes Monday 2 May 2016 as the sample. On Monday the number of customers need to be deliver are 9 customers, which is bakso dimas, hero distribution centre (DC), hypermart distribution centre (DC), kimbo, Grogol traditional market, Senen traditional market, yusuf catering, carefour ITC Depok and at last hypermart Depok. Based on the real life data, for 9 customers the company use 2 vehicles to accompany all shipment of goods. Two route are made, the first one is south route in delivering 3 customers as Senen market, carefour ITC Depok, and hypermart Depok. Next for the second vehicle they use east route and start from Grogol market to bakso dimas, yusuf catering, kimbo, hypermart DC, and hero DC. The real life data for the distribution are shown as figure 5.1.

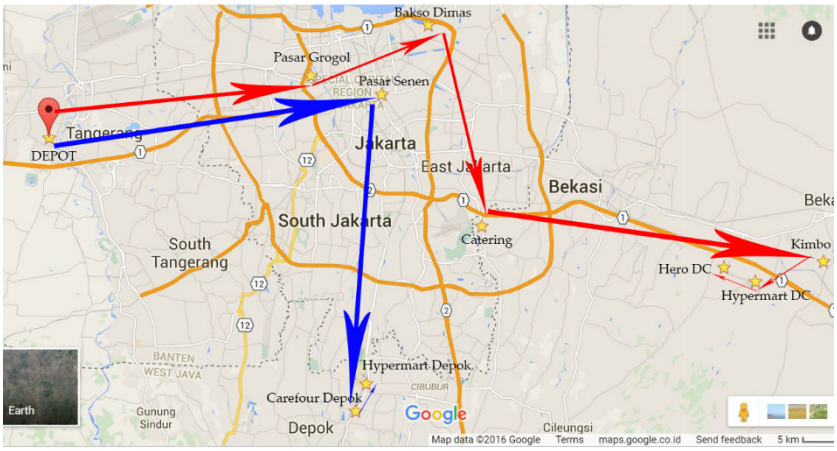

Figure 5.1 Distribution Route Real Data

5.1.Comparison Route

According to the data on Monday 2 May 2016, the total time of delivery is 790 minutes by using 2 vehicles. For each vehicle with the route as shown in figure 5.1 the delivery time for red route is 505 minutes which is more than the worker time (480 minutes). On the other side, the blue route delivery time is 285 minutes which is far from the standard worker time. Imbalance of vehicle distribution may occur an additional cost for red route vehicle and idle time for blue route vehicle. After calculating by using model distribution the result is 791 for total time of 2 vehicles, it seems that the simulation time is higher than the real data. However, the delivery time for each vehicle didn't exceed the capacity of worker time. The amount of delivery time for the first vehicle and second vehicle are 462, 329 respectively. By optimizing the delivery time for each vehicle it prevents from additional cost of worker overtime and minimize idle time. The comparison of simulation model distribution and historical data distribution is shown as table 5.1 and present in figure 5.2.

Table 5.1 Comparison real route and simulation model distribution on Monday 2 May 2016

Data Customer		Real Route		Simulation Route	
Code	Customer Name	Vehicle 1	Vehicle 2	Vehicle 1	Vehicle 2
2	Bakso dimas	1	1	1	1
3	Hero DC	6	8	7	6
4	Hyper DC	2	13	5	2
5	Kimbo	7	15	3	8
6	Grogol	5		4	13
7	Catering	4			15
8	Senen	3			
13	ITC depok				
15	Hyper depok	1	1	1	1
Departure		4:15	4:15	4:15	4:15
Arrival		12:40	9:00	11:57	9:44
Time Durations (minutes)		505	285	462	329
Total Time (minutes)		790		791	

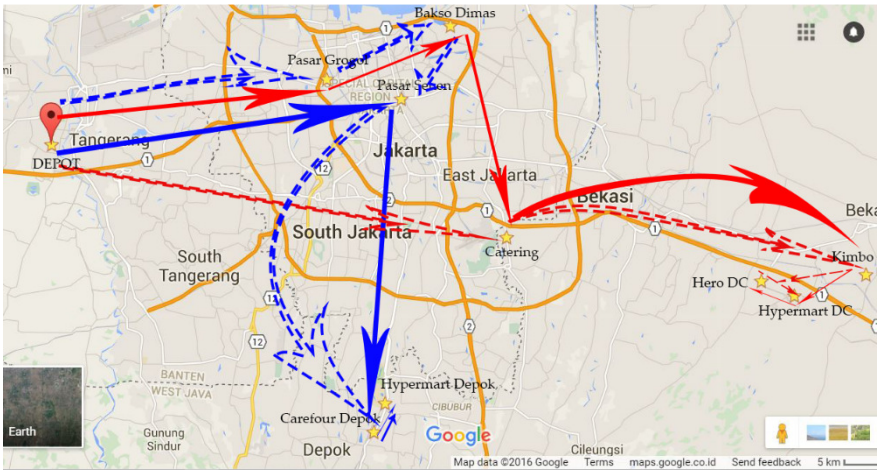

Figure 5.2 Comparison route of simulation and historical data

5.2.Utilization

Further calculation for each day over a week there are variant numbers of time for vehicle 1 and vehicle 2. To compare data simulation and historical data in this thesis it takes 6 days of working day which is Monday 2 May 2016, Tuesday 3 May 2016, Wednesday 11 May 2016, Thursday 5 May 2016, Friday 6 May 2016 and Saturday 7 May 2016. For the comparison time of each vehicle it shown at table 5.2.

Table 5.2 Data comparison delivery time

Delivery Time (minutes)				
Day / Date	Real Data		Simulation Data	
	Vehicle 1	Vehicle 2	Vehicle 1	Vehicle 2
Monday / 2 May 2016	505	285	462	329
Tuesday / 3 May 2016	465	255	294	413
Wednesday / 11 May 2016	585	345	476	364
Thursday / 5 May 2016	435	175	432	193
Friday / 6 May 2016	545	375	463	479
Saturday / 7 May 2016	195	0	185	0
Total Time in 1 Week	2730	1435	2312	1778

The total time capacity for each vehicle in 1 week is 2610 minutes, with a calculation of half day on Saturday. Based on the real data for vehicle 1 it takes 2730 minutes on the total time delivery which is exceed the capacity of time. The extra time will be paid as the worker overtime cost. The amount of time that vehicle 1 use it exceeds the utilization over 100% with number of 104.6%. Next, for vehicle 2 it has shipment time 1435 minutes with the capacity over 5 days is 2400 minutes. The utilization of vehicle 2 is 59.8% and it quite low for utilization rate of vehicle because around 40% of time are idle for vehicle 2. By optimize the distribution route using the AIMMS model it create a higher efficiency over vehicle 1 and vehicle 2. The calculation in one week it turns out that by using simulation model it optimize the distribution for vehicle 1 to prevent from worker overtime. The rate of vehicle 1 become 88.6% it is high for a utilization rate. On the other hand, the simulation model increases the delivery time of vehicle 2 from 1435 minutes to 1778 minutes. Increasing the amount of time will affect the utilization rate from 59.8% to 74.1%. The graph of delivery time comparison shown as figure 5.3.

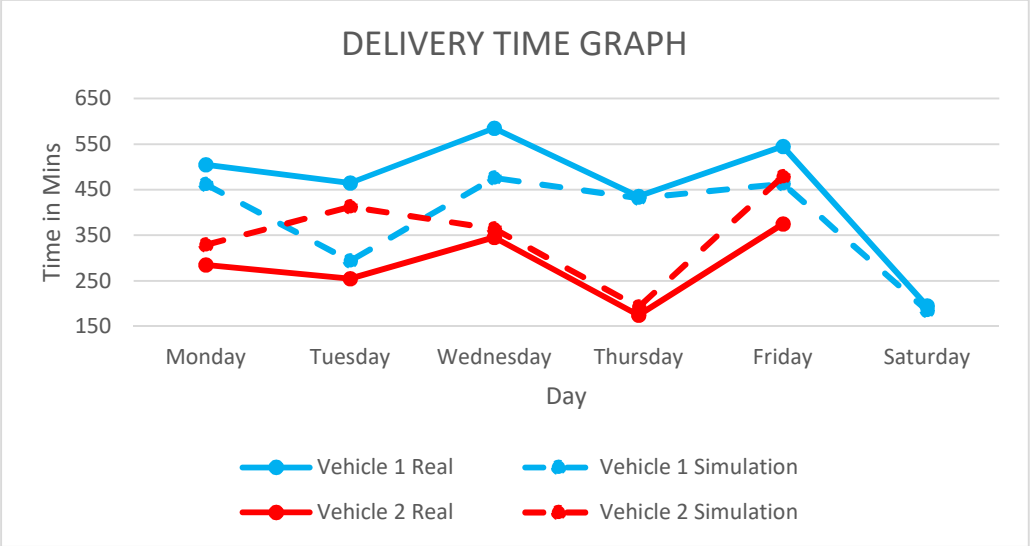

Figure 5.3 Comparison delivery time graph

5.3.Cost comparison

Next step is cost comparison between historical data and simulation data. The cost of each day over a week will be shown as table 5.3. Total cost obtained from fuel which is Indonesia Rupiah /minutes add by the worker overtime and wage.

Table 5.3 Comparison shipping cost data

Shipping cost data		
Day / Date	Real Data	Simulation Model
Monday / 2 May 2016	Rp608,100	Rp558,490
Tuesday / 3 May 2016	Rp530,800	Rp525,730
Wednesday / 11 May 2016	Rp615,900	Rp577,600
Thursday / 5 May 2016	Rp487,900	Rp493,750
Friday / 6 May 2016	Rp658,800	Rp617,380
Saturday / 7 May 2016	Rp326,050	Rp322,150
Total Cost in 1 Week	Rp3,227,550	Rp3,095,100

Based on the comparison data over shipment cost in one week. The total cost of real data is Rp3,227,550 for both vehicles. However, the total cost that obtained from the model simulation is Rp3,095,100. The difference in cost between real data and simulation data is Rp132,450 for 1 week or Rp529,800 per month. The company could make a saving around 4.1% by using the model simulation. The graph of shipment cost comparison is shown as figure 5.4.

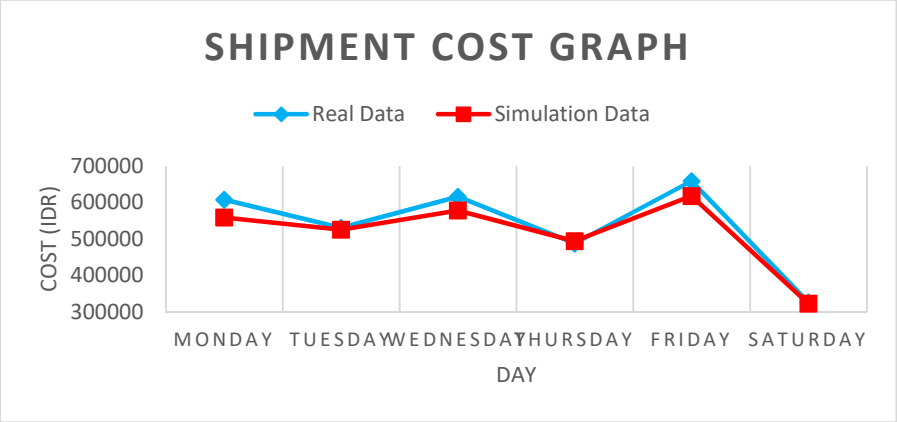

Figure 5.4 Comparison shipment cost graph

6. Conclusion

Transportation of goods is an important issue that need to be concern to minimize the cost. The thesis explains about observation and calculation model of distribution in PT Anugrah Citra Boga. The distribution software model use to optimize the routing is AIMMS software, by comparing the total cost between historical data and model simulation it concludes that this software could minimize the distribution cost around 4.1% or Rp529,800 in one month. Furthermore, the calculation of model using capacitated vehicle routing problem method could optimize the utilization of each vehicle. For the first vehicle, according to the historical data they use to have 104.6% utilization rate which is affect the worker overtime. On the other hand, for vehicle 2 the utilization rate quite low with a number around 59.8%. Using the simulation model it can increase the efficiency of the two vehicle to be more optimal in delivering goods. The utilization rate by the simulation model become 88.6% and 74.1% respectively for both vehicles 1 and 2.

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