PENENTUAN RUTE DARI PRODUK FMCG DI PT.ABC DENGAN VEHICLE ROUTING PROBLEM-MULTI-TRIP, TIME WINDOW MENGGUNAKAN METODE BRANCH AND BOUND UNTUK MEMINIMASI JARAK TEMPUH KENDARAAN.

DESIGNING DISTRIBUTION ROUTES Of FMCG PRODUCT IN PT ABC WITH VEHICLE ROUTING PROBLEM MULTI-TRIP, AND TIME WINDOW USING BRANCH AND BOUND METHOD TO MINIMIZE TRAVEL DISTANCE.

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Abstrak—Proses distribusi merupakan sebuah rangkaian penting di dalam logistik yang memiliki peran penting untuk menunjang faktor kepuasan pelanggan. Dalam proses ditribusinya, PT ABC memilki 29 customer lokal yang tersebar di daerah Jawa Barat. Dimana proses konfirmasi pengiriman dilakukan sehari sebelum pengiriman barang dilakukan ke customer. Dalam proses distribusi, PT ABC mengalami keterlambatan sebesar 21% dalam kurun waktu 6 bulan. Kondisi ini membuat PT.ABC harus membayar bea penalty sehingga ongkos transportasi menjadi naik. Dimana keterlambatan keberangkatan armada memiliki prosentase terbanyak, yaitu sebesar 61%.. Keterlambatan keberangkatan armada disebabkan tidak adanya penjadwalan keberangkatan armada dan tidak adanya pemilihan rute yang tepat untuk setiap customer sehingga jarak tempuh customer menjadi lebih besar. Pada penelitian kali ini, akan dilakukan penjadwalan keberangkatan armada dan penentuan rute setiap customer dengan tipe VRP yaitu Multi-Trip Vehicle Routing Problem (VRPMT) dan Vehicle Routing Problem with Time Window (VRPTW) menggunakan salah satu metode eksak yaitu algoritma Branch and Bound dengan fungsi tujuan meminimasi jarak tempuh kendaraan. Hasil akhir dari algoritma Branch and Bound dapat meminimasi jarak tempuh sebesar 17,1%.

Kata kunci: Vehicle Routing Problem (VRP), VRP Multi-Trip (VRPMT), VRP Time Window (VRPTW), Scheduling, Branch and Bound Algorithm.

Abstract— PT.ABC is a food industry that produces chocolate and cocoa products that have been established for 175 years and located in Bandung. In a distribution process PT ABC have 29 local customer around West Java, with delivery confirmation done one day before loading date to customer. Delay in delivery to customer is the main problem of PT ABC that need to solve, they reach 21% delay in distribution customer order for 6 month. It will affect increase in transportation cost because PT ABC should pay penalty cost. There are 4 factors impact delay of distribution process, but delay in departure of fleet has the biggest rate , about 61%. It caused by there is no schedule in fleet departure and there is no right designing route for each customer. In this research, this case will be done by create scheduling and vehicle routing problem with characteristic contained Multi-Trip Vehicle Routing Problem and Vehicle Routing Problem with Time Window using Branch and Bound Algorithm to minimize travel distance. In the end, the travel distance can be minimized 17,1%.

Keywords: Vehicle Routing Problem (VRP), VRP Multi-Trip (VRPMT), VRP Time Window (VRPTW), Scheduling, Branch and Bound Algorithm.

I. INTRODUCTION

On the supply chain the delivery of goods occurs at the beginning of incoming materials (inbound logistics) and when the finished goods is delivered to the customer (outbound logistics), and at the right time and place. And will involve transportation services. In the scope of distribution activities, companies should be able to design an appropriate distribution network. Decisions on the design of distribution networks should consider trade-offs between cost aspects, flexibility aspects, and responsiveness to consumers. When the customer order can not distribute well, it will cause decrease in service level of customer. The lateness of distribution delivery to customer is happened in PT.ABC with total customer around 70 local customer, but in this research the researcher using customer that allocated in around west java. Below, in Figure 1.1 shown about the number of delivery delays occurring during the period January to June 2017 :

Month	Total Departure	Total Delay of Delivery	Delivery Achievement
January	575	94	84%
February	534	114	79%
March	534	294	45%
April	421	8	98%
May	528	148	72%
June	381	11	97%

Figure 1.1: Total Delay of Delivery to Customer

Based on the table above, the average of total delay of finished good delivery to customer is 111 order, with average of delivery achievement is 79%. Below is the reason of delivery delay on customer order:

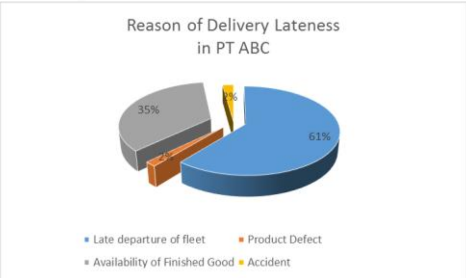

Figure 1.2: Reason of Delivery Lateness in PT ABC
(Source: Data of PT ABC)

Based on the graph I.1 above, there are 4 reason of delivery delay. The most reason that because the delivery lateness is late in departure of fleet. It caused by there is no schedule in fleet departure and there is no right designing route for each customer. During the distribution process, the selection of customer delivery routes is based on the driver intuition, this results in the travel distance for each delivery becomes larger and makes the delivery time becomes longer so that delivery of goods to the customer can be late because it exceeds the customer's time window.

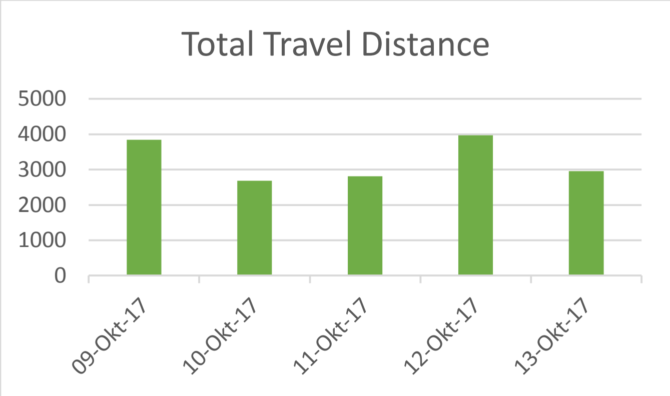

Figure 1.3: Graph of travel distance each day
(Source: Data of PT ABC)

Based on the comparison graph above shown about the travel distance each day in one week . The existing travel distance will be compared with the proposed travel distance that will be solve using branch and bound algorithm in a Bab IV.

The researcher will perform the process of determining the optimal route for the distribution of finished goods and scheduling the departure of each fleet for every customer with the objective purpose is minimizing travel distance. In determining the route, the researcher uses VRP (vehicle routing problem) method by considering multiple trips, and time windows. This research is conducted in accordance with the problems that exist in PT ABC

II. STUDY OF LITERATURE

A. Vehicle Routing Problem

In determining the route and delivery schedule it is necessary to determine what modes of transportation to use, what number and capacity, and which route to travel for each fleet that fulfills the optimal objective function [1]. Vehicle routing problem (VRP) is general term that given specially for vehicle routing problem with variance of characteristic such as tota depot, total route, classification of vehicle, etc. The objectives of VRP is to serve customer with minimum operational cost. VRP was first studied by Dantzig and Ramser [2] in the form of truck routes and scheduling. Clarke and Wright [3] then continued this research by introducing the term depot as a place of departure and return of the vehicle.Clarke and Wright use saving algorithm. The VRP solution is used to determine transportation routes so that the requirements of the suppliers are met, and minimize the total transportation cost by Ripaldi 2017 [4] .

The main objective function of the VRP problem is to minimize the number of vehicles used and minimize the total travel distance. Minimize the number of vehicles is usually placed as the main objective function and then minimize vehicle mileage. While the other objective function is to minimize the completion time for each vehicle, as well as the time range of completion between vehicles, or other types of objective functions according to the needs and characteristics of each case.

B. Multi-Trip Vehicle Routing Problem

Multi-Trip VRP (VRPMT) is applied by considering the number of routes taken, where there are more than 1 routes that can be taken by the fleet. Thus the fleet can travel several routes by returning to the depot first.

C. Vehicle Routing Problem with Time Window

VRP with Time Window (VRPTW) is applied by considering the time window owned by the customer. Time window is the time frame specified by the supplier or depot where the activity should only be done in that time span

D. Exact Algorithm

Is an algorithm that will generate a direct solution by trying out all the permutations and see which one is the cheapest. This approach lies in the polynomial factor of O (n!), Factorial from some cities, so this solution becomes impractical even for only 20 cities [5]. Two algorithms that fall within the exact algorithms are the branch and bound algorithm, and the cutting plane algorithm

E. Branch and Bound Algorithm

To solve a problem of LP in order to obtain optimal results can be done with several methods, one of which is using the simplex method developed by Dantzig in 1947. This method is an iterative method in solving linear programming problems. In simple terms, the LP model with an additional delimiter of its integer value is referred to as integer programming (IP) by Iskandar [6]. LP obtained from the IP by eliminating the constraintt of integers or constraintts 0-1 on the variable is called linear programming relaxation (LP relaxation) taht define by Winston [7]. The advantages of branch and bound methods lie in their level of effectiveness in solving problems with accurate results.

The basic principle of the branch and bound method is to break the feasible area of the LP problem by creating a new subproblem so that IP can be unsolved. The feasible region of an LP is the region containing the dots can meet all linear problem constraintts LP by Taha [8]

Each subproblem is limited in three ways :

1. The limit of the optimum solution subproblem obtained (z *)
2. LP-relaxation has no feasible solution
3. The optimum solution of LP-relaxation is integer. If this solution is better than the optimum obtained before then this solution becomes the new optimum solution and the first way is reused for all subproblems with larger new value * z.

The branch and bound method has been used extensively in recent decades in solving the CVRP problem which is an extension of the problem closely related to traveling salesman problem (TSP), to the problem of determination optimization of vehicle travel mileage based on Toth, P., Vigo [9].

The objective function of this research is to minimize travel distance. Below, is a mathematical model that has been formulated from the problem on the existing condition :

Indeks:

i = index of notation, where i = 0.1,2,3, ... n is the customer / warehouse / distribution center that started.

j = index of notation, where i = 0.1,2,3, ... n is the customer / warehouse / distribution center that started.

k = index of notation, k = 0.1,2,3, ... k is the type of distribution fleet used

r = index of notation, r = 0.1,2,3, ... r is the route through which the type of distribution vehicle.

Parameter:

d_ij = Travel Distance from i to j (m)

S_i= Service Time in node i using fleet k (minute).

t_ijk =Travel time each types of fleet from node i to j for each types of fleet k(minute).

ot_i= The initial time window limit at point i (minutes).

ct_i= The end time window limit at point i (minutes).

q = Demand from each customer (box).

Q_k = Capacity of fleet.

S = Real number of great value.

a_i = Arrival of fleet in customer i.

p_i = Departure of fleet from customer i.

Decision Variabel :

x_ij^k = 1, Which mean if distribution route going to i to j by using types of fleet k. It will 0, Otherwise.

y^k = 1, Which mean if types of fleet k is used to travel.

= 0, Otherwise.

Objective Function :

$$min \sum_{k=1}^{T} \sum_{j=0}^{M} \sum_{i=0}^{M} d_{ij} \quad X_{ij}^{k}$$

Based on the objective function above, explained that the main objective of solving the existing problems in this research is to minimize the travel distance.

Constraint :

$$\sum_{k=1}^{T} \sum_{i=0}^{M} x_{ij}^{k} = 1 \quad \forall \mathrm{j} = 1,2,3, \ldots \mathrm{M} \tag{1}$$

Constraint (1) shown that any selected route will only have 1 used or selected. For each route from i to j will started at depot, that denote by i = 0,1,2,...M. Which mean, 0 is a depot and M is the set of customer goals., M

$$\sum_{k=1}^{T} \sum_{j=0}^{M} x_{ji}^{k} = 1 \quad \forall \mathrm{i} = 1,2,3, \ldots \mathrm{M} \tag{2}$$

Constraint (2) shown that any selected route will only have 1 used or selected. For each route from i to j will started at depot, that denote by j = 0,1,2,...M. Which mean, 0 is a depot and M is the set of customer goals.

$$\sum_{i,j=0}^{M} X_{ij}^{k} - \sum_{j,i}^{M} X_{ji}^{k} = 0 \quad \forall \mathrm{k} = 1,2, \ldots \mathrm{T} \ \forall \ l = 2, \ldots \mathrm{M} \tag{3}$$

Constraint (3) used for each route that will be passed by each type of fleet which distribute the customer's order i exactly one time and leave then go to the next customer. So this constraint explains the route of the vehicle to be connected continuously and the vehicle departs from the last position visited.

$$\sum_{i,j=0}^{M} X_{i\,(n+1)}^{k} = 1 \quad \forall \mathrm{k} = 1,2, \ldots \mathrm{k} \tag{4}$$

Constraint (4) ensure that fleet will be back to depot as a end route. Which is end route demoted by n+1.

$$\sum_{i=1}^{M} \sum_{j=1}^{M} x_{ij}^{k} \, q_j \leq Q_k \tag{5}$$

Constraint (5) guarantees that the demand of customer each tour will not over capacity of the fleet.

P_i+S_ik+t_ij-S(1-x_ij^k)≤a_(j) ∀i = 1,2,3,...M ∀j = 1,2,3...M (6)

Constraint (6) ensures that the arrival fleet time in j should be greater than departure time of fleet in i.

$$ot_i \leq S_{ik} \leq ct_i \quad \forall \mathrm{i} = 1,2,3,\ldots\mathrm{M} \quad \forall \mathrm{k} = 1,2,\ldots\mathrm{T} \tag{7}$$

Constraint (7) is a logic constraint that ensure arrival time of fleet in customer must be within the specified time window range.

$$\sum_{k=1}^{T} \sum_{j=1}^{M} x_{ij}^{k} \geq 1 \quad \forall \mathrm{i} = 0,1, \ldots \mathrm{M} \tag{8}$$

$$\sum_{j=0}^{M} \sum_{k=1}^{T} x_{ijk}^{r} \leq \sum_{j=0}^{M} \sum_{k=1}^{T} x_{ijk}^{r+1} \quad \forall \mathrm{i} = 0,1, \ldots \mathrm{M} \tag{9}$$

Constraint (8) and (9) explain that each type of fleet can travel to customer more than once. Which k types of fleet can start the route in r+1 after r route finished then back to the distribution center.

X_(ijk)∈{0,1}, ∀i,j = 0,1,...,M, ∀k= 1,...,T (10)
y_(k)∈{0,1},∀k=1,...,T (11)

Constraint (10) and (11) indicates that value for each decision variabel is 1 when there are selected route from i nodes to j and otherwise when the value is 0.

III. RESEARCH METHODOLOGY

A. Collecting Stage

Data collecting and processing stage is when required data are collected and processed to obtain the desired output as the optimum solution of case of this research.

a. Data Collecting

In this stage, researcher require data to support this research is obtained, which are as follows:

1. Data of Customer Demand
   Data demand was obtained from the historical data of company in period of September 2016 – Juni 2017. The data of customer demand is needed to know the quantity of finished goods that ordered by customer. This data will be used for data processing to determine allocation of goods placement.
2. Data of Location
   Data location is used to find out the the purpose of delivery of vehicles to the customer, this data will also be used to conduct the preparation of routes and departure hours of the distribution fleet.
3. Data of Travel Time
   Data of travel time is data that used to know the travel time between depot to customer and between customers to other customer.
4. Data of Time Window and Service Time
   Data of time window is used to find out time limit of service provided by each outlet and to determine route and optimum departure time. While the data service time is the time measured directly in the field when the vehicle began to queue until the unloading process where each customer has a different service time different.
5. Data of Transportation Cost
   Data of transportation cost consist of fixed cost and variable cost. Fixed cost of transportation cost that used in this research is fuel cost, while variable cost that used in this research is depreciation cost and maintenance cost.
6. Data of Mileage from Warehouse to Customer
   Mileage form warehouse to customer is a data that aims to know distance between warehouses with customer location.
7. Data of Distance between Customers
   This data is used to know the distance between customer that wil be addressed. To support the data processing, mileage data is required.
8. Data of Fleet Capacity
   This data is aimed to be reference in measuring volume capacity.

B. Data Processing Stage

1. Formulation of mathematic models
   At this stage will be modeling problems of distribution of goods mathematically on the condition of the initial conditions. The resulting mathematical model is the objective function of the optimization performed along with the limiting function. Later this model will be used as a reference in the stage of doing the route determination using exact method modeling with Branch and Bound Algorithm. In this research, the mathematical model of the problem outline has the objective function to minimize the frequency of delivery delay and transportation cost.

2. Verification of Mathematics Model
   After formulating the mathematical model will be done Mathematical Model. Verification consists of 2 parts: verification of left-right segment and model verification with matlabcode. The purpose of verifying the left and right sides is to match the objectives and limits on the research of the left and right sides. The purpose of verifying mathematical models with matlabcode is to match whether the matlabcode is matched with the constraintts contained in the mathematical model.

3. Validation of Mathematics Model
   After the verification of the mathematical model, the next is the validation of mathematical models with influence diagram and pair t test. Validation of mathematical models with influence diagrams is useful to ensure that mathematical models with influence diagrams are the same and corresponding. So there is no mistake in the mathematical model. Then the purpose of pair t test to determine whether the valid or not data has been collected and mathematical models.

4. Optimum Distribution Route Calculation
   After verification and validation then next is the calculation of route solution using Branch and Bound algorithm. Route route calculation using Matlab software. The calculation of Branch and Bound begins with determining the initial weight of each customer and will be selected the smallest weight of each customer. So it will produce an optimal route.

5. Verification the Distribution Route Result with Constraint
   After getting route solution using Branch and Bound algorithm, next is verification of route result with delimiter. The delimiter consists of the customer's time window, the vehicle's capacity is not exceeded, and the vehicle can send back when it is returned to the depot.

IV. RESULT AND ANALYSIS

A. Proposed Distribution Route

Picture IV.1 shown about proposed distribution route by using branch and bound algorithm :

Fleet	Distribution Route									
1	DC	A010	A015	A020	A012	DC	A012	DC	A022	DC
2	DC	A012	A026	A007	DC					
3	DC	A016	A007	DC						
4	DC	A006	A019	Depot	A009					
5	DC	A029	A019	A011	A008	A005	Depot			
6	DC	A023	A005							

Picture IV.1 Proposed Distribution Route

B. Fleet Usage

In the existing condition, there are 7 fleet needed to conduct distribution process to each customer.But, in this research based on Table IV.1, the usage of fleet in one day for 17 customer is 6 fleet .

C. Comparison between existing and proposed Travel Distance and Travel Time.

Below is the comparison of travel distance between the existing condition and the proposed condition:

Table IV.1 Travel Distance

Fleet	Travel Distance (km)	
	Existing	Proposed
1	547	102,3
2	197,8	449,7

Fleet	Travel Distance (km)	
	Existing	Proposed
3	86	306
4	251,6	301,5
5	333,7	322,6
6	508,6	343,4
7	276	
Total	2201,1	1825,5

Based on the Table V.2, travel distance in existing condition is 2201,1 km , then the travel distance of proposed distribution route is 1825,5 km. The difference between the existing and the proposal is 17,1% smaller than the existing condition.

Below is the comparison of travel time between the existing condition and the proposed condition:

Table IV.2 Travel Time

Fleet	Travel Time (Hour)	
	Existing	Proposed
1	9,033	3,467
2	3,037	5,600
3	2,7	7,483
4	4,250	8,267
5	6,817	5,867
6	10,800	5,967
7	4533	
Total	41,170	36,650

Based on the Table V.3, travel time in existing condition is 41,17 hour , then the travel distance of proposed distribution route is 36,650 hour. The difference between the existing and the proposal is 11 % smaller than the existing condition.

D. Schedule of Fleet Departure

Determination of schedule is urgent to know time calculation, when fleet should be arrive to customer and when fleet should be back to the depot. Below in table V wil show about the departure time schedule in 1 day horizon planning :

Fleet	Dep Time	Distribution Route									
1	7:30	DC	A010	A015	A020	A012	DC	A012	DC	A022	DC
2	7:30	DC	A012	A026	A007	DC					
3	7:30	DC	A016	A007	DC						
4	7:30	DC	A006	A019	DC	A009					
5	7:30	DC	A029	A019	A011	A008	A005	DC			
6	7:30	DC	A023	A005							

Picture IV.2 Schedule of Fleet Departure

V. CONCLUSION

In this research the main topic is how to designing the optimal distribution route with objective function minimizing travel distance by using branch and bound algorithm. The conclusion of this research are:

1. Optimal route that obtain by using branch and bound algorithm in 1 day horizon planning are for distribution route for fleet 1 is Depot-A010-A015--A020-A012-Depot-A012-Depot-A022-Depot, distribution route for fleet 2 is Depot-A022-A026-A002- Depot., distribution route for fleet 3 is Depot-A016-A007-Depot-A002-Depot, distribution route for fleet 4 is Depot-A007-A006- Depot-A006- Depot, distribution route for fleet 5 is Depot-A005-A029-A019-A011-A008-Depot, distribution route for fleet 6 is Depot-A023-A008-A009 –Depot. This design of distribution route just need 6 fleet to distribute the customer's order, while the existing condition PT ABC need 9 fleet to distribute the customer order.

2. The departure time schedule for each fleet is explain that each kind of fleet should be depart form depot/distribution center at 07:30.
3. Total reduction travel distance of fleet is 17, 1% smaller than existing condition.
4. Total reduction of total transportation cost is 11 % smaller than existing condition.

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