CHAPTER III

LITERATURE REVIEW

There are some techniques, which have been applied in finding out the solution to manage vehicles that have been divided by two parts as Vehicle Routing Problem (VRP) and Vehicle Routing – Scheduling Problem.

1. Study of Vehicle Routing Problem (VRP)

The classical routing problem is defined on graph G = (V,A) where $V = \{v_1, \ldots, v_n\}$ is a set of vertices and $A = \{(v_i, v_j): i \neq j, v_i, v_j \in V\}$ is the arc set . Vertex v_1 is a depot at which is located a fleet of m identical vehicles of capacity Q. The remaining vertices represent customers. Each customer is associated with a nonnegative demand d_j to be collected or delivered by a vehicle. A matrix $C = (c_{ij})$ is defined on A; each edge (v_i, v_j) is associated with a distance or travel cost c_{ij}.

The VRP is to design a set of m vehicle routes of minimum total cost, each starting and ending at the depot, such that each vertex of $V \setminus \{v_1\}$ is visited exactly once by one vehicle and satisfied some side constraints. A route is a sequence of locations that a vehicle must visit along with the service it provides. The routing of vehicles is primarily a spatial problem. It is assumed that no temporal or other restrictions. Impact the routing decision except for (possibly) maximum routing length constraints.

The basic of Branch and Bound for solving the Travelling Salesman Problem (TSP) has been described by Little Et (1963). The main principle is to divide the route into the smallest part to calculate the lower limit of costs and find the best vehicle route.

Formulations;

C = c(i,j) Matrix of costs for transportation between city i and j

t = Transportation route shown in set "n" ex.(i1,i2),(i2,i3),...,(in,i1)

Z(t) = Costs for transportation route "t"

X,Y,Z = Points

W(X) = Lower limit of costs for transportation route "X"

Z_0 = Lowest costs

$$Z(t) = \sum_{(i,j) in\ t} c(i,j) \tag{1}$$

The best-known approach to the VRP problem is the Savings Algorithm of Clarke and Wright (1964). Its basic idea is very simple by considering a depot D and n demand points. Suppose that initially the solution to the VRP consists of using n vehicles and dispatching one vehicle to each one of the n demand points. The total tour length of this solution is $2\sum_{i=1}^{n} d(D,i)$

If now using one vehicle to serve two points, say i and j, on a single trip, the total distance is reduced by;

$$\begin{aligned} s(i,j) &= 2d(D,i) + 2d(D,j) - [d(D,i) + d(i,j) + d(D,j)] \\ &= d(D,i) + d(D,j) - d(i,j) \end{aligned} \tag{2}$$

The quantity s(i, j) is known as the "Savings" resulting from combining points i and j into a single tour. The larger s(i, j) is, the more desirable it becomes to combine i and j in a single tour. However, i and j cannot be combined if the result violates one or more of the constraints of the VRP.

The algorithm can now be described as follows.

1: Calculate the savings s(i, j) = d(D, i) + d(D, j) - d(i, j) for every pair (i, j) of demand points.

2: Rank the savings s(i, j) by descending order of magnitude. This creates the "savings list". Process the savings list beginning with the topmost entry in the list (the largest s(i, j)).

3: For the savings s(i, j) under consideration, include link (i, j) in a route if no route constraints will be violated through the inclusion of (i, j) in a route.

4: If the savings list s(i, j) has not been exhausted, return to Step 3, processing the next entry in the list; otherwise, stop: the solution to the VRP consists of the routes created during Step 3.

Tyagi (1968) developed a simple method, which did not limit in problem capacities and variables (unaffected to the result). He focused on the maximum of loading capacity and simulated the problem by referring to Travelling Salesman Problem (TSP) to proceed the needs of vehicle capacity and a route for example; the total distance were calculated based on the shortest route.

Formulations;

$p_1, p_2, \ldots, p_n$		The end of tour that needs $q_1, q_2, \ldots, q_n$
p_0	=	Depot
C	=	Truck capacity
d_{ij}	=	Distance between i, j
x_{ij}	=	1 (if select route i-j) or 0 (if not select i-j)

This will show the minimum x_{ij} to find the minimum total distance.

$$MinT = \sum_{i,j=0}^{n} d_{ij} x_{ij} \tag{3}$$

"Sweep Algorithm" method explained by Gillet (1974) was able to solve the problem (10-250 demand points) with constraints of truck capacity and tour distance. The terminal can be located by "Polar Coordinates" method. The algorithm can now be described as follows.

1. Select point A by sampling and connect with the Depot B.
2. Sweep line AB counter clock wise until full vehicle capacity.
3. Use the method of "travelling Salesman Problem" with a single salesman to find proper route.

4. Calculate tour time. If over than limit, return line AB and reduce points then find the new tour and recalculate time.

5. Repeat until getting complete route.

Formulations;

N	=	Number of demand points (including the Depot used as point 1)
Q(I)	=	Capacity demand for position I
(X(I), Y(I))	=	Position of point I
C	=	Truck capacity limit
D	=	Maximum tour distance of vehicle
A(I, J)	=	Distance between I and J
An(I)	=	Angle of point I (I = 2, 3, ..., N) limited by
An(I)	=	arc tan [(Y(I) – Y(1)) / (X(I)-X(1))] (4)

So $-n < An(I) < 0$ if $Y(I) - Y(1) < 0$

And $0 < An(I) < n$ if $Y(I) - Y(1) > 0$

R(I) = Radius from point 1 to point I (I = 2, 3, ..., N)

Equations are;

$Q(I) < C$	For every I	(5)
$A(I, J) > 0$	For every I and J	(6)
$A(I, J) = 0$		(7)
$A(I, 1) + A(1, I) < D$	For every I	(8)
By $An(I) < An(I+1)$	For every I	

Holmes and Parker (1976) studied about standard vehicle routing problem on the concept of the minimum costs by developing from Clark and Wright research. Saving cost $S_{ij} = C_{i1} + C_{1j} - C_{ij}$ had been applied same algorithm as Clark and Wright.

Bodin and Golden (1981) researched on Node Routing Problem solved by considering the minimum costs, the shortest route, and possibility of the routing for each vehicle and listed 13 dimensions in their classification of vehicle routing problems, each of which is divided into several categories as in Table 3.1.

Table 3.1 Characteristics of Routing Problem by Bodin and Golden (1981)

Characteristics	Possible Options
1. Size of available vehicle	One vehicle
	Multiple vehicles
2. Type of available fleet	Homogeneous (only one type of vehicle)
	Heterogeneous (multiple types of vehicle)
	Special vehicle types
3. Housing of vehicle	Single depot
	Multiple depots
4. Nature of demand	Deterministic (known) demand
	Stochastic demand
	Partial satisfaction of demand
5. Location of demand	At nodes
	At arcs
	Mixed
6. Underlying network	Undirected
	Directed
	Mixed
	Euclidean
7. Vehicle capacity restrictions	Imposed (all the same)
	Imposed (different route)
	Not imposed (unlimited capacity)
8. Maximum route times	Imposed (same for all routes)
	Imposed (different for each route)
	Not imposed
9. Operation	Pick ups only
	Drop-offs (delivery) only
	Mixed (pickup and delivery)
10. Cost	Variable or routing cost
	Fixed operating or vehicle cost
	Common carrier cost
11. Objective	Minimize total routing cost
	Minimize number of vehicle required
	Minimize utility function based on service or convenience
	Minimize utility function based on customer priorities

Turnquist and Jordan (1988) presented the model to find the best value for continuous transportation and decided waste movement from assemble plant to dealers. They studied at General Motor Company (GM) with its dealers. They grouped 75 zones of dealers and this problem was shown by Linear programming model that analyzed the result between total costs and vacant vehicle movement.

Savelsbergh and Goetschalacx (1995) was debated about any truck accent and transportation problem, they was submit the general clear up model which able to manage truck complexity and transportation problem also. Moreover, they show an opinion poll of any problem types and the way to clear up each problem also.

2. Vehicle Routing – Scheduling Problem

The Vehicle scheduling problem can be thought of as a routing problem with additional constraints related to the time various activities may be carried out. The routing problem gives special importance to the spatial characteristics of the activity. In scheduling problem, however, a time is associated with each activity. Thus, the temporal aspects of vehicle movements now have to be considered explicitly. As a result, the activities are followed in both space and time.

The feasibility of an activity is also influenced by both space and time characteristics, e.g. a single vehicle could not service two locations with identical delivery or pickup time. The sequencing of vehicle activities in both space and time is at the heart of the vehicle scheduling problem (Bodin et al. 1983).Real-world constraints commonly determine the complexity of the VSP. The restrictions are:

a) Constraint on the length of total time or distance a vehicle may be in-service before it must return to the depot;

b) The restriction that certain task can only be serviced by certain types of vehicles;

c) The time allowed for vehicles to service at each location (or time windows);

d) The precedence requirement of the service (such as pick-ups should be done before a delivery);

e) The presence of variety of depots where vehicles may be housed.

Bodin et al. (1983) explained the category of vehicle routing problem and scheduling by applying the algorithm techniques. They improved the overview of solution including the application as well. The basic concept in finding the vehicle route and schedule- planning was the same. The vehicle route and transportation time must be specified. For the vehicle route, they specified the series of pickup point. On the other hand for the schedule, they specified the timing for each activity in each pickup point.

They presented the limitation, which was the condition of complex vehicle routing schedule problem such as

1. The condition of period of time which vehicle consumed for checking and fuel filling up.
2. The condition of some tasks which were assigned for some specific vehicle only
3. The vehicle parking in different place

The schedule arrangement problems of different kind of vehicle and the data warehouse in different place are represented by the formula of linear equation.

Solomon and Desrosiers (1988) presented the formula to solve the transportation within the limited time with 3 variables as follows;

1. Binary flow variables to show the routing path of each vehicle
2. Time variable to show the activity time in each place
3. Load variables to show loading capacity

The objective of this model was to reduce the total cost. However, no researcher applied this formula later.

Boppana and Arun (1993) studied from the case-study of school bus in Delhi India to manage the sufficient number of buses and the number of students in 3 school's branches. The objective is to reduce the costs, average time of transportation and buses' capacity. The used information including 1. The position of bus-stop and school 2. The number of students in each bus-stop 3. Travelling time and the distance of transportation between each bus-stop. Their principle was "Arrange the vehicles within the condition of distance and the capacity then calculate the suitable path by using Travelling Salesman Problem again".

Asawa (1993) studied the problem of transportation and was interested in planning of loading capacity. He created the model by using the weight and capacity of goods as condition. The study was based on the assumption of Initial basic feasible solution of model and the benefit of transportation.

Speranza and Ukovich (1992) studied the model presenting the approximated value result by continuously collecting the combined result. Then in Year 1994 they analyzed with the real-case by just specific the possible frequency only, so many strategies concerning with Shipment were analyzed and then there was the model presentation to calculate the best variable. In year 1996 both of them studied more to create the model, which provided the best variable by applying the branch-and-bond theory to find out the solution, which specified the especial location.