CHAPTER III

RESEARCH METHODOLOGY

This research methodology contains several sub chapter such research object, model development, model analysis, data requirement, data processing and analysis, research result, tools, and research framework. The detail steps of the research arranged in sub chapters as below:

3.1   Research Object

This research conducted in the Circulation Division and Koperasi of PT. Aksara Solopos located at Griya Solopos, Adisucipto Street, No. 190, Solo. The Circulation Division of PT. Aksara Solopos provides service for the customers (agents) for the newspaper request, inspection of newspaper production, and complaint management; while The Koperasi regulates the driver and vehicles used to support the newspaper distribution.

3.2   Model Development

3.2.1   Description

The mathematical formulation is adopted from the inductive study that proposed by Kewei *et.al.* (2010) named as the Heterogeneous Fixed Fleet Vehicle Routing Problem (HFFVRP). HFFVRP is a variant of Vehicle Routing Problem (VRP), which

makes routes for a heterogeneous fleet of vehicles with various capacity, fixed costs, and variable costs. This problem called as fixed fleet because it has fixed number of the vehicle fleet. The problem is to find a set of routes which minimizes the total cost that starts and ends at the depot such and each customer visited exactly once with demand from the customers can not more than the capacity of assigned vehicle. The cost related in this research composed from the fixed cost and variable cost of each vehicle.

Based on the description above, the mathematical formulation of the problem can be shown below:

Notations:

i : index for origin point depot 0 and customers $(1,\ldots,n)$.

j : index for destination point depot 0 and customers $(1,\ldots,n)$.

d_{ij} : distance from origin point i to destination point j.

d_{max} : maximum distance stated.

c_i : demand of customer i, and $i = (1,\ldots,I)$.

C_t : vehicle capacity type t.

cv_k : variable cost of each vehicle k.

cc_t : fixed cost of vehicle type t.

k : vehicle index $(1,\ldots,K)$.

TC : total cost.

V : vertex/node/point.

S : subset of vertex V.

N_t : number of available vehicles in a fleet.

x_i : decision variable for customer i, and $i = (1,\dots,I)$.

α_{ijk} : decision for arch i,j $i,j = (1,\dots,I)$ with vehicle index k, $k = (1,\dots,K)$.

β_{kt} : decision variable of vehicle type t, $t = (1,\dots,T)$ with vehicle index k, $k = (1,\dots,K)$.

$$Min\ (TC) = \sum_{k \in K} \left[\left(cv_k \left(\sum_{i \in I} \sum_{j \in I\ i \neq j} d_{ij} \cdot \alpha_{ijk} \right) \right) + \left(cc_t \cdot \sum_{t \in T} \beta_{kt} \right) \right] \quad (3.1)$$

Subject to:

$$\sum_{k \in K} x_{ik} = 1 \qquad \forall i \in I \setminus \{0\} \tag{3.2}$$

$$\sum_{i \in I} \alpha_{i0k} = 1 \qquad \forall k \in K \tag{3.3}$$

$$\sum_{j \in I} \alpha_{0jk} = 1 \qquad \forall k \in K \tag{3.4}$$

$$\sum_{j \in I,\ j \neq i} \alpha_{ijk} - \sum_{j \in I,\ j \neq i} \alpha_{jik} = 0 \qquad \forall i \in I \setminus \{0\},\ \forall k \in K \tag{3.5}$$

$$\sum_{i \in I \setminus \{0\}} x_{ik} \cdot c_i \leq \sum_{t \in T} \beta_{kt} \cdot C_t \qquad \forall k \in K \tag{3.6}$$

$$\sum_{k \in K} \beta_{kt} \leq N_t \qquad \forall t \in T \tag{3.7}$$

$$\sum_{j \in S, j \neq i} \sum_{i \in S} \alpha_{ijk} \leq |S| - 1 \qquad \forall S \subseteq V \setminus \{0\}, |S| \geq 2, \forall k \in K \tag{3.8}$$

$$cv_k \left(\sum_{i \in I} \sum_{j \in I\ i \neq j} d_{ij} \cdot \alpha_{ijk} \right) \leq (cv_k \cdot d_{max}) \qquad \forall k \in K \tag{3.9}$$

The decision variables are:

$$x_{ik} = \begin{cases} 1, & \text{if vehicle } k \text{ serves customer } i \text{ and;} \\ \\ 0, & \text{other wise.} \end{cases}$$

It decides which customers i are served by which vehicle k.

$$\alpha_{ijk} = \begin{cases} 1, \text{ if arc } (v_i, v_j) \text{ is served by vehicle } k; \\ \\ 0, \text{ other wise.} \end{cases}$$

It decides the visiting sequence of the vehicle.

$$\beta_{kt} = \begin{cases} 1, \text{ if vehicle } k \text{ is of type } t; \\ \\ 0, \text{ other wise.} \end{cases}$$

It decides the type of used vehicle k.

The objectives function of the HFFVRP shown in the formula (3.01). Constraint (3.2) shows that any customer can only served by one vehicle except depot. Constraint (3.3) and (3.4) shows that the routes are starting and ending at the depot. Constraint (3.5) confines the balance between the flow in and flow out in each node except depot. Constraint (3.6) shows the capacity limit for each vehicle. Constraint (3.7) shows the used number of vehicle must be less than or equal to the available fleet number. Constraint (3.8) shows the sub tour elimination constraint that guarantees every vehicle conduct one route. Constraint (3.9) the total variable cost of each vehicle k can not more than the total maximum variable cost of each vehicle k.

3.3   Model Analysis

Based on the mathematical formulation of HFFVRP above, there are several parameters that must be calculated which are distance between nodes (distance matrix), number of demand for each customer, vehicles capacity, variable cost, maximum distance traveled by each vehicle k, and fixed cost of each vehicle.

3.3.1   Distance Matrix

The graph used is directed graph (digraph) with the distances are asymmetric which means the distance from i to j will be different with the distance j to i $d_{ij} \neq d_{ji}$. The distance calculation based on the real urban transport condition (non-euclidean) and measured using software Google earth version 5.0.

3.3.2   Demand Conversion and Vehicle Capacity

The demand converted into a unit called as bulk. One bulk contains three bundles which are Soloraya, Solopos, and Sisipan and those three called as subnewspaper. The number of subnewspaper in a bundle is in variant. The number of newspaper in one bulk may contain less than 200, exactly 200 called as a koli, and more than 200 newspapers called as head. If one bulk of newspaper contains 1 to 200 newspapers, it will be located in one location in the vehicle (in the box or cabin). If the number of newspaper in a bulk is more than 200, suppose 350, it is still used in one location because it is categorized as head. If the number of newspaper in a bulk suppose 450, then it will located in the two locations, one location for 200 newspapers (one koli) and the rest 250 newspapers (head) in another location. The reason of the newspaper

placement is to avoid a missing newspaper and to make easier for the driver for newspaper placement that there are three times of docking process for a bulk of newspaper. The production of Soloraya finished at 12 pm, Solopos at 3 am, and Sisipan at 3.30 am. There are two docking area which first docking are provides Soloraya and Sisipan, the second provides the Solopos. There are two versions (possibilities) of newspaper placement inside the box as drawn in the Figure 3.1 and 3.2.
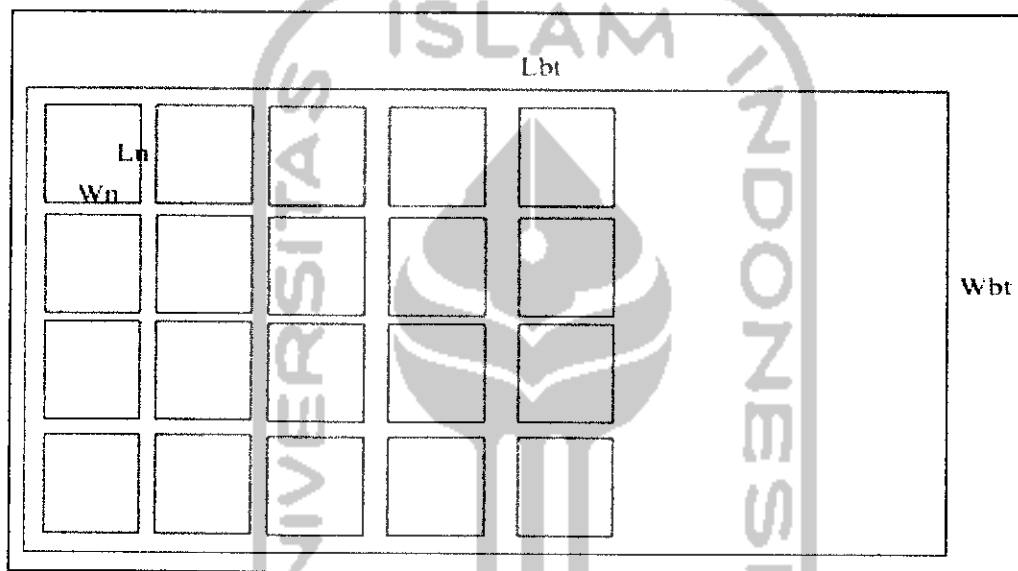

Figure 3.1 Dimension of Vehicle's Box to the Newspaper Dimension (First Version)
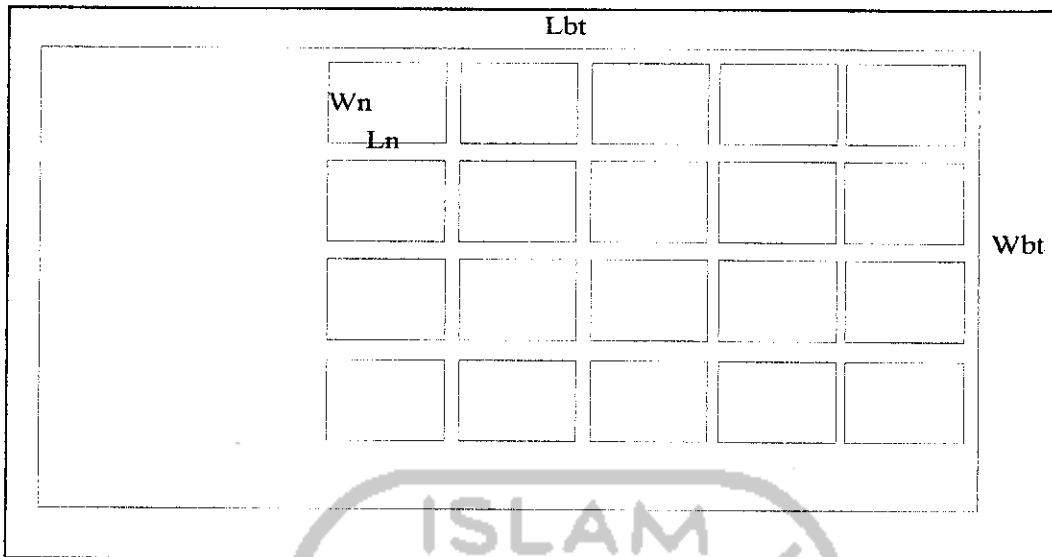
Figure 3.2 Dimension of Vehicle's Box to the Newspaper Dimension (Second

Version)

Where:

L_n *(cm)* = newspaper length

W_n *(cm)* = newspaper width

L_{bt} *(cm)* = vehicle's box type *t* length

W_{bt} *(cm)* = vehicle's box type *t* width

The calculation of the capacity of vehicle is involve the dimension of length and width both newspaper and vehicle. The formula to calculate the capacity is shown below:

The first version:

Vehicle capacity *(bulks)* = $((L_{bt}/W_n) * (W_{bt}/L_n))$ | 2   (3.10)

The second version:

Vehicle capacity *(bulks)* = *((L$_{bt}$/L$_n$)* * *(W$_{bt}$/W$_n$))* + *2*   (3.11)

The additional value of two bulks newspaper on above formula is because utilizing the space 90 centimeters beside the driver's seat for two bulks of newspaper and some promotion newspapers with the position like in the second version. The version that will be used is the version with biggest capacity.

3.3.3 Vehicle Variable Cost and Fixed Cost

Several costs that related with this problem are variable cost and fixed cost. The variable cost related with the traveling cost for each vehicle to serve node to node and it will be accumulated in monthly calculation, while fixed costs that occurred also measured in a month. The formula of the vehicle cost shown below.

The variable cost formula:

cv_k *(IDR/ meter/ month)* = fuel rate consumption of vehicle *(liter/ meter)* * 30 *(days)* *

fuel price *(IDR)*   (3.12)

The fixed cost formula:

cc_t *(IDR/ month)* = driver wages *(IDR)* + maintenance in a month *(IDR)* + insurance

(IDR)   (3.13)

Related with the maximum distance of each vehicle k (d_{max}), it can be stated by determine the rational maximum distance that vehicle must traveled.

3.4 Data Requirement

The data used for the research mentioned below:

    a.   General Profile of Company

    b.   Newspaper Dimension

    c.   Vehicles Profile

    d.   Customers Profile

    e.   Recent Routes

    f.   Fuel Cost

The data above taken from some ways, which are:

    a.   The interview method, which is done by asking directly some questions to the relevant parties.

    b.   Field study, directly measure and record the data such as vehicle type and its capacity, customer demand, and the data related with cost.

3.5 Data Processing and Analysis

The data that already collected then processed by using mathematical calculation which appropriate with the model of HFFVRP and analyzed by using Holmes and Parker algorithm. From the data processing and analyzing, the result can be generated and will be used to provide conclusion for the research.

3.6   Research Result

After the result that generated after the data processing and analysis has done, then continued for discussion to know the result from this research and will be used for the suggestion for the next research.

3.7   Tool

The research conducted with some supporting tools to assist for data collecting and problem solving. GPS built in from digital camera of PANASONIC DMC-TZ10 is used to collect the coordinates of depot and customers. The coordinates is placed in the Google Earth version 5.0 is used to measure the distances between depot and customers. Microsoft Excel 2007 is used to record of the data required also processing data. Data that recorded in the Microsoft Excel 2007 are the distances between nodes (customers and depot). The processing data using Holmes and Parker algorithm also conducts in the Microsoft Excel 2007.

3.8   Problem Solving Framework

A study can be said to be correct if the steps to be taken can be categorized appropriately. This because the steps are correlated each other, so, to understanding of the problems that occurred, then a framework to solve the problem created. Flow chart contains the framework of solving the problem shown in below.