TOTAL COST MINIMIZATION OF HETEROGENEOUS FIXED FLEET VEHICLE ROUTING PROBLEM USING HOLMES AND PARKER ALGORITHM

THESIS

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Fadly Arrachman

05 522 125

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DEDICATION

This thesis is dedicated to:

My Beloved Mother, Komarrukmi

My Beloved Father, Achmad Solatun

My Beloved Brother, Muhammad Ibnu Ramdhani

My Beloved Sister, Nindya Mirfa Triana

Thanks for everything, May Allah bless us. Amin.

MOTTO

".....And whosoever keepeth his duty to Allah (Takwa), Allah will appoint a way out for him. And will provide for him from (a quarter) whence he hath no expectation...". (Quran Surah Ath-Thalaq: Verse 2nd to 3rd)

"And whosoever keepeth his duty to Allah (Takwa), He maketh his course easy for him...." (Quran Surah Ath-Thalaq: Verse 4th)

".....And whoso keepeth his duty to Allah (Takwa), He will remit from him his evil deeds and magnify reward for him." (Quran Surah Ath-Thalaq: Verse 5th)

8. All of my friends in the IP FTI UII, thanks for the support.
9. All of my religion teachers that gives me knowledge from Allah SWT and Rasulullah SAW
10. Mrs. Diana for the support.
11. Profesor G. Srinivasan for replying my email.
12. All of staff in the PT. Aksara Solopos.
13. All of the employees of Koperasi Solopos and Solo Grafika Utama.
14. All of newspapers agents at Surakarta city.

Jazzakumullah Khairan.

Wassalammu'alaikum Wr. Wb.

Yogyakarta, May 30th , 2011

Fadly Arrachman

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ABSTRACT

A distribution activity in a company will related the problem of vehicle routing. There are several of Vehicle Routing Problem variants and one of them is Heterogeneous Fixed Fleet Vehicle Routing Problem. The problem has several main characteristic which are there is several different type of vehicles with limited number in a fleet which has also different capacity and also cost. The objective is to design the vehicle routes that minimize the total relevant cost with satisfying all customers demand, visiting each customer exactly once, and originating and terminating at a depot. In this research a classical heuristic Holmes and Parker algorithm used to solve cost minimization of Heterogeneous Fixed Fleet Vehicle Routing Problem. The proposed algorithm is easy to implement and understand and also can provide a good solution. The solution generated by proposed algorithm shown the better than the current route in the total relevant cost that implemented by the company.

Keywords: distribution, vehicle routing problem, heterogeneous fixed fleet, Holmes and Parker algorithm

CHAPTER I

INTRODUCTION

1.1 Background

Heterogeneous Fixed Fleet Vehicle Routing Problem (HFFVRP) is a variant of Vehicle Routing Problem (VRP) that occasionally exists in the company for distribution activity. HFFVRP is the extension of VRP with addition terms of the heterogeneity of vehicle used with fixed fleet. Feiyue *et. al.* (2007) explain the words of heterogeneous terms respect to different in capacity, fixed cost, and variable cost of the vehicle in the distribution activity while fixed fleet represents the number of available vehicle used in a fleet is limited. The problem is related with designing a set of vehicle route to distribute the goods in order to satisfy the customer needs and also to minimize the sum of the total relevant cost (fixed cost and variable cost). The route that designed must ensuring that each customer visited exactly only one times by one vehicle with the route start and ending at a depot, the accumulated cargo cannot exceed the capacity of each vehicle and also use no more vehicles than those available.

The research of HFFVRP firstly suggested by Tailard (1999) with the name of Vehicle Routing Problem with Heterogeneous Fixed Fleet. The first published research about HFFVRP done by Tarantilis *et. al.* (2003) that used a method called List Based Threshold Accepting (LBTA). Until now, the HFFVRP research mostly focused on the method used. Only one researcher Tuntuncu (2010) that extended the

HFFVRP to becomes Heterogeneous Fixed Fleet Vehicle Routing Problem with Backhauls. The other different also mostly about the asymmetric and symmetric distance that used, urban transport or Euclidean calculation, and the involvement of fixed cost (used or not used). Different with the mostly research about VRP that use homogeneous vehicle and unlimited number of vehicle, HFFVRP has more level of difficulties. Several researchers stated some difficulties to solve the HFFVRP for exact solution. Gencer *et. al.* (2006) stated that HFFVRP becomes one of the most difficult and complicated in the VRP. Brandao (2011) mentioned that HFFVRP is categorized as nondeterministic polynomial time combinatorial problem, it means this problem requires long computational in order to find the optimal (exact) solution. The problem is also becomes harder if the problem has the ratio of customer's total demand and the total capacity of the vehicle is close to one and the demand in various number, means even to find a feasible solution can be very difficult.

The problem that faced by a company where the research conducted is current vehicle routes created has not considering to minimize the total relevant cost and distance yet. The current vehicle routes created based on the estimation of the drivers to divides the distribution area into two west and east. In the real condition, implementing of vehicle routes always related with the cost that yielded from the summation of vehicle fixed cost and variable cost (from the multiplication of distance traveled and fuel price), so that, for the company considering the cost to creates a set of vehicle route is important to save the money spent in distribution activity. With minimized the total cost, it will impact the distance traveled by vehicle getting shorter.

This research will design a set of vehicle routes that considering minimizing the total relevant cost in the newspaper distribution which has specific name HFFVRP. To design a new set of vehicle routes, this research will use Holmes and Parker algorithm.

1.2 Problem Formulation

Based on the background, the problem that can be defined in routing of vehicles of Heterogeneous Fixed Fleet for a company as follows:

a. How is the design of vehicle routes that minimizes the total relevant cost by using Holmes and Parker algorithm?
b. How long the distance of the new vehicle routes created from Holmes and Parker algorithm?

1.3 Research Scope

The research scope contains of two things which are problem limitation and assumption. There problem limitations can be described as follow:

a. The Objects of the research are in the PT. Aksara Solopos and Koperasi Solopos.
b. The regions that will be used are only East Solo and West Solo.
c. The distance is measured in real urban transport.
d. The distance is between two nodes are in asymmetric condition.

There are also several assumptions used in this research so that appropriate with the mathematical model proposed, which are:

a. The customers demand is deterministic.

b. The speed fluctuation and obstacles such traffic light, railway crossing, and parking area that can influence of variable cost spent (fuel used) are assumed to be ignored because difficult to measured.

1.4 Research Objective

The objectives of the research are

a. To determine the vehicle routes for the company so that the total relevant cost is minimized.

b. To determine the minimum distance traveled of the vehicles.

1.5 Research Benefit

The benefits of the research are:

a. Enrich the knowledge of Vehicle Routing Problem, especially for Heterogeneous Fixed Fleet Vehicle Routing Problem and its problem solver method.

b. For the company can improve the current set of vehicle route into the better one.

1.6 Thesis Structure

To becomes an organized writing of research, here below the arrangement of writing systematic:

CHAPTER II LITERATURE REVIEW

Literature review is the backbone to determine the current study from the previous related ones. It contains information about the result of related previous studies and supporting literatures underlying the research.

CHAPTER III RESEARCH METHODOLOGY

Research methodology contains flow chart, model that used, the requirement to build the model, the method to analysis the model, and how the data is taken from the source and the tools to get the data.

CHAPTER IV DATA COLLECTING AND PROCESSING

In this sub chapter contains of the recapitulation the data collected, model building, data processing and analysis. This sub chapter becomes the basic for result discussion in sub chapter V.

CHAPTER V DISCUSSION

Results and analysis contains the results after the data are processed and analyzed.

CHAPTER VI CONCLUSION AND SUGGESTION

Conclusion and suggestion are the end of the research, consists of the conclusion of the reserach and suggestion for the next reserach.

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CHAPTER II

LITERATURE REVIEW

2.1 Previous Research

PT. Aksara Solopos is one of Newspaper Company in the Surakarta city that produces a well known newspaper Solopos. The company provides newest update of national, Surakarta city, and surrounds region news. This type of business requires distribution activity in every day. The newspaper as the finish product has to be delivered to the all customers in the early morning time. One main concern in the distribution activity is about assigning of vehicles or some vehicles to deliver the products. PT. Aksara Solopos, has two types of vehicles that distribute newspaper for Surakarta region. The two types of vehicles have different capacity, fixed cost, and variable cost. The current routes are created based on the estimation of the drivers and didn't consider the cost (fixed and variable). Considering that situation, assigning which customers must be served by which vehicle is becomes important thing because it is related with the satisfying the customers with minimize the money spent by company. So that in order to get those objectives, the company requires good routing for distribution vehicles.

The problem exist in the PT. Aksara Solopos is related with Vehicle Routing Problem (VRP) with particular name is Heterogeneous Fixed Fleet Vehicle Routing Problem (HFFVRP). Heterogeneous Fixed Fleet corresponds to the heterogenic vehicles (capacity, fixed cost, and variable cost) in the limited number (two vehicles in a fleet). As stated in the chapter one about the difficulties of HFFVRP, all researches has conducted using heuristic. The HFFVRP research begun from the suggestion of Taillard (1999) that heuristic column generation method is applicable to HFFVRP. Then Tarantilis, *et. al.* (2003) began their research to solve HFFVRP using List Based Threshold Accepting (LBTA). Tarantilis *et. al.* (2004) continued their research to solve HFFVRP using Back Tracking Adaptive Threshold Accepting (BATA) algorithm. Gencer, *et. al.* (2006) solved HFFVRP by Passenger Pickup Algorithm that has principle to make clustering of customers first then routing the vehicle for the customers clustered. Feiyue, *et. al.* (2007) solved HFFVRP by Record to Record Travel algorithm. Jalel and Habib (2010) have solved HFFVRP by using Hybrid Tabu Search algorithm. Tuntuncu (2010) used Greedy Randomized Adaptive Memory Programming Search (GRAMPS) to solve HFFVRP. Xiangyong, *et. al.* (2010) combined Multistart Adaptive Memory Programming (MAMP) and path relinking algorithm to solve HFFVRP. Kewei *et. al.* (2010) used Parallel Improving Tabu Search algorithm and provide a mathematical model of HFFVRP. Brandao (2011) using Tabu Search algorithm to solve the HFFVRP.

This research will use a classical heuristic Holmes and Parker algorithm (1976) that an extension of Clarke and Wright algorithm (1964) to solve the problem faced by the company. Holmes and Parker (1976) tested this algorithm to the Heterogeneous Fleet Vehicle Routing Problem (HVRP) type. This research uses the Holmes and Parker algorithm to solve HFFVRP which is variants of VRP. The different between HVRP and HFFVRP are in the number of vehicle available unlimited and limited (Tarantilis *et. al.*, 2003). HVRP is more appropriate for strategic decision to purchase or hire the vehicles required by the company, while HFFVRP the vehicles are already in the company.

2.2 Theoretical Background

2.2.1 Vehicle Routing Problem

Vehicle Routing Problem (VRP) becomes one of the optimization problems in Operational Research that has practical role in the distribution activity. The distribution activity concerns with the service, in a given time period, for a set of customers by a set of vehicles, which are located in one or more depots, operated by a set of crews (drivers), and perform their movements by using an appropriate road network (Toth and Vigo, 2002). The Vehicle Routing Problem lies at the heart of distribution management. It is faced each day by thousands of companies and organizations engaged in the delivery and collection of goods or people (Cordeau *et. al.*, 2007). Much progress has been made since the publication of the first article on the "truck dispatching" problem by Dantzig and Ramser (1959). The Classical Vehicle Routing Problem (VRP) is one of the most popular problems in combinatorial optimization, and its study has given rise to several exact and heuristic solution techniques of general applicability. Toth and Vigo (2002) gives a brief introduction for the basic things from Vehicle Routing Problem (VRP). This problem has several basic important things that will always exist in any kinds of VRP types. Here below the explanations of VRP.

In particular, the solution of a VRP calls for the determination of a set of routes that each performed by a single vehicle that starts and ends at its own depot, such that all the requirements of the customers are fulfilled, all the operational constraints are satisfied, and the global transportation cost is minimized. There are several main characteristic or components of VRP which are road network, customers, depots, vehicles, and drivers, the different operational constraints that can be imposed on the construction of the routes, and the possible objectives to be achieved in the optimization process.

The road network, used for the transportation of goods, is described through a graph, whose arcs represent the road sections and vertices may correspond to the depot, terminal, and customer locations. The arcs can be directed or undirected, depending on whether they can be traversed in only one direction (for instance, because of the presence of one-way streets, typical of urban or motorway networks) or in both directions, respectively. Each arc is associated with a cost, which generally represents its length, and a travel time, which is possibly dependent on the vehicle type or on the period during which the arc is traversed. The arc representation in distance d can be in symmetric $d_{ij} = d_{ji}$ or asymmetric $d_{ij} \neq d_{ji}$. The distance also can be measured in Euclidean or in real urban transport.

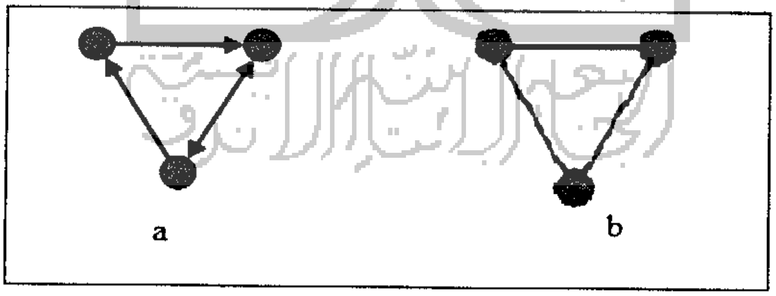

Figure 2.1 Directed Graphs (a) and Undirected Graphs (b)

The customers also have several characteristics. Each customer has own demand and possibly in different number that must be collected (waste collection) or delivered (newspaper). The demand itself can be in deterministic and stochastic, depend in the cases faced. The routes performed to serve customers start and end at one or more depots, located at the vertices of the road graph. Each depot is characterized by the number and types of vehicles associated with it and by the global amount of goods it can deal with.

Transportation of goods is performed by using a fleet of vehicles whose composition and size can be fixed or can be defined according to the requirements of the customers. Usually the vehicle is starting at a depot and returning can be to the initial depot or terminal (other depot or home). Vehicle has capacity and usually represent by maximum weight and volume that the vehicle can load. The capacity of vehicle can be homogeny or heterogenic and also the number can be limited or unlimited. Also there is a special vehicle that has special capability depends on the goods carried (refrigerator inside). The vehicle also has two works like loading and unloading the goods. There are several costs that occur in operating vehicle such variable cost (per distance unit, per time unit, per route, etc.) and fixed cost (insurance, maintenance, driver wages, etc).

The routes has to satisfy several of operational constraints. The constraints can be coming from the nature of the transported goods, on the quality of the service level, and on the characteristics of the customers and the vehicles. Some general operational constraints like along each route, the current load of the assigned vehicle cannot exceed the vehicle capacity; the customers served in a route can only the delivery (unloading goods) or the collection of goods, or both possibilities can exist; and customers can be served only within their time windows and the working periods of the drivers associated with the vehicles visiting them. Precedence constraints can be imposed on the order in which the customers served in a route are visited. One type of precedence constraint requires that a given customer be served in the same route serving a given subset of other customers and that the customer must be visited before (or after) the customers belonging to the associated subset. This is the case, for instance, of the so-called pickup and delivery problems, wherein the routes can perform both the collection and the delivery of goods, and the goods collected from the pickup customers must be carried to the corresponding delivery customers by the same vehicle.

Vehicle Routing Problem also has several objectives that want to be accomplished, such as:

a. minimization of the global transportation cost, dependent on the global distance traveled (or on the global travel time) and on the fixed costs associated with the used vehicles (and with the corresponding drivers).
b. minimization of the number of vehicles (or drivers) required to serve all the customers.
c. balancing of the routes, for travel time and vehicle load.
d. minimization of the penalties associated with partial service of the customers.

2.2.2 Heterogeneous Fleet Vehicle Routing Problem

Heterogeneous Fleet Vehicle Routing Problem (HVRP) is a variant of VRP that has heterogeneous vehicle in a fleet. The vehicles inside the HVRP have different capacity and also the cost (either fixed and variable cost or only variable cost). This HVRP also has several variants; two of them are Heterogeneous Mixed Fleet Vehicle Routing Problem (HMFVRP) and Heterogeneous Fixed Fleet Vehicle Routing Problem (HFFVRP).

A. Heterogeneous Mixed Fleet Vehicle Routing Problem

Heterogeneous Mixed Fleet Vehicle Routing Problem; Shuguang *et. al.*, (2009) explained that Heterogeneous Mixed Fleet Vehicle Routing Problem (HMFVRP) has to decide how many vehicles of each type to use given a mix of vehicle types differing in capacity and costs. The fleet is heterogeneous and the available number of vehicles for each type remains unlimited. The objectives are to find both the fleet composition and the vehicle routing that minimize the summation of variable cost and fixed cost. Some times the HFMVRP is only named as HVRP.

B. Heterogeneous Fixed Fleet Vehicle Routing Problem

Heterogeneous Fixed Fleet Vehicle Routing Problem; Heterogeneous Fixed Fleet Vehicle Routing Problem (HFFVRP) is the variant of VRP, extension of HVRP. HFFVRP has same characteristic with HMFVRP (HVRP) which is the used of the vehicle is heterogenic. The differences are in the objective and the size of vehicle fleet. Brandao (2010) explained that HFFVRP consists of defining a set of routes and the vehicles assigned to them so that the following constraints; use no more vehicles than those available, satisfy customers' demand, visit each customer exactly once, a vehicle route starts and finishes at the depot, and do not exceed the capacity of the vehicle. The objective of HFFVRP is to design a set of vehicle route to distribute the goods in order to satisfy the customer needs and also to minimize the sum of the fixed cost and variable cost with subject to the previous constraints. For HMFVRP the objective are to determine the fleet composition and also make a set of route that minimizes the total cost. Another difference is the number of vehicle in a fleet for HFFVRP is limited while HMFVRP is unlimited. For the mathematical formulation of HFFVRP will be given in the chapter III. This research is focused on HFFVRP. To solve the HFFVRP, this research will use an algorithm coming from the classical heuristic called as Holmes and Parker algorithm. To be more understands of the method that used in this research to solve HFFVRP, here below the explanation.

2.2.3 Clarke and Wright Algorithm

Route construction methods were among the first heuristics for the VRP and still form the core of many software implementations for various routing applications. These algorithms typically start from an empty solution and iteratively build routes by inserting one or more customers at each iteration, until all customers are routed. Construction algorithms are further subdivided into sequential and parallel, depending on the number of eligible routes for the insertion of a customer. Sequential methods expand only one route at a time, whereas parallel methods consider more than one route simultaneously. Route construction algorithms are fully specified by their three main ingredients, namely an initialization criterion, a selection criterion specifying which customers are chosen for insertion at the current iteration, and an insertion criterion to decide where to locate the chosen customers into the current routes (Cordeau *et. al.*, 2007).

Clarke and Wright algorithm was developed by Clarke and Wright (1964). Clarke and Wright algorithm classified as classical heuristic. This algorithm is a constructive algorithm that gradually builds a feasible solution while keeping on eye on solution cost. Clarke and Wright was introduced a concept called as savings. Savings s becomes the main point of the algorithm work.

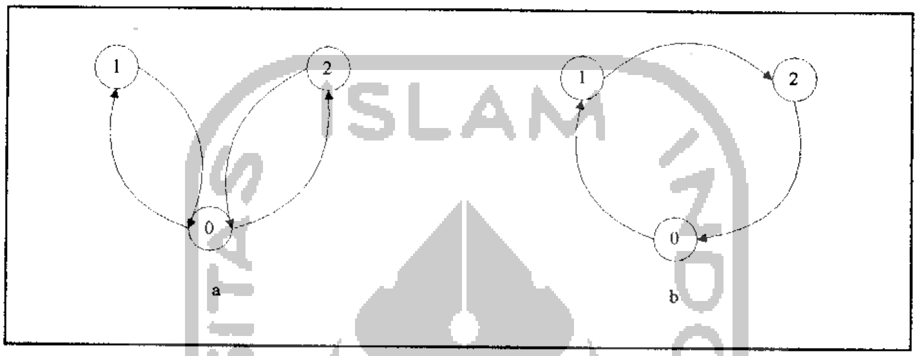

Figure 2.2 Savings Concept

Figure 2.3 shows the different of condition without savings (a) and with savings (b). Saving is the reduction of distance if the vehicle doing the loop 0-1-2-0 without return again to the depot 0-1-0-2-0. Saving between depot 0 and two customers i and j is formulated below;

$s_{i,j}$ = Saving value of customer i and j

$$s_{i,j} = d_{i,0} + d_{0,j} - d_{i,j} \qquad i \neq j,\ \forall i,j = 1,2,3,\dots,n \qquad (2.1)$$

The algorithm can work in two versions which are sequential and parallel version. The algorithm works as follows:

Step 1 (savings computation). Compute the savings as in the equation (2.1). Create n vehicle routes (0, i, 0) for $i = 1,\dots,n$. order the savings in a non increasing fashion.

Step 2 (parallel version). Starting from the top of saving list, execute the following. Given a saving s_{ij}, determine whether there exist two routes, one containing arc or edge $(0, j)$ and the other containing arc or edge $(i, 0)$, that can feasibly merged. If so, combine these two routes by deleting $(0, j)$ and $(i, 0)$ and introducing (i, j).

Step 2 (sequential version). Consider in turn each route $(0, i, \ldots, j, 0)$. Determine the first saving s_{ki} or s_{jl} that can feasibly be used to merge the current route with another route containing arc or edge $(k, 0)$ or containing arc or edge $(0, i)$. Implement the merge and repeat this operation to current route. If no feasible merge exist, consider the next route and reapply the same operations. Stop when no route merge is feasible.

2.2.4 Holmes and Parker Algorithm

Holmes and Parker algorithm was developed by Holmes and Parker (1976). This algorithm is using the Clarke and Wright algorithm with parallel version as the foundation in generating routes. There are several additional concepts in this algorithm from Clarke and Wright algorithm which are suppression schemas. With these schema, the solutions that produced by Clarke and Wright algorithm can be explored deeper and a new better solution can be found. The suppression means the prohibition of an ordered pair to involve in the current iteration. The suppression schemas are temporary suppression and permanent suppression. The temporary suppression is applied to an ordered pair i, j (with specific rule) to the current best solution for the next iteration so then a new solution is produced. When the new solution result is better than the current best solution, the ordered pair i, j is suppressed permanently to avoid the ordered pair i, j chosen again for the next iteration. To apply the Holmes and Parker algorithm into HFFVRP, there are some additional modifications. In the step 4.4.1, the additional rule added so that the solution will not violate constraint (3.2). Then in the step 4.5 the Total Cost *TC* calculated based on the objective function of HFFVRP (3.1). The additional rule is added in the step 4.4.3 that limits the total distance of each vehicle to the distance maximum (use the current vehicle routes distance). This research using Holmes and Parker algorithm because the Clarke and Wright algorithm can be used to create a solution for HFFVRP as stated by Taratilis *et. al.* (2003). As the beginning of Holmes and Parker algorithm, the initialization is required for the basic of the algorithm works. The steps of Holmes and Parker algorithm shown below:

A. Initialization

In initialization step, there are several steps used to generate the distance matrix then saving matrix.

Step 1: Distance matrix

1.1 Construct an initial distance matrix D, such that $D = [d_{ij}]$; $i, j = 0,1,2,..,n$ where 0 represent depot and $1,2,\ldots,n$ is customer. When $i = j$, let $d_{ij} = 0$.

1.2 Determine the demand of each point c_i, the number of vehicle of type t is N_t and the capacity of each is C_t.

Step 2; Construct the saving matrix $[s_{i,j}]$

1.1 Compute saving s_{ij} as in the equation (2.1);

if $s_{i,j} < 0$, set $s_{i,j} = 0$. Set $s_{i,j} = 0$ for all $i = j$.

1.2 Let $s_{i,0} = s_{0,j} = -1$, $\forall i,j = 1,2,3\ldots,n$. note that $s_{i,j} = -1$ indicates the presence of (i,j) in a current solution.

B. Iteration

The iteration begins to create an initial solution without any suppression schema. After the initial solution generated, the suppression schema is begun.

Step 3: Determine a candidate pair

3.1 Find the ordered pair i,j with the greatest feasible saving such that $s_{i,j} = max\ [s_{i,j}]$ where (i,j) is defined over all ordered pairs such that $s_{i,0}$ and $s_{0,j} \neq 0$. Go to step 4.

3.2 If $s_{i,j} = 0$, go to step 4.6.

Step 4: Join the point i and j on a route

4.1 If neither of the points is on a route, construct a new route z and compute the required demand c_z such that

$$c_z = c_i + c_j \tag{2.2}$$

Then go to step 4.4

4.2 If one point is currently assigned to a route, say $z\ (i,j)$, attempt to join the new pair (j,k) with unassigned point (k) to z. compute total demand c_z where

$$c_z \rightarrow c_z + c_k \tag{2.3}$$

Then go to step 4.4

4.3 If both point are currently assigned to routes, say u (i,j) firstly selected, then v (k,l) after u selected, attempt to join both routes into one route, z. Compute the total demand c_z where

$$c_z = c_u + c_v \tag{2.4}$$

Then go to step 4.4

4.4 Join (merging) key concept has several principals.

4.4.1 First, check the routes whether two same points are in the same route or not. As an example the ordered pair selected i,j and j,k from the descending from the largest saving as $s_{i,j}$; $s_{j,k}$ respectively. If there is an ordered pair that has smaller saving value than two ordered pairs before, and it is suggested (feasible to be selected) such as k,i with saving $s_{k,i}$, this merged cannot be performed because it is not allowed to visit the point or node more than one time by one type of vehicle which is in the example is point i. Then, like the example $s_{k,i}$ is set to be 0. Then go to step 4.4.2. This step is added to Holmes and Parker algorithm, so that the result generated will not violate the constraint (3.2)

4.4.2 Second, Check the capacity restrictions. For the condition 4.1, select the vehicle with the smallest capacity first C_t such that $C_t \geq c_z$, if no such C_t exist, set $s_{ij} = 0$ and proceed to step 3. For the condition in step 4.2, if the capacity of the vehicle is not enough, then the merged cannot be conducted and set the $s_{jk} = 0$ and proceed to step 3. For the condition step 4.3, If the c_z is exceed the capacity of vehicle C_t, separate the *u (i,j)* and *v (k,l)* then select the next vehicle for the last ordered pair *v (k,l)* that has smaller capacity (if exist) or same capacity or larger capacity and proceed to step 3. The priority of vehicles used is the lowest capacity first. Then go to the step 4.4.3.

4.4.3 Third, check the distance restrictions. The routes that created can not exceed the maximum distance stated. In order to make easy the distance are converted to the cost which can be calculated from multiplying the distance with each vehicle variable cost.

4.5 Update the savings matrix after an ordered pair selected such that $s_{i,j} = -1$, $s_{j,i} = 0$ and si,0 = $s_{0,j} = 0$. Repeat the iteration from step 3 until the condition of step 3.2 happen.

4.6 Save all pair with its saving value $s_{i,j}$ that already join for every vehicle. Then compute the total cost *TC* of all routes as in the equation (3.1). Then go to step 5.

Step 5: Save the best solution

5.1 If this is the first solution (initial solution), save the cost *TC'*, such that *TC'* = *TC*. Maintain all routes and the order in which points were joined. Go to step 6.

5.2 If this is not the first solution and $TC \geq TC'$, set $TC' = TC$, the suppression number increase, for first suppression L=1; second suppression L=2 and so on, and then set $s_{i,j} = 0$ in the saving matrix. Note that (i,j) is the pair just suppressed (suppressed temporally) and further that (i,j) remains suppressed (suppressed permanently) in all subsequent solution. Go to step 5.4.

5.3 If $TC < TC'$, let $L+1$ Go to step 5.4.

5.4 Maintain the routes formed and the order in which point were joined. Proceed to the step 6.

Step 6: Suppress specified pairs

6.1 If there is still feasible ordered pair in the current best solution that has not been suppressed exist, suppress (suppressed temporally) the ordered pair that joined next in the current best solution, say (i', j') such that $s_{i'j'} = 0$ in the saving matrix and begin iteration with return to step 3.

6.2 If there is no more joined pair in the current best solution that can be suppressed, terminate the algorithm.

This algorithm assisted by the tree diagram to know the next suppression pair and the summary of the solution.

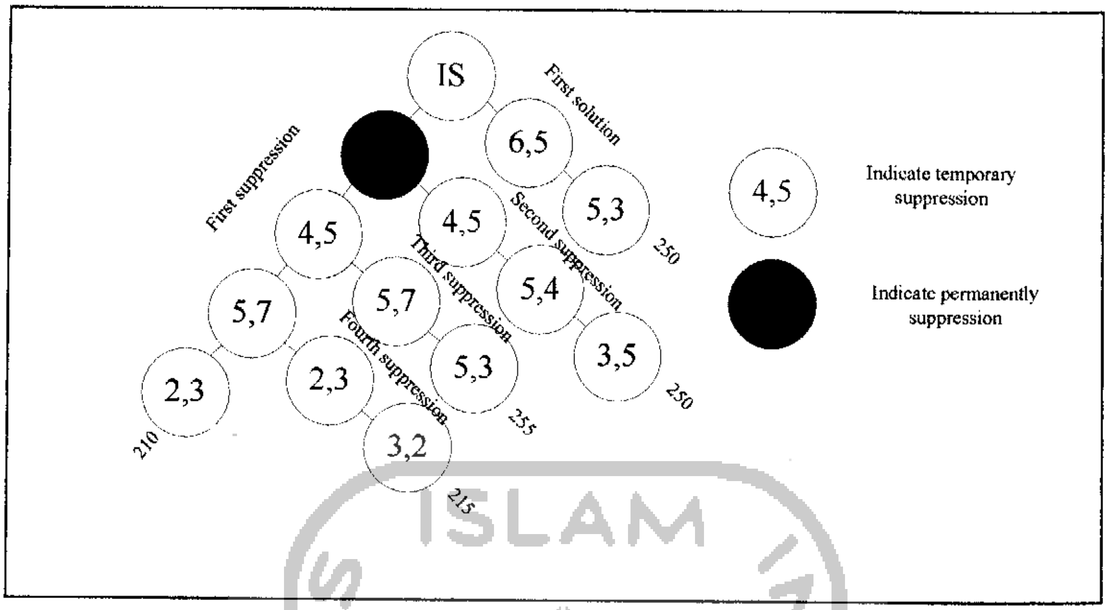

Figure 2.3 Tree Diagram

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 $i = (1,\ldots,I)$.

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

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

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

Subject to:

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

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

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

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

$$\sum_{i \in I \setminus \{0\}} x_{ik} \,.\, c_i \leq \sum_{t \in T} \beta_{kt} \,.\, C_t \qquad \forall k \in K \quad (3.6)$$

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

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

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

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.

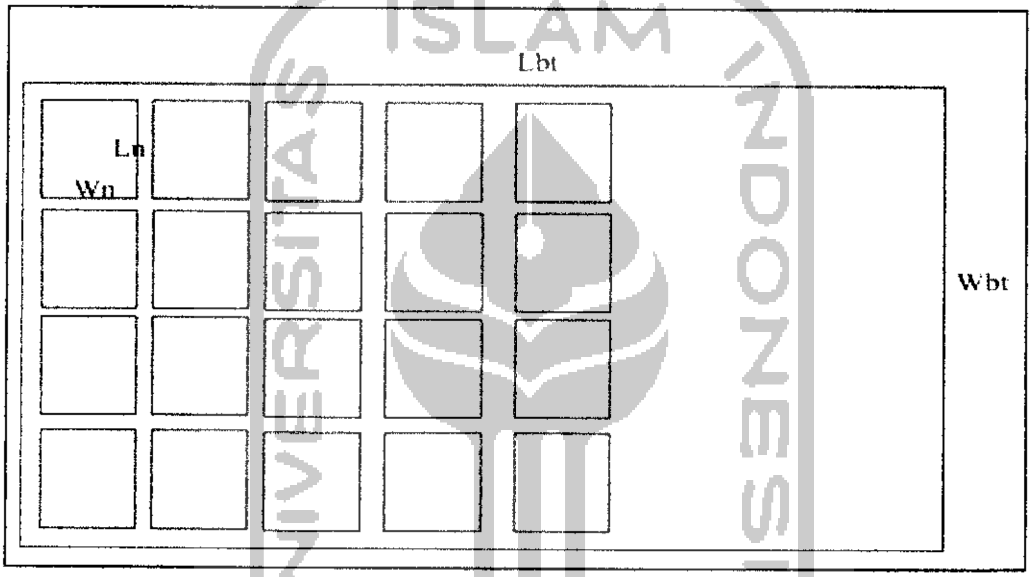

Figure 3.1 Dimension of Vehicle's Box to the Newspaper Dimension (First Version)

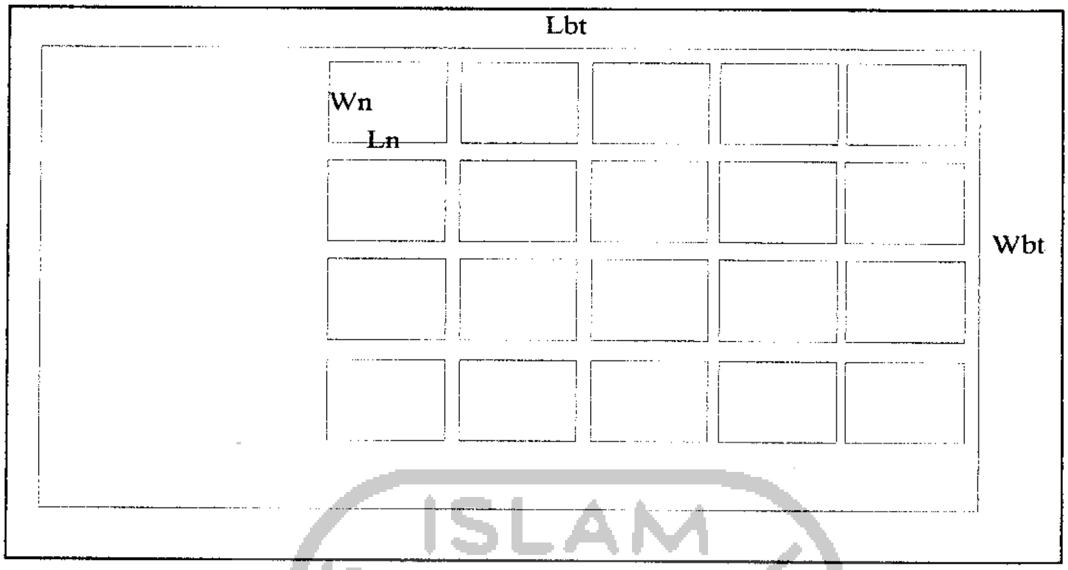

Figure 3.2 Dimension of Vehicle's Box to the Newspaper Dimension (Second Version)

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:

$$\text{Vehicle capacity } (bulks) = ((L_{bt}/W_n) * (W_{bt}/L_n)) + 2 \quad (3.10)$$

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.

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collecting

4.1.1 Company Profile

PT. Aksara Solopos and Koperasi Solopos are parties of business in in the Griya Solopos. PT Aksara Solopos becomes the front company in the Griya Solopos that has main business related with the news collector to produce as printed newspaper or published in the web. There are several divisions which exist; such news editorial division, Human resource division, circulation division, radio, and advertisement division. Especially for the Circulation division where this research is taken place, there are two shifts called as morning circulation division and night circulation division. The morning shift regulates the customer request and complaints, make a billing for customer request, and distribution of newspaper in general. Night shift work as the inspector of the after production process which are ensuring the number of customer delivery to customer, informs the obstacles that happen in the night production as allowance when there is a complaint from customer (lateness of newspaper delivery). For Koperasi Solopos regulates as koperasi in general, provide a cafeteria for employee, and has special task which is regulates driver and car that used for daily operational in the Griya Solopos. Driver wages, car maintenance, insurance of car, and fuel cost are handled by Koperasi.

There are several cities of solopos printed newspaper consumer, such Surakarta, Kartasura, Solobaru, Sragen, Karanganyar, Sukoharjo, Wonogiri, Klaten, Jogja, Boyolali, Salatiga, Semarang, and Purwodadi. For Surakarta itself there are two region, which are west Solo (Kartasura and west Surakarta) and east Solo (east Surakarta and Solobaru). Vehicles that are used have several types such truck with four tires and pick up car.

Solopos newspaper divides into three parts, Soloraya, Solopos, and Sisipan. The production of Soloraya finish on 12 pm, Solopos 3 am, and Sisipan 3.30 am. The docking process done in two places, Soloraya and Sisipan is in the old machine and the Solopos in the new machine. In the normal situation, the schedules of vehicle departure are:

a. Semarang, Salatiga, Boyolali on 3.30 am serviced by kijang pickup
b. Klaten and Jogja on 3.45 am serviced by kijang pickup
c. Purwodadi on 4 am serviced by kijang pickup
d. Sragen and Karanganyar 4.15 serviced by kijang pickup
e. Sukoharjo and Wonogiri on 4.30 serviced by suzuki carry
f. East and west Solo on 4.45 serviced by truck and panther pick up.

4.1.2 Newspaper Dimension

The dimension that used to measure the newspaper are only length and width. Length (ln)= 35cm ; width (wn) = 29cm

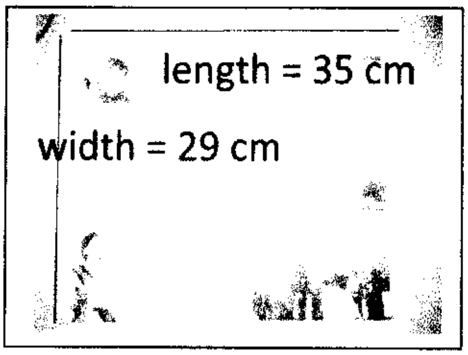

Figure 4.1 Newspaper Dimension

4.1.3 Vehicle Profile

In this research, the focus only in the Surakarta region only (east and west Surakarta), so the vehicle used are only two vehicles, which are:

a. Truck 4 tires HINO DYNA 2004, 3700 cc, fuel solar, fuel rate consumption 1litre: 8000 meters;

   Inner box dimension box length (lb_1) = 247 cm and width (wb_1) = 166 cm.

   Driver wages = IDR 1.100.000

   Maintenance cost = IDR 220.000

   Insurance = IDR 150.000

b. Panther pick up low deck with full box type 2005, 2500cc, fuel solar, fuel rate consumption 1litre: 10000 meters;

   Inner box dimension box length (lb_2) = 188 cm and width (wb_2) = 151cm.

   Driver wages = IDR 1.100.000

   Maintenance cost = IDR 140.000

Insurance = IDR 150.000

The figure of both vehicles are in the appendix.

4.1.4 Customer Profile

The customer profile includes several things; name, coordinates, and demand.

Table 4.1 Depot and Customer Profile

No	Name	Longitude	Latitude	Demand (newspaper)
0	Depot (solopos)	110.779	-7.5466	0
1	Taji Nasrudin	110.789	-7.55	2125
2	Surya	110.824	-7.5686	1080
3	Teguh	110.824	-7.5708	840
4	Matahari	110.825	-7.5694	680
5	ABC	110.826	-7.5711	295
6	Sendang Mulia	110.832	-7.5695	573
7	Muhammad dkk	110.82	-7.5822	430
8	Indomet	110.814	-7.6028	450
9	Prasasti	110.819	-7.6085	290
10	Palang kereta Hotel Agas	110.808	-7.5593	475
11	Iskak	110.82	-7.5615	660
12	Kendali	110.821	-7.5635	85
13	Hadi S	110.817	-7.5685	187
14	Agus	110.798	-7.5631	340
15	Budi Sondakan	110.787	-7.5594	126
16	Maju Mapan	110.783	-7.5562	340
17	RS Yarsis	110.771	-7.5585	70
18	Londo	110.739	-7.551	815
19	Bandara	110.749	-7.513	110

4.1.5 Current Route

The original or current route that conducted by driver to deliver the newspaper in the Surakarta is shown below.

Truck: Depot-Taji Nasrudin- Surya- Teguh- Matahari- ABC- Sendang Mulia- Muhammad- Indomet- Prasati- Depot (0-1-2-3-4-5-6-7-8-9-0). The distance traveled is 260.92 meters in a day.

Panther: Depot- Palang Kereta Api Hotel Agas- Iskak- Kendali- Hadi Sondakan- Agus- Budi Sondakan- Maju Mapan- RS Yarsis- Londo- - Bandara Adi Soemarmo- Depot (0-10-11-12-13-14-15-16-17-18-19-0). The distance traveled is 29.725 meters in a day.

The current route graph are in the appendix.

4.1.6 Fuel Prices

Both vehicles are using same type of fuel which is solar with the prices is IDR 4.500 per liter.

4.2 Mathematical Model Building of Heterogeneous Fixed Fleet Vehicle Routing Problem

To build the model of HFFVRP, there are several data need to be processed first, which are customer's demand, distance between vertex (distance matrix), vehicles capacity, vehicle's variable cost, the maximum distance of each vehicle, and vehicle's fixed cost.

4.2.1 Demand Conversion

The demand of newspaper that shown in the Table 4.1 must be converted first to bulk measurement. Here is below the conversion of newspaper demand.

Table 4.2 Demand Conversion

No	Name	Demand (newspaper)	Converted Demand (bulk)
0	Depot (solopos)	0	0
1	Taji Nasrudin	2125	10
2	Surya	1080	5
3	Teguh	840	4
4	Matahari	680	3
5	ABC	295	1
6	Sendang Mulia	573	2
7	Muhammad dkk	430	2
8	Indomet	450	2
9	Prasasti	290	1
10	Palang kereta Hotel Agas	475	2
11	Iskak	660	3
12	Kendali	85	1
13	Hadi S	187	1
14	Agus	340	1
15	Budi Sondakan	126	1
16	Maju Mapan	340	1
17	RS Yarsis	70	1
18	Londo	815	4
19	Bandara	110	1

4.2.2 Distance Matrix

The distance between node-to-node (depot to customer, customer-to-customer, and customer to depot) are measured as real urban transport. To calculate the distance firstly must know the coordinate of every node, and then the distance measured by using a tool called as ruler from software Google Earth 5.0. The step of using Ruler to measure the distance is below:

1. Find the Ruler in the toolbar

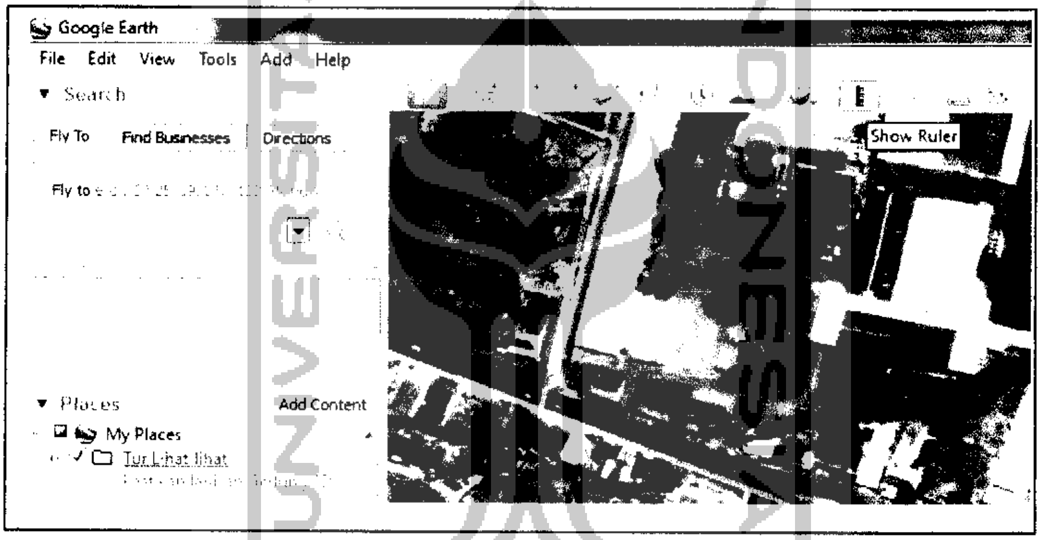

Figure 4.2 Step 1 Measuring Distance Using Google Earth

2. Choose path to measure the distance

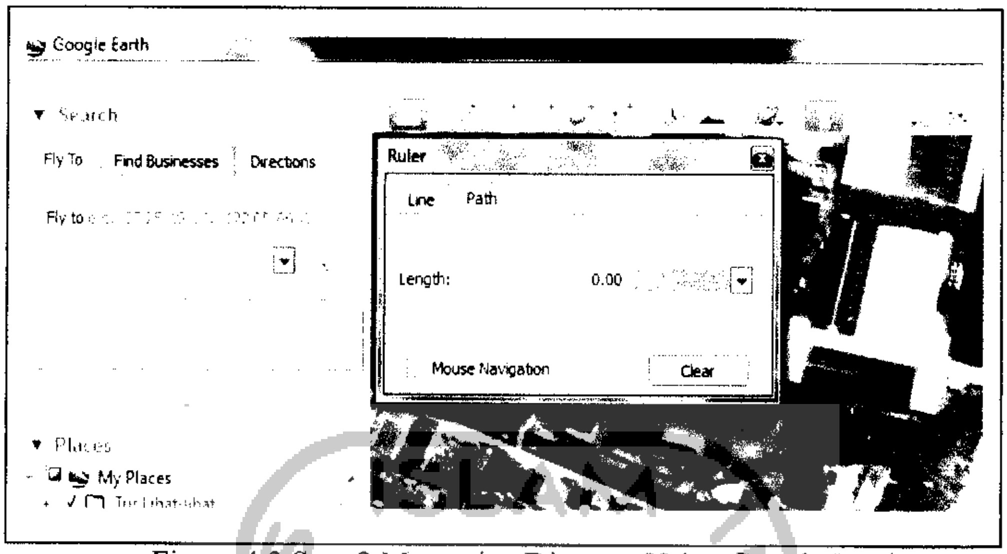

Figure 4.3 Step 2 Measuring Distance Using Google Earth

3. Measure the distance

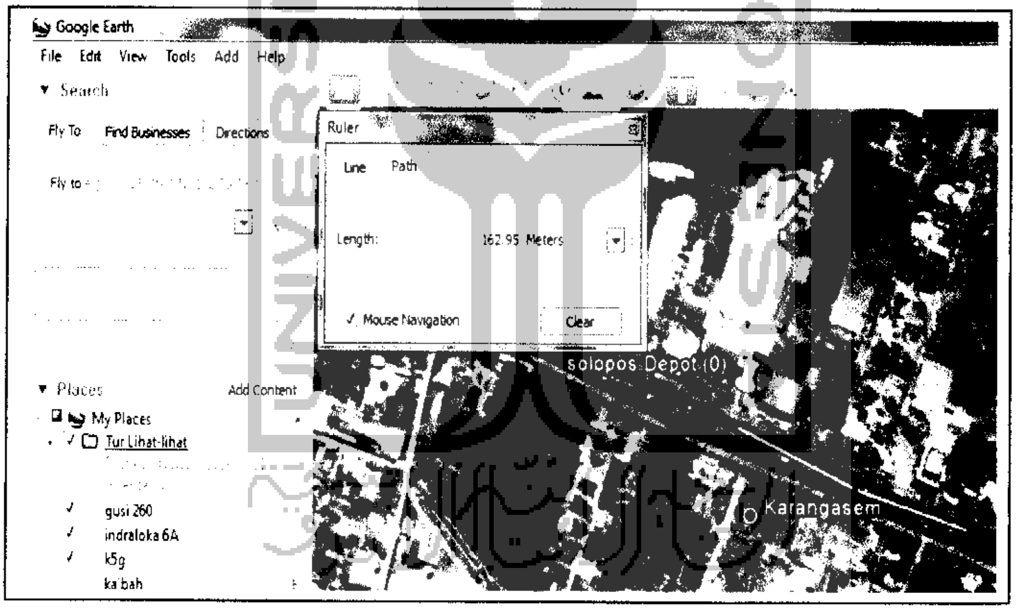

Figure 4.4 Step 3 Measuring Distance Using Google Earth

The distance matrix is shown below and the graphs are attached in the appendix.

Table 4.3 Distance Matrix

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	-	1093	5991	6303	6160	6452	7130	7630	10031	11091	3520	5027	5207	5434	3543	2238	1646	2771	6409	7372
1	1103	-	5015	5220	5188	5374	6160	6548	8952	10014	2433	3925	4118	4348	2493	1195	1658	2798	6546	8438
2	5815	4722	-	333	221	490	1211	1673	4072	5145	2322	1195	902	954	3083	4400	5140	6283	10026	13150
3	6144	5065	358	-	167	159	1248	1347	3747	4818	2672	1537	1221	885	3011	4330	5065	6206	9957	13483
4	5978	4895	208	172	-	316	1086	1511	3914	4977	2496	1365	1048	1067	3194	4510	5252	6396	10140	13314
5	6277	5194	502	169	337	-	1090	1475	3876	4945	2791	1659	1345	1050	3173	4492	5237	6376	10124	13614
6	6859	5776	1092	1151	983	987	-	2490	4891	5959	3373	2252	1936	2049	4173	5493	6232	7374	11121	14197
7	7485	6403	1683	1357	1521	1485	2566	-	2405	3470	3999	2861	2543	2203	4326	5640	6387	7530	11273	14815
8	10340	9253	4535	4209	4376	4343	5436	2865	-	1521	6852	5731	5412	5069	7193	8512	9256	10397	14183	17675
9	11662	10578	5865	5535	5702	5670	6762	4193	1858	-	8175	7060	6741	6397	8521	9840	10580	11721	15509	18993
10	3490	2403	2476	2816	2645	2936	3622	4157	6561	7624	-	1502	1696	1924	1580	2897	3645	4783	8566	10827
11	5001	3914	1094	1431	1261	1553	2239	2763	5162	6228	1515	-	309	901	3026	4345	5090	6234	9973	12332
12	5181	4098	785	1124	954	1246	1926	2462	4857	5926	1686	317	-	1062	3188	4507	5256	6390	10134	12514
13	5423	4338	944	875	1049	1031	2132	2193	4611	5674	1935	891	1052	-	2140	3459	4201	5345	9087	12753
14	3533	2503	3093	3021	3184	3163	4264	4344	6750	7816	1570	3036	3198	2150	-	1319	2058	3203	6945	10872
15	2248	1210	4390	4320	4491	4473	5568	5650	8052	9119	2879	4331	4498	3446	1309	-	773	1910	5652	9576
16	1656	1643	5150	5075	5241	5224	6323	6399	8802	9865	3626	5081	5246	4197	2068	763	-	1613	5362	8593
17	2788	2764	6260	6189	6358	6341	7432	7512	9920	10980	4745	6198	6363	5314	3182	1882	1585	-	3913	8541
18	6399	6536	10036	9964	10130	10114	11208	11291	13692	14757	8520	9969	10144	9092	6957	5663	5352	3923	-	6170
19	7404	8480	12372	13710	13541	13837	14531	15051	17456	18516	10906	12399	12591	12822	10925	9627	8641	8567	6227	

= ((188 cm/ 35 cm) * (151 cm/ 29 cm)) + 2

= ((5,3) * (5,2)) + 2

= (5 * 5) + 2 = 27 bulks

The second version of capacity calculation will be used for this research.

4.2.4 Vehicle Variable Cost

Variable cost calculated based on the fuel price and fuel rate consumption of vehicle in a month. The calculation based on the formula number 3.11.

Truck variable cost cv_1 (IDR/ meter/ month) = fuel rate consumption of truck (liter/ meters)* 30 (days) * fuel price (IDR)

= 1liter/8000 meters * 30days * 4500

= IDR 16,875/ meter / month

Panther variable cost cv_2 (IDR/ meter / month) = fuel rate consumption of truck (liter/ meters)* 30 (days) * fuel price (IDR)

= 1liter/10000 meters * 30 days * IDR 4500

= IDR 13,5 /meters / month

The maximum distance of each vehicle stated at 30.000 meters.

4.2.5 Vehicle Fixed Cost

The calculation of fixed cost of every vehicle will use formula number 3.12.

Truck fixed cost (cc_1) (IDR/ month) = driver wages (IDR) + maintenance in a month (IDR) + insurance (IDR)

= IDR 1.100.000 + IDR 220.000 + IDR 150.000

= IDR 1.470.000 / month

Panther fixed cost (cc_2) (IDR/ month) = driver wages (IDR) + maintenance in a month (IDR) + insurance (IDR)

= IDR 1.100.000 + IDR 140.000 + IDR 150.000

= IDR 1.390.000 / month

4.2.6 Mathematical Formulation of Heterogeneous Fixed Fleet Vehicle Routing Problem

Objective function from equation 3.1

Minimize Total Cost =

$$\sum_{k=1}^{2} \left[\left(cv_k \left(\sum_{i=0}^{19} \sum_{j=0, j \neq i}^{19} d_{ij} \cdot \alpha_{ijk} \right) \right) + \left(cc_t \cdot \sum_{t=1}^{2} \beta_{kt} \right) \right]$$

Subject to:

Constraint 3.2

$x_{1,1} + x_{1,2} = 1$; $x_{2,1} + x_{2,2} = 1$; $x_{3,1} + x_{3,2} = 1$; $x_{4,1} + x_{4,2} = 1$; $x_{5,1} + x_{5,2} = 1$; $x_{6,1} + x_{6,2} = 1$; $x_{7,1} + x_{7,2} = 1$; $x_{8,1} + x_{8,2} = 1$; $x_{9,1} + x_{9,2} = 1$; $x_{10,1} + x_{10,2} = 1$; $x_{11,1} + x_{11,2} = 1$; $x_{12,1} + x_{12,2} = 1$; $x_{13,1} + x_{13,2} = 1$; $x_{14,1} + x_{14,2} = 1$; $x_{15,1} + x_{15,2} = 1$; $x_{16,1} + x_{16,2} = 1$; $x_{17,1} + x_{17,2} = 1$; $x_{18,1} + x_{18,2} = 1$; $x_{19,1} + x_{19,2} = 1$

Constraint 3.3

$$\sum_{i=1}^{19} \alpha_{i0k} = 1 \quad k = 1$$

$$\sum_{i=1}^{19} \alpha_{i0k} = 1 \quad k = 2$$

Constraint 3.4

$$\sum_{j=1}^{19} \alpha_{0jk} = 1 \quad k = 1$$

$$\sum_{j=1}^{19} \alpha_{0jk} = 1 \quad k = 2$$

Constraint 3.5

$$\sum_{j=0, j\neq i}^{19} \alpha_{ijk} - \sum_{j=0, j\neq i}^{19} \alpha_{jik} = 0 \quad i = (1), \quad k = (1,2)$$

$$\sum_{j=0, j\neq i}^{19} \alpha_{ijk} - \sum_{j=0, j\neq i}^{19} \alpha_{jik} = 0 \quad i = (2), \quad k = (1,2)$$

$$\sum_{j=0, j\neq i}^{19} \alpha_{ijk} - \sum_{j=0, j\neq i}^{19} \alpha_{jik} = 0 \quad i = (3), \quad k = (1,2)$$

$$\sum_{j=0, j\neq i}^{19} \alpha_{ijk} - \sum_{j=0, j\neq i}^{19} \alpha_{jik} = 0 \quad i = (4), \quad k = (1,2)$$

$$\sum_{j=0, j\neq i}^{19} \alpha_{ijk} - \sum_{j=0, j\neq i}^{19} \alpha_{jik} = 0 \quad i = (5), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (6), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (7), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (8), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (9), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (10), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (11), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (12), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (13), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (14), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (15), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (16), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (17), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (18), \quad k = (1,2)$$

$$\sum_{j=0,j\neq i}^{19} \alpha_{ijk} - \sum_{j=0,j\neq i}^{19} \alpha_{jik} = 0 \quad i = (19), \quad k = (1,2)$$

Constraint 3.6

$$\sum_{i=1}^{19} x_{ik} \cdot c_i \leq \sum_{t=1}^{2} \beta_{kt} \cdot C_t \qquad k = 1$$

$$\sum_{i=1}^{19} x_{ik} \cdot c_i \leq \sum_{t=1}^{2} \beta_{kt} \cdot C_t \qquad k = 2$$

Constraint 3.7

$\beta_{11} \leq 1$; $\beta_{22} \leq 1$

Constraint 3.8

$$\sum_{j=1, j\neq i}^{19} \sum_{i=1}^{19} \alpha_{ijk} \leq |S| - 1 \qquad \forall S \subseteq V = (1,2,3,\ldots,19)\,, |S| \geq 2, k = (1)$$

$$\sum_{j=1, j\neq i}^{19} \sum_{i=1}^{19} \alpha_{ijk} \leq |S| - 1 \qquad \forall S \subseteq V = (1,2,3,\ldots,19)\,, |S| \geq 2, k = (2)$$

Constraint 3.9

$$cv_k \left(\sum_{i=0}^{19} \sum_{j=0, j\neq i}^{19} d_{ij} \,.\, \alpha_{ijk} \right) \leq (cv_k \,.\, 30.000) \qquad k = 1$$

$$cv_k \left(\sum_{i=0}^{19} \sum_{j=0, j\neq i}^{19} d_{ij} \,.\, \alpha_{ijk} \right) \leq (cv_k \,.\, 30.000) \qquad k = 2$$

4.2.7 Current Route Cost

To know the money spent by the company in implementing current vehicle routes, here below is the calculation.

Total cost = (16,875 ($1093\alpha_{0,1,1}$ + $5015\alpha_{1,2,1}$ + $333\alpha_{2,3,1}$ + $167\alpha_{3,4,1}$ + $316\alpha_{4,5,1}$ + $1090\alpha_{5,6,1}$ + $2490\alpha_{6,7,1}$ + $2405\alpha_{7,8,1}$ + $1521\alpha_{8,9,1}$ + $11662\alpha_{9,0,1}$) + 1.470.000 β_{11}) + (13,5 ($3520\alpha_{0,10,2}$ + $1502\alpha_{10,11,2}$ + $309\alpha_{11,12,2}$ + $1062\alpha_{12,13,2}$ + $2140\alpha_{13,14,2}$ + $1319\alpha_{14,15,2}$ + $773\alpha_{15,16,2}$ + $1613\alpha_{16,17,2}$ + $3913\alpha_{17,18,2}$ + $6170\alpha_{18,19,2}$ + $7404\alpha_{19,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 5015 . 1 + 333 . 1 + 167 . 1 + 316 . 1 + 1090 . 1 + 2490 . 1 + 2405 . 1 + 1521 . 1 + 11662 . 1) + 1.470.000 . 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 1062 . 1 + 2140 . 1 + 1319 . 1 + 773 . 1 + 1613 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1) + 1.390.000 . 1) = IDR 3.701.590 per month

4.3 Total Cost Minimization of Heterogeneous Fixed Fleet Vehicle Routing Problem Using Holmes and Parker Algorithm

To analyze the data, this research applies the Holmes and Parker algorithm. Below are the steps of the algorithm.

4.3.1 Initialization

Before beginning the iteration, the initialization is required to ease the iteration process. The initialization steps are below:

Step 1

This step already finished in the sub chapter 4.2.1 and 4.2.2.

Step 2

2.1 In this step, to calculate the saving of each pair, the formula 2.1 is used. The calculations are:

$s_{1,2} = d_{1,0} + d_{0,2} - d_{1,2}$ = 5815 + 6303 - 333 = 11785

There are several savings that have negative value $s_{i,j} < 0$. Then the value is changed to 0 which are $s_{19,3}$, $s_{19,7}$, $s_{19,8}$, and $s_{19,9} = 0$

The other saving calculations are recorded in the saving matrix below.

2.2 This step the value of pairs; $s_{0,1}$, $s_{0,2}$, $s_{0,3}$, $s_{0,4}$, $s_{0,5}$, $s_{0,6}$, $s_{0,7}$, $s_{0,8}$, $s_{0,9}$, $s_{0,10}$, $s_{0,11}$, $s_{0,12}$, $s_{0,13}$, $s_{0,14}$, $s_{0,15}$, $s_{0,16}$, $s_{0,17}$, $s_{0,18}$, $s_{0,19}$, $s_{1,0}$, $s_{2,0}$, $s_{3,0}$, $s_{4,0}$, $s_{5,0}$, $s_{6,0}$, $s_{7,0}$, $s_{8,0}$, $s_{9,0}$, $s_{10,0}$, $s_{11,0}$, $s_{12,0}$, $s_{13,0}$, $s_{14,0}$, $s_{15,0}$, $s_{16,0}$, $s_{17,0}$, $s_{18,0}$, and $s_{19,0}$ are changed to -1.

Table 4.4 Saving Matrix

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	-	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
1	-1	-	2079	2186	2075	2181	2073	2185	2182	2180	2190	2205	2192	2189	2153	2146	1091	1076	966	37
2	-1	2186	-	11785	11754	11777	11734	11772	11774	11761	7013	9647	10120	10295	6275	3653	2321	2303	2198	37
3	-1	2172	11777	-	12137	12437	12026	12427	12428	12417	6992	9634	10130	10693	6676	4052	2725	2709	2596	33
4	-1	2176	11761	12109	-	12114	12022	12097	12095	12092	7002	9640	10137	10345	6327	3706	2372	2353	2247	36
5	-1	2176	11766	12411	12100	-	12317	12432	12432	12423	7006	9645	10139	10661	6647	4023	2686	2672	2562	35
6	-1	2176	11758	12011	12036	12324	-	11999	11999	11991	7006	9634	10130	10244	6229	3604	2273	2256	2147	34
7	-1	2175	11793	12431	12124	12452	12049	-	15111	15106	7006	9651	10149	10716	6702	4083	2744	2726	2621	42
8	-1	2180	11796	12434	12124	12449	12034	15105	-	19910	7008	9636	10135	10705	6690	4066	2730	2714	2566	37
9	-1	2177	11788	12430	12120	12444	12030	15099	19835	-	7007	9629	10128	10699	6684	4060	2728	2712	2562	41
10	-1	2180	7005	6977	7005	7006	6998	6963	6960	6957	-	7015	7001	7000	5453	2831	1491	1478	1333	35
11	-1	2180	9898	9873	9900	9900	9892	9868	9870	9864	7006	-	9899	9534	5518	2894	1557	1538	1437	41
12	-1	2176	10387	10360	10387	10387	10385	10349	10355	10346	7015	9891	-	9553	5536	2912	1571	1562	1456	39
13	-1	2178	10470	10851	10534	10844	10421	10860	10843	10840	7008	9559	9578	-	6826	4202	2868	2849	2745	42
14	-1	2123	6431	6815	6509	6822	6399	6819	6814	6808	5483	5524	5542	6817	-	4452	3121	3101	2997	33
15	-1	2131	3849	4231	3917	4227	3810	4228	4227	4220	2889	2944	2957	4236	4482	-	3121	3109	3005	44
16	-1	1106	2497	2884	2575	2884	2463	2887	2885	2882	1550	1602	1617	2893	3131	3131	-	2814	2703	435
17	-1	1117	2519	2902	2590	2899	2486	2906	2899	2899	1563	1617	1632	2908	3149	3144	2849	-	5284	1619
18	-1	956	2354	2738	2429	2737	2321	2738	2738	2733	1399	1457	1462	2741	2985	2974	2693	5247	-	7601
19	-1	17	1023	0	23	19	3	0	0	0	18	32	20	16	22	15	409	1608	7586	-

4.3.2 Iteration

The iteration begun with creates initial solution without any suppression or solved in the parallel version of Clarke and Wright algorithm. The suppression schemas start after initial solution found.

A. Initial Solution

The initial solution created without any suppression schemas.

Table 4.5 Iteration of Initial Solution

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	yes	13	1	6	37	0,13,4,3,7,8,9,5,6,2,0	
14	2.13	10295	no			6	37		
15	2.12	10120	yes	12	1	5	37	0,13,4,3,7,8,9,5,6,2,12,0	
16	12.11	9891	yes	11	3	2	37	0,13,4,3,7,8,9,5,6,2,12,11,0	

Table 4.5 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.13	9534	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	11.10	7006	yes	10	2	0	32	0,13,4,3,7,8,9,5,6,2,12,11,10,0	
20	10.13	7000	no			0	32		
21	14.13	6817	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

There are several savings that feasible selected, but infeasible to be merged. The reason is because the saving violating the principle in the step 4.4. The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{2,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 ($1093\alpha_{0,1,1} + 1658\alpha_{1,16,1} + 763\alpha_{16,15,1} + 1309\alpha_{15,14,1} + 3203\alpha_{14,17,1} + 3913\alpha_{17,18,1} + 6170\alpha_{18,19,1} + 7404\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 ($5434\alpha_{0,13,2} + 1049\alpha_{13,4,2} + 172\alpha_{4,3,2} + 1347\alpha_{3,7,2} + 2405\alpha_{7,8,2} + 1521\alpha_{8,9,2} + 5670\alpha_{9,5,2} + 1090\alpha_{5,6,2} + 1092\alpha_{6,2,2} + 902\alpha_{2,12,2} + 317\alpha_{12,11,2} + 1515\alpha_{11,10,2} + 3490\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1) + (13,5 (5434 . 1 + 1049 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 902 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.641.586 per month

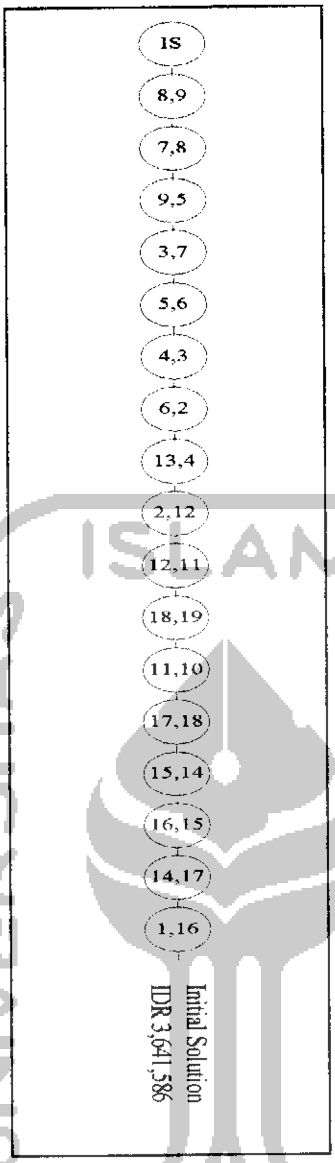

Figure 4.5 Initial Solution's Tree Diagram

B. First Suppression

The first suppression saving is taken from the current best solution (initial solution) which is $s_{8,9}$ and set $s_{8,9} = 0$ in the current saving matrix.

Table 4.6 Iteration of First Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	Temporary suppress						
2	9.08	19835	yes	9	1	-1	37	0,9,8,0	
				8	2	-3	37		
3	7.09	15106	yes	7	2	-5	37	0,7,9,8,0	
4	8.07	15105	no			-5	37		
5	8.05	12449	yes	5	1	-6	37	0,7,9,8,5,0	
6	5.07	12432	no			-6	37		
7	3.07	12427	yes	3	4	-10	37	0,3,7,9,8,5,0	
8	5.03	12411	no			-10	37		
9	5.06	12317	yes	6	2	-12	37	0,3,7,9,8,5,6,0	
10	4.03	12109	yes	4	3	-15	37	0,4,3,7,9,8,5,6,0	
11	6.04	12036	no			-15	37		
12	6.02	11758	yes	2	5	-20	37	0,4,3,7,9,8,5,6,2,0	
13	2.04	11754	no			-20	37		
14	13.04	10534	yes	13	1	-21	37	0,13,4,3,7,9,8,5,6,2,0	
15	2.13	10295	no			-21	37		
16	2.12	10120	yes	12	1	-22	37	0,13,4,3,7,9,8,5,6,2,12,0	

Table 4.6 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	12.11	9891	yes	11	3	-25	37	0,13,4,3,7,9,8,5,6,2,12,11,0	
18	11.13	9534	no			-25	37		
19	18.19	7601	yes	18	4		33		0,18,19,0
				19	1		32		
20	11.10	7006	yes	10	2	0	32	0,13,4,3,7,9,8,5,6,2,12,11,10,0	
21	10.13	7000	no			0	32		
22	14.13	6817	no			0	32		
23	10.14	5453	no			0	32		
24	17.18	5284	yes	17	1	0	31		0,17,18,19,0
25	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
26	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
27	14.16	3121	no			0	28		
28	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
29	1.13	2189	no			0	28		
30	10.01	2180	no			0	28		
31	10.16	1491	no			0	28		
32	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
33	19.01	17	no			0	18		
34	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{8,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{2,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = $(16{,}875\,(1093\alpha_{0,1,1} + 1658\alpha_{1,16,1} + 763\alpha_{16,15,1} + 1309\alpha_{15,14,1} + 3203\alpha_{14,17,1} + 3913\alpha_{17,18,1} + 6170\alpha_{18,19,1} + 7404\alpha_{19,0,1}) + 1.470.000\,\beta_{11}) + (13{,}5\,(5434\alpha_{0,13,2} + 1049\alpha_{13,4,2} + 172\alpha_{4,3,2} + 1347\alpha_{3,7,2} + 3470\alpha_{7,9,2} + 1858\alpha_{9,8,2} + 4343\alpha_{8,5,2} + 1090\alpha_{5,6,2} + 1092\alpha_{6,2,2} + 902\alpha_{2,12,2} + 317\alpha_{12,11,2} + 1515\alpha_{11,10,2} + 3490\alpha_{10,0,2}) + 1.390.000\,\beta_{22})$

(16,875 (1093 . 1 + 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1) + 1.470.000 . 1)+ (13,5 (5434 . 1 + 1049 . 1 + 172 . 1 + 1347 . 1 + 3470 . 1 + 1858 . 1 + 4343 . 1 + 1090 . 1 + 1092 . 1 + 902 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000 . 1) = IDR 3.642.598 per month

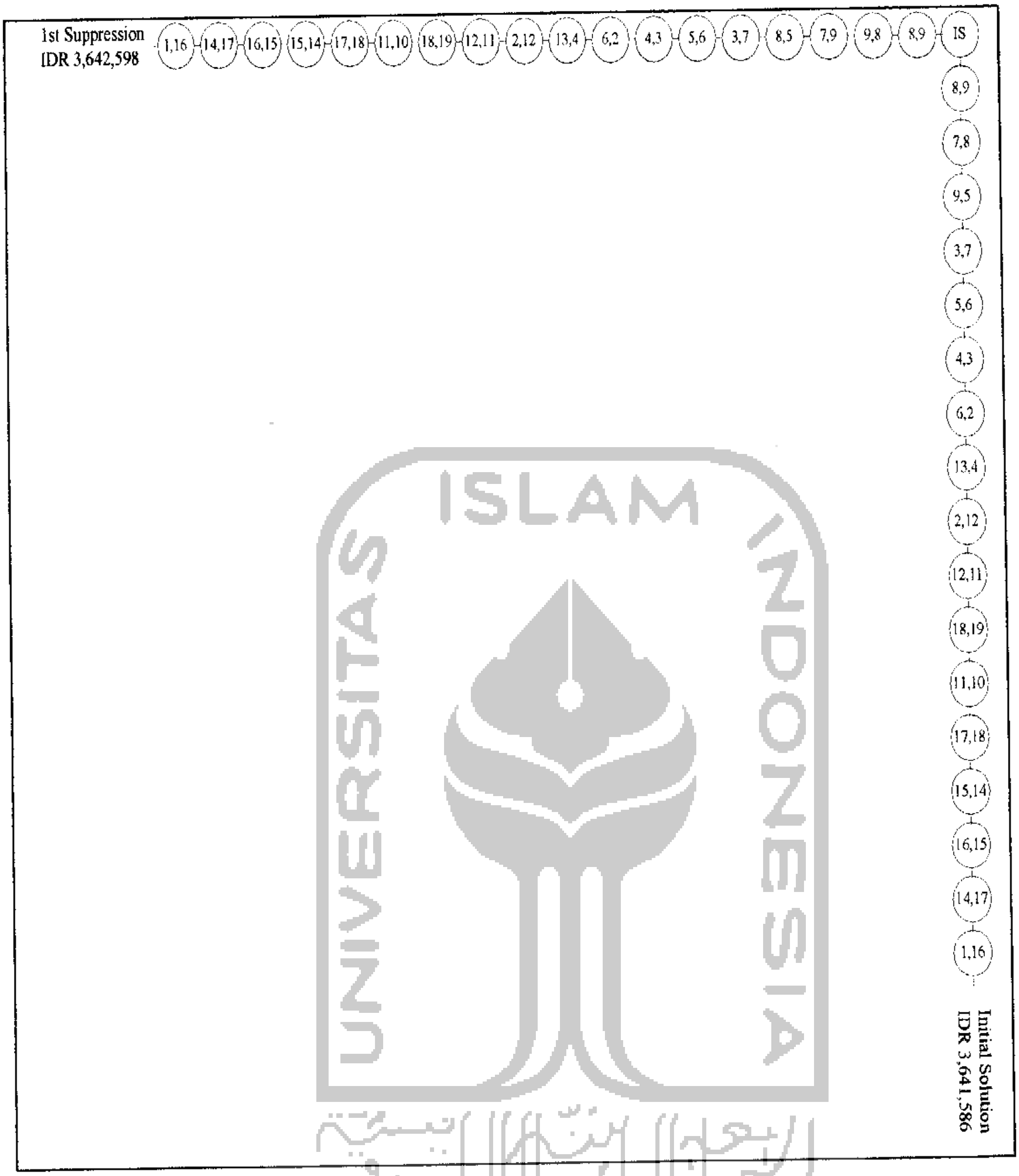

Figure 4.6 First Suppression's Tree Diagram

C. Second Suppression

The current best solution still initial solution and the first suppression pair are returned to its value in the current saving matrix. The second suppression pair is saving $s_{7,8}$ and set $s_{7,8} = 0$ in the current saving matrix.

Table 4.7 Iteration of Second Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	Temporary suppress						
3	9.07	15099	yes	7	2	22	37	0,8,9,7,0	
4	7.05	12452	yes	5	1	21	37	0,8,9,7,5,0	
5	5.08	12432	no			21	37		
6	3.08	12428	yes	3	4	17	37	0,3,8,9,7,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,8,9,7,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,8,9,7,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,8,9,7,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	yes	13	1	6	37	0,13,4,3,8,9,7,5,6,2,0	
14	2.13	10295	no			6	37		
15	2.12	10120	yes	12	1	5	37	0,13,4,3,8,9,7,5,6,2,12,0	
16	12.11	9891	yes	11	3	2	37	0,13,4,3,8,9,7,5,6,2,12,11,0	

Table 4.7 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.13	9534	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	11.10	7006	yes	10	2	0	32	0,13,4,3,8,9,7,5,6,2,12,11,10,0	
20	10.13	7000	no			0	32		
21	14.13	6817	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{5,8}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{2,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$) + 1.470.000 β_{11})+ (13,5 (5434$\alpha_{0,13,2}$ + 1049$\alpha_{13,4,2}$ + 172$\alpha_{4,3,2}$ + 3747$\alpha_{3,8,2}$ + 1521$\alpha_{8,9,2}$ + 4193$\alpha_{9,7,2}$ + 1485$\alpha_{7,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 902$\alpha_{2,12,2}$ + 317$\alpha_{12,11,2}$ + 1515$\alpha_{11,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1) + 1.470.000. 1)+ (13,5 (5434 . 1 + 1049 . 1 + 172 . 1 + 3747 . 1 + 1521 . 1 + 4193 . 1 + 1485 . 1 + 1090 . 1 + 1092 . 1 + 902 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000 . 1) = IDR 3.641.626 per month

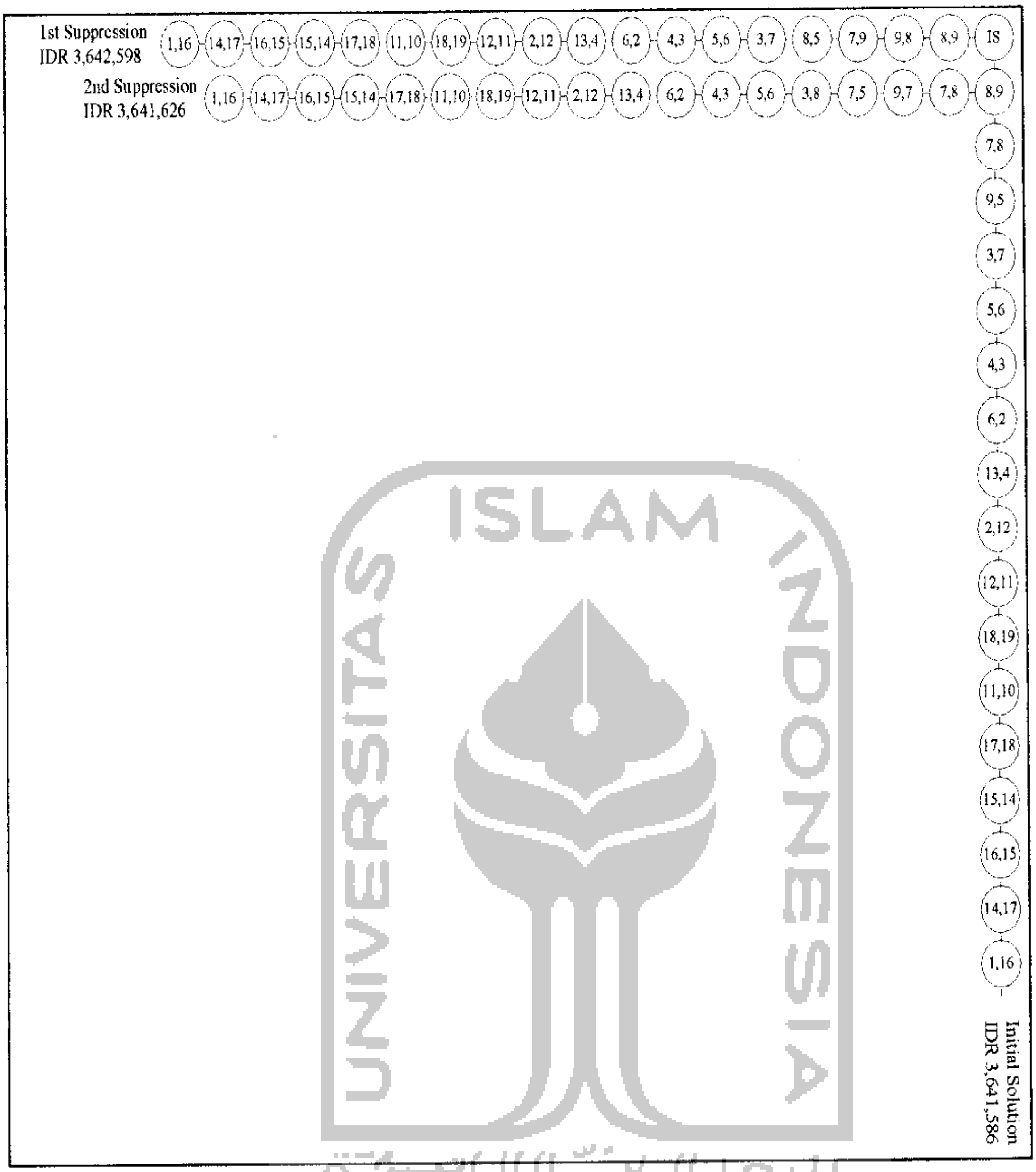

Figure 4.7 Second Suppression's Tree Diagram

D. Third Suppression

The current best solution still initial solution and the second suppression pair are returned to its value in the current saving matrix. The third suppression pair is saving $s_{9,5}$ and set $s_{9,5} = 0$ in the current saving matrix.

Table 4.8 Iteration of Third Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	Temporary suppress						
5	3.05	12437	yes	3	4	18	37	0,7,8,9,0;0,3,5,0	
				5	1	17	37		
6	5.07	12432	yes			17	37	0,3,5,7,8,9,0;	
7	9.03	12430	no			17	37		
8	9.04	12120	yes	4	3	14	37	0,3,5,7,8,9,4,0;	
9	4.03	12109	no			14	37		
10	4.06	12022	yes	6	2	12	37	0,3,5,7,8,9,4,6,0;	
11	6.03	12011	no			12	37		
12	2.03	11785	yes	2	5	7	37	0,2,3,5,7,8,9,4,6,0;	
13	6.02	11758	no			7	37		
14	13.02	10470	yes	13	1	6	37	0,13,2,3,5,7,8,9,4,6,0;	
15	6.13	10244	no			6	37		
16	6.12	10130	yes	12	1	5	37	0,13,2,3,5,7,8,9,4,6,12,0;	

Table 4.8 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	12.11	9891	yes	11	3	2	37	0,13,2,3,5,7,8,9,4,6,12,11,0;	
18	11.13	9534	no			2	37		
19	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
20	11.10	7006	yes	10	2	0	32	0,13,2,3,5,7,8,9,4,6,12,11,10,0;	
21	10.13	7000	no			0	32		
22	14.13	6817	no			0	32		
23	10.14	5453	no			0	32		
24	17.18	5284	yes	17	1	0	31		0,17,18,19,0
25	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
26	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{9,3}$, $s_{4,3}$, $s_{6,3}$, $s_{6,2}$, $s_{6,13}$, $s_{11,13}$, $s_{10,13}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 ($1093\alpha_{0,1,1} + 1658\alpha_{1,16,1} + 763\alpha_{16,15,1} + 1309\alpha_{15,14,1} + 3203\alpha_{14,17,1} + 3913\alpha_{17,18,1} + 6170\alpha_{18,19,1} + 7404\alpha_{19,0,1}$) + 1.470.000 β_{11})+ (13,5 ($5434\alpha_{0,13,2} + 944\alpha_{13,2,2} + 333\alpha_{2,3,2} + 159\alpha_{3,5,2} + 1475\alpha_{5,7,2} + 2405\alpha_{7,8,2} + 1521\alpha_{8,9,2} + 5702\alpha_{9,4,2} + 1086\alpha_{4,6,2} + 1936\alpha_{6,12,2} + 317\alpha_{12,11,2} + 1515\alpha_{11,10,2} + 3490\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1) + 1.470.000. 1)+ (13,5 (5434 . 1 + 944 . 1 + 333 . 1 + 159 . 1 + 1475 . 1 + 2405 . 1+ 1521 . 1+ 5702 . 1 + 1086 . 1 + 1936 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000 . 1) = IDR 3.645.811 per month

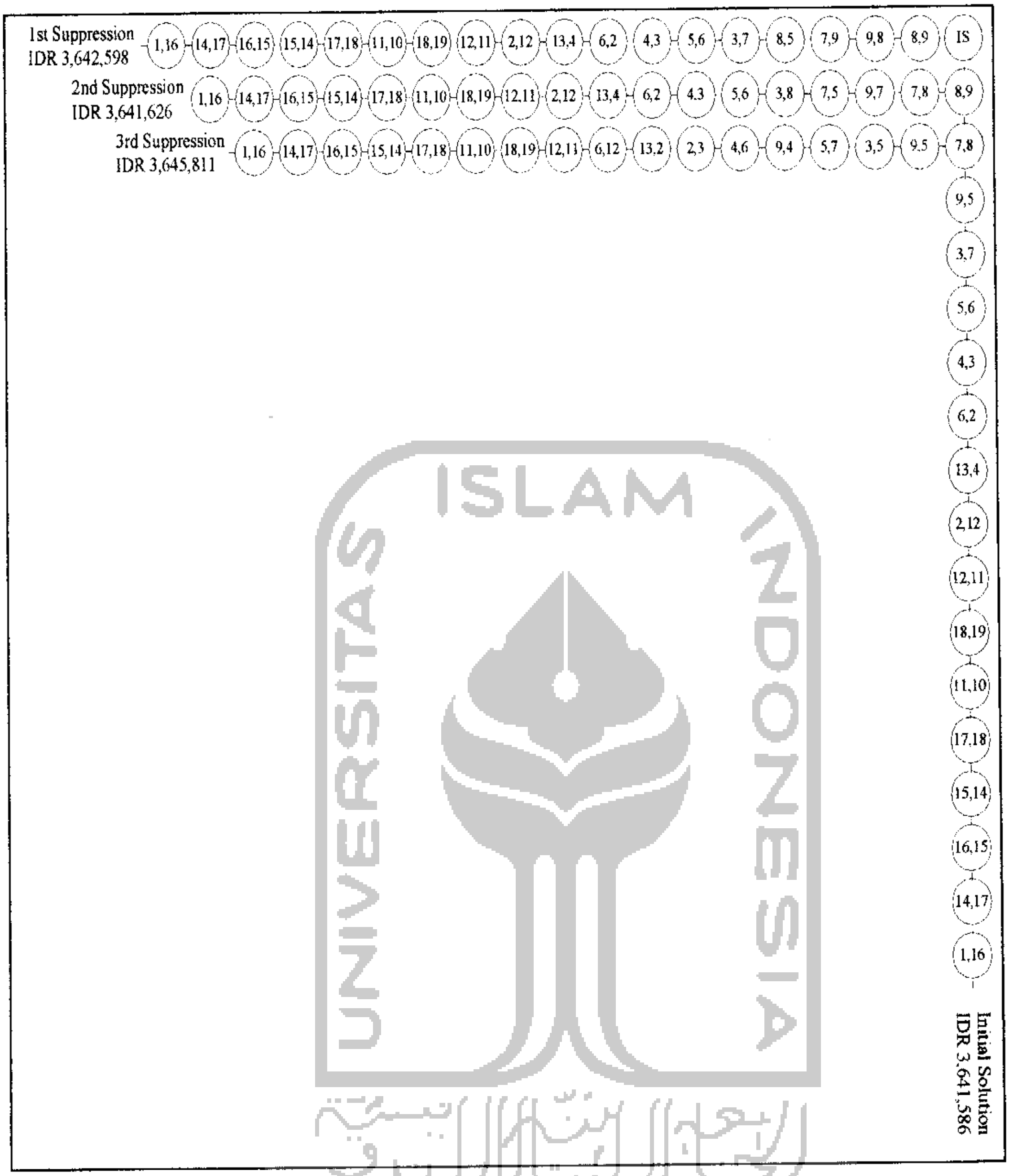

Figure 4.8 Third Suppression's Tree Diagram

E. Fourth Suppression

The current best solution still initial solution and the third suppression pair are returned to its value in the current saving matrix. The fourth suppression pair is saving $s_{3,7}$ and set $s_{3,7} = 0$ in the current saving matrix.

Table 4.9 Iteration of Fourth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	Temporary suppress						
7	5.03	12411	yes	3	4	17	37	0,7,8,9,5,3,0	
8	3.04	12137	yes	4	3	14	37	0,7,8,9,5,3,4,0	
9	4.07	12097	no			14	37		
10	4.06	12022	yes	6	2	12	37	0,7,8,9,5,3,4,6,0	
11	6.07	11999	no			12	37		
12	2.07	11772	yes	2	5	7	37	0,2,7,8,9,5,3,4,6,0	
13	6.02	11758	no			7	37		
14	13.02	10470	yes	13	1	6	37	0,13,2,7,8,9,5,3,4,6,0	
15	6.12	10130	yes	12	1	5	37	0,13,2,7,8,9,5,3,4,6,12,0	
16	12.11	9891	yes	11	3	2	37	0,13,2,7,8,9,5,3,4,6,12,11,0	

Table 4.9 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.13	9534	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	11.10	7006	yes	10	2	0	32	0,13,2,7,8,9,5,3,4,6,12,11,10,0	
20	10.13	7000	no			0	32		
21	14.13	6817	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{4,7}$, $s_{6,7}$, $s_{6,2}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = $(16{,}875\ (1093\alpha_{0,1,1} + 1658\alpha_{1,16,1} + 763\alpha_{16,15,1} + 1309\alpha_{15,14,1} + 3203\alpha_{14,17,1} + 3913\alpha_{17,18,1} + 6170\alpha_{18,19,1} + 7404\alpha_{19,0,1}) + 1.470.000\ \beta_{11}) + (13{,}5\ (5434\alpha_{0,13,2} + 944\alpha_{13,2,2} + 1673\alpha_{2,7,2} + 2405\alpha_{7,8,2} + 1521\alpha_{8,9,2} + 5670\alpha_{9,5,2} + 169\alpha_{5,3,2} + 167\alpha_{3,4,2} + 1086\alpha_{4,6,2} + 1936\alpha_{6,12,2} + 317\alpha_{12,11,2} + 1515\alpha_{11,10,2} + 3490\alpha_{10,0,2}) + 1.390.000\ \beta_{22})$

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1) + (13,5 (5434 . 1 + 944 . 1 + 1673 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 169 . 1 + 167 . 1 + 1086 . 1 + 1936 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.645.946 per month

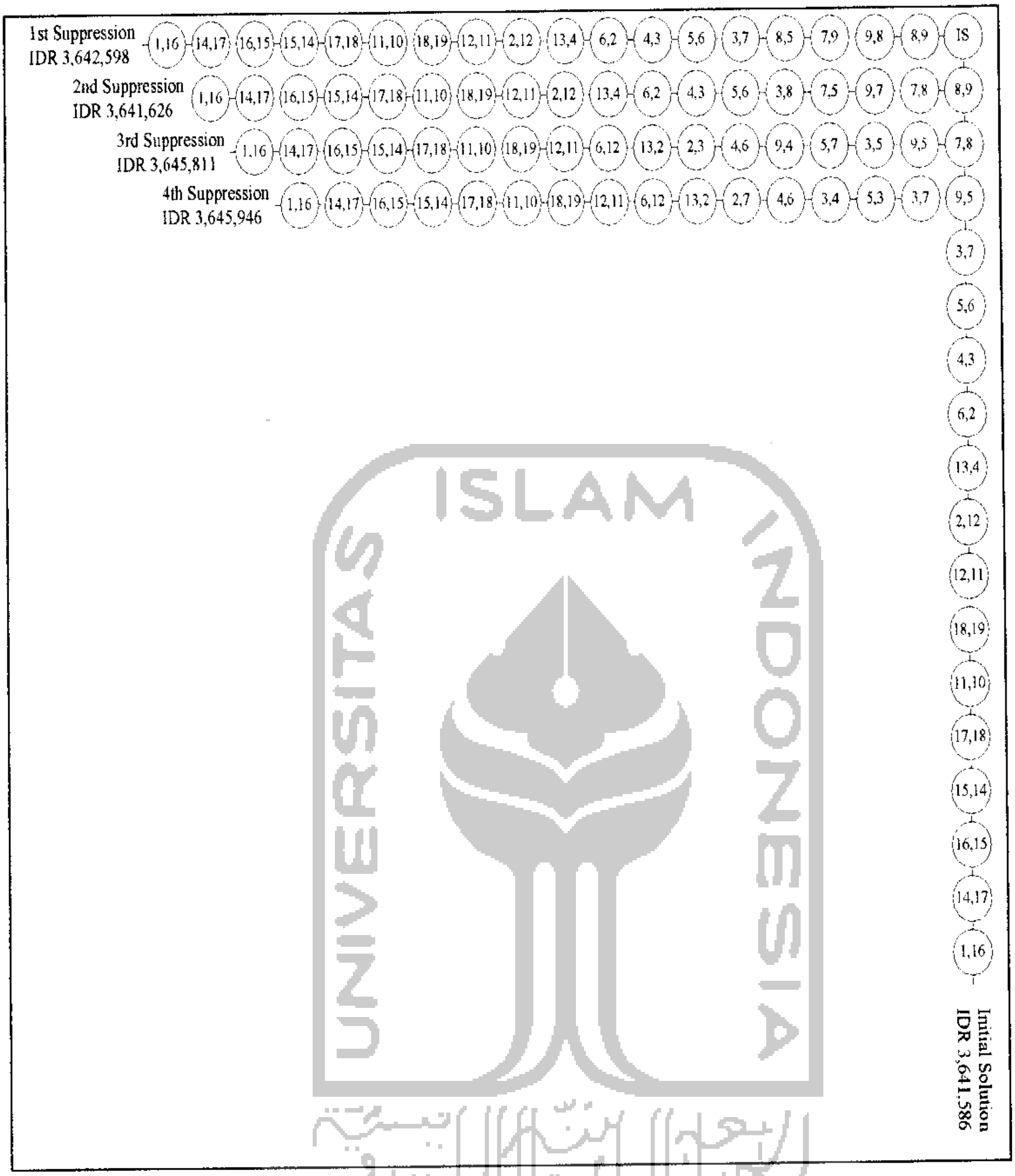

Figure 4.9 Fourth Suppression's Tree Diagram

F. Fifth Suppression

The current best solution still initial solution and the fourth suppression pair are returned to its value in the current saving matrix. The fifth suppression pair is saving $s_{5,6}$ and set $s_{5,6} = 0$ in the current saving matrix.

Table 4.10 Iteration of Fifth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	Temporary suppress						
9	4.03	12109	yes	4	3	14	37	0,4,3,7,8,9,5,0	
10	5.04	12100	no			14	37		
11	6.04	12036	yes	6	2	12	37	0,6,4,3,7,8,9,5,0	
12	5.02	11766	yes	2	5	7	37	0,6,4,3,7,8,9,5,2,0	
13	2.06	11734	no			7	37		
14	13.06	10421	yes	13	1	6	37	0,13,6,4,3,7,8,9,5,2,0	
15	2.13	10295	no			6	37		
16	2.12	10120	yes	12	1	5	37	0,13,6,4,3,7,8,9,5,2,12,0	

Table 4.10 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	12.11	9891	yes	11	3	2	37	0,13,6,4,3,7,8,9,5,2,12,11,0	
18	11.13	9534	no			2	37		
19	18.19	7601	yes	18	4	2	33		
				19	1	2	32		0,18,19,0
20	11.10	7006	yes	10	2	0	32	0,13,6,4,3,7,8,9,5,2,12,11,10,0	
21	10.13	7000	no			0	32		
22	14.13	6817	no			0	32		
23	10.14	5453	no			0	32		
24	17.18	5284	yes	17	1	0	31		0,17,18,19,0
25	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
26	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
27	14.16	3121	no			0	28		
28	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
29	1.13	2189	no			0	28		
30	10.01	2180	no			0	28		
31	10.16	1491	no			0	28		
32	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
33	19.01	17	no			0	18		
34	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{5,4}$, $s_{2,6}$, $s_{2,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5434$\alpha_{0,13,2}$ + 2132$\alpha_{13,6,2}$ + 983$\alpha_{6,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 502$\alpha_{5,2,2}$ + 902$\alpha_{2,12,2}$ + 317$\alpha_{12,11,2}$ + 1515$\alpha_{11,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (543 . 1 + 2132 . 1 + 983 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 502 . 1 + 902 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.646.797 per month

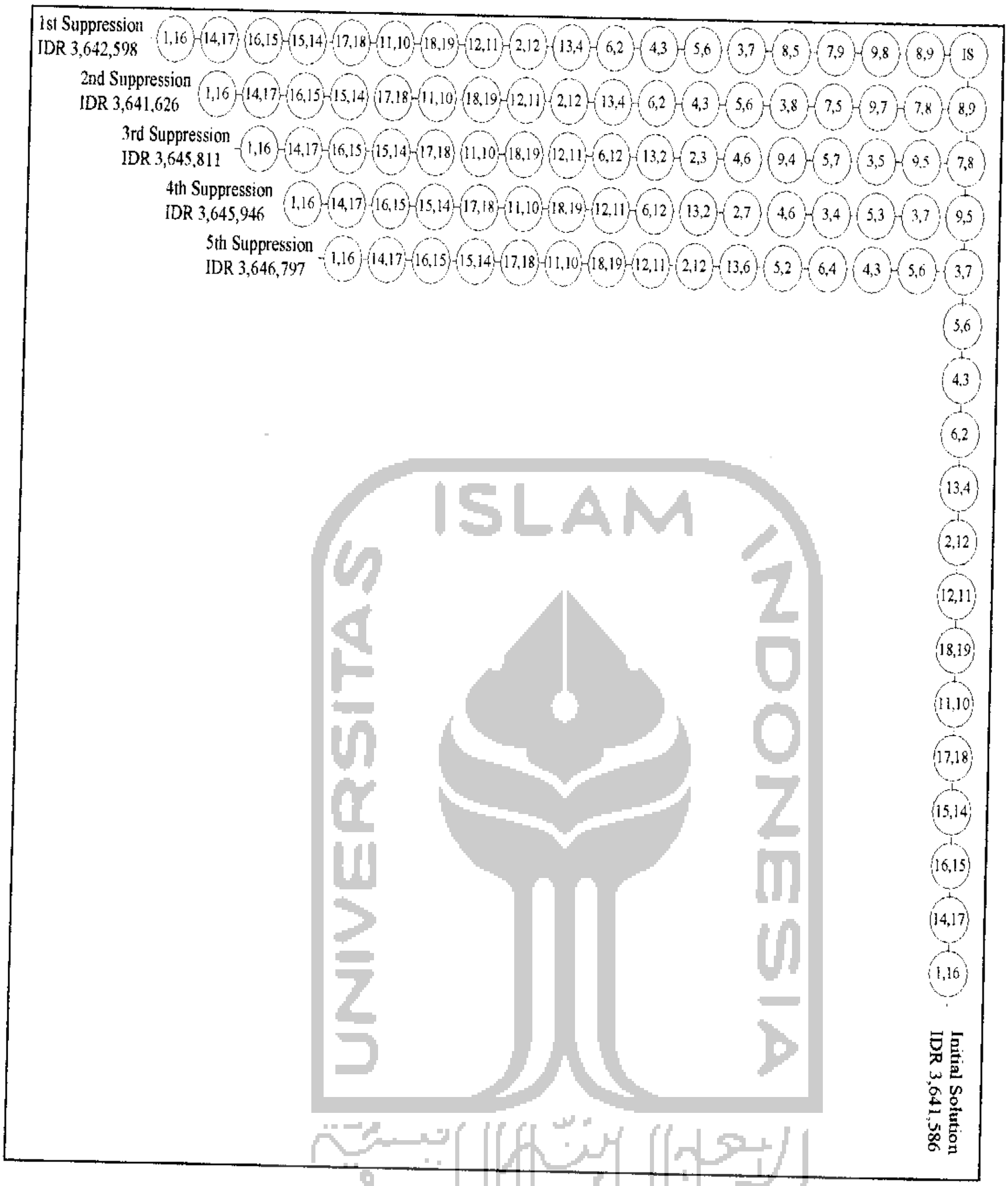

Figure 4.10 Fifth Suppression's Tree Diagram

G. Sixth Suppression

The current best solution still initial solution and the fifth suppression pair is returned to its value in the current saving matrix. The sixth suppression pair is saving $s_{4,3}$ and set $s_{4,3} = 0$ in the current saving matrix.

Table 4.11 Iteration of Sixth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	Temporary suppress						
10	6.04	12036	yes	4	3	12	37	0,3,7,8,9,5,6,4,0	
11	2.03	11785	yes	2	5	7	37	0,2,3,7,8,9,5,6,4,0	
12	4.02	11761	no			7	37		
13	13.02	10470	yes	13	1	6	37	0,13,2,3,7,8,9,5,6,4,0	
14	4.13	10345	no			6	37		
15	4.12	10137	yes	12	1	5	37	0,13,2,3,7,8,9,5,6,4,12,0	
16	12.11	9891	yes	11	3	2	37	0,13,2,3,7,8,9,5,6,4,12,11,0	

Table 4.11 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.13	9534	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	11.10	7006	yes	10	2	0	32	0,13,2,3,7,8,9,5,6,4,12,11,10,0	
20	10.13	7000	no			0	32		
21	14.13	6817	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{4,2}$, $s_{4,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5434$\alpha_{0,13,2}$ + 944$\alpha_{13,2,2}$ + 333$\alpha_{2,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 983$\alpha_{6,4,2}$ + 1048$\alpha_{4,12,2}$ + 317$\alpha_{12,11,2}$ + 1515$\alpha_{11,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5434 . 1 + 944 . 1 + 333 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 983 . 1 + 1048 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.642.841 per month

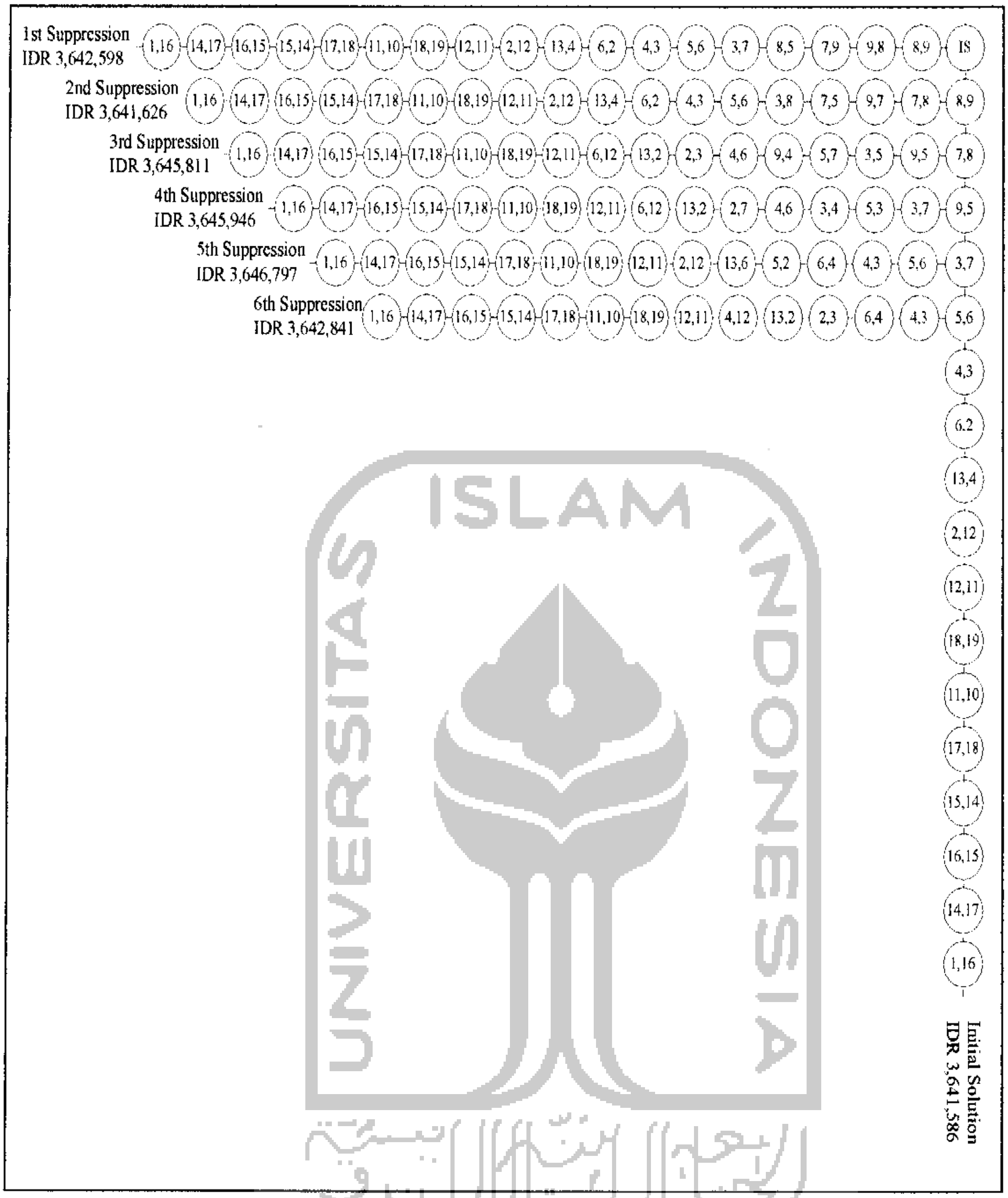

Figure 4.11 Sixth Suppression's Tree Diagram

H. Seventh Suppression

The current best solution still initial solution and the sixth suppression pair are returned to its value in the current saving matrix. The seventh suppression pair is saving $s_{6,2}$ and set $s_{6,2} = 0$ in the current saving matrix.

Table 4.12 Iteration of Seventh Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	Temporary suppress						
12	2.04	11754	yes	2	5	7	37	0,2,4,3,7,8,9,5,6,0	
13	13.02	10470	yes	13	1	6	37	0,13,2,4,3,7,8,9,5,6,0	
14	6.13	10244	no			6	37		
15	6.12	10130	yes	12	1	5	37	0,13,2,4,3,7,8,9,5,6,12,0	
16	12.11	9891	yes	11	3	2	37	0,13,2,4,3,7,8,9,5,6,12,11,0	

Table 4.12 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.13	9534	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	11.10	7006	yes	10	2	0	32	0,13,2,4,3,7,8,9,5,6,12,11,10,0	
20	10.13	7000	no			0	32		
21	14.13	6817	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.13	2189	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.01	17	no			0	18		
33	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{6,13}$, $s_{11,13}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$,

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5434$\alpha_{0,13,2}$ + 944$\alpha_{13,2,2}$ + 221$\alpha_{2,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1936$\alpha_{6,12,2}$ + 317$\alpha_{12,11,2}$ + 1515$\alpha_{11,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5434 . 1 + 944 . 1 + 221 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1936 . 1 + 317 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.642.369 per month

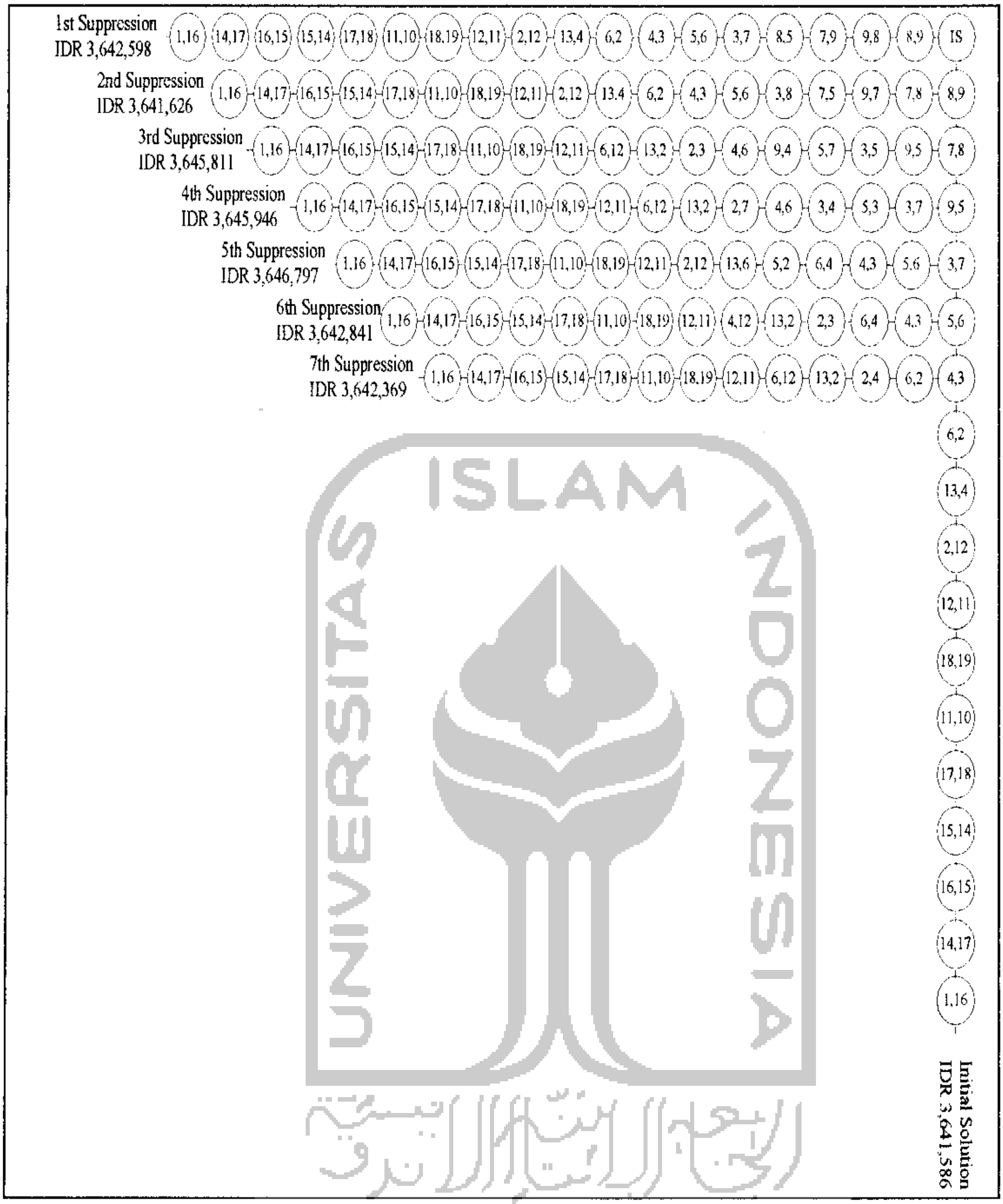

Figure 4.12 Seventh Suppression's Tree Diagram

I. Eighth Suppression

The current best solution still initial solution and the seventh suppression pair are returned to its value in the current saving matrix. The eighths suppression pair is saving $s_{13,4}$ and set $s_{13,4} = 0$ in the current saving matrix.

Table 4.13 Iteration of Eighth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Temporary suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.13 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.14	6826	no			0	32		
21	17.18	5284	yes	17	1	0	31		0,17,18,19,0
22	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
23	13.15	4202	no			0	29		
24	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
25	14.16	3121	no			0	28		
26	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
27	13.16	2868	no			0	28		
28	1.10	2190	no			0	28		
29	13.01	2178	no			0	28		
30	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
31	19.10	18	no			0	18		
32	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{14,16}$, $s_{19,1}$

Violating step 4.4.2 = $s_{13,14}$, $s_{13,15}$, $s_{13,16}$, $s_{1,10}$, $s_{13,1}$, $s_{19,10}$,

Total cost = (16,875 ($1093\alpha_{0,1,1}$ + $1658\alpha_{1,16,1}$ + $763\alpha_{16,15,1}$ + $1309\alpha_{15,14,1}$ + $3203\alpha_{14,17,1}$ + $3913\alpha_{17,18,1}$ + $6170\alpha_{18,19,1}$ + $7404\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 ($3520\alpha_{0,10,2}$ + $1502\alpha_{10,11,2}$ + $309\alpha_{11,12,2}$ + $954\alpha_{12,4,2}$ + $172\alpha_{4,3,2}$ + $1347\alpha_{3,7,2}$ + $2405\alpha_{7,8,2}$ + $1521\alpha_{8,9,2}$ + $5670\alpha_{9,5,2}$ + $1090\alpha_{5,6,2}$ + $1092\alpha_{6,2,2}$ + $954\alpha_{2,13,2}$ + $5423\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5423 . 1) + 1.390.000. 1) = IDR 3.640.978 per month

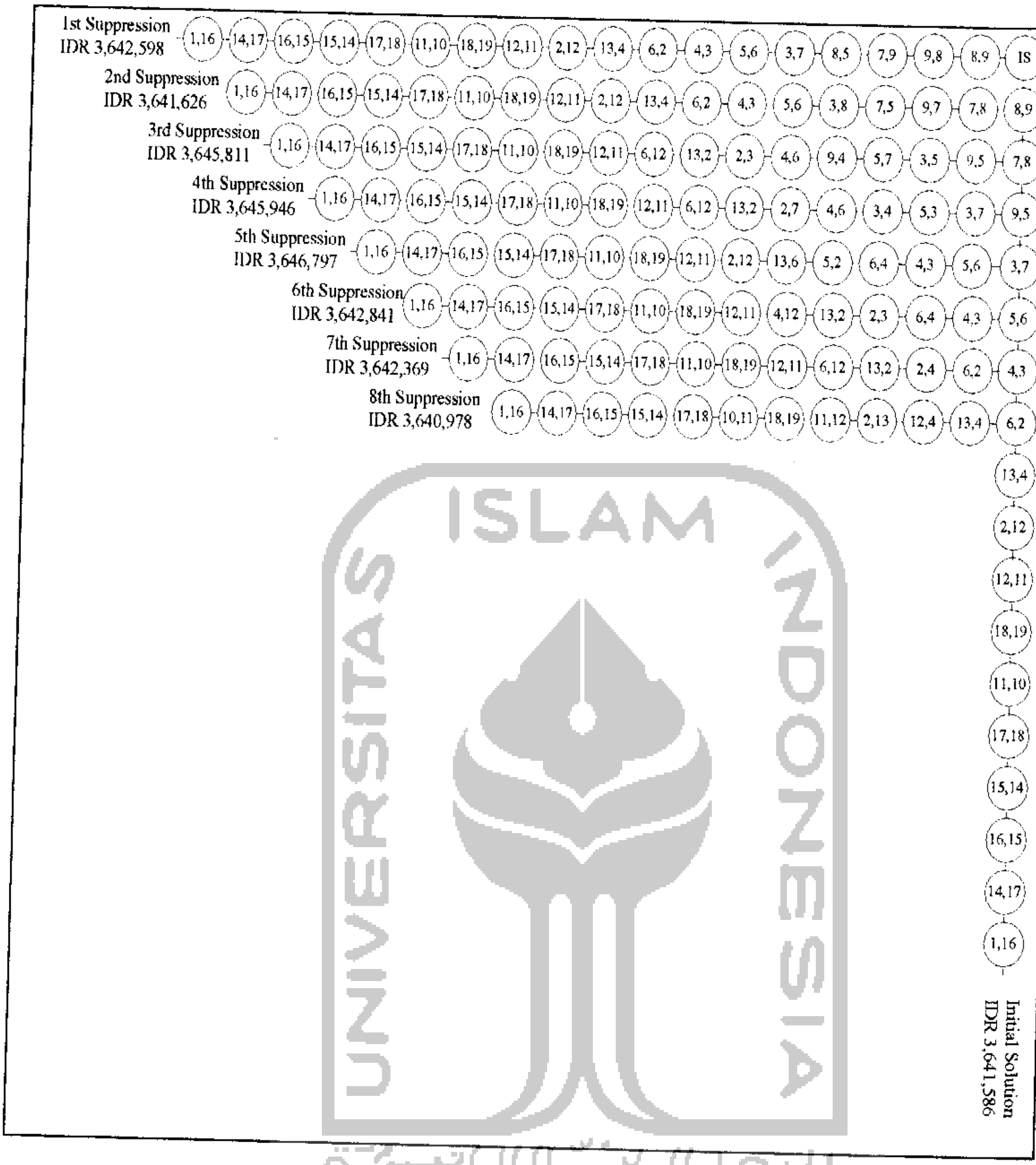

Figure 4.13 Eight Suppression's Tree Diagram

J. Ninth Suppression

The current best solution is change to the result in eighth suppression and then the eighth suppression pair is removed permanently from the current saving matrix $s_{13,4}$ and set $s_{13,4} = 0$ in the current saving matrix and remains zero in all next iterations. The ninth suppression pair is saving $s_{12,4}$ and set $s_{12,4} = 0$ in the current saving matrix.

Table 4.14 Iteration of Ninth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	Temporary suppress						
15	2.13	10295	yes	13	1	6	37	0,4,3,7,8,9,5,6,2,13,0	
16	11.04	9900	yes	11	3	3	37	0,11,4,3,7,8,9,5,6,2,13,0	

Table 4.14 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	12.11	9891	yes	12	1	2	37	0,12,11,4,3,7,8,9,5,6,2,13,0	
18	13.12	9578	no			2	37		
19	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
20	13.10	7008	yes	10	2	0	32	0,12,11,4,3,7,8,9,5,6,2,13,10,0	
21	10.12	7001	no			0	32		
22	14.12	5542	no			0	32		
23	10.14	5453	no			0	32		
24	17.18	5284	yes	17	1	0	31		0,17,18,19,0
25	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
26	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
27	14.16	3121	no			0	28		
28	14.17	3101	yes						0,16,15,14,17,18,19,0;
29	1.12	2192	no			0	28		
30	10.01	2180	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.12	20	no			0	18		
33	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,12}$, $s_{10,12}$, $s_{14,16}$, $s_{19,1}$

Violating step 4.4.2 = $s_{14,12}$, $s_{10,14}$, $s_{1,12}$, $s_{10,1}$, $s_{19,12}$,

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5207$\alpha_{0,12,2}$ + 317$\alpha_{12,11,2}$ + 1261$\alpha_{11,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 1935$\alpha_{13,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5207 . 1 + 317 . 1 + 1261 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 1935 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.647.755 per month

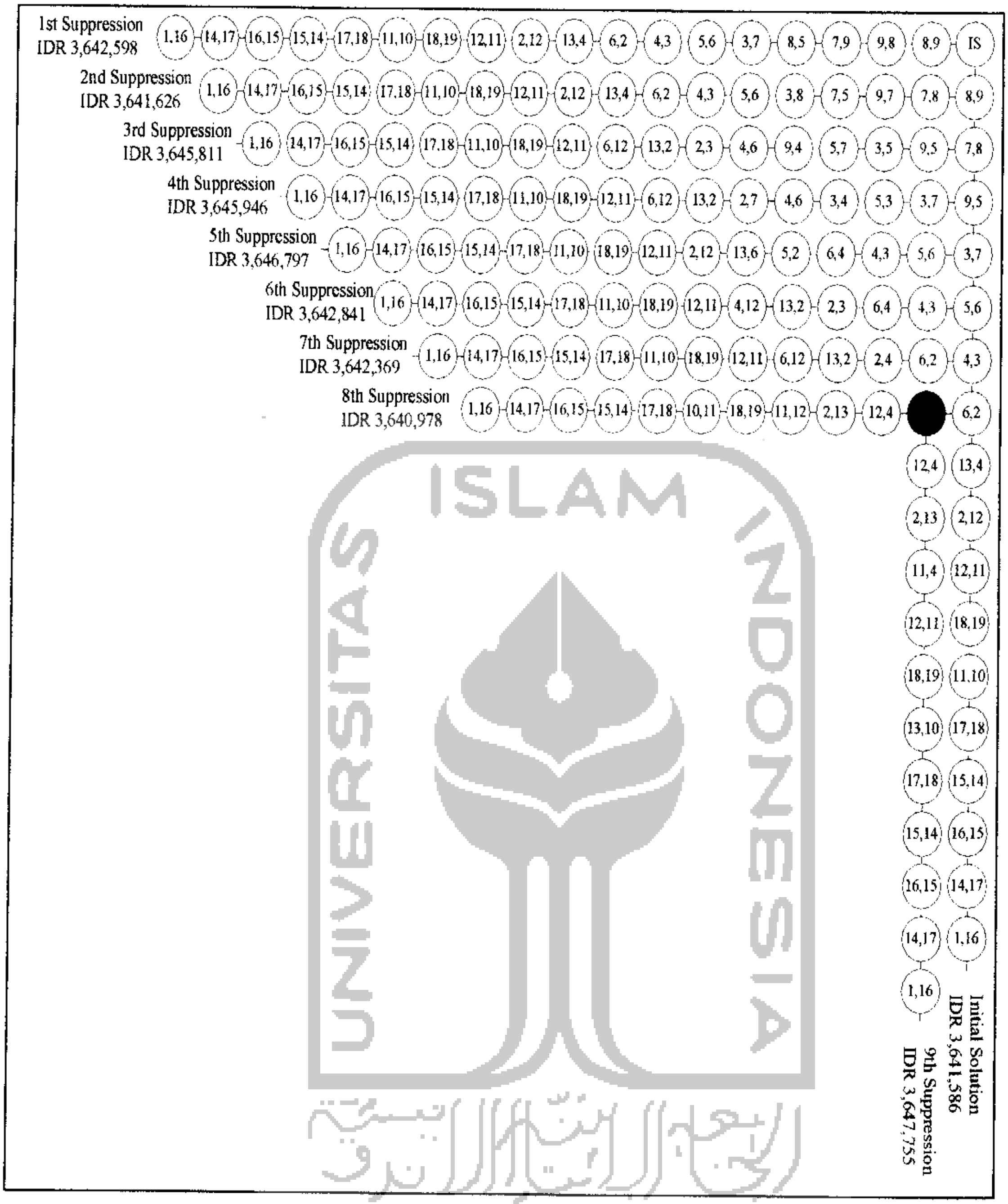

Figure 4.14 Ninth Suppression's Tree Diagram

K. Tenth Suppression

The current best solution still eighth suppression and the ninth suppression pair are returned to its value in the current saving matrix. The tenth suppression pair is saving $s_{2,13}$ and set $s_{2,13} = 0$ in the current saving matrix.

Table 4.15 Iteration of Tenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	Temporary suppress						
16	2.12	10120	no			6	37		

Table 4.15 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	11.12	9899	yes	11	3	3	37	0,11,12,4,3,7,8,9,5,6,2,0	
18	2.11	9647	no			3	37		
19	13.11	9559	yes	13	1	2	37	0,13,11,12,4,3,7,8,9,5,6,2,0	
20	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
21	2.10	7013	yes	10	2	0	32	0,13,11,12,4,3,7,8,9,5,6,2,10,0	
22	10.13	7000	no			0	32		
23	14.13	6817	no			0	32		
24	10.14	5453	no			0	32		
25	17.18	5284	yes	17	1	0	31		0,17,18,19,0
26	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
27	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
28	14.16	3121	no			0	28		
29	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
30	1.13	2189	no			0	28		
31	10.01	2180	no			0	28		
32	10.16	1491	no			0	28		
33	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
34	19.01	17	no			0	18		
35	19.13	16	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{2,12}$, $s_{2,11}$, $s_{10,13}$, $s_{14,16}$, $s_{19,1}$,

Violating step 4.4.2 = $s_{14,13}$, $s_{10,14}$, $s_{1,13}$, $s_{10,1}$, $s_{10,16}$, $s_{19,13}$

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5434$\alpha_{0,13,2}$ + 891$\alpha_{13,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 2322$\alpha_{2,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5434 . 1 + 891 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 2322 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.650.941 per month

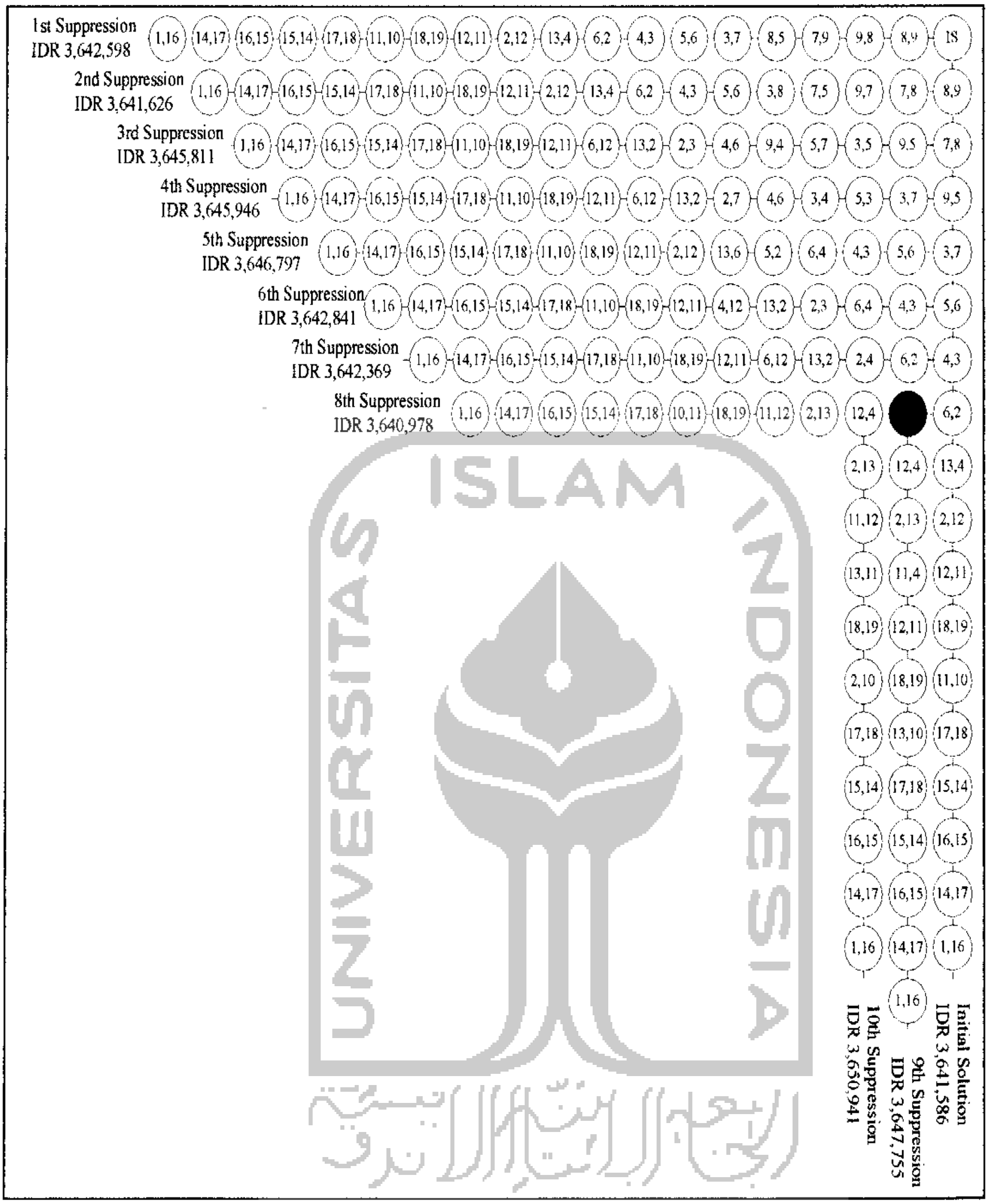

Figure 4.15 Tenth Suppression's Tree Diagram

L. Eleventh Suppression

The current best solution still eighth suppression and the tenth suppression pair are returned to its value in the current saving matrix. The eleventh suppression pair is saving $s_{11,12}$ and set $s_{11,12} = 0$ in the current saving matrix.

Table 4.16 Iteration of Eleventh Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	Temporary suppress						

Table 4.16 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.12	9578	no			5	37		
18	13.11	9559	yes	11	3	2	37	0,12,4,3,7,8,9,5,6,2,13,11,0	
19	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
20	11.10	7006	yes	10	2	0	32	0,12,4,3,7,8,9,5,6,2,13,11,10,0	
21	10.12	7001	no			0	32		
22	10.14	5453	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
26	14.16	3121	no			0	28		
27	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
28	1.12	2192	no			0	28		
29	10.01	2180	no			0	28		
30	10.16	1491	no			0	28		
31	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
32	19.12	20	no			0	18		
33	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,12}$, $s_{10,12}$, $s_{14,16}$, $s_{19,1}$

Violating step 4.4.2 = $s_{10,14}$, $s_{1,12}$, $s_{10,1}$, $s_{10,16}$, $s_{19,12}$,

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5207$\alpha_{0,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$+ 891$\alpha_{13,11,2}$ + 1515$\alpha_{11,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5207 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 891 . 1 + 1515 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.645.690 per month

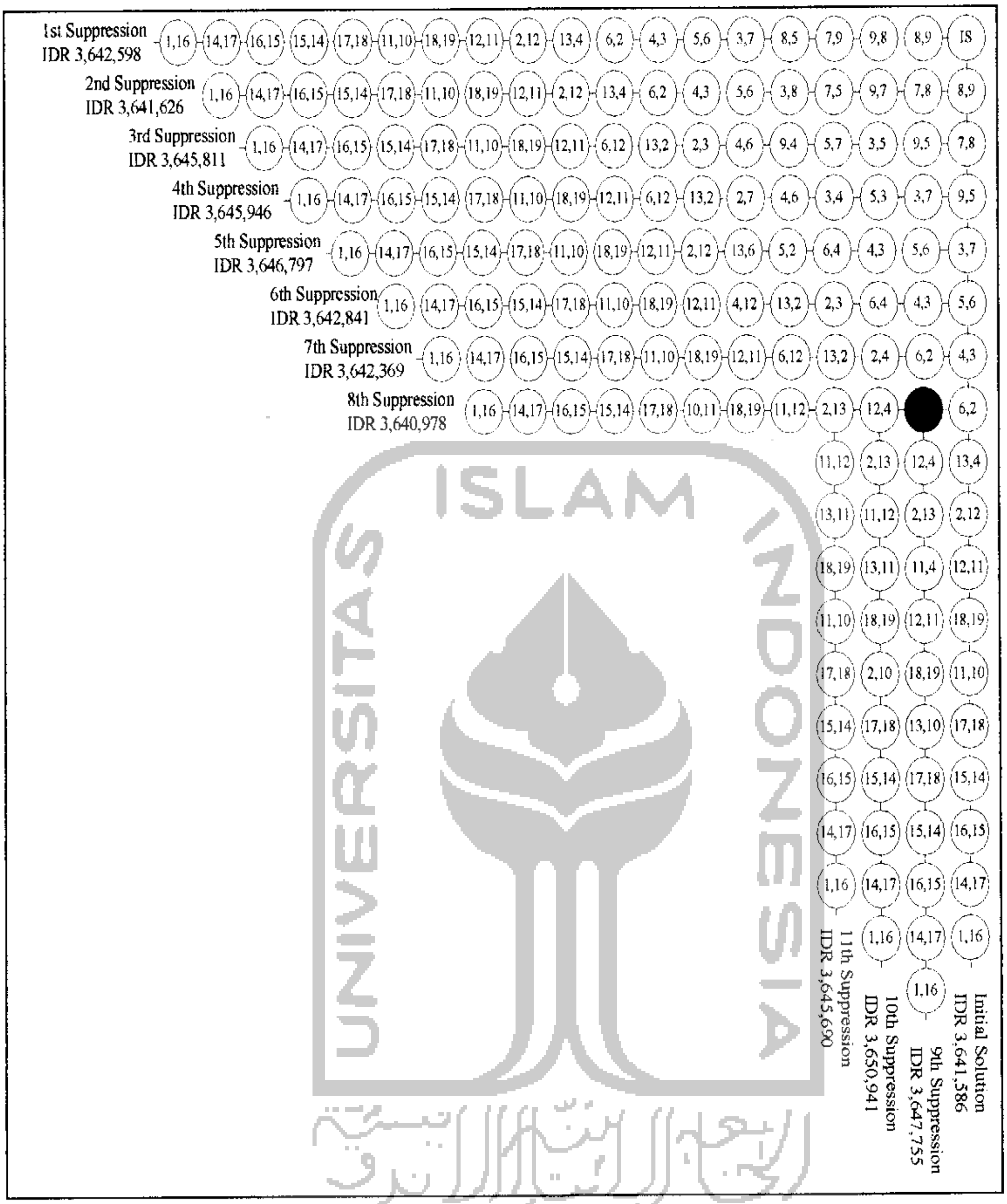

Figure 4.16 Eleventh Suppression's Tree Diagram

M. Twelfth Suppression

The current best solution still eighth suppression and the eleventh suppression pair are returned to its value in the current saving matrix. The twelfth suppression pair is saving $s_{18,19}$ and set $s_{18,19} = 0$ in the current saving matrix.

Table 4.17 Iteration of Twelfth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.17 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	Temporary suppress						
19	19.18	7586	yes	19	1	2	36		0,19,18,0
				18	4	2	32		
20	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
21	13.10	7008	no			0	32		
22	13.14	6826	no			0	32		
23	14.10	5483	no			0	32		
24	18.17	5247	yes	17	1	0	31		0,19,18,17,0
25	15.14	4482	yes	15	1	0	30		0,19,18,17,0;0,15,14,0
				14	1	0	29		
26	13.15	4202	no			0	29		
27	17.15	3144	yes			0	29		0,19,18,17,15,14,0
28	14.16	3121	yes	16	1	0	28		0,19,18,17,15,14,16,0
29	1.10	2190	no			0	28		
30	13.01	2178	no			0	28		
31	16.10	1550	no			0	28		
32	16.01	1106	yes	1	10	0	18		0,19,18,17,15,14,16,1.0
33	13.19	42	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$,

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,15}$, $s_{1,10}$, $s_{13,1}$, $s_{16,10}$, $s_{13,19}$

Total cost = (16,875 ($7372\alpha_{0,19,1}$ + $6227\alpha_{19,18,1}$ + $3923\alpha_{18,17,1}$ + $1882\alpha_{17,15,1}$ + $1309\alpha_{15,14,1}$ + $2058\alpha_{14,16,1}$ + $1643\alpha_{16,1,1}$ + $1103\alpha_{1,0,1}$)+ 1.470.000 β_{11})+ (13,5 ($3520\alpha_{0,10,2}$ + $1502\alpha_{10,11,2}$ + $309\alpha_{11,12,2}$ + $954\alpha_{12,4,2}$ + $172\alpha_{4,3,2}$ + $1347\alpha_{3,7,2}$ + $2405\alpha_{7,8,2}$ + $1521\alpha_{8,9,2}$ + $5670\alpha_{9,5,2}$ + $1090\alpha_{5,6,2}$ + $1092\alpha_{6,2,2}$ + $954\alpha_{2,13,2}$ + $5423\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (7372 . 1 + 6227 . 1 + 3923 . 1 + 1882 . 1 + 1309 . 1 + 2058 . 1 + 1643 . 1 + 1103 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5423 . 1) + 1.390.000. 1) = IDR 3.641.046 per month

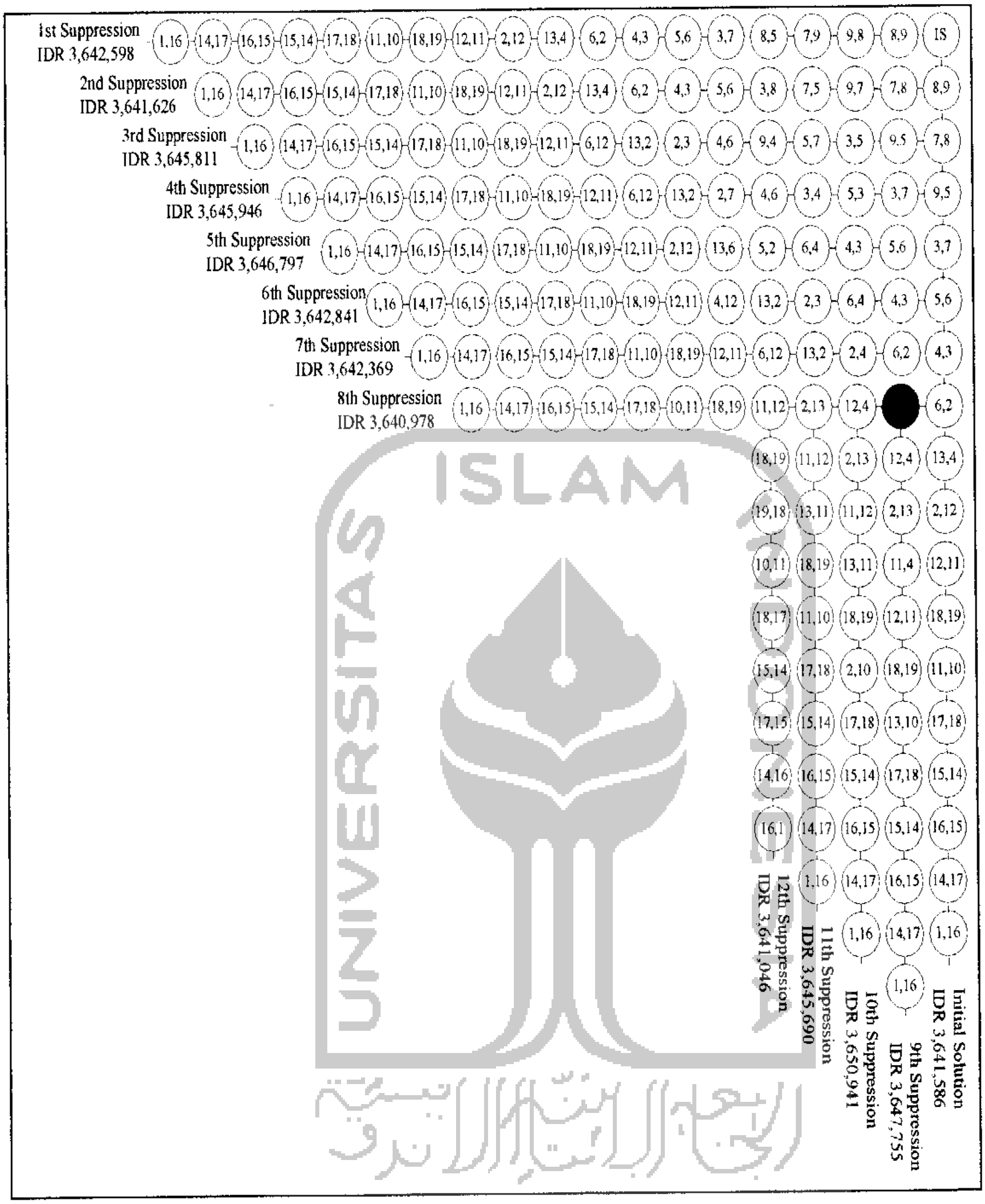

Figure 4.17 Twelfth Suppression's Tree Diagram

N. Thirteenth Suppression

The current best solution still eighth suppression and the twelfth suppression pair are returned to its value in the current saving matrix. The thirteenth suppression pair is saving $s_{10,11}$ and set $s_{10,11} = 0$ in the current saving matrix.

Table 4.18 Iteration of Thirteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.18 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	Temporary suppress						
20	13.10	7008	yes	10	2	0	32	0,11,12,4,3,7,8,9,5,6,2,13,10,0	
21	14.11	5524	no			0	32		
22	17.18	5284	yes	17	1	0	31		0,17,18,19,0
23	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
24	16.15	3131	yes	16	1	0	28		0,17,18,19,0;0,16,15,14,0
25	14.16	3121	no			0	28		
26	14.17	3101	yes			0	28		0,16,15,14,17,18,19,0;
27	1.11	2205	no			0	28		
28	10.01	2180	no			0	28		
29	10.16	1491	no			0	28		
30	1.16	1091	yes	1	10	0	18		0,1,16,15,14,17,18,19,0;
31	19.11	32	no			0	18		
32	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{14,16}$, $s_{19,1}$

Violating step 4.4.2 = $s_{14,11}$, $s_{1,11}$, $s_{10,1}$, $s_{10,16}$, $s_{19,11}$,

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 763$\alpha_{16,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (5027$\alpha_{0,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 1935$\alpha_{13,10,2}$ + 3490$\alpha_{10,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1+ 1658 . 1 + 763 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (5027 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 .1 + 1092 . 1 + 954 . 1+ 1935 . 1 + 3490 . 1) + 1.390.000. 1) = IDR 3.641.073 per month

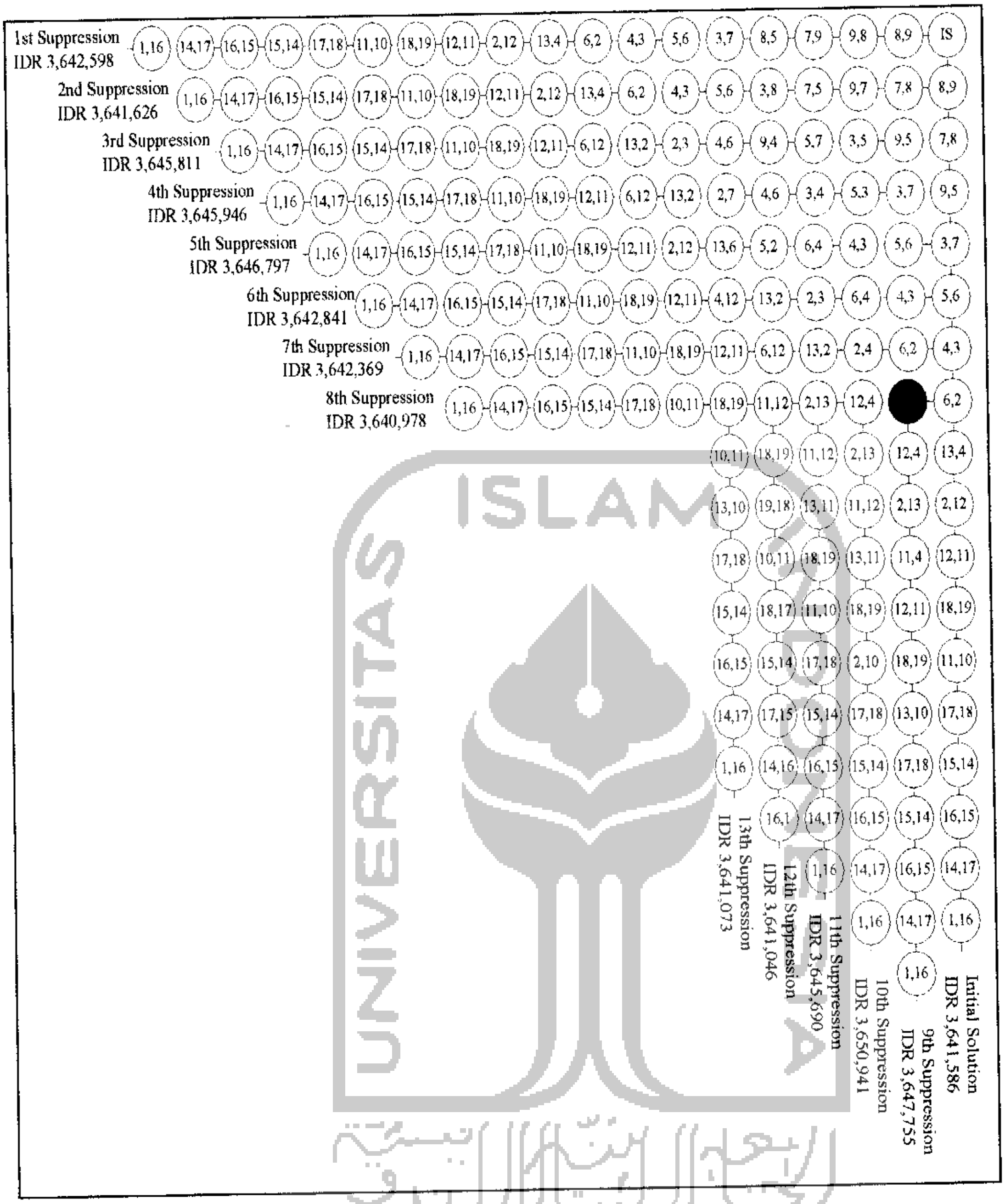

Figure 4.18 Thirteenth Suppression's Tree Diagram

O. Fourteenth Suppression

The current best solution still eight suppression and the thirteenth suppression pair is returned to its value in the current saving matrix. The fourteenth suppression pair is saving $s_{17,18}$ and set $s_{17,18} = 0$ in the current saving matrix.

Table 4.19 Iteration of Fourteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.19 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	Temporary suppress						
24	15.14	4482	yes	15	1	0	31		0,18,19,0;0,15,14,0
				14	1	0	30		
25	13.15	4202	no			0	30		
26	17.15	3144	yes	17	1	0	29		0,18,19,0;0,17,15,14,0
27	14.16	3121	yes	16	1	0	28		0,18,19,0;0,17,15,14,16,0
28	13.17	2849	no			0	28		
29	16.17	2814	no			0	28		
30	13.18	2745	no			0	28		
31	16.18	2703	yes			0	28		0,17,15,14,16,18,19,0;
32	1.10	2190	no			0	28		
33	13.01	2178	no			0	28		
34	1.17	1076	yes	1	10	0	18		0,1,17,15,14,16,18,19,0;
35	19.10	18	no			0	18		
36	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$, $s_{16,17}$, $s_{19,1}$

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,15}$, $s_{13,17}$, $s_{13,18}$, $s_{1,10}$, $s_{13,1}$, $s_{19,10}$,

Total cost = (16,875 ($1093\alpha_{0,1,1} + 2798\alpha_{1,17,1} + 1882\alpha_{17,15,1} + 1309\alpha_{15,14,1} + 2058\alpha_{14,16,1} + 5362_{16,18,1} + 6170\alpha_{18,19,1} + 7404\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 ($3520\alpha_{0,10,2} + 1502\alpha_{10,11,2} + 309\alpha_{11,12,2} + 954\alpha_{12,4,2} + 172\alpha_{4,3,2} + 1347\alpha_{3,7,2} + 2405\alpha_{7,8,2} + 1521\alpha_{8,9,2} + 5670\alpha_{9,5,2} + 1090\alpha_{5,6,2} + 1092\alpha_{6,2,2} + 954\alpha_{2,13,2} + 5432\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 2798 . 1 + 1882 . 1 + 1309 . 1 + 2058 . 1 + 5362 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.684.229 per month

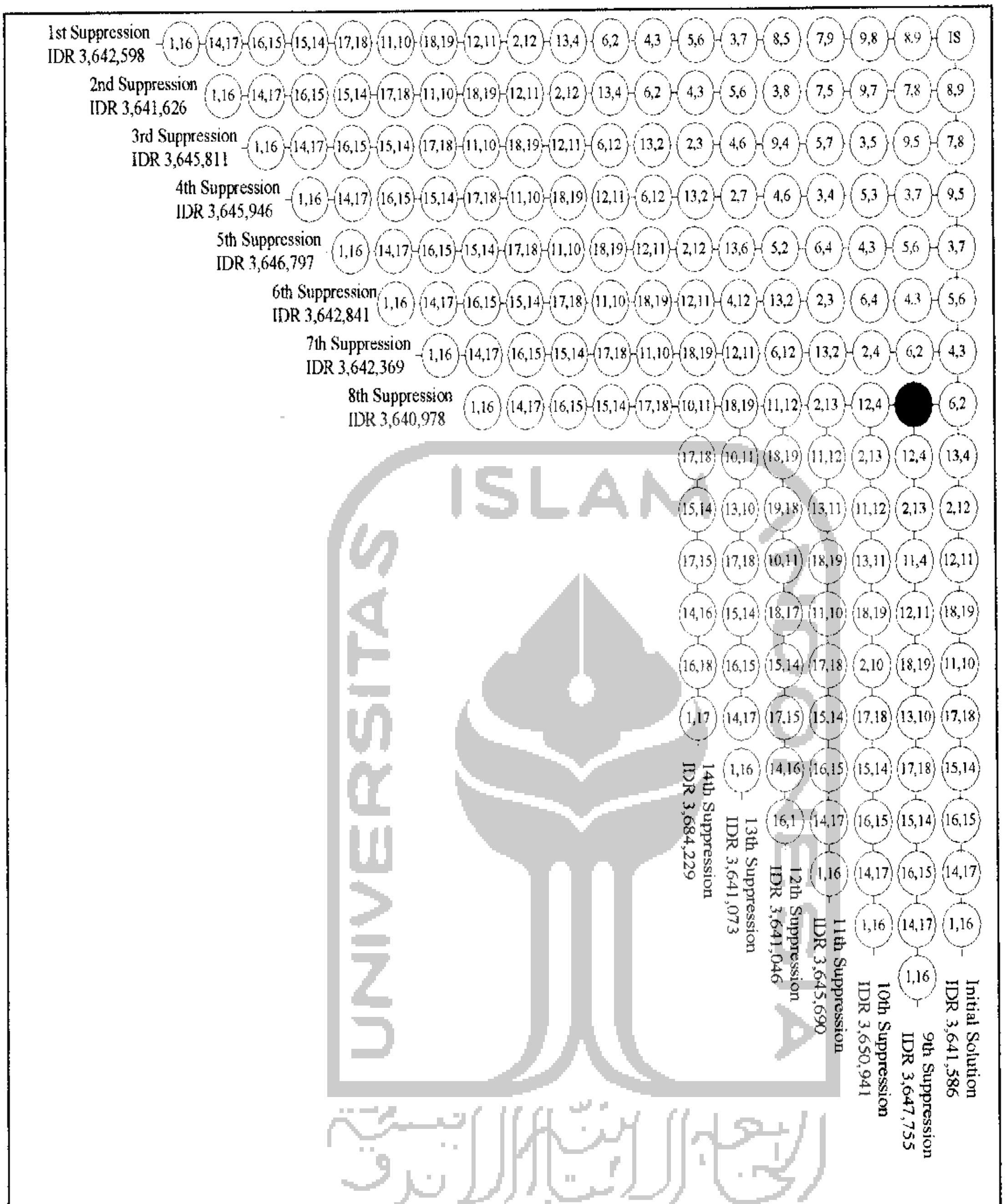

Figure 4.19 Fourteenth Suppression's Tree Diagram

P. Fifteenth Suppression

The current best solution stills eight suppression and the fourteenth suppression pair is returned to its value in the current saving matrix. The fifteenth suppression pair is saving $s_{15,14}$ and set $s_{15,14} = 0$ in the current saving matrix.

Table 4.20 Iteration of Fifteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.20 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	Temporary suppress						
25	14.15	4452	yes	14	1	0	30		0,17,18,19,0;0,14,15,0
				15	1	0	29		
26	16.14	3131	yes	16	1	0	28		0,17,18,19,0;0,16,14,15,0
27	15.16	3121	no			0	28		
28	15.17	3109	yes			0	28		0,16,14,15,17,18,19,0;
29	13.16	2868	no			0	28		
30	1.10	2190	no			0	28		
31	13.01	2178	no			0	28		
32	1.16	1091	yes	1	10	0	18		0,1,16,14,15,17,18,19,0;
33	19.10	18	no			0	18		
34	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$, $s_{15,16}$, $s_{19,1}$

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,16}$, $s_{1,10}$, $s_{13,1}$, $s_{19,10}$,

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1658$\alpha_{1,16,1}$ + 2068$\alpha_{16,14,1}$ + 1319$\alpha_{14,15,1}$ + 1910$\alpha_{15,17,1}$ + 3913 $\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (3520$\alpha_{0,10,2}$ + 1502$\alpha_{10,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 5432$\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 1658 . 1 + 2068 . 1 + 1319 . 1 + 1910 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.641.350 per month

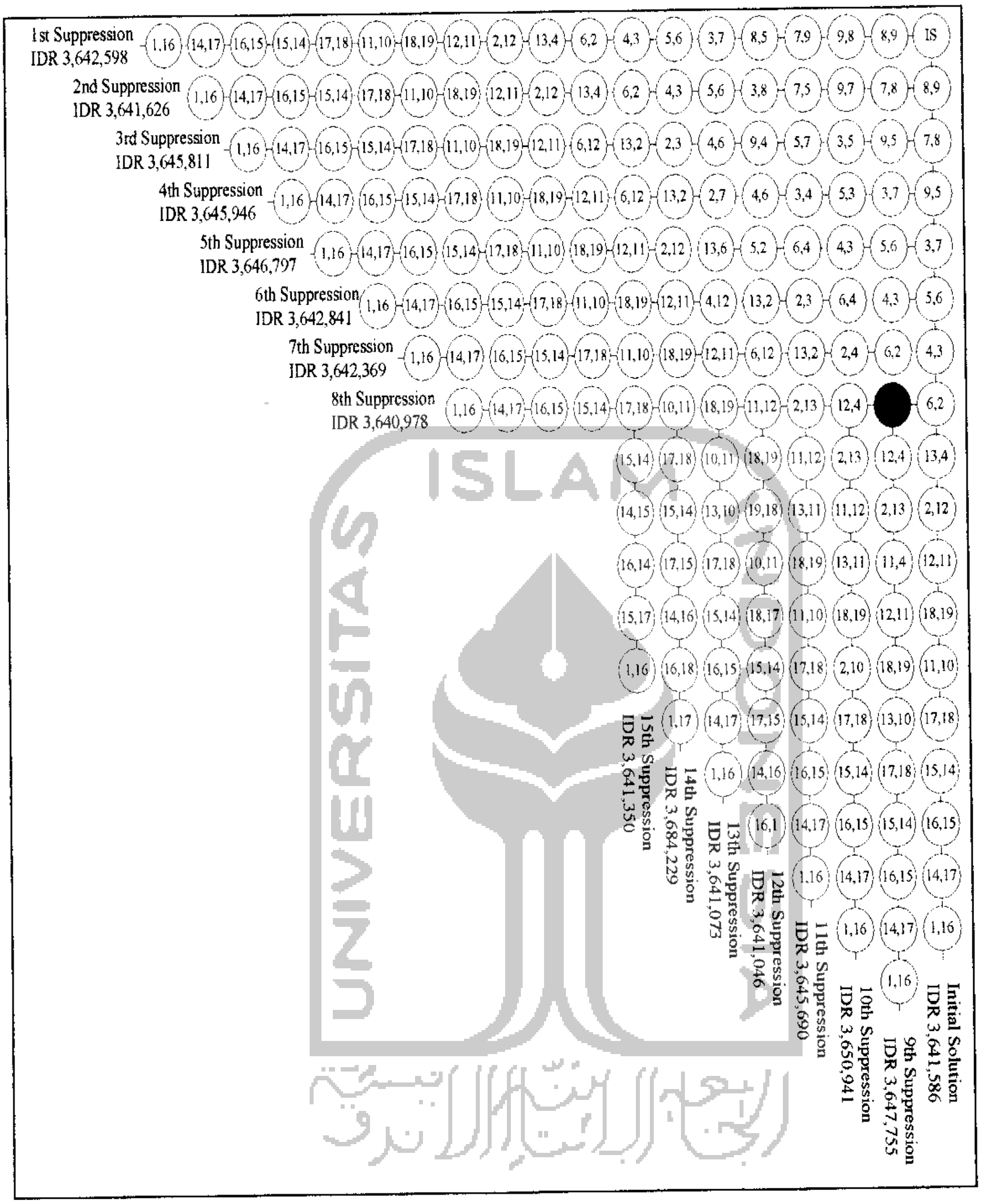

Figure 4.20 Fifteenth Suppression's Tree Diagram

Q. Sixteenth Suppression

The current best solution still eight suppression and the fifteenth suppression pair is returned to its value in the current saving matrix. The sixteenth suppression pair is saving $s_{16,15}$ and set $s_{16,15} = 0$ in the current saving matrix.

Table 4.21 Iteration of Sixteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.21 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	13.15	4202	no			0	29		
26	16.15	3131	Temporary suppress						
27	14.16	3121	yes	16	1	0	28		0,17,18,19,0;0,15,14,16,0
28	13.17	2849	no			0	28		
29	16.17	2814	yes			0	28		0,15,14,16,17,18,19,0;
30	1.10	2190	no			0	28		
31	13.01	2178	no			0	28		
32	1.15	2146	yes	1	10	0	18		0,1,15,14,16,17,18,19,0;
33	19.10	18	no			0	18		
34	19.01	17	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}, s_{5,7}, s_{5,3}, s_{6,4}, s_{2,4}, s_{13,11}, s_{13,10}, s_{19,1}$

Violating step 4.4.2 = $s_{13,14}, s_{14,10}, s_{13,15}, s_{13,17}, s_{1,10}, s_{13,1}, s_{19,10},$

Total cost = (16,875 (1093$\alpha_{0,1,1}$ + 1195$\alpha_{1,15,1}$ + 1309$\alpha_{15,14,1}$ + 2058$\alpha_{14,16,1}$ + 1613$\alpha_{16,17,1}$ + 3913 $\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (3520$\alpha_{0,10,2}$ + 1502$\alpha_{10,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 5432$\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1093 . 1 + 1195 . 1 + 1309 . 1 + 2058 . 1 + 1613 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.628.187 per month

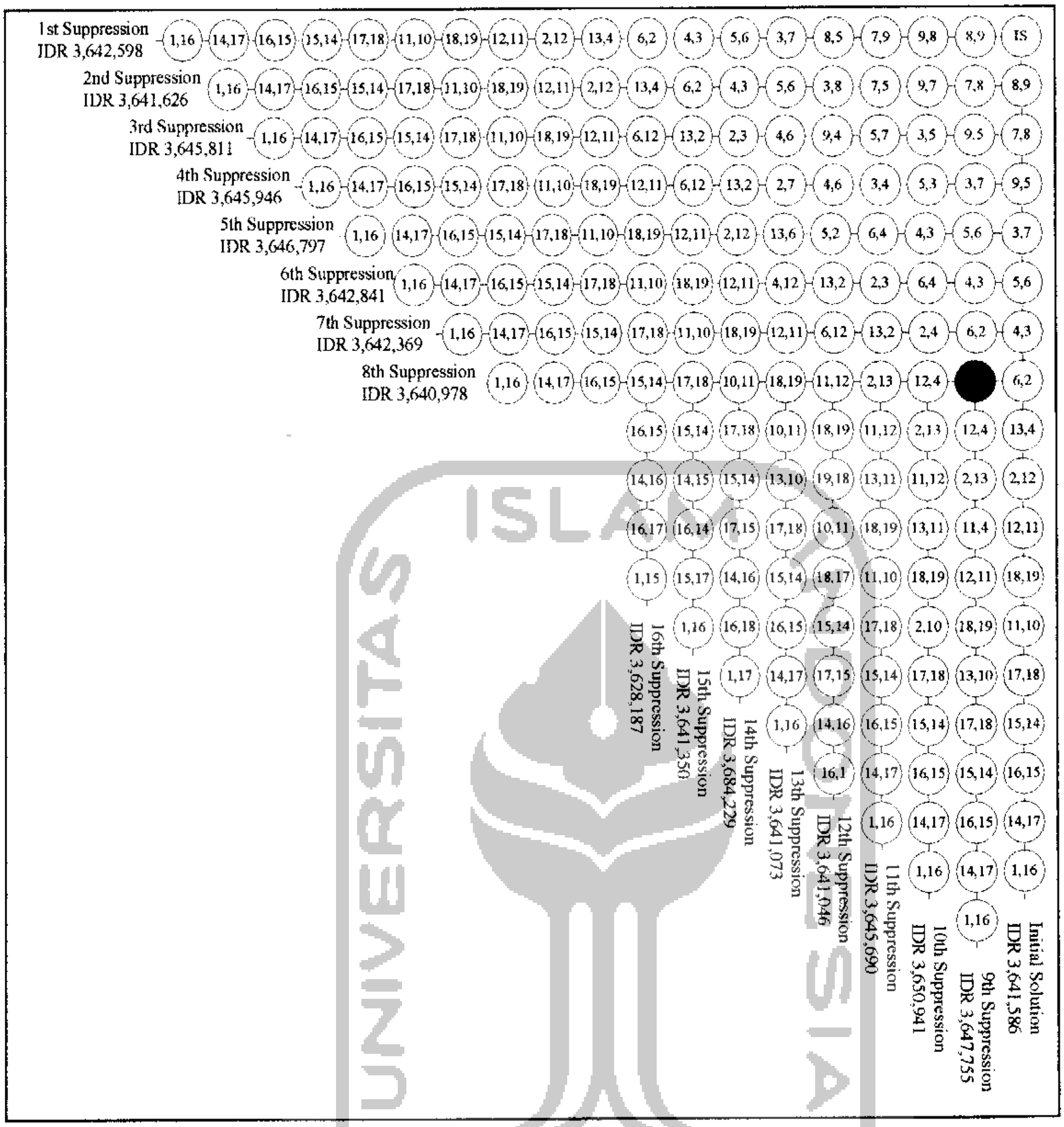

Figure 4.21 Sixteenth Suppression's Tree Diagram

R. Seventeenth Suppression

The current best solution is change to the result in sixteenth suppression and then the sixteenth suppression pair is removed permanently from the current saving matrix $s_{13,4}$ and set $s_{13,4} = 0$ in the current saving matrix and remains zero in all next iterations. The seventeenth suppression pair is saving $s_{14,16}$ and set $s_{14,16} = 0$ in the current saving matrix.

Table 4.22 Iteration of Seventeenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.22 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	Permanently suppress						
26	14.16	3121	Temporary suppress						
27	14.17	3101	yes			0	29		0,15,14,17,18,19,0;
28	13.16	2868	no			0	29		
29	1.10	2190	no			0	29		
30	13.01	2178	no			0	29		
31	1.15	2146	yes	1	10	0	19		0,1,15,14,17,18,19,0;
32	16.10	1550	no			0	19		
33	16.01	1106	yes	16	1	0	18		0,16,1,15,14,17,18,19,0;
34	19.16	409	no			0	18		
35	19.10	18	no			0	18		

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$, $s_{19,16}$,

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,16}$, $s_{1,10}$, $s_{13,1}$, $s_{16,10}$, $s_{19,10}$

Total cost = (16,875 (1646$\alpha_{0,16,1}$ + 1643$\alpha_{16,1,1}$ + 1195$\alpha_{1,15,1}$ + 1309$\alpha_{15,14,1}$ + 3203$\alpha_{14,17,1}$ + 3913 $\alpha_{17,18,1}$ + 6170$\alpha_{18,19,1}$ + 7404$\alpha_{19,0,1}$)+ 1.470.000 β_{11})+ (13,5 (3520$\alpha_{0,10,2}$ + 1502$\alpha_{10,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 5432$\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (1646 . 1 + 1643 . 1 + 1195 . 1 + 1309 . 1 + 3203 . 1 + 3913 . 1 + 6170 . 1 + 7404 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.657.347 per month

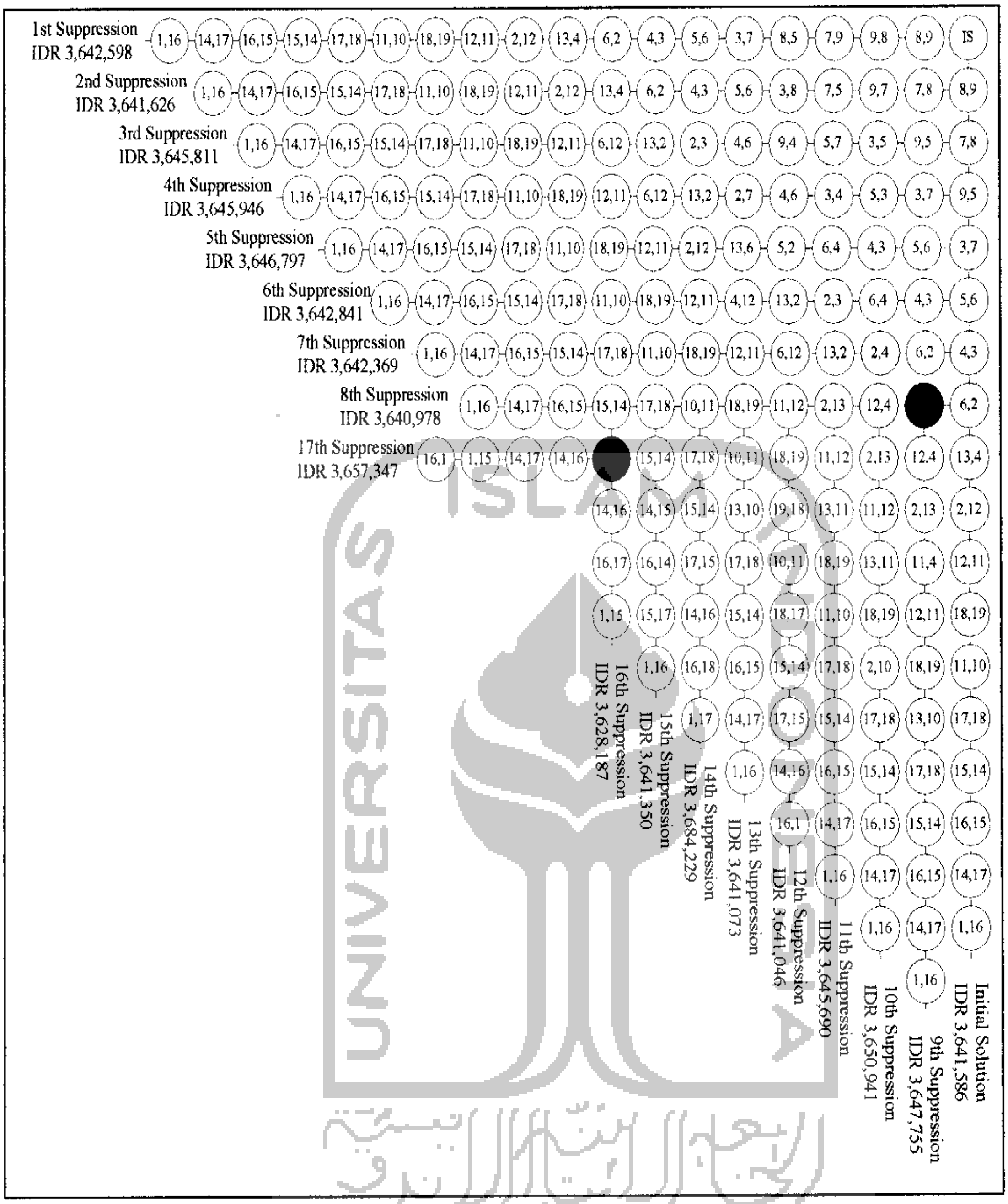

Figure 4.22 Seventeenth Suppression's Tree Diagram

S. Eighteenth Suppression

The current best solution still sixteenth suppression and the seventeenth suppression pair is returned to its value in the current saving matrix. The eighteenth suppression pair is saving $s_{16,17}$ and set $s_{16,17} = 0$ in the current saving matrix.

Table 4.23 Iteration of Eighteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.23 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	Permanently suppress						
26	14.16	3121	yes	16	1	0	28		0,17,18,19,0;0,15,14,16,0
27	13.17	2849	no			0	28		
28	16.17	2814	Temporary suppress						
29	1.10	2190	no			0	28		
30	13.01	2178	no			0	28		
31	1.15	2146	yes	1	10	0	18		0,17,18,19,0;0,1,15,14,16,0
32	19.17	1608	no			0	18		
33	16.10	1550	no			0	18		
34	16.01	1106	no			0	18		
35	19.10	18	no			0	18		
36	19.01	17	yes			0	18		0,17,18,19,1,15,14,16,0

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$, $s_{19,17}$, $s_{16,1}$,

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,17}$, $s_{1,10}$, $s_{13,1}$, $s_{16,10}$, $s_{19,10}$

Total cost = (16,875 ($2771\alpha_{0,17,1} + 3913\alpha_{17,18,1} + 6170\alpha_{18,19,1} + 8480\alpha_{19,1,1} + 1195\alpha_{1,15,1} + 1309\,\alpha_{15,14,1} + 2058\alpha_{14,16,1} + 1656\alpha_{16,0,1}$)+ 1.470.000 β_{11})+ (13,5 ($3520\alpha_{0,10,2} + 1502\alpha_{10,11,2} + 309\alpha_{11,12,2} + 954\alpha_{12,4,2} + 172\alpha_{4,3,2} + 1347\alpha_{3,7,2} + 2405\alpha_{7,8,2} + 1521\alpha_{8,9,2} + 5670\alpha_{9,5,2} + 1090\alpha_{5,6,2} + 1092\alpha_{6,2,2} + 954\alpha_{2,13,2} + 5432\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (2771 . 1 + 3913 . 1 + 6170 . 1 + 8480 . 1 + 1195 . 1 + 1309 . 1 + 2058 . 1 + 1656 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.675.387 per month

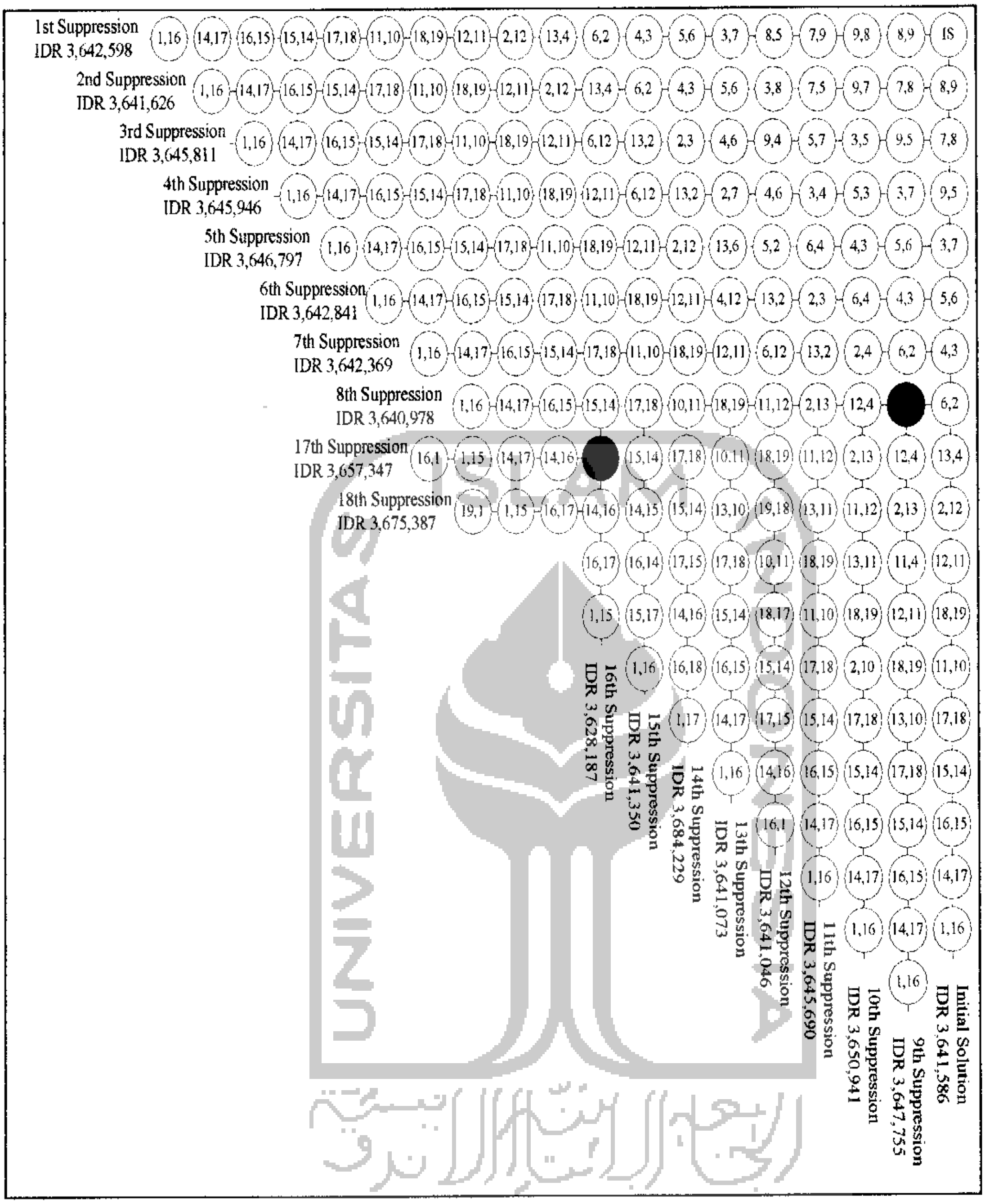

Figure 4.23 Eighteenth Suppression's Tree Diagram

T. Nineteenth Suppression

The current best solution still sixteenth suppression and the eighteenth suppression pair is returned to its value in the current saving matrix. The nineteenth suppression pair is saving $s_{1,15}$ and set $s_{1,15} = 0$ in the current saving matrix.

Table 4.24 Iteration of Nineteenth Suppression

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
1	8.09	19910	yes	8	2	25	37	0,8,9,0	
				9	1	24	37		
2	7.08	15111	yes	7	2	22	37	0,7,8,9,0	
3	9.07	15099	no			22	37		
4	9.05	12444	yes	5	1	21	37	0,7,8,9,5,0	
5	5.07	12432	no			21	37		
6	3.07	12427	yes	3	4	17	37	0,3,7,8,9,5,0	
7	5.03	12411	no			17	37		
8	5.06	12317	yes	6	2	15	37	0,3,7,8,9,5,6,0	
9	4.03	12109	yes	4	3	12	37	0,4,3,7,8,9,5,6,0	
10	6.04	12036	no			12	37		
11	6.02	11758	yes	2	5	7	37	0,4,3,7,8,9,5,6,2,0	
12	2.04	11754	no			7	37		
13	13.04	10534	Permanently suppress						
14	12.04	10387	yes	12	1	6	37	0,12,4,3,7,8,9,5,6,2,0	
15	2.13	10295	yes	13	1	5	37	0,12,4,3,7,8,9,5,6,2,13,0	
16	11.12	9899	yes	11	3	2	37	0,11,12,4,3,7,8,9,5,6,2,13,0	

Table 4.24 Continued

No.	Feasible Pair	Saving	Merge Feasibility Yes/No	xi	ci	Remain Capacity		Route	
						C2 (27)	C1 (37)	Panther (C2)	Truck (C1)
17	13.11	9559	no			2	37		
18	18.19	7601	yes	18	4	2	33		0,18,19,0
				19	1	2	32		
19	10.11	7015	yes	10	2	0	32	0,10,11,12,4,3,7,8,9,5,6,2,13,0	
20	13.10	7008	no			0	32		
21	13.14	6826	no			0	32		
22	14.10	5483	no			0	32		
23	17.18	5284	yes	17	1	0	31		0,17,18,19,0
24	15.14	4482	yes	15	1	0	30		0,17,18,19,0;0,15,14,0
				14	1	0	29		
25	16.15	3131	Permanently suppress						
26	14.16	3121	yes	16	1	0	28		0,17,18,19,0;0,15,14,16,0
27	13.17	2849	no			0	28		
28	16.17	2814	yes			0	28		0,15,14,16,17,18,19,0;
29	1.10	2190	no			0	28		
30	13.01	2178	no			0	28		
31	1.15	2146	Temporary suppress						
32	19.10	18	no			0	28		
33	19.01	17	yes	1	10	0	18		0,15,14,16,17,18,19,1,0;

The infeasible merging saving are:

Violating step 4.4.1 = $s_{9,7}$, $s_{5,7}$, $s_{5,3}$, $s_{6,4}$, $s_{2,4}$, $s_{13,11}$, $s_{13,10}$,

Violating step 4.4.2 = $s_{13,14}$, $s_{14,10}$, $s_{13,17}$, $s_{1,10}$, $s_{13,1}$, $s_{19,10}$

Total cost = (16,875 (2238$\alpha_{0,15,1}$ + 1309$\alpha_{15,14,1}$ + 2058$\alpha_{14,16,1}$ + 1613$\alpha_{16,17,1}$ + 3913$\alpha_{17,18,1}$ + 6170 $\alpha_{18,19,1}$ + 8480$\alpha_{19,1,1}$ + 1103$\alpha_{1,0,1}$)+ 1.470.000 β_{11})+ (13,5 (3520$\alpha_{0,10,2}$ + 1502$\alpha_{10,11,2}$ + 309$\alpha_{11,12,2}$ + 954$\alpha_{12,4,2}$ + 172$\alpha_{4,3,2}$ + 1347$\alpha_{3,7,2}$ + 2405$\alpha_{7,8,2}$ + 1521$\alpha_{8,9,2}$ + 5670$\alpha_{9,5,2}$ + 1090$\alpha_{5,6,2}$ + 1092$\alpha_{6,2,2}$ + 954$\alpha_{2,13,2}$ + 5432$\alpha_{13,0,2}$) + 1.390.000 β_{22})

Total cost = (16,875 (2238 . 1 + 1309 . 1 + 2058 . 1 + 1613 . 1 + 3913 . 1 + 6170 . 1 + 8480 . 1 + 1103 . 1)+ 1.470.000. 1)+ (13,5 (3520 . 1 + 1502 . 1 + 309 . 1 + 954 . 1 + 172 . 1 + 1347 . 1 + 2405 . 1 + 1521 . 1 + 5670 . 1 + 1090 . 1 + 1092 . 1 + 954 . 1 + 5432 . 1) + 1.390.000. 1) = IDR 3.664.114 per month

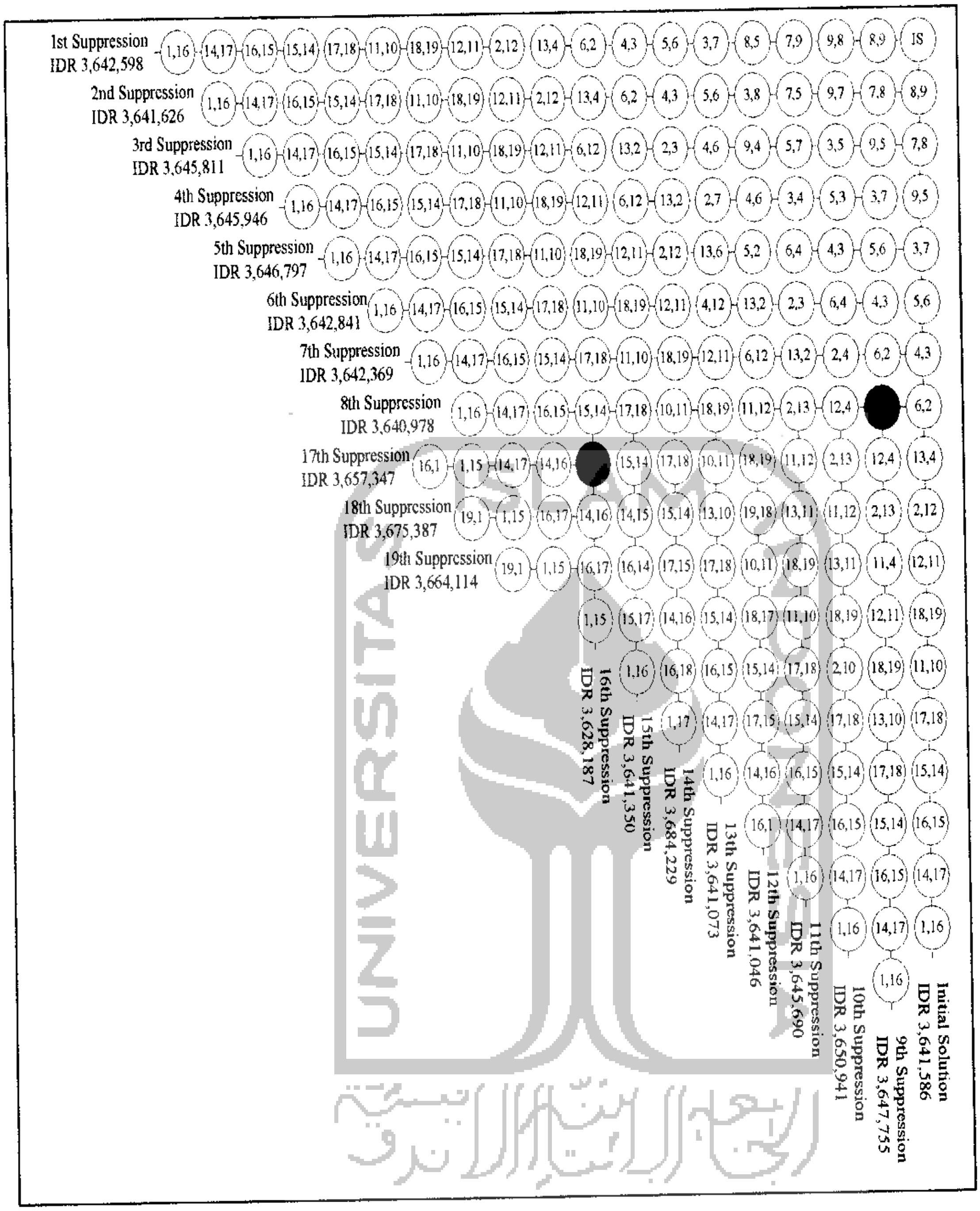

Figure 4.24 Nineteenth Suppression's Tree Diagram

4.4 Total Cost and Distance Difference

The current vehicle routes compared with the best result from Holmes and Parker algorithm to know the difference of the routes based on the total cost. The best result of new vehicle routes from Holmes and Parker algorithm is in the sixteenth suppression. The total cost of sixteenth suppression is IDR 3.628.187 per month.

The difference of Total cost = IDR 3.701.590 per month - IDR 3.628.187 per month

= IDR 73.403

The graph of sixteenth suppression is in the appendix.

The difference of distance travelled between current routes and new routes for every vehicle is below.

The difference of distance travelled by Truck

= Distance travelled by truck in current route – distance travelled by truck in new vehicle route

= 26.092 meters per day - 24.755 meters per day

= 1.337 meters

The difference of distance travelled by Panther

= Distance travelled by panther in current route – distance travelled by panther in new vehicle route

= 29.725 meters per day - 25.959 meters per day

= 3.766 meters

CHAPTER V

DISCUSSION

5.1 Result Discussion

This research has objective to find the set of a routes for HFFVRP that minimize the summation of fixed cost and variable cost of vehicles used. Holmes and Parker algorithm is used to determine the routes that appropriate with research object.

The result from the data processing and analyzing in chapter IV, the total cost that produced from summation of fixed cost (driver wages, maintenance, and insurance) and variable cost (the fuel consumption of each vehicle) in a month that must be spent by the company for implements current routes is IDR 3.701.590 per month.

The optimization process begins with converting the data collected so that can be formulated into mathematical formulation of HFFVRP. Then the Holmes and Parker algorithm then applied by using Microsoft Excel 2007. The route generation by Holmes and Parker algorithm has three times of improvement. First improvement is initial solution with total cost that spent by the company IDR 3.641.586 per month. Then initial solution is improved by the eight suppression which produced total cost IDR 3.640.978 per month. The last improvement is in the sixteenth suppression which improved the eight suppression solution with total cost IDR 3.628.187 per month. The best solution that can be reached by Holmes and Parker algorithm is in the sixteenth suppression with the routes are; Truck: Depot- Taji Nasrudin- Budi Sondakan- Agus-Maju Mapan- RS Yarsis- Londo- Bandara- Depot, Panther: Depot- Palang Kereta Hotel Agas- Iskak- Kendali- Matahari- Teguh- Muhammad dkk- Indomet- Prasasti-ABC-Sendang Mulia- Surya- Hadi S- Depot.

The Holmes and Parker algorithm used the lowest vehicle first to build the route until the capacity is full. It will affect the last vehicle chosen usually the largest vehicle capacity one will get low of utilization, as in this research the utilization of panther is 100 percents while the truck is only 48,6 percents. It happens because the ration of the total demands and total vehicle capacity is not 1 but 0,71 (46:64). If the ration of total demand and total vehicle capacity is 1, it will give a hundred percents of vehicle utilization. But when the ratio is 1, there is also probability of infeasible solution occurs especially if the demands of customers are in vary number, not in homogeny number. The balancing of vehicle utilization can be achieved by modified the constraint capacity (equation 3.6) from a hundred percents becomes only 90 or 80 percents of capacity utilization so that the ration of total demands with total vehicle capacity is closely to 1. The effect of this modification will lead to the different result produced (from the hundred percents of capacity utilization) because capacity can influence the vehicle route making.

The Holmes and Parker algorithm can solve a HFFVRP in designing routes that minimized the total cost. The result shows that by using Holmes and Parker algorithm the vehicle routes is better than the current routes implemented by the company. The difference between two routes is IDR 73.403 per month with the new vehicle routes total cost is IDR 3.628.187 per month. The new vehicle routes created by Holmes and Parker algorithm are: Truck: Depot- Taji Nasrudin- Budi Sondakan- Agus- Maju Mapan- RS Yarsis- Londo- Bandara- Depot, Panther: Depot- Palang Kereta Hotel Agas- Iskak- Kendali- Matahari- Teguh- Muhammad dkk- Indomet- Prasasti- ABC-Sendang Mulia- Surya- Hadi S- Depot. The impact of difference total cost between two routes also gives difference in distance travelled by every vehicles. The current route gives distance to the truck 26.092 meters in a day and panther 29.725 meters in a day. The new route gives distance to the truck 24.755 meters in a day and panther 25.959 meters in a day. The differences are 1.337 meters for truck and 3.766 meters for panther.

CHAPTER VI

CONCLUSION AND SUGGESTION

6.1 Conclusion

Based on the discussions above, the researcher has made a conclusion in response to the problems formulation in the previous chapter. The conclusion is as follows:

1. The Holmes and Parker result shows that by using Holmes and Parker algorithm the vehicle routes is better than the current routes implemented by the company. The difference of total cost between two routes is IDR 73.403 per month with the new vehicle routes total cost is IDR 3.628.187 per month and vehicle routes are Truck: Depot- Taji Nasrudin- Budi Sondakan- Agus- Maju Mapan- RS Yarsis- Londo- Bandara- Depot, Panther: Depot- Palang Kereta Hotel Agas- Iskak- Kendali- Matahari- Teguh- Muhammad dkk- Indomet- Prasasti- ABC-Sendang Mulia- Surya- Hadi S- Depot.
2. The Holmes and Parker algorithm generates the distance of two vehicles to conduct the new routes are shorter than the current route. The distances traveled by truck in the new route are 24.755 meters in a day and panther are 25.959 meters in a day. With the difference with current route 1.337 meters for truck and 3.766 meters for panther.

6.2 Suggestion

Finally, the researcher added some suggestions as a consideration for the next future research about Heterogeneous Fixed Fleet Vehicle Routing Problem:

1. To solve the HFFVRP with big problem (number of customers and vehicle) using Holmes and Parker algorithm requires a computer programming to produce solution in short time and also to solve the HFFVRP which has ration of total demand in vary and vehicles capacity is close to one, it necessaries to modify the objective function to adequate the infeasibility solution, especially if using Holmes and Parker algorithm.
2. It necessary to solve HFFVRP in the exact solution because there is still no research to solve the HFFVRP with exact solution yet.

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Tarantilis, C.D., Kiranoudis, C.T., and Vassiliadis, V.S., (2004). a threshold accepting metaheuristic for the heterogeneous fixed fleet vehicle routing problem. *European Journal of perational Reserach*, **152**, no.1, 148-158

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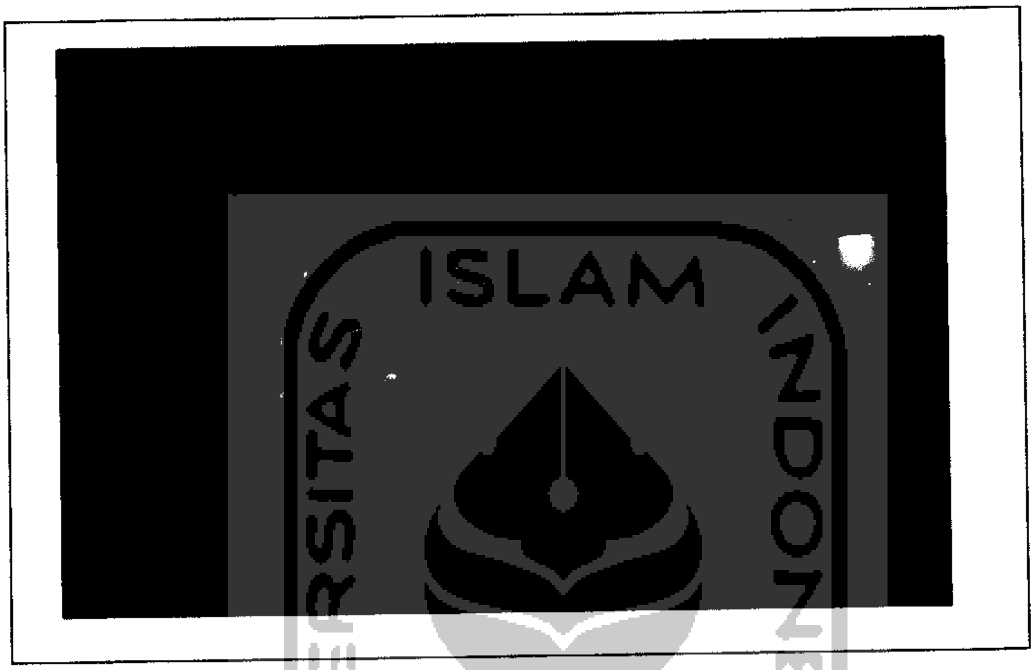
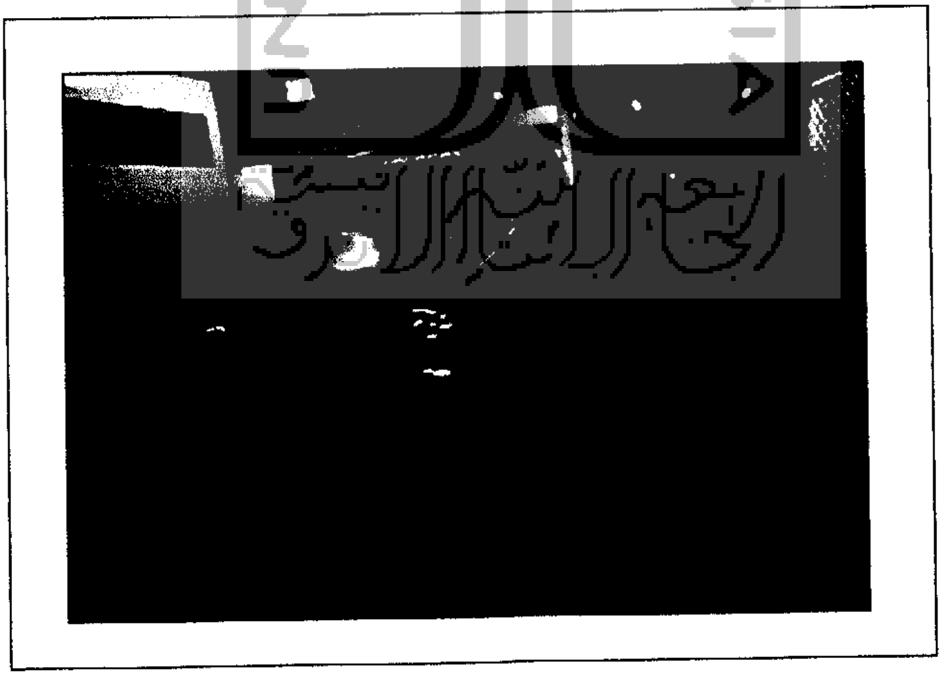
APPENDIX

Appendix 1. Figure of Vehicle Used in the Company (Truck and Panther)



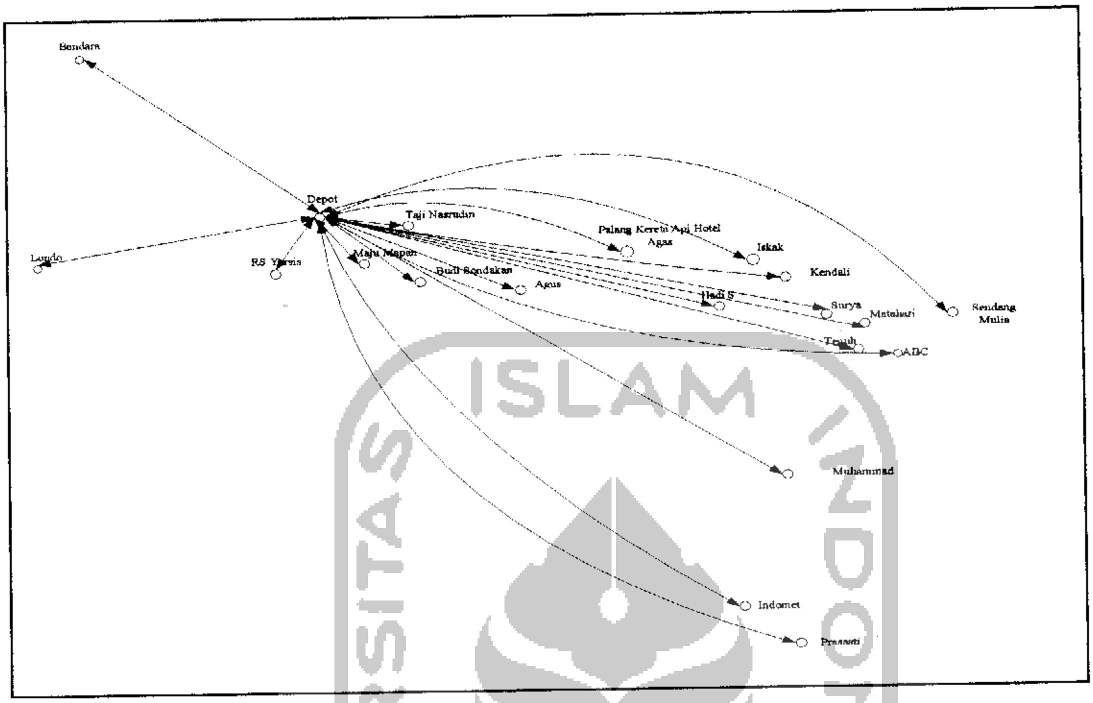
Truck



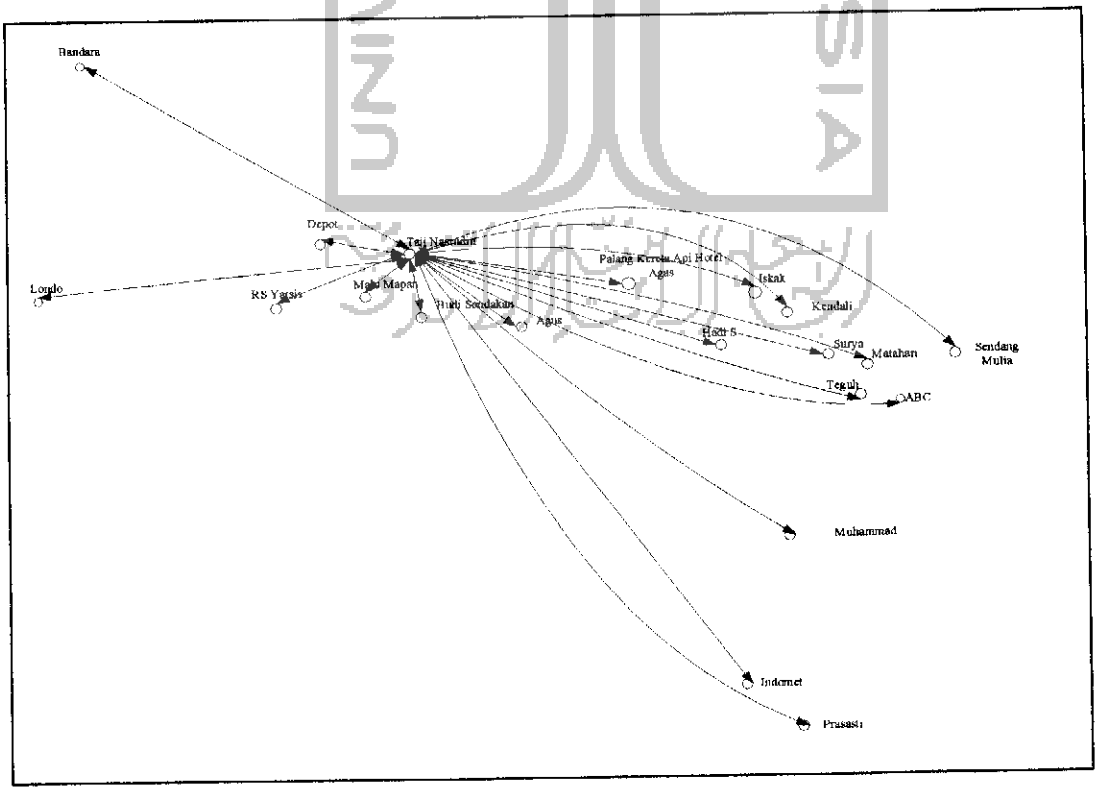
Panther

Appedix 2. Graph of Every Node

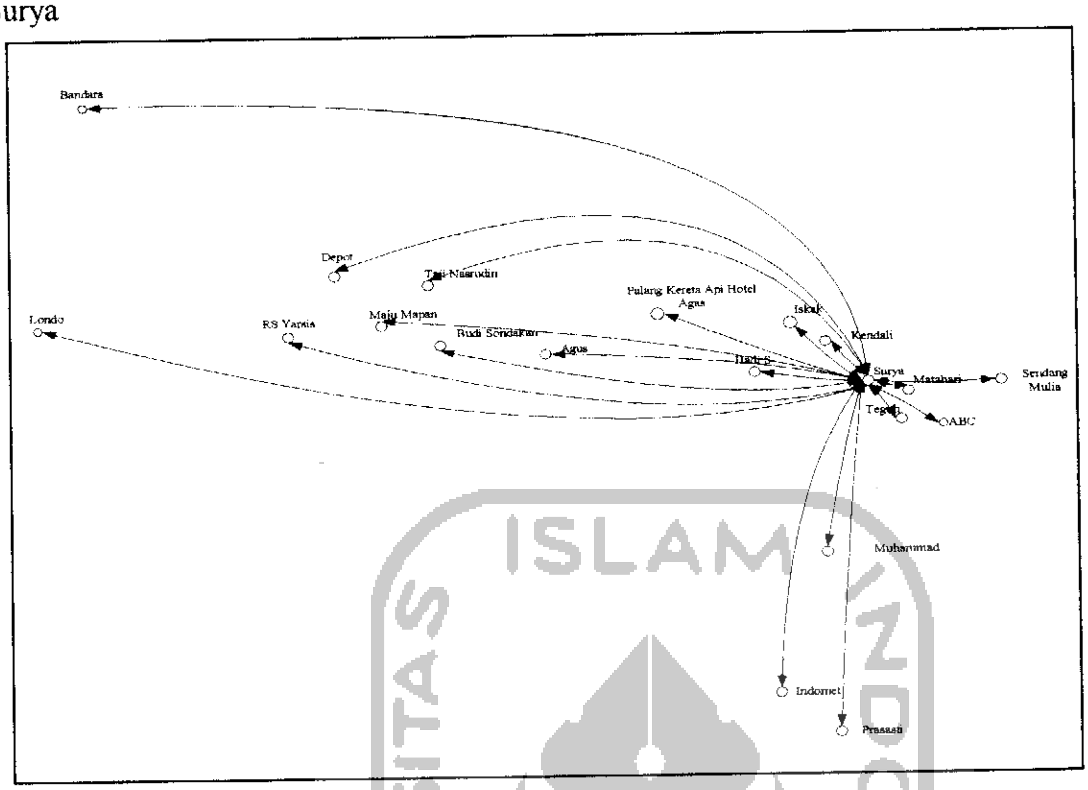
Depot



Taji Nasrudin

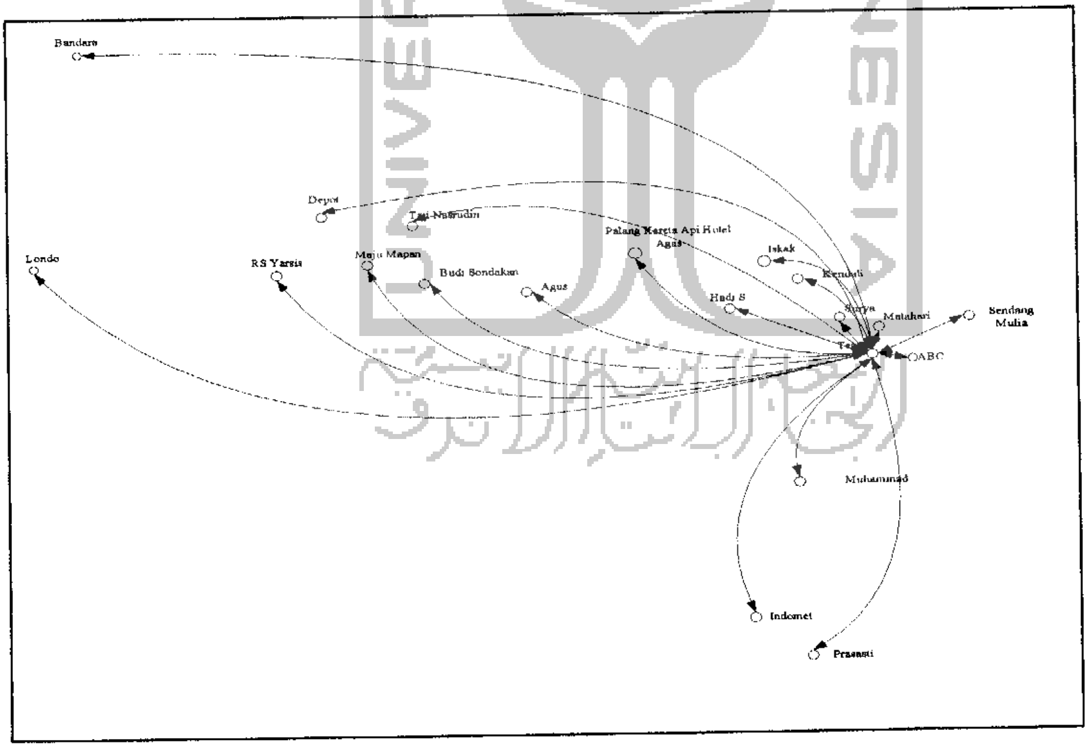


Surya



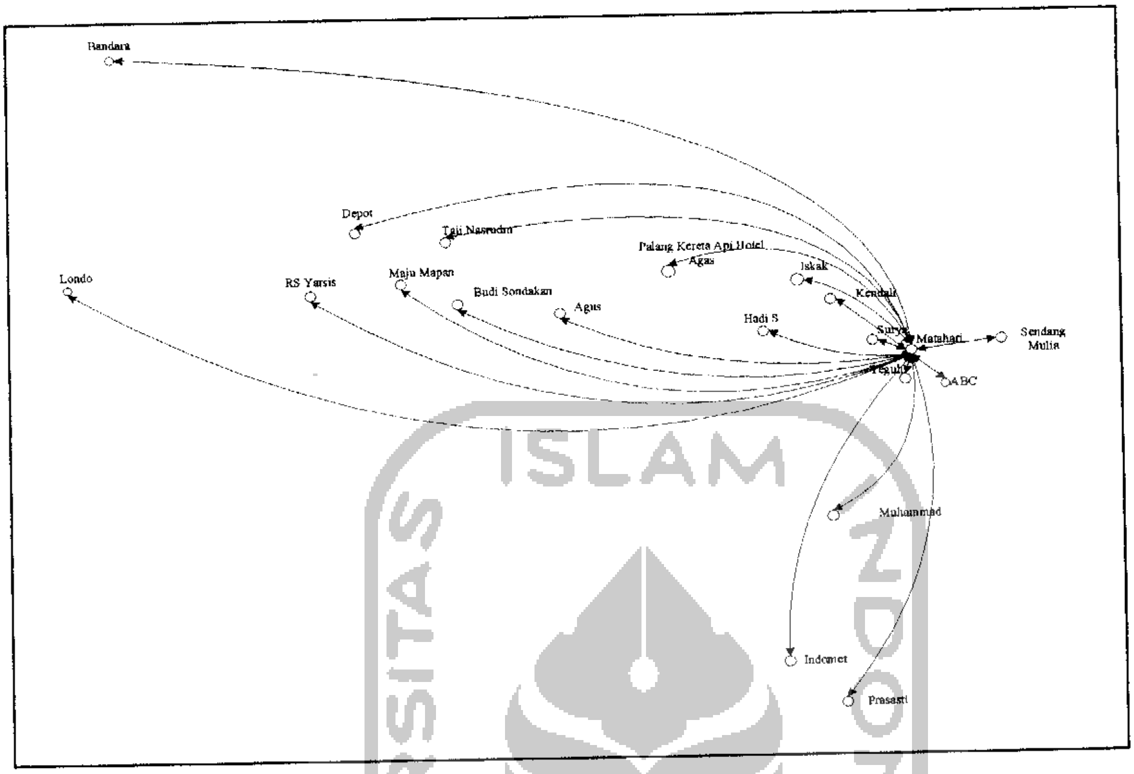
Bandara
Depot
Taxi Nasrudin
Palang Kereta Api Hotel Agas
Londo
RS Yarsis
Maju Mapan
Budi Sondakan
Agus
Iskak
Kendali
Surya
Matahari
Sendang Mulia
Teguh
ABC
Muhammad
Indomet
Prasasti

Teguh

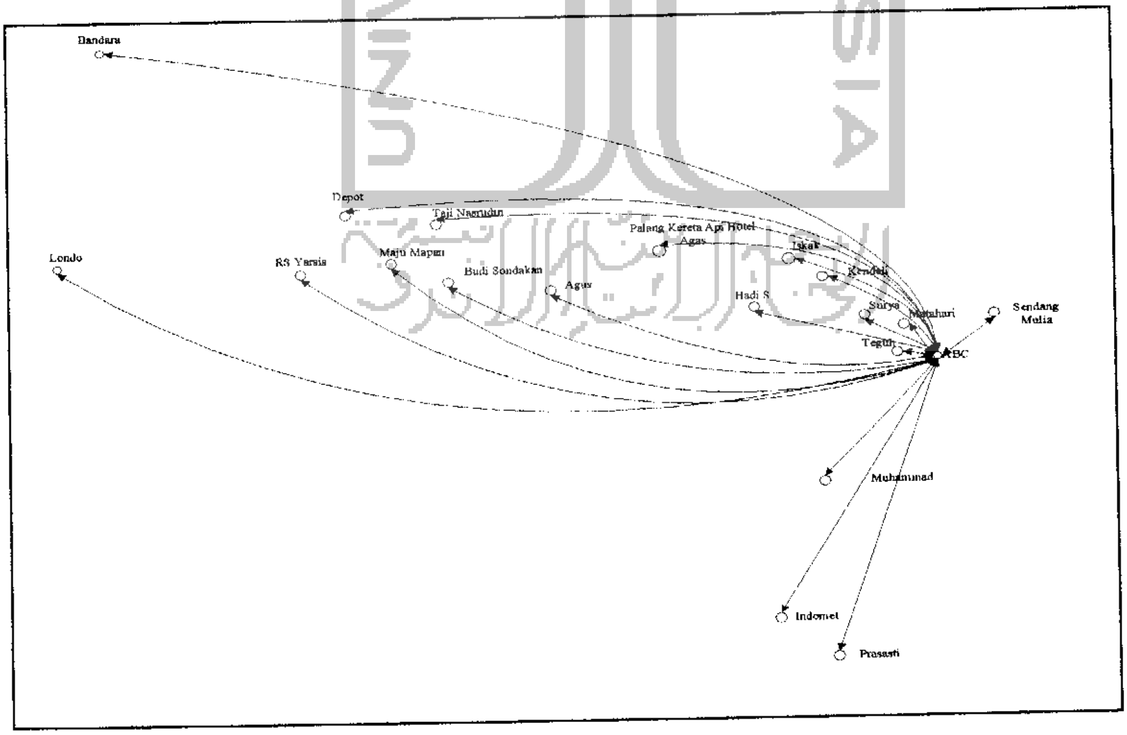


Bandara
Depot
Taxi Nasrudin
Palang Kereta Api Hotel Agas
Londo
RS Yarsis
Maju Mapan
Budi Sondakan
Agus
Iskak
Kendali
Hadi S
Surya
Matahari
Sendang Mulia
ABC
Muhammad
Indomet
Prasasti

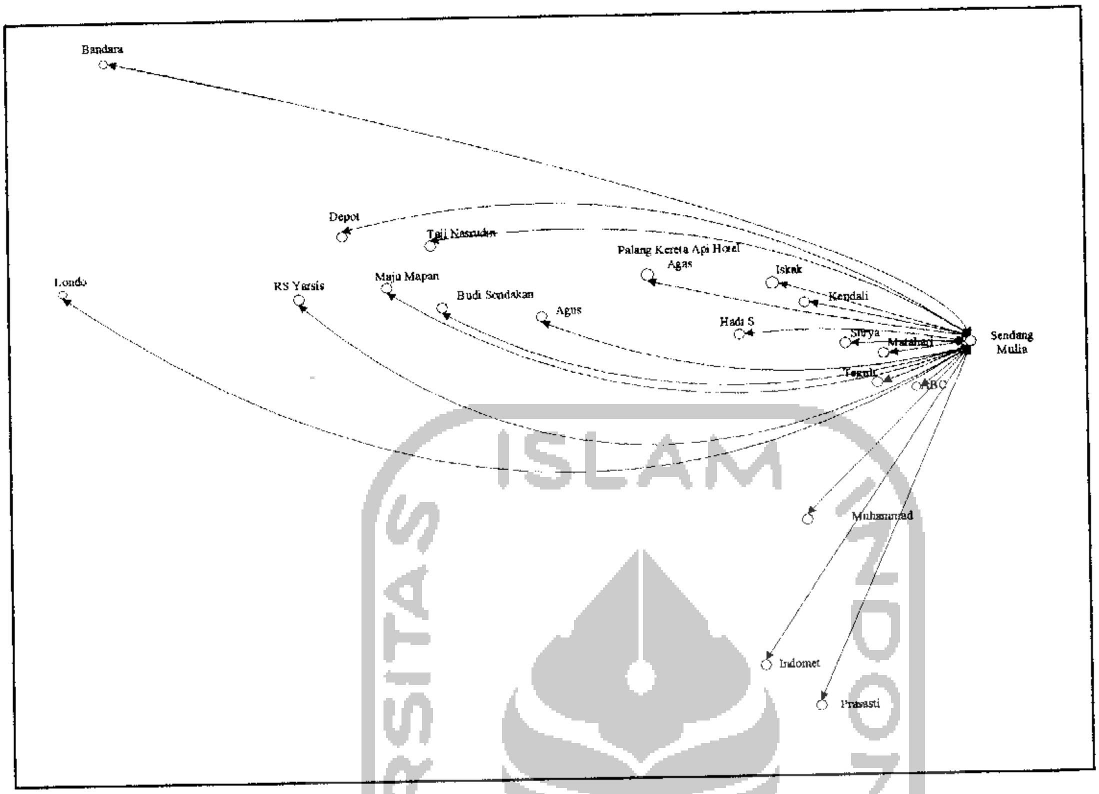
Matahari



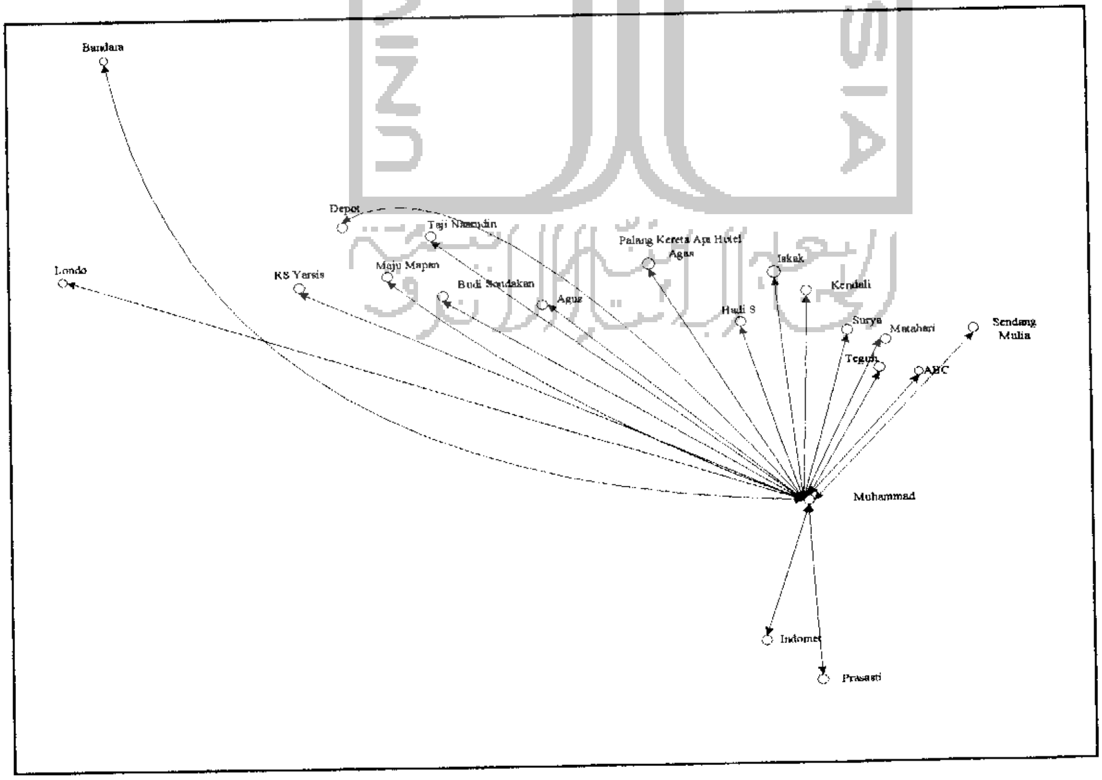
ABC



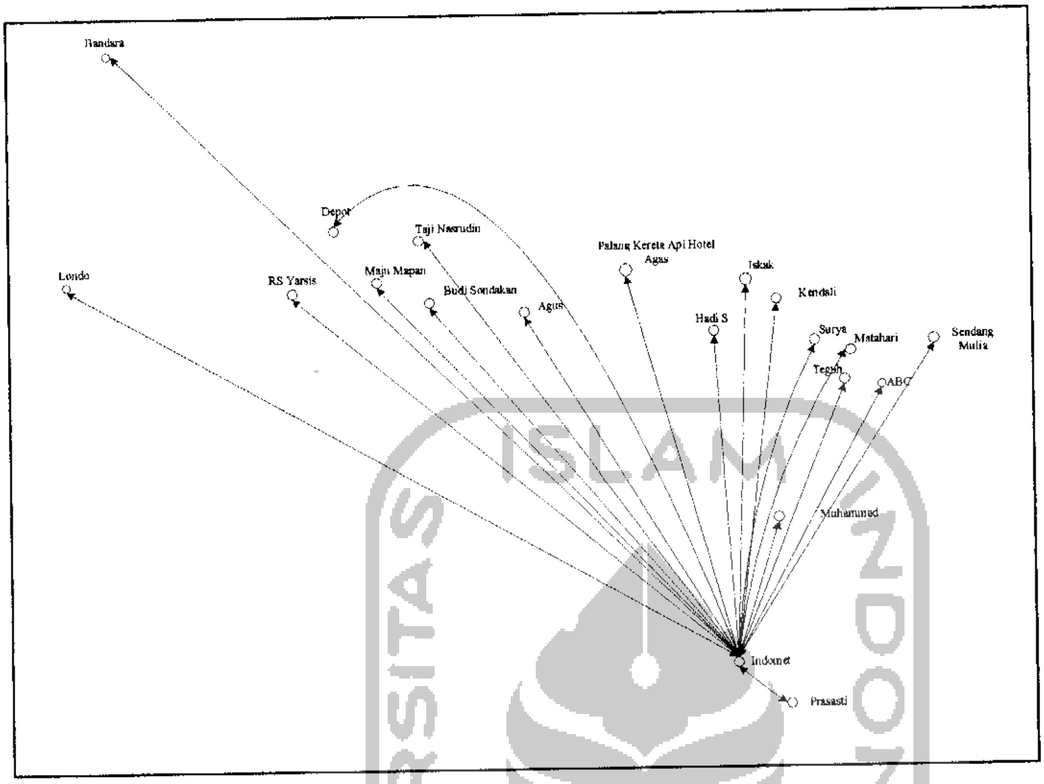
Sendang Mulia



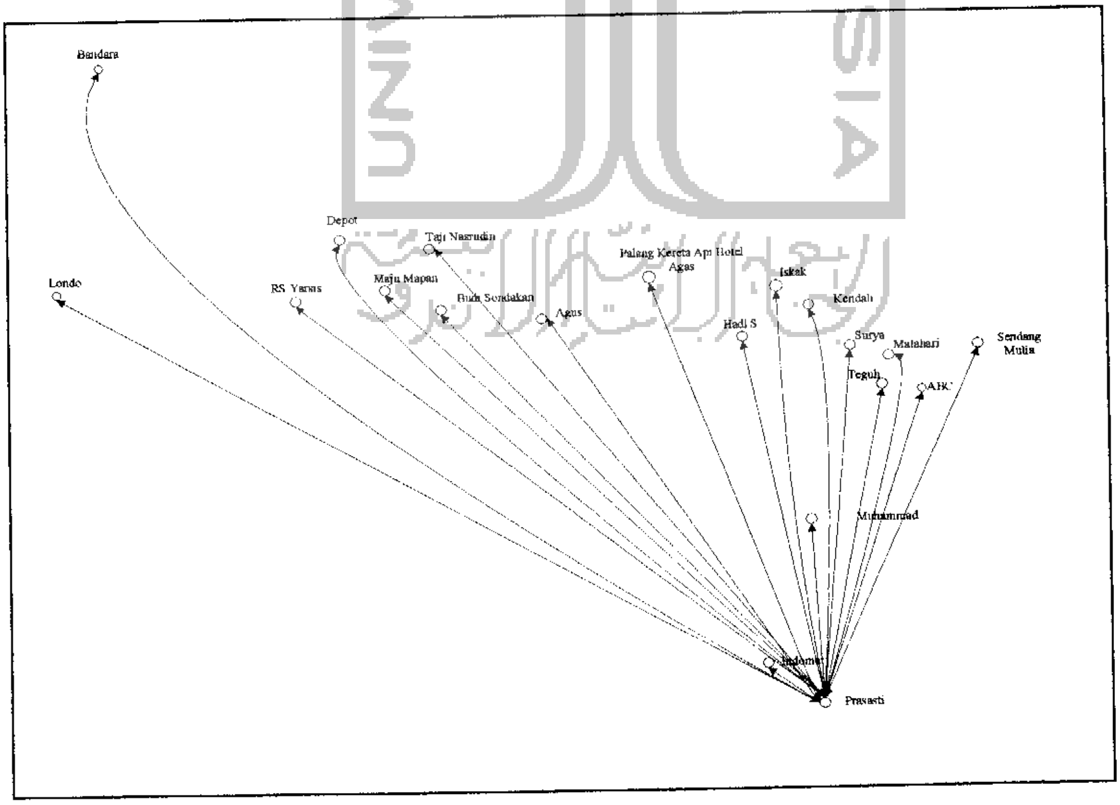
Muhammad dkk



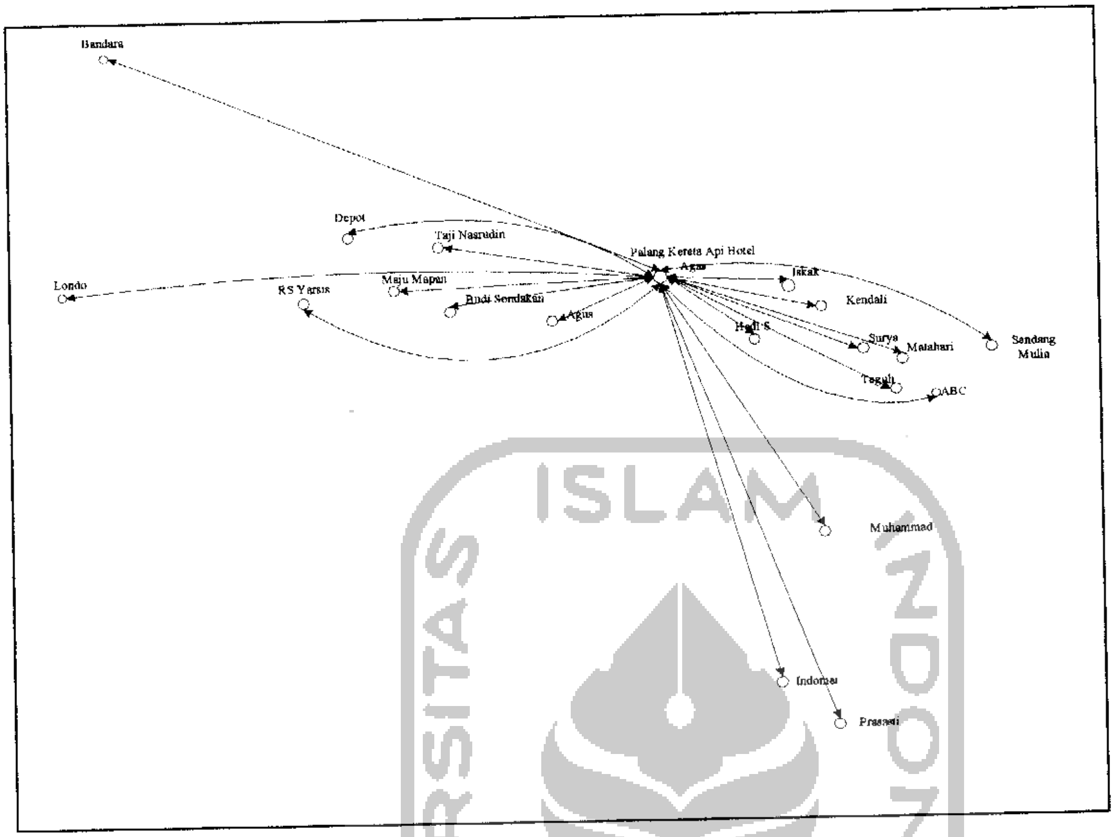
Indomet



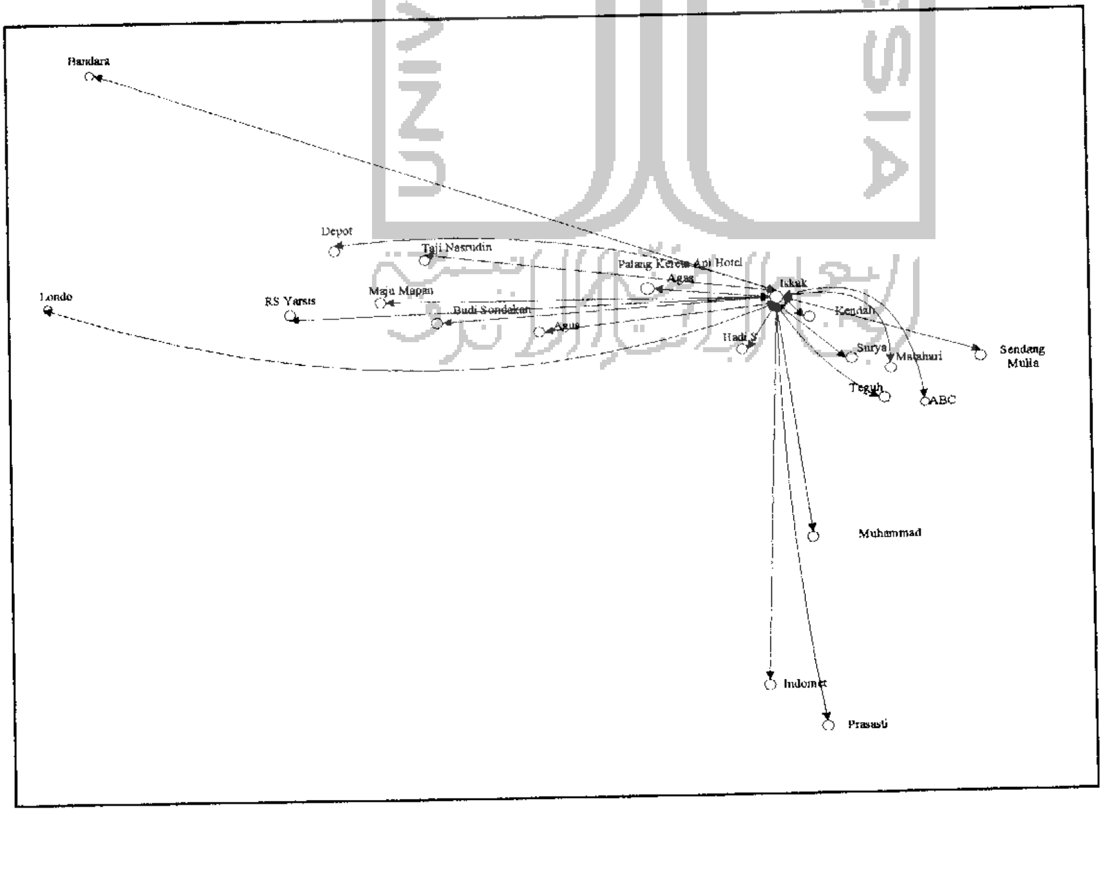
Prasasti



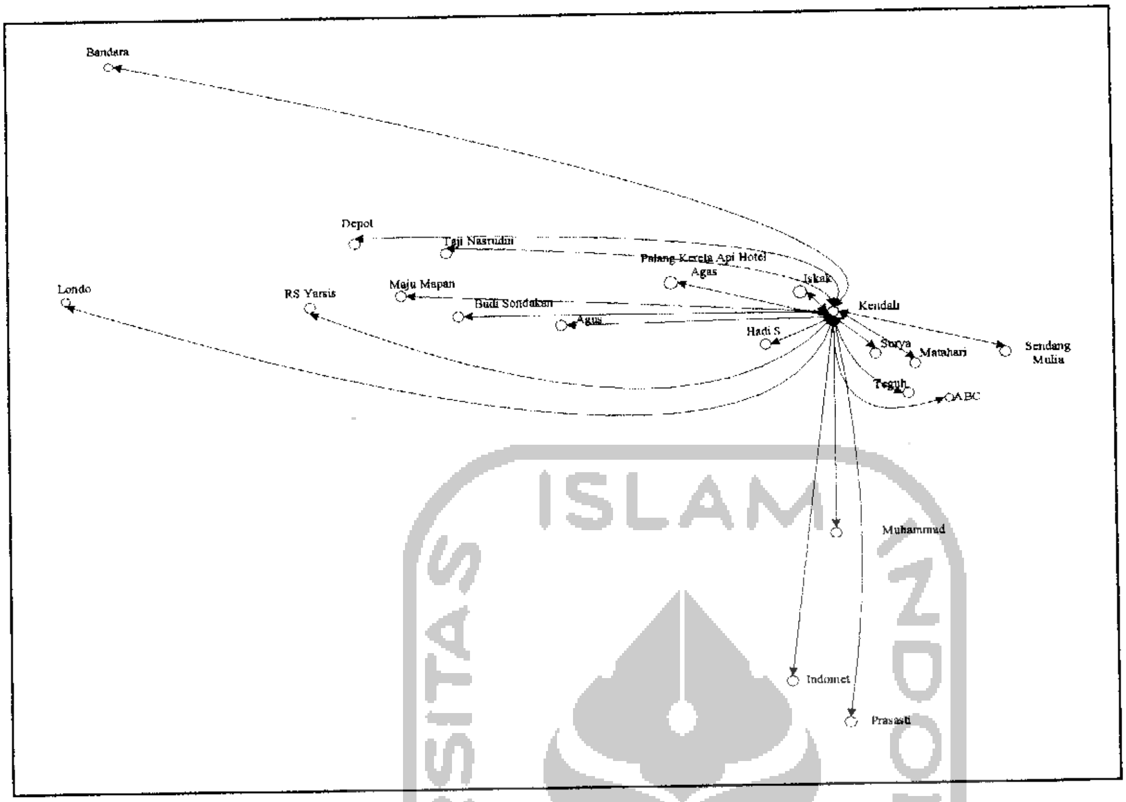
Palang Kereta Api Hotel Agas



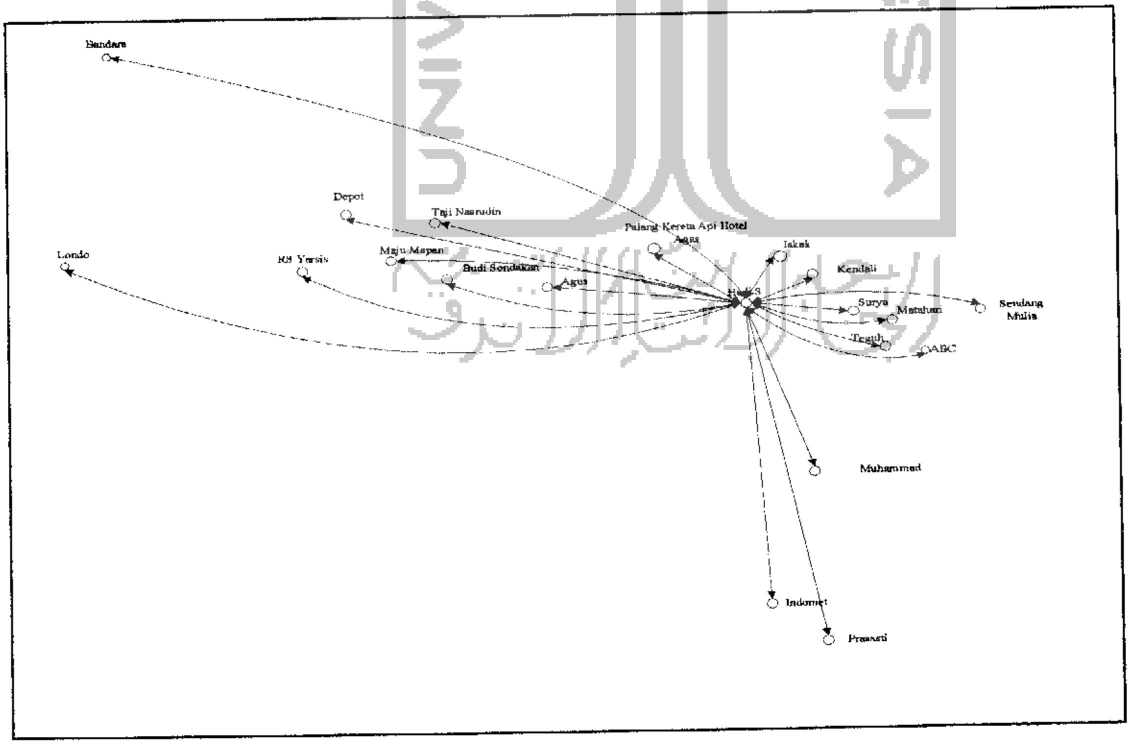
Iskak



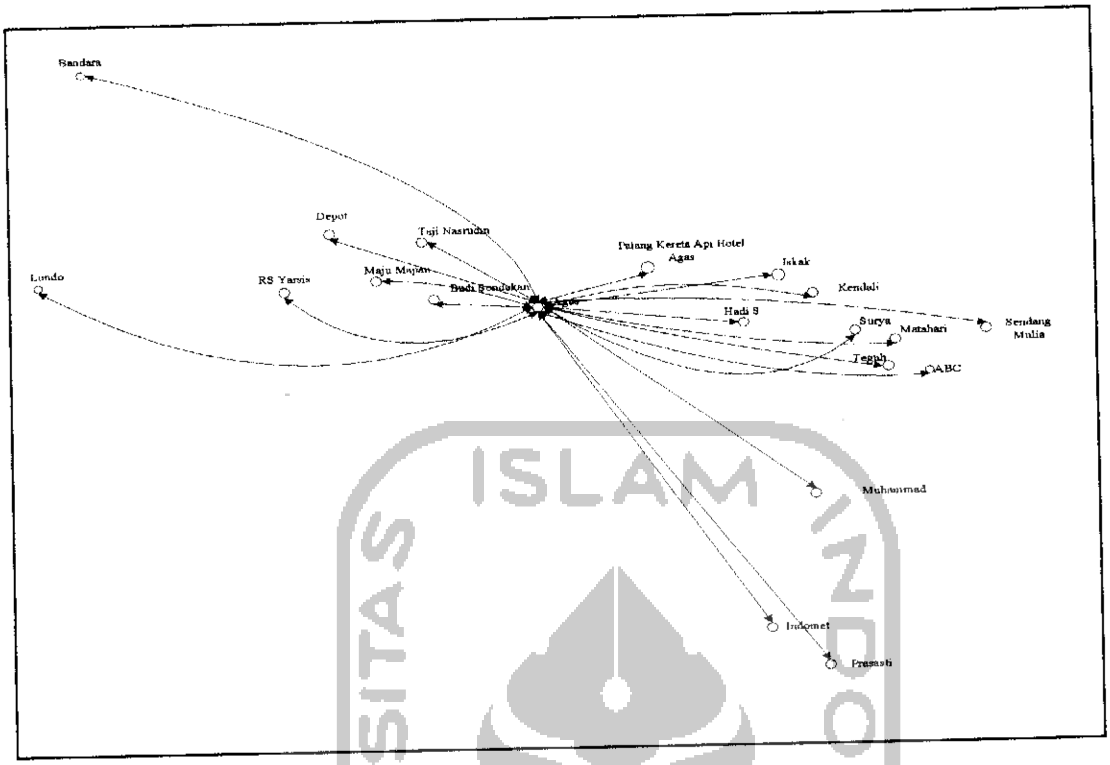
Kendali



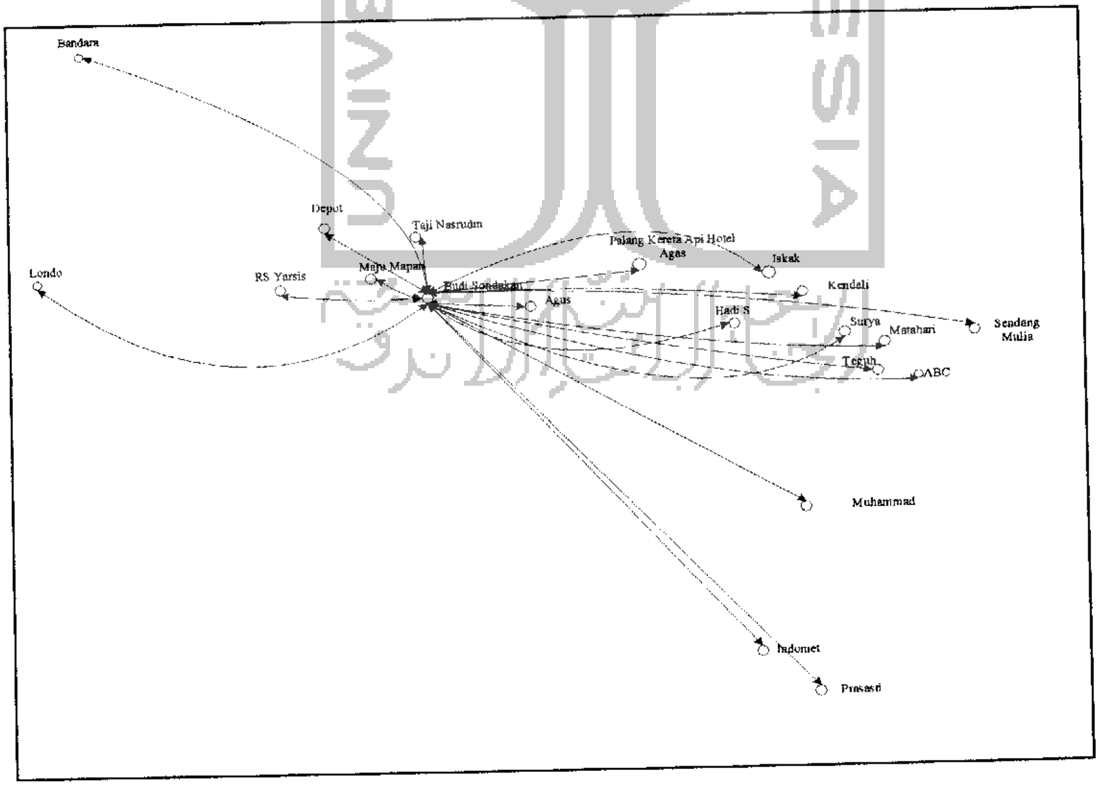
Hadi S



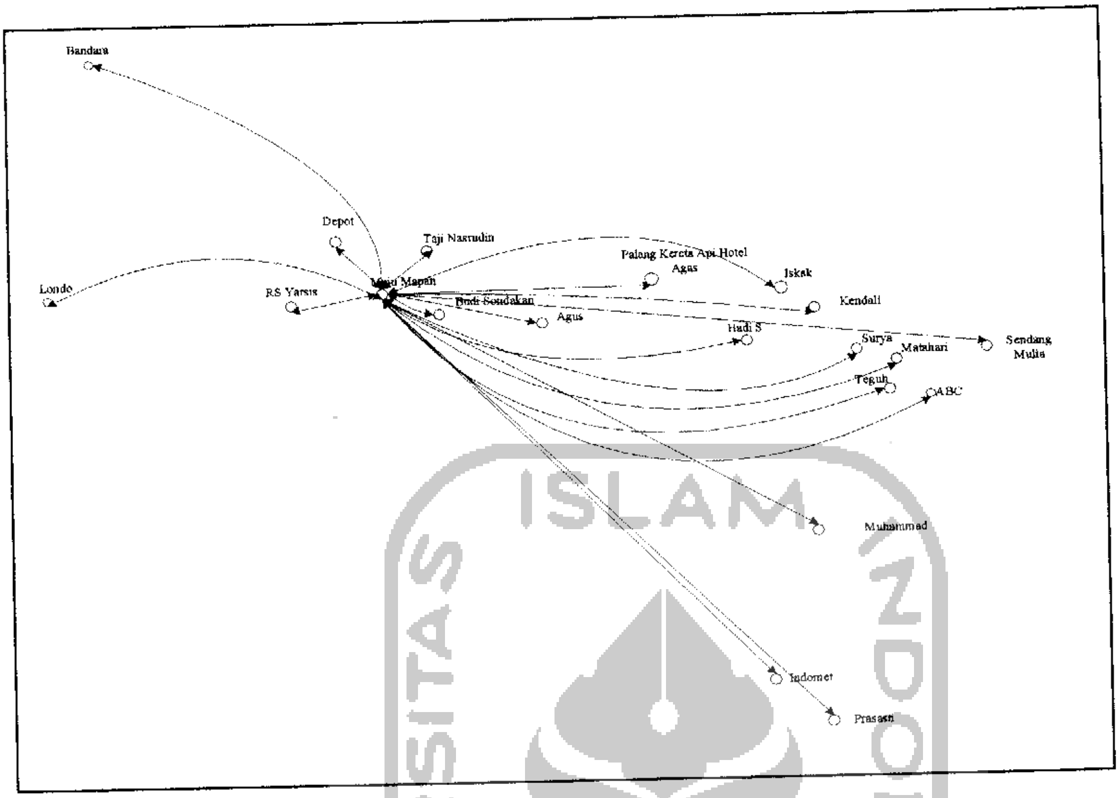
Agus



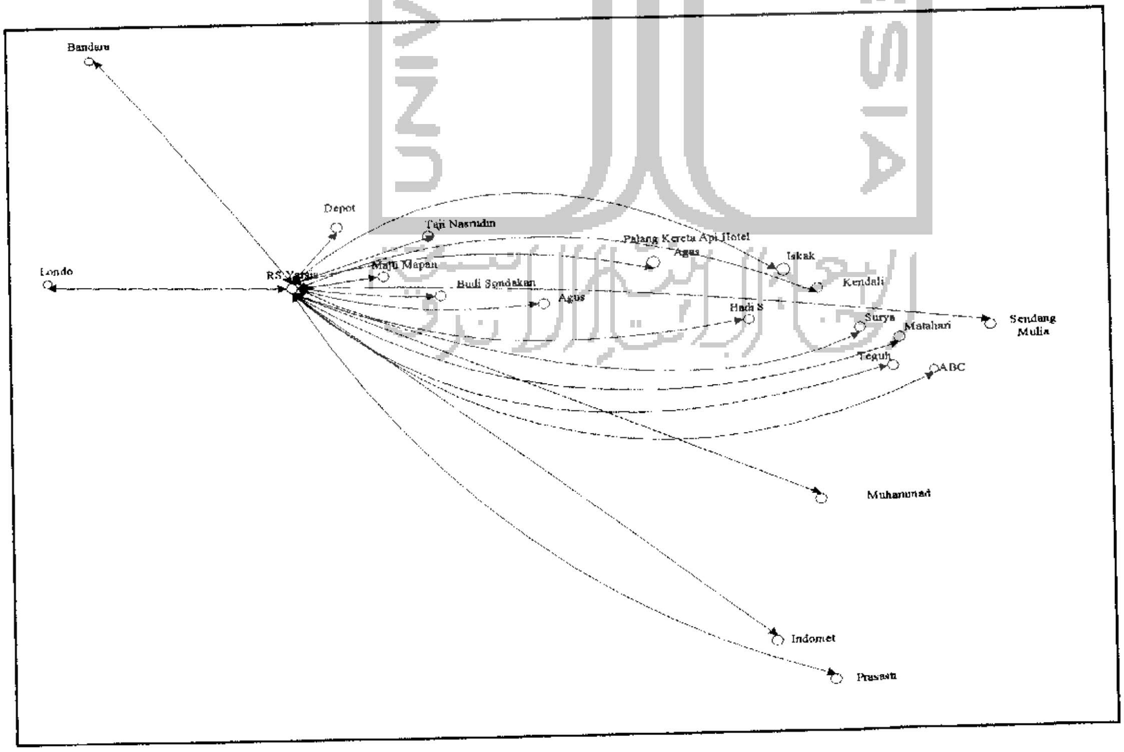
Budi Sondakan



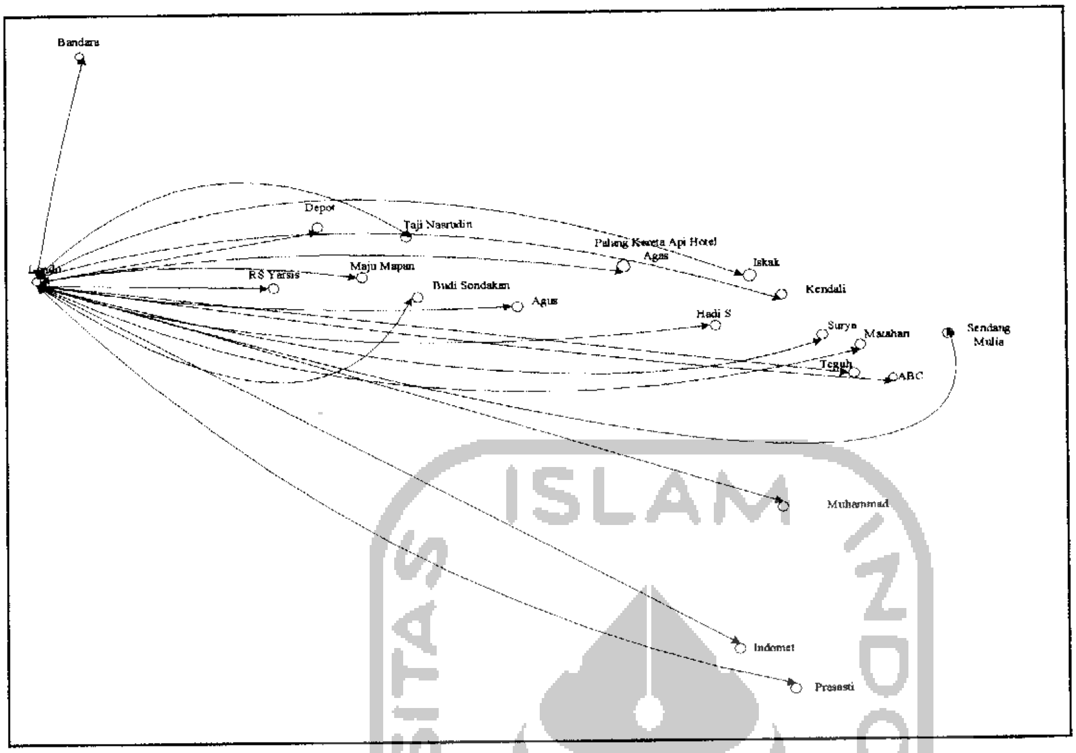
Maju Mapan



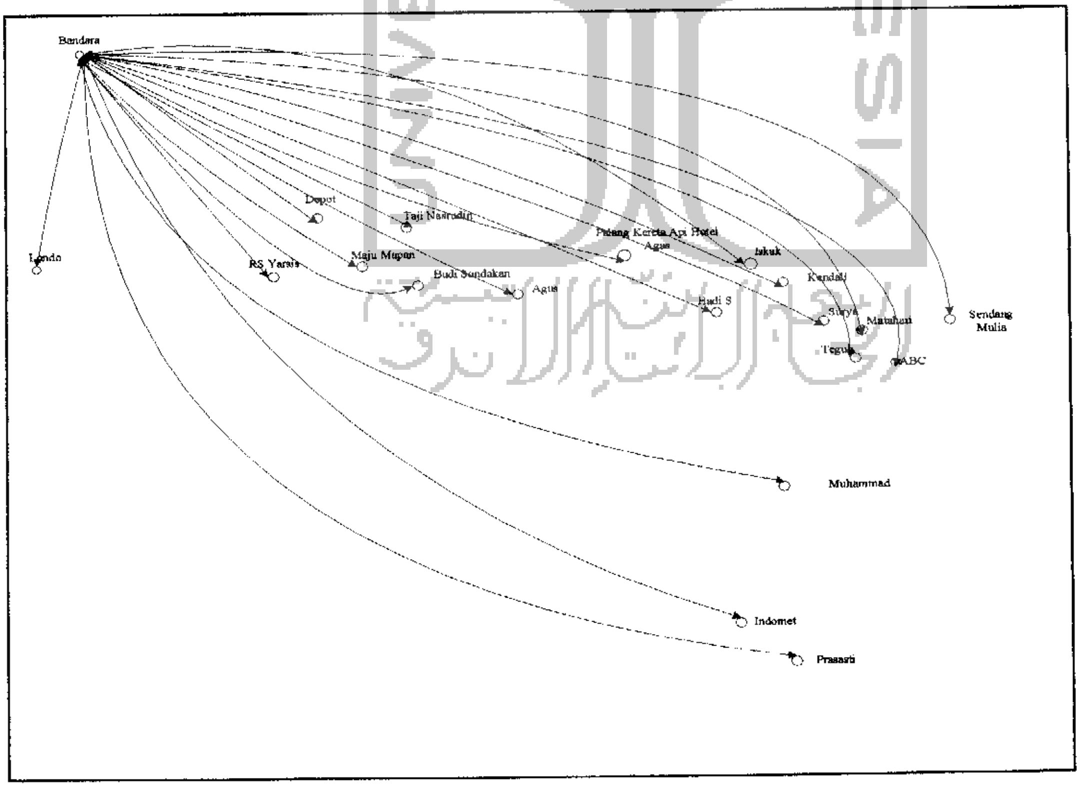
RS Yarsis



Londo

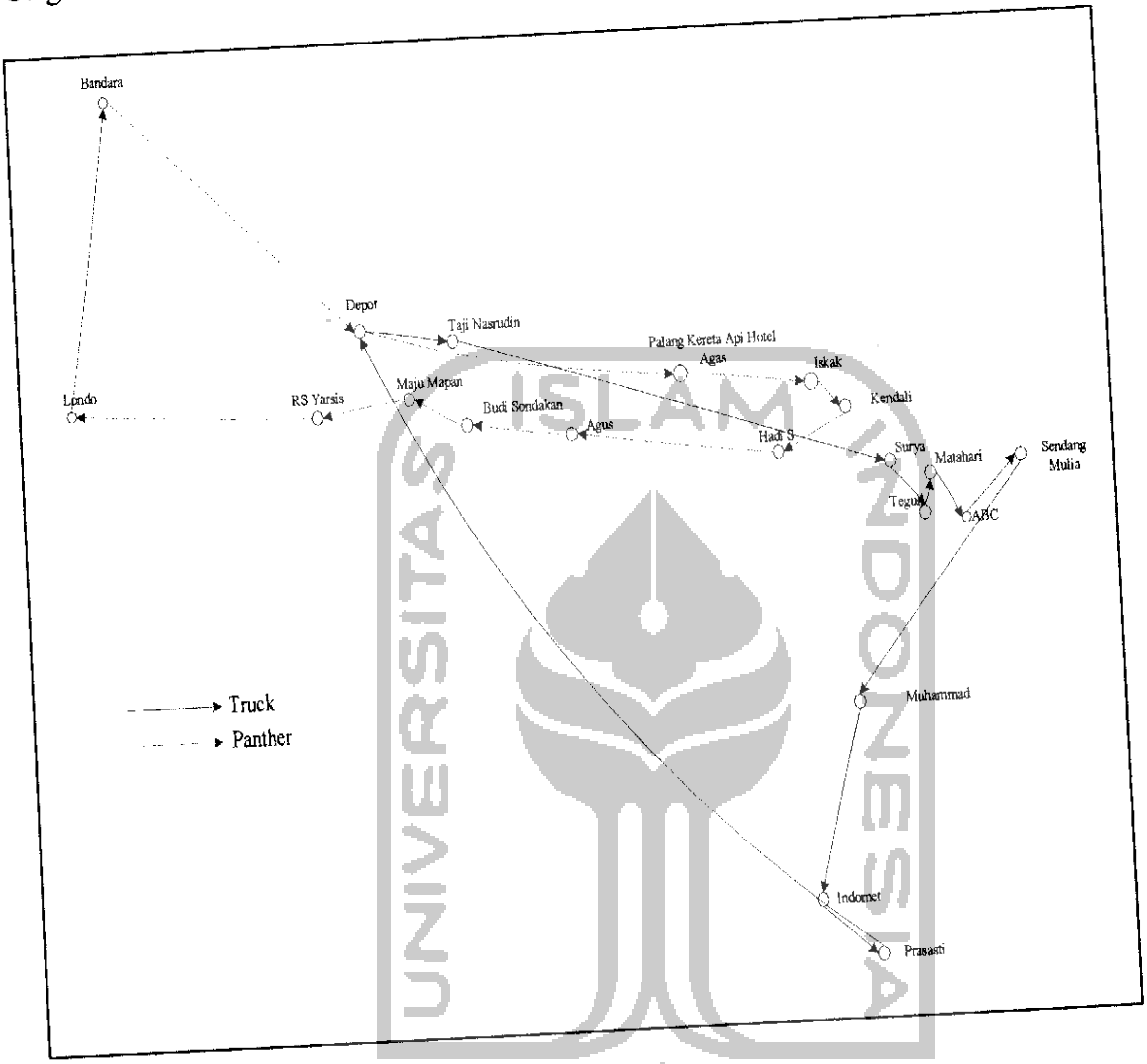


Bandara



Appendix 3. Graph of Current Route

Original / Current Route



Appendix 4. Graph of Sixteenth Suppression

Sixteenth Suppression