COST REDUCTION IN NATURAL RUBBER MILK COLLECTION

Mr. Kriwut Yanawimuti

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การลดต้นทุนในกระบวนการรวบรวมวัตถุดิบน้ำยางสด

นายไกรวุฒิ ยานะวิมุติ

จุฬาลงกรณ์มหาวิทยาลัย
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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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ไกรวุฒิ ยานะวิมุติ : การลดต้นทุนในกระบวนการรวบรวมวัตถุดิบน้ำยางสด (COST REDUCTION IN NATURAL RUBBER MILK COLLECTION) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. ปวีณา เชาวลิตวงศ์, 155 หน้า.

วัตถุประสงค์ของการทำงานวิจัยนี้เพื่อจะศึกษาปัญหาในกระบวนการรวบรวมน้ำยางสดจากโรงงานแปรรูปยางพาราแห่งหนึ่ง โดยมุ่งเน้นการลดต้นทุนซึ่งเป็นปัญหาหลักเพื่อที่จะรวบรวมน้ำยางให้ได้มากสุดจากต้นทุนที่น้อยที่สุด ต้นทุนที่ใช้ในการรวบรวมยางส่วนใหญ่มาจากต้นทุนการขนส่งทั้งฝั่งเกษตรกรมาส่งยางยังจุดรวบรวมยางในแต่ละที่และฝั่งโรงงานที่ต้องขับรถมารับยางจากจุดรวบรวมในแต่ละที่กลับไปยังโรงงาน รวมไปถึงต้นทุนค่าใช้จ่ายต่างๆในการเปิดจุดรวบรวมยางในแต่ละจุด

ในการลดต้นทุน การประเมินตำแหน่งและจำนวนที่เหมาะสมของจุดรวบรวมยางให้เพียงพอต่อการขนส่งยางของเกษตรกร จะช่วยในการลดต้นทุนการขนส่งจากการเดินทางที่สะดวกขึ้นของทั้งของฝั่งเกษตรกรและโรงงานและจากการสิ้นเปลืองค่าใช้จ่ายในการเปิดจุดรวบรวมยางบางจุดในกรณีที่มีจุดรวบรวมยางมากเกินความจำเป็น จากปัญหาของโรงงานแห่งนี้พบว่ามีต้นทุนสูงเกินความจำเป็นจากการรวบรวมยาง จึงมีการประเมินตำแหน่งและจำนวนจุดรวบรวมยางที่มีอยู่เพื่อปิดจุดรวบรวมยางบางจุดที่เป็นสาเหตุของการสิ้นเปลืองค่าใช้จ่าย โดยใช้กระบวนตัดสินใจเชิงลำดับชั้นและโปรแกรมเชิงเส้นภายใต้เงื่อนไขและข้อจำกัดที่ตกลงกันขึ้น

ผลจากการปิดจุดรวบรวมยางบางจุด ทำให้มีเกษตรกรบางส่วนต้องทำการขนส่งยางมายังโรงงานโดยไม่ผ่านจุดรวบรวม ซึ่งส่งผลให้เกษตรกรต้องรับภาระค่าใช้จ่ายในการขนส่งที่สูงขึ้นหรือไม่ก็ยกเลิกการส่งยางกับโรงงานแห่งนี้ ดังนั้นผู้วิจัยจึงเสนอแนวทางการจัดเส้นทางการเดินรถเพื่อช่วยสนับสนุนเกษตรกรกลุ่มนี้ และลดค่าใช้จ่ายในการขนส่งของเกษตรกรจากจำนวนยาพาหนะที่ใช้ โดยการจัดตั้งรถจำนวนหนึ่งขึ้นมาเพื่อวิ่งไปรับยาง ณ สวนของเกษตรกรในแต่ละรายท้ายสุดจากการประเมินตำแหน่งและจำนวนที่เหมาะสมของจุดรวบรวมและการจัดเส้นทางการเดินรถสามารถช่วยลดต้นทุนโดยรวมของระบบรวบรวมวัตถุนี้กว่า 1.485 ล้านบาทต่อปี ลดลงประมาณ 32.4% ของค่าใช้จ่ายทั้งหมด

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต ....
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The objective of this research is to study the problem of rubber milk collection process in the selected rubber factory. This research emphasizes on the collecting cost reduction to achieve the maximum amount of collected rubber at the minimum cost. The major cost in the collection system occurs from transportation and facility management (rubber collection centre). Strategically, in order to minimize cost effectively, the location and number of rubber collection centre should be optimally determined as distance of centre affects to transportation cost, and number of facility affects to management cost and conveniently available facility. Nowadays, the high cost of the collection centre management in the rubber factory is a challenging problem. Decision making to close unnecessary collection centre is one of the possible ways to cope such a problem. Therefore, this research aims to propose Analytical Hierarchy Process (AHP) combined with Linear Programming (LP) to help factory, farmer and entrepreneur to make a good decision in the facility management problem. After closing some collection centres, there are some amount of farmers facing with the higher transportation cost or terminating their rubber supplies. In this research, we adopt Vehicle Routing (milk-run) to minimize transportation cost to a number of farmers' vehicle and fully utilize the truck space. From our numerical experiment, we show that the optimal number of collection centre and the effective routing design can reduce cost approximately 32.4% or 1.485 Million Thai Baht per year.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Engineering Management		
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CHAPTER 1 INTRODUCTION

Rubber is the most important industrial crop in Thailand accordding to the largest plantation area and production number of processed rubber. For this reason, there are a lot of developed researches to increase more benefit and enable to find out the problems for solution. In this research, there is a case study of one processed rubber factory which faces obstacles in today. Therefore, the background of the rubber factory in general and stated obstacles of this factory are described in this chapter as following

1.1 Background of the Research

Natural rubber is the major crop in southern Thailand and the number one valuable agricultural export in the country with earnings of 8,746 million US dollars and employing 6 million farm workers in 2012 (Office of Agricultural Economics, 2013). Thailand is the world's biggest producer of natural rubber but today's economy could affect the future standing of the country in terms of rubber production due to a very competitive market. In order to maintain Thailand's rank as the biggest supplier of natural rubber, logistic management becomes very important to have a competitive advantage especially in terms of transportation which is the main process in the logistics system.

Focusing on transportation in Thai natural rubber industry, direct shipment is still a weaken point which occurs regularly in raw-material collection process and it causes the collection cost to increase when there are more number of routes taken and more vehicles used as figure 1-1 shows. Moreover, collection center location is another factor that affects the effectiveness of transportation and cost management in the collection system. There should be an appropriate number of collection center locations to accommodate effective and timely transfer of raw materials. For example, when the number of collection center is lower than the demand of suppliers, some suppliers as farmers will have a longer travel time from their farms to the collection centers. In the contrary, if the number of collection center is more than the demand, entrepreneur has to pay more operation cost in the collection centers which is unnecessary.

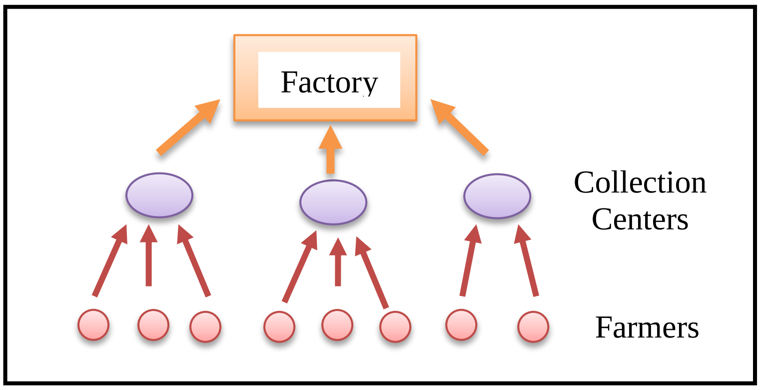

Figure 1-1Rubber transportation (Direct Shipment) in raw-material collection process

In line with this, the stated issues are the reason to study the raw-material collection system in the natural rubber industry with a goal of finding ways to reduce the cost of the collection system and Betong City was chosen as the case study area. Betong City is located in Yala province and is the southernmost point which is situated nearly the Thailand-Malaysia border. It could be found at the lower southern part of Thailand which has 6,947 household. It has a large number of rubber plantations consists of 354,489 unit area and 79,906 tons of average output (Yala Provincial Agricultural Extension Office, 2009). The case study area (Betong City) that has been chosen is an economic zone for transportation and shipment of the natural rubber products to China which is the number one importer of natural rubber in the world through Penang Port, Malaysia. Therefore, this research is going to study the natural rubber collection system of one company in Betong City named XYZ Company which is a processing factory of rubber compound. Rubber compound is a kind of processed rubber that has no tax when exporting it to China within the contract of 6 years (2012-2016) and it is the most in-demand rubber product more than the other kind of processed rubber.

1.2 Company Background

The XYZ Company is a processing factory of natural rubber that is located in Betong City and is about 40 kilometers away from Thailand-Malaysia border. It has been operating for 26 years as farmers' district organization with 508 members including both farmers in the local area and members who live outside. The main businesses of the company are rubber processing and rubber collection service.

Rubber processing

To produce Rib Smocked Sheet (RSS)
To Produce rubber compound

Rubber Collection Service

Latex or Rubber Milk Collection
Raw Rubber Sheet Collection
Rib Smocked Sheet (RSS) Collection

Figure 1-2 The rubber milk collection system of the factory

Focusing on the rubber milk collection system of the factory, the rubber transportation for collecting is started from farmers or suppliers who send the rubber milk to the factory through the nearest rubber collection centres. Then, the factory would send the vehicles to pick up the rubber that is collected from farmers in each collection centre and return back to the factory.

1.3 Statement of the Problems

In the current collection system, there are eight collection centers which are located in different areas. In figure 1-3, there are a varying number of members in each of the eight collection centers.

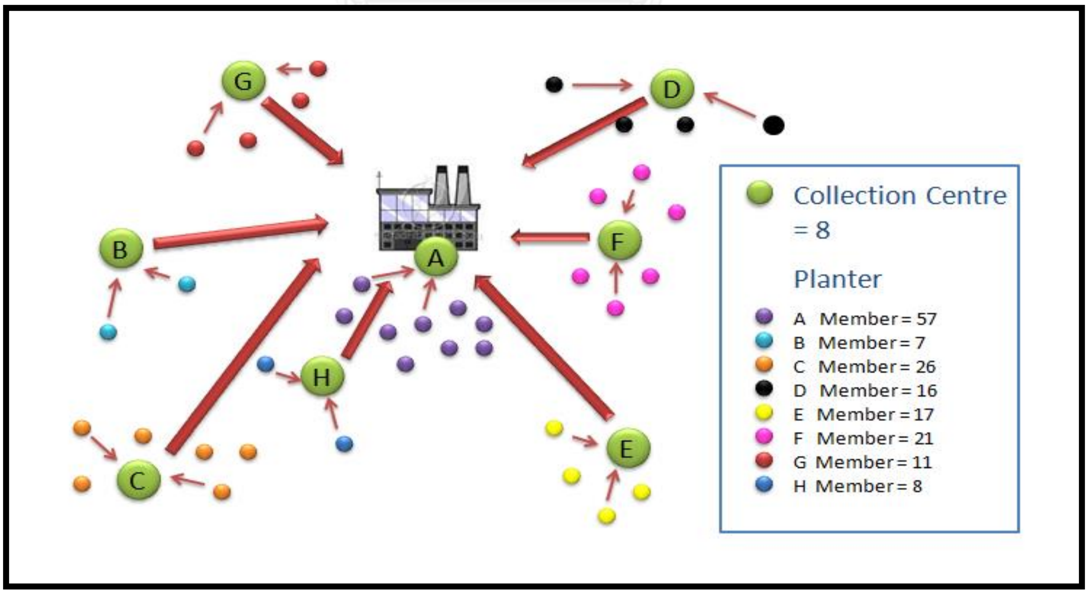

Figure 1-3 Raw-material collection system of the factory

According to the raw-material collection system of the factory, the problem of entrepreneur are found that collection cost of the system is still high since some collection centers with low density of member, like point B, experiences a deficit or operation loss because it has to pay for fixed cost (Collection centre's cost) for low density of members. Thus, it is better to close some collection centers to reduce cost. However, to decide on which collection center that should be closed is still a challenge. Hence, in order to make decision, the entrepreneur needs to consider the characteristic of each collection centers like the historical data in Table 1-1 which shows the fact for the amount of collected rubber, transportation cost, and facility cost. Then, next process is making criteria for each one of them.

Objective	Factors / Centres	A	B	C	D	E	F	G	H
Maximum of collected rubber	Number of members	57	7	26	16	17	21	11	8
	Amount of Raw-material (kg/month)	22,696	4,736	9,233	6,918	8,984	7,772	5,093	3,301
Minimum transportation cost	Travelling Cost for farmers (Inbound) (THB)	59,452	5,543	16,093	13,319	2,676	14,923	10,138	3,485
	Travelling Cost for factory (Outbound) (THB)	0	5,390	7,629	6,155	8,093	7,194	8,145	3,211
Minimum fixed cost	Collection centre's Cost (Fixed Cost) (THB)	43,500	17,500	27,500	24,500	27.500	26,000	27,000	17,000

Table 1-1 Historical data about cost, rubber volume, and location in each collection center

Closing some the collection centers is a possible strategy to reduce unnecessary cost, but it should be carefully planned. In order to make a good decision or criteria on such a strategy, entrepreneurs have to consider the characteristic of each center and many related factors in table 1-1 such as its capacity (amount of raw-material) and distance (total length). According to the table 1-1, collection center H has the lowest capacity to collect the raw-material, but it is located close to the factory and consumes the low fixed cost. On the other hand, center G is located far from the factory but it can collect the higher amount of raw-material. Thus, the decision makers have to trade off which factors are more important to be focused firstly

After finished closing the collection centers, farmers or suppliers who are transporting at the closed collection centers have to make a new choice to transform the rubber to another collection centers or might change to another factory. For this problem, vehicle routing or milk-run is able to deal with this group of farmers in order to keep the amount of rubber receiving but the price of rubber receiving has to be negotiated to be lower according to routing cost

1.4 Objective of the Research

The objective of this research is to identify the ways to achieve a minimized cost in the raw-material (rubber milk) collection system.

1.5 Scope of the Research

The research will focus on the raw-material (rubber milk) collection system as outsider’s point of view from suppliers (farmers) to the factory which located in Betong city, through 8 collection centres and include 162 suppliers. The time schedule of receiving rubber is set at 8 o’clock in every morning and the frequency for receiving is a step of continue working for 3 days and stop 1 day. In addition, the research will utilize the process as following.

Opened-Closed Collection Centers: The research will select the optimum collection centers based on current operation without any changes in the system.

Vehicle Routing: The transportation in some part of this raw-material collection system (Closed Collection Centers) will be renewed and decided under given of supplier’s coordinate in order to group supplier for routing. In addition, the capacities of vehicles are assigned to be the same and time window will be considered.

Analysis of the collection systems, these are based on historical data from purchasing rubber (Rubber Milk or Latex) during April – August (2014).

1.6 Methodology

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1. Study the current operation in raw-material collection system and identify problems
2. Analyze the problem and gather related information
3. Literature review on the concerned theories
4. Study AHP-LP Model
    - Data Collection and criteria identification
    - Calculate overall priorities of alternatives and criteria
    - Use Linear programming to find the selected collection centers
5. Study Vehicle Routing Problem (VRP)
    - Collect the data and related information
    - Construct mathematical model
    - Develop suitable model to solve the problem

- Evaluate result from the solving problem

6. Conclude the result from AHP-LP and VRP solution
7. Thesis Completion

1.7 Expected Benefit

1. To reduce the transaction cost and improve the current collection system more effectively
2. To develop a new collection system that can plan the routing task more effectively. It can reduce total length, time and total collection system cost
3. To generate more profit and reduce cost
4. To save energy and pollution through the reduction of number of vehicles and fuel consumption.
5. To apply the methodology to other areas of which characteristics are the same.
6. To create a framework for the future study

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CHAPTER 2 LITERATURE REVIEW

In Chapter 2, the knowledge about the natural rubber industry and rubber collection system is provided. It includes research reviews from other researchers especially with regard to supply chains and logistics management to understand situations and faced problems in this industry. Moreover, there are also helpful tools to reduce the cost in this term due to the given problems of this case study. After the analysis of Chapter 1 questions, making of the decision to close the rubber collection centre would be the next step. Analytical Hierarchy Process (AHP) could be a tool to support the decision making and decide the optimum number of collection center by Linear Programming (LP) to save operation cost. After all the given processes, Vehicle Routing Problem (VRP) can also be used to support the cost reduction in terms of transportation. All of these are elaborately described in the following:

2.1 Natural Rubber Industry in Thailand

Natural rubber is the industry that is vital to the economy of Thailand. This industry is able to generate revenue for the country, especially among of farmers in the Thailand Southern. The industry is also important in terms of employment and exports which the value of exported goods is ranked No. 1 in the product of the country as well as the world's No. 1 exporter of rubber industry (Office of Industrial Economics, 2005). According to the valued revenue generating, there were many researches to develop the natural rubber industry in the various terms such as cost reduction, logistics and supply chain improvement, production process improvement, technology of natural rubber production and so on. In today’s situation, depressed rubber prices are a huge effect to all participants that still does not solve anything much whether the government will try to maintain the price. Or even at the beginning of fiscal year 2012, the government has approved a budget of 4.5 billion baht to stabilize the price of rubber (Office of Agricultural Economics, 2013).

From the foregoing, there are also many concern department try to solve the issues including The Thailand Research Fund (TRF). There were many researches focusing on solution of depressed rubber price, for example, Sure-wullee and Pisithsuphakul (2013) explained the causes of depressed rubber price that it is happen from global economy and China's economy slowed in the last 2-3 years. Moreover, rubber price in futures market at Tokyo Commodity Exchange (TOCOM) and Singapore Commodity Exchange (SICOM) is in a downtrend. Investors are concerned about oversupply and stock tires which is high. While the demand for tires in the downturn. In order to survive, it is not just the government’s responsibility to make the policy to support farmers and entrepreneur. The farmers and entrepreneur also need to consider about the actual cost of rubber tapping, producing, and transporting. It is over expenditure or not and how to reduce cost when the rubber operation is too much cost (Somboonsuk, Wedbundith, and Niyombundith, 2012).

Kritchanchai and Somboonwiwat (2009) had researched about abilities of integration between supply chain and logistics management in the rubber industry. In the research, all information is from interviewing all players in the supply chain starting from downstream (farmers) to upstream (factory). Then, the problems were discussed by focusing on group by group as following.

2.1.1 Supply Chain and Logistics Management in the Natural Rubber Industry

In general, supply chain in the natural rubber industry consist of farmers, middleman or commission merchants, farmer cooperative, central market for rubber, rubber carriers, and processed factory. The process is started from farmers who produce rubber. In term of rubber form, first process of rubber production is rubber tapping that the farmer will get the rubber milk. Then, it is depend on farmer and the upstream about what is the form of product that they prefer. It is might be the form of originate rubber milk or transformed rubber milk like raw-rubber sheet and cup lump. The process of rubber tapping would explain more in the following.

Figure 2-1Rubber production from tapping process

After that, first rubber production will transport to the factory in order to continue the production process as processed rubber or transformed rubber such as concentrated latex, block rubber, smocked rubber sheet, and rubber compound. These processed rubbers will export to overseas and the factories who are rubber used as raw material like tire factory, rubber gloves, and rubber wire.

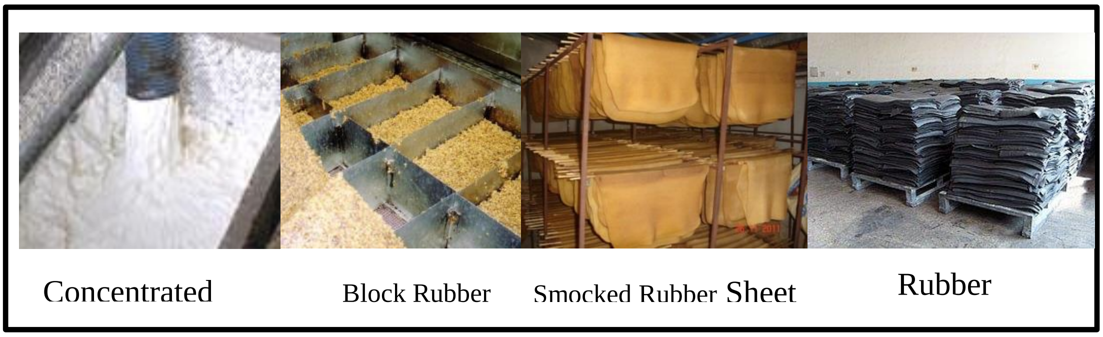

Figure 2-2 Types of processed rubber

In addition, travelling of rubber is not direct to the factory by farmers. The rubber would be collected first before transporting to the factory by collection center as central market for rubber, farmer cooperative, middleman, or collection center that the factory provide. For more information, it would be explained in rubber collecting and transportation by following.

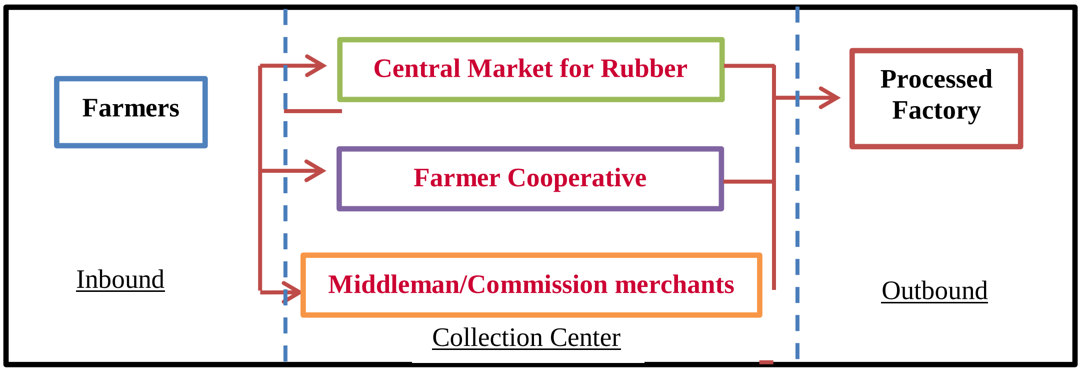

Figure 2-3 Elements of supply chain in the Natural Rubber Industry.

Rubber Tapping

According to research provided from Office of the Rubber Replanting Aid Fund, there were a lot of researches to be knowledge about rubber tapping process and show the practical term of farmer to do rubber tapping. In general, farmers would like to do the tapping after midnight till before sunrise which depend on the area and number of rubber trees. Intarayotha, Boonjaroen, and Toruksa (2012) have resulted that doing the rubber tapping during 08:00 p.m. – 06:00 a.m. is affect to decreasing amount of rubber milk approximately 6%, during 06:00 – 08:00 a.m. is decreasing around 13%, during 09:00 – 11:00 a.m., 12:00 a.m. – 02:00 p.m., 03:00 – 05:00 p.m., and 06:00 – 08:00 p.m., the amount of rubber milk output might be reduced at 20%, 31%, 23%, and 6% respectively.

In order to get the highest amount of rubber milk output, 08:00 p.m. – 06:00 p.m. is the best period time to do the rubber tapping. The reason that farmers do not tapping in the daytime because the sunlight is able to make the tree have transpiration of water and rubber milk inside which affect to reducing pressure in rubber pipe to be output. Therefore, the majority of farmers would like to do the tapping after midnight and then, leaving the time about 1-2 hours to make the rubber milk outflow from the tree. Finally, the farmers will pick up their rubber milk after 6 o'clock in the morning.

Figure 2-4 The process for raw rubber material production with the container

In addition, environment is another factor that effect to rubber tapping such as weather, moistness in the air and soil, temperature, and relative humidity. Considering the outflow of rubber milk in the rainy season, it could be seen clearly that there will be the high moistness and relative humidity. This means the tree will get more water until it is saturated and then, bark of tree will be softer. This causes the water in the cell wall of the pipe which affects to increase in amount of rubber milk but there will be low intensity of latex and it is result to low quality in productivity. Moreover, raining is still a problem for the farmers to do the rubber tapping.

Another consideration is the rubber tree cannot do the tapping every day because the tree needs to refresh. It is able to affect to the growth and life time of rubber tree that why the farmers do tapping for 3 days and stop 1 day. Besides, the rubber tree is stop to do tapping in order to breaking out of leaves and slow down to be activating growth in dry season and spring. As a result, June – August is the best period time to do tapping after it's refreshing and December – January is another perfect tapping time because of the winter which has the appropriate moistness to get well outflow of rubber milk.

2.1.2 Rubber Collecting and Transportation

According to figure 2-3, the first player in this supply chain is the farmers as the position of suppliers. Rubber tapping activity may be self-tapping by owner of rubber plantation or employee depends on number of rubber trees. In general, the farmers will finished their rubber milk picking up around 7 – 8 o'clock. Then, the rubber milk would be transfer to a nearby collection center by the farners with a motorcycle.

Next player who deal with transportation of rubber milk is collection center. After collecting rubber milk from the farmers, the rubber milk is poured together into the tank. Then, Ammonia or formic acid is added in order to do preservation and prevent coagulation of rubber. In this stage, there are many forms of rubber collectors which could be categorized by following.

- **Middleman/Commission merchants**

Middleman or merchant has to deal with the rubber which is purchased from farmers directly or it might be purchased by bid rubber from any organization. Then, they will trade the rubber to collector in each district or might sell to processed factory directly. In the position of middleman or merchant, it uses to support small scale plantation of farmer who can produce low amount of rubber milk. Moreover, it is convenient because the merchant will go and pick up the rubber at the farmer place by a car but the sell price might be higher and there is the problem of cheating price following.

- **Farmer Cooperative**

There are many farmer cooperative in each area which uses to support local agriculture product including rubber which is the major production. According to the rubber area, there is rubber plantation fund cooperative to support the farmers or rubber planters directly. This cooperative is benefit in term of providing fair sell price to the farmers as memberships. The cooperative is able to prevent cheating rubber price from middleman and do primary processed rubber in order to increase value before selling to buyers or the central rubber market in order to export. In term of selling, the cooperative will do a contract with processed factory or they can sell to anyone who offers the better price but they always sell to central market for exporting to China. Then, profit is returned to all members which normally is the farmers. Moreover, the cooperative also can delivery some number of the processed rubber to the local factory or the factory might come and pick up at the cooperative by a car.

● **Central Market for Rubber**

Central market for rubber was established by government in order to create rubber trading system under the rules and laws of competition. The central market use to support all farmers' cooperative in their sub- region country including the group of farmers who are located away from communities. Since the farmers who are not belong to any corporative and membership of rubber organization, the central market could be replaced as a collection center but they will not collect for the rubber milk. The reason that rubber milk is not accepted because it would be coagulated within 2 hours before arriving to the market center and there are only few central markets in Thailand which are located in each province of the country. For the duty of central rubber market, they try to collect the processed rubber as much as they can from the cooperative and then, the buyers will come to buy the rubber at the market. In addition, the buyer can categorize into 3 groups by following.

Rubber Exporter: The exporter might be a person who has a contact with overseas factory or they might be processed factory to do primary processed rubber from raw rubber sheet and smocked rubber sheet to be compound rubber and then, export to overseas.

Merchant: Besides from buying rubber product from the farmers, merchant also buy any rubber products to trade to the exporter or any processed factory.

Distributor: The distributor could do the similar thing like the merchant but there is different in term of indicated rubber price. The merchant can decide for the rubber price by themselves but the distributor will get the specific price from the exporters. Then, they will sell to the exporter who gives them the highest price.

Finally, there are the processed factories that do processed rubber like smocked rubber sheet and compound rubber and continue advanced process to be raw-material of product for end user such as tire and rubber gloves. In order to find the raw-material (rubber milk, primary processed rubber), there are two different ways that the factory do the rubber pick up. First, the factory will buy the rubber from the collector (Middleman, Farmer cooperative and central rubber market). Second, the factory has its own collectors which are provided in different area to cover all membership. The idea of provided collector is work only for the rubber milk because the rubber milk cannot be stock coagulation. So, it is easier to buy directly from framers via the factory's collection center that is provided. In addition, the processed factory is a last part from the supply chain but it is still in midstream of the natural rubber industry. After the processed rubber from the factory, the rubber product will continue to upstream process by exporting to overseas especially to the factory in China or it might be sold to tire factory as figure below.

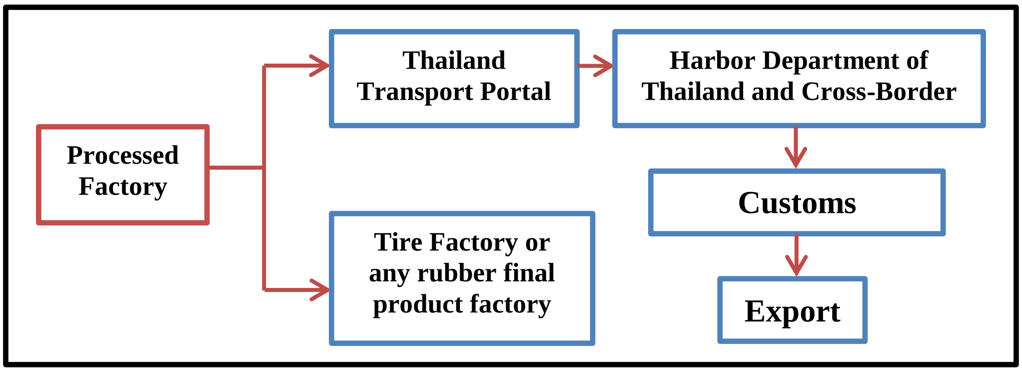

Figure 2-5 Process for Rubber Exportation

Major Problems faced and Opportunities of the Natural Rubber Industry

In the real world of the natural rubber industry, Kritchanchai and Somboonwiwat (2009) have concluded the major problems by collecting from many research including interview from all players in the natural rubber supply chain (Farmers, Collectors, and Processed Rubber Factory). The problems could be separated into 3 groups depend on characteristic of player.

Problems from farmers: The major problem is mostly concern about depressed rubber price. It is quite hard to raise the rubber price to achieve at 80 THB (Thai Bath) from 50 – 60 THB. Another problem is lacking of labor that is not sufficient to do rubber tapping. Because of low benefit that effect to low wage, lot of labor have change their work to be factory worker. Last problem is weather that is uncontrollable factor.

Problems from collectors: There are uncertainties that happened between collector and farmers. If they do not have a strong relationship, it is quite hard for collectors to predict amount of rubber received from farmers and the time when farmers will come as well as number of farmers who are going to send the rubber in the day. In term of factory, sometime there will be competition faced between among of competitors such as cutting price (Auckara-aree, 2010).

Problems from processed rubber factories: The problem faced of processed factory is similar to collectors that they could not predict the amount of rubber receiving and this is going to affect directly to the provided collection center from the factory. Sometimes, the collection center has to deal with high expenditure in fixed cost with small of rubber receiving. Next problem is about future market plan in the future. Due to government policy to support expanding of rubber plantation, 1 million unit area of rubber tree were planted and it is going to be rubber output in the next 10 years. This issue needs to be considered in order to find the market for exporting and releasing the product.

According to the case study, the collection centers are provided which is belonging to the processed compound rubber factory. It could be seen that there are only 2 character in the supply chain which is facing the problems same as the mentioned above. From the processed factory side, the problem occurred is an over expenditure in the number of collection centers. Some collection centers are only cater few number of farmers as well as number of rubber receiving and some are located away from the factory and number of farmers locating which cost too much in term of travelling cost. Therefore, there should be some collection centers to be closed in order to save cost by considering these above issues. For making decision to close some collection centers, Analytical Hierarchy Process (AHP) plays an important role to support decision making method which is describe in 2.2.

At the farmer side, depressed rubber price is still a major problem but they can deal with this situation by the suggestion from Somboonsuk, Wedbundith, and Niyombundith (2012). In order to survive in the depressed rubber price crisis, reducing unnecessary cost is the primary things that farmer can do and many researches also agree that vehicle routing problem (VRP) is the possible way to aid the farmers to save cost which is describe in 2.4

2.2 Analytic hierarchy process (AHP)

Analytic hierarchy process was proposed by Thomas Saaty in the 1970s. The object of AHP is to develop decision making method by building a hierarchy of decision items as criterion and using comparisons between each pair of items. Then, the result of comparison will be drawn up into a matrix. After that, weighting score will be calculated from paired comparison in order to measure how much importance items and criteria have with each other (Alexander, 2012). The whole AHP process is able to describe step by step as following.

1) Identify decision items or element in the decision which consist of 4 parts

- Goal: The started point of problem solution that is the reason of decision making. The goal of making decision should be specific in order to identify criteria easily and directly.
- Factors or Criteria: These criteria should be brain storming from decision makers who concern in the problem. The decision makers need to look the issue widely and consider all factors that could affect to the goal in both tangible and intangible term.
- Attributes or Sub-Criteria: These criteria subdivide from the major criteria above in order to cover all issues that are more sophisticated. The attributes will support the making decision method to be more effective.
- Alternatives: There are choices limited or the selections that are more than one. In this research, the alternatives are given under the current operation of factory in term of facility selection.

To facilitate AHP model, the chart is used to decompose all decision items into a multi-level hierarchy as figure 2-6.

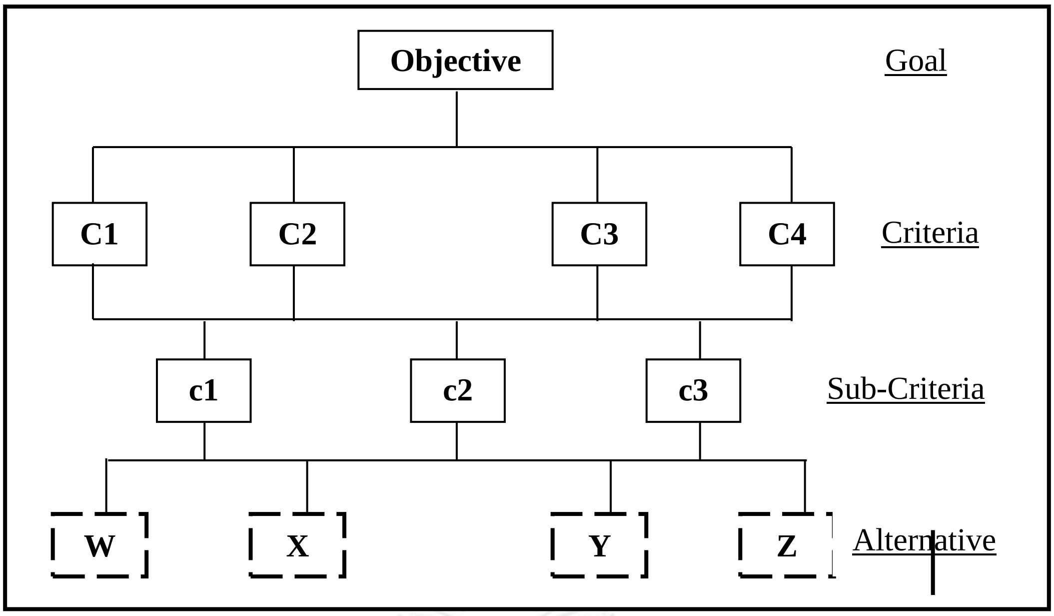

Figure 2-6 Hierarchical Levels in Decision Making

2) Compare criteria and alternatives pair-wise

The criteria employ an underlying scale with scores from 1 to 9. The object is to level the relative preferences for two items as table 3 following.

Level	Importance	Explanation
1	Equal	The equal contribution of two factors to the objective
3	Moderate	Experience and judgment slightly favour one factor over another one
5	Strong	Experience and judgment strongly favour one criterion over another one
7	Very strong	A factor is favoured very strongly over another; its dominance demonstrated in practise
9	Extreme	The evidence favouring one factor over another is of the highest possible of affirmation

Table 2-1 Scale of AHP pair-wise comparison

After that, Pair-wise comparisons in each level will be presented in term of square matrix form. "a_{ij}" of the matrix was used as an element to represent the measures of preference of the criteria in row *i* when compared to the criteria in column *j*.

Criteria C1 C2 ...... C Judgmen

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

tA1
A2
...
^

a_{ij} are the judgments or the relative importance of alternative i over alternative j, and $a_{ij}=1$ for i=j and $a_{ij}=1/a_{ji}$ for $i \neq j$

Then, normalized matrix will be calculated at each row in the level to level, which is able to explain easily by following table 4 below.

Criteria		Judgment				
C1, C2, C3,…, Cn		A1	A2	A3	…	An
Judgment	A1	1	a_{12}	a_{13}	…	a_{1n}
	A2	1/ a_{12}	1	a_{23}	…	a_{2n}
	A3	1/ a_{13}	1/ a_{23}	1	…	a_{3n}
	:	:	:	:	:::	:
	An	1/ a_{1n}	1/ a_{2n}	1/ a_{3n}	…	1

Table 2-2 Matrix table for AHP pair-wise comparison

Following these process, the result will show in term of computing the eigenvector.

3) Checking result consistency

In order to check result of the comparison, the computing was checked to measure that is consistent or not, by using Consistency Ratio (CR) as formula:

Consistency Index (CI): $CI = \frac{\lambda_{\max} - n}{n-1}$

Consistency Ratio (CR): $CR = \frac{CI}{RI}$

Random Index:

N	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1,.11	1.25	1.35	1.40

If consistency ratio is smaller or equal to 0.1, the result is acceptable. In contrary, if the consistency ratio is more than 0.1, the subjective judgments have to be considered to revise again.

4) Calculate overall priorities of alternatives and criteria

The output of this process will show in form of criteria and alternative weight result after the calculation. Then, these weight results will continue using in Linear Programming.

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2.2.1 Simulation Model of Analytical Hierarchy Process (AHP)

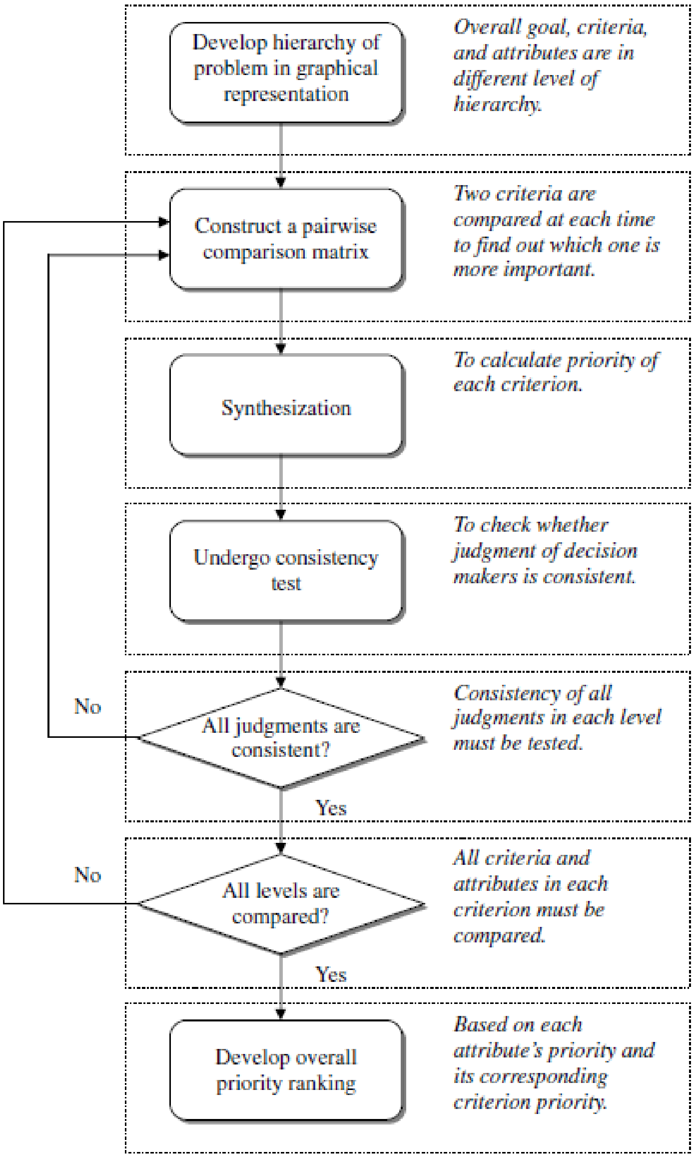

Figure 2-7 The flowchart of the analytic hierarchy process (Ho et al., 2006).

The Analytical Hierarchy Process or AHP is a process that consists of three main and vital operations: hierarchy construction, priority analysis, and consistency verification. As a systematic process, a decision maker must break down all the variety of intricate and complex criteria decision problems. One must simplify it into a number of component parts in order to arrange them in a multiple hierarchical stages. Then, the decision make will do some comparison and differentiation on each stage in order to determine which belongs to the same level based on expertise and experience. To cite an example, if there are two criteria found on the second hierarchical stage or level, they will be compared at the same time according to the existing goal while another two attributes under the same criterion will be compared at the same time in accordance to the corresponding criterion.

As inconsistency is difficult to contain and may occur since judgment is based on experience, expertise and subjective judgment, there is another operation which can guarantee consistency in judgment called consistency verification. This process has been recognized as one of the most effective advantage of AHP. It is being incorporated in the process as it measures the degree of consistency among the pairwise comparisons by computing the consistency ratio. Once found that there is an excess in the consistency ratio limit then a review and possible revision is required in the pairwise comparison.

After finishing the process and once it has been successfully investigated and the result says that all pairwise comparison are proved to be consistent then the judgment can be created to finally set the priority ranking of each criterion and its corresponding attributes. The overall AHP procedure has been shown in Figure 2.2 Once all pairwise comparisons are carried out at every level and are proved to be consistent, the judgments can then be synthesized to find out the priority ranking of each criterion and its attributes. The overall procedure of the AHP is shown in Figure 2-2.

2.3 Linear programming and goal programming for decision making

Linear Programming

In order to have a systematic technique to come up with a decision, "linear programming" will be use. It is a mathematical equation that seeks to find the best use of a certain firm or an entity's restricted and limited resources in order to fulfill a specific set of objectives. It will take into a form as either profit maximization or cost minimization. To cite an example, when a certain manufacturer has limited resources like the plant capacity, then the cost operation and amount of production will based on such capacity. By the use of simple algebraic terms, one can formulate a problem as an approach to finding the solution under linear programming. Every problem will have two aspects; one will be either for cost minimization or profit maximization. Then, the second one is the necessity to identify the production limit

In term of formulating linear programming, the profit function that the manufacturer wishes to increase represents the objective of making the decision on the production quantities and is called "Objective Function". The conditions matching the resource availability and resource requirement are called "Constraints" and the problem variable X and Y are called "Decision Variable" which represent the solution or the output decision from the problem. The problem that has written down in algebraic form represents the mathematical model of the given system and is called "Problem Formulation"

Goal Programming

A goal programing comes hand in hand with linear programming and does have some similarity. It is being used in order to solve any existing linear problem with multiple objectives that are being referred to as a "goal".

To do goal programming, the deviation variables (di+ and di-) which "di+" is the amounts of a targeted goal that "i" is overachieved and "di-" is the amounts of a targeted goal that "i" is underachieved.

The goals are added as the constraint in the programming by setting di+ to show the over constraints of resource limitation and di- + to show the below constraints of resource limitation

The goal programming is also satisfied the various goals in a different priority. The highest priority goal will be focused firstly.

In each priority level, there is the objective function that uses to minimize or maximize the (weighted) sum of the goal deviations.

Goal Programming Approach

Step 1: Decide the precedence of each goal. (Which one is on top, in between and the least priority?)

Step 2: Decide the significance and how important each goal is. Now, if a number of priority goal is more than one, for each goal i represents the weight, wi, use to be placed for each deviation(s) (di + and/or d i -) from the goal.

Step 3: The linear program is set up. Then, new objective (minimize deviations) subject to all functional constraints will be considered as well as Goal Constraints.

Step 4: The current linear program is used.

2.3.1 Linear programming and CPLEX Optimizer

As we have a goal of solving the linear programming stated above, we will be using the CPLEX which is being use today in optimization problem solving. There has been a transformation with linear programming when the CPLEX software became a part of the process for the past 20 years. It is a linear increased in the commercial pioneer in the market written in the C language, and will provide researchers conducted its unparalleled flexibility and performance to be able to create an algorithm optimization, models, and applications. For the starting, the name itself CPLEX is created from the concept of Simplex algorithm, written in C: C-Simplex for CPLEX. In 1947, simplex algorithm was found by George Dantzig which became the basis for all fields of optimization mathematical and practical approach first to solve linear programming.

A linear programming problem is categorized into four parts:

- Decision variables which determined the quantities.
- Objective function to show the decision variables which affect to the minimized or maximized constraints such as cost and any resources limitation.
- Constraints to show the decision variables from the resources limitation, which represent in term of limited quantities
- Data quantifies the relationships which describes in term of the objective function and the constraints.

For linear programming, objective function and constraints are the factors that affect to the decision variables. Moreover, the objective function and constraints are also proportional to its magnitude. While this requirement might seem too strict which the real-world business problems have formulated in this way. This analysis method is strong and effective tool for decision support based on fact.

As an example: if you have been pondering on how you can provide for a certain product of each kind but you need to have a cost minimization then you must decide within a set of limitation or constraints. To make it clear, you have to provide the number of devices that can meet the demand in the market. But you must do it according to your ability to produce products that are free of charge. The figure below shows the linear program that would similar more mathematical term using OPL Languange:

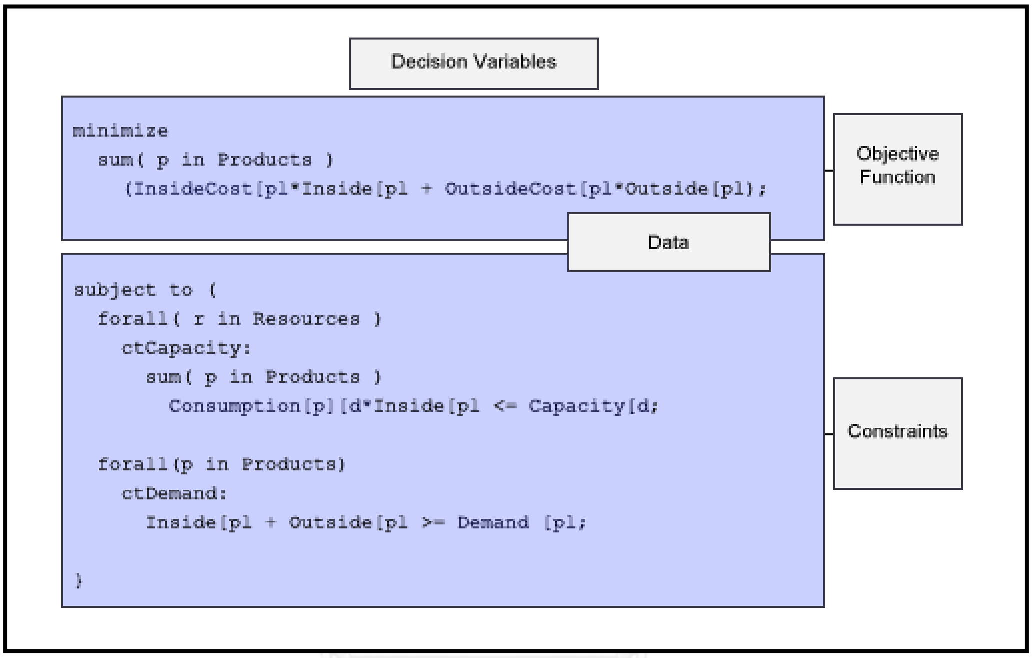

Figure 2-8 Linear Programming in the OPL language
Available from: http://www-01.ibm.com/software/commerce/optimization/linear-programming/

Figure 2-8 is an example of linear program. Manufacturers want to sell their products which are made within the plant and outside. For production inside, the production capacity utilizations are rare and internal costs per unit of production. Acquisitions outside has the higher cost per unit to buy. In the contrast, there is no shortage of capacity and the source of these requirements that need to be satisfied according to minimized cost of the goal.

2.4 Vehicle Routing Problem (VRP)

Vehicle routing problem was introduced firstly by Golden et al. (1977). The vehicle routing problem is the way of designing the optimal set of routes for a fleet of vehicles in order to serve a given set of customers (Wen, 2010). Chuin Lau , Melvyn Sim, and Meng Teo (2003) have mentioned the objective of vehicle routing problem that is to minimize cost on vehicle routes plan delivering a set of customers with known demands. Each customer will be assigned to one vehicle route and the total demand of any route will not exceed the defined vehicle capacity.

The vehicle routing problem is able to start from identifying a number of vehicles and identical capacity for each vehicle. Next, it is looking for a depot where the vehicle routes is originating and terminating and a number of customers who are located in a different location.

In term of customer, the location and a certain demand have to be known in order to limit the capacity and able to manage delivering from one customer to others. When considering the vehicles, each vehicle has to visit a number of customers one by one which is started and finished at the depot and one customer is visited one time only by one vehicle. Lastly, the total demand of any route cannot exceed the capacity of the vehicle. This process will minimize the overall distance by decreasing number of routes and vehicles which affect to the lowing cost. In term of vehicle routing use, the place that vehicle start and end is called “depot” and number of customer that the vehicle have visited is call “Node”.

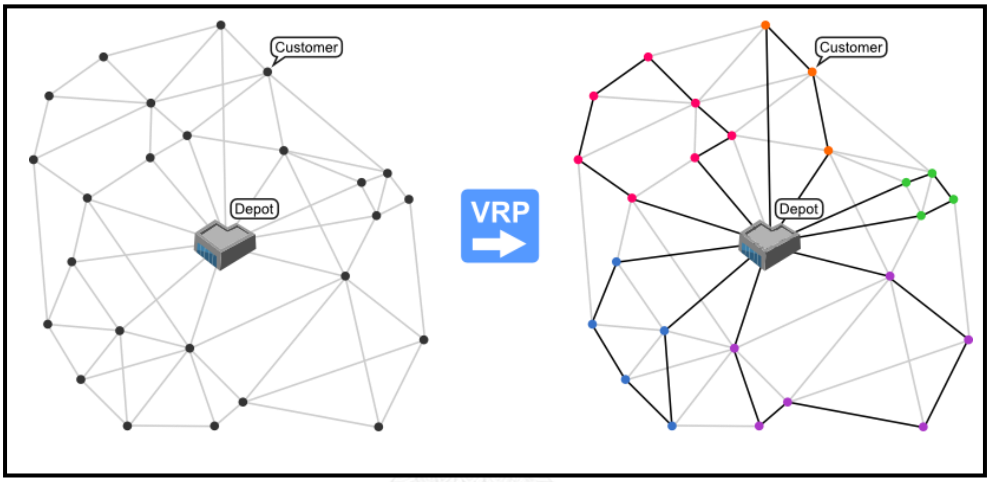

Figure 2-9 Vehicle Routing Plan

In order to solve the vehicle routing problem (VRP), there are two solutions that many research have utilized as the following:

Exact Approach

This solution is to find any possible way to solve the problem until the best solution is founded out. In addition, Vehicle Routing Problem (VRP) refers to a linear programming which main goal is to attain the finest result (make the most of profit or minimalize cost) in a scientific model. In case of a large problem, the exact approach method has taken a lot of time to solve in order to find the best result. Therefore, this method is suitable to solve a small problem and the large problem will use heuristic to solve which is described below.

Heuristic

Heuristic is whichever method to solving problem or a rule that delivers a shortcut to answering tough and any huge problems. The solution of heuristic might not be the best result it is able to solve problem faster or easier. Although the result of heuristic solution is not the best answer, but it is acceptable and is not obviously different from the best solution. In order to solve the problem with heuristic, there are many possible ways to do based on how difficult the problems. In the case of a large problem, 2 methods are suggested as in 2.4.1 and 2.4.2.

2.4.1 Cluster-First Route Second

The routing is started by determining the group of customers or node where the vehicles travel to. Then, prioritizing the shipping of the route map must follow. For instance, Tupdara and Sawetseranee (2010) have planned the waste collection system in Bangkok by dividing the area of Bangkok into 50 zones. Every area is accountable for gathering all produced rubbishes in the zone. With this waste collection scheme plan, every vehicle/truck is being allocated to a certain cluster group of waste collection point. The itinerary of the vehicle/truck will begin from the parking place then proceed to all the assigned waste collection points and then to the waste transfer stations, are being generated.

2.4.2 Rout-First Cluster-Second

It is started by studying the route map first by searching for the customer located place and finding a route between each customer. Then, all customers are separated into several sub-route due to considered capacity of vehicle and time window.

In this case study and according to figure 2-5, route first-cluster second is applied by studying the map of Bethong city firstly in order to see where the place of farmer located. Then, the capacity of vehicle is determine as well as time window to specific a number of customer in each route (Clustering) and following with their scheduling to pick up the raw-material. In the process of clustering and scheduling is going to use optimization and integer programming problem seeking number of customer that is called "Vehicle Routing Problem (VRP).

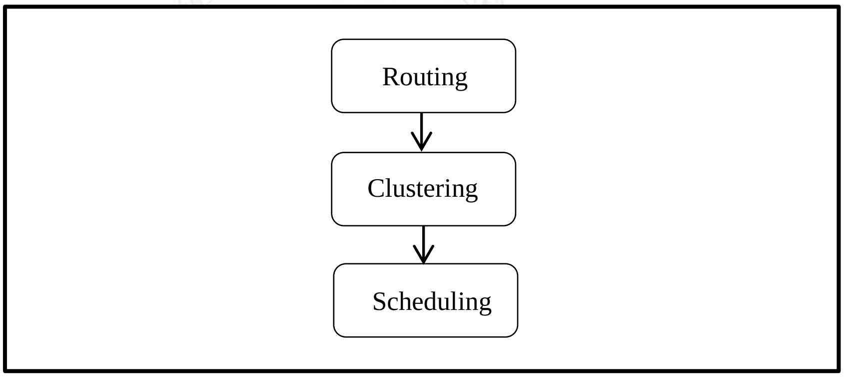

Figure 2-10 Decision Making in Vehicle Routing Problem

2.4.3 Simulation Model

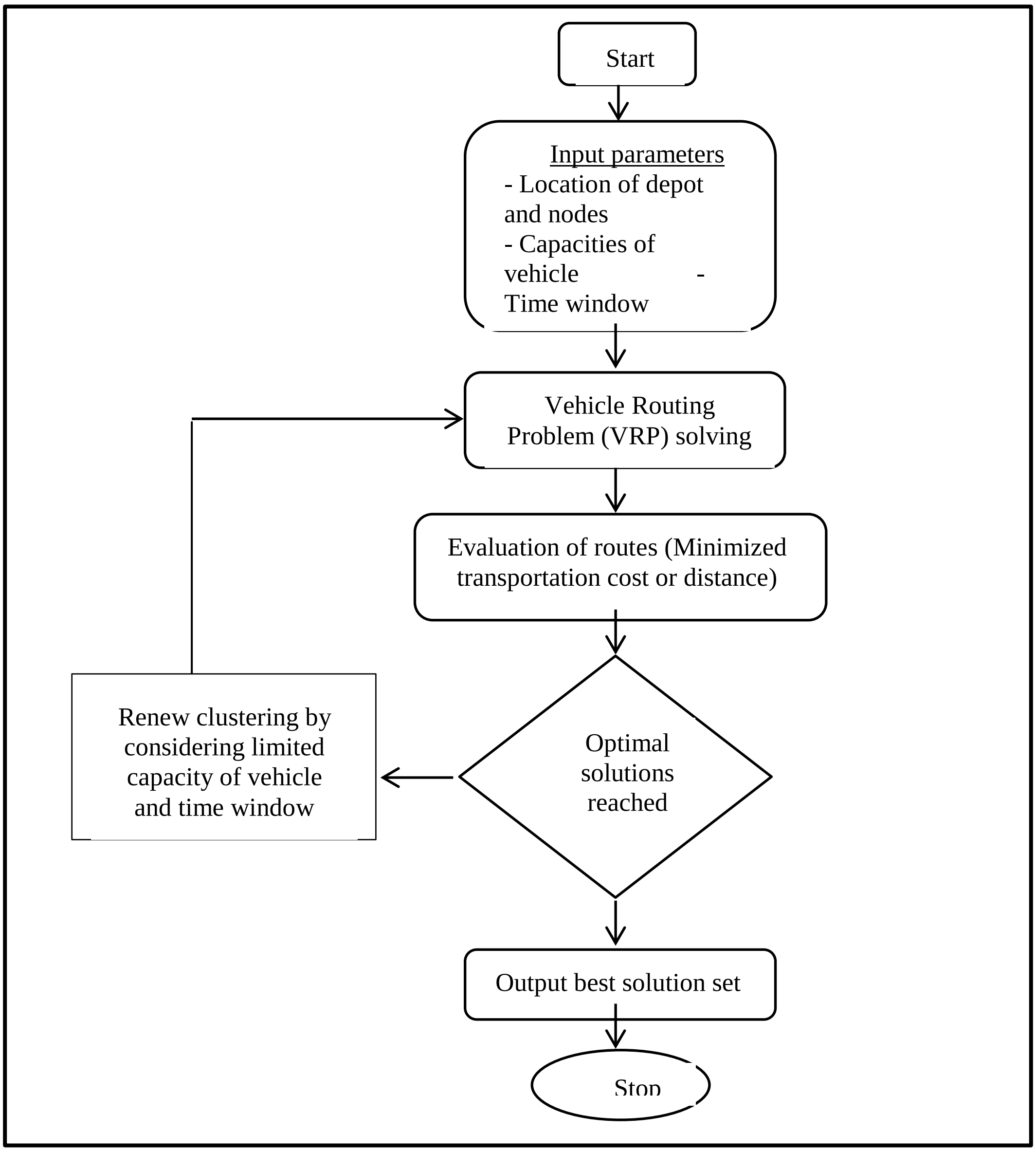

Figure 2-11 The flow chart of the vehicle routing problem (VRP)

After the routing process, next is the clustering and scheduling that are enabled by applying the Vehicle Routing Problem (VRP). When the nodes have already been divided into the zone, vehicle capacities and time window are used to do a clustering of group node in which one vehicle will take one group and one route under time window controlling it. After that, number of routes is then evaluated in order to achieve the output of minimized transportation cost or distance through optimized programming which then gives the result of the best output of node set.

2.5 Literature Review

In Thai natural rubber industry, {Auckara-aree, 2010 #1}has studied the raw-material collection system and found out the way to maximize profit in the collection system by establish new system as following. 1) Location allocation: To design opened-closed collection station by considering potential set of suppliers who are able to provide profit for the system. Then, the selected collection stations will continue operating. 2) Routing Improvement: To construct routes from the selected collection stations by using milk run and considering time duration and vehicle capacity constraints. 3) Suppliers screening: To select the possible suppliers in the rout who have more rubber quantity to be collected which affect to maximized profit when step-price policy of rubber are considered (If the total collected quantity of rubber is more, the prices of selling rubber will be higher following the specific step-price policy). Therefore, the more suppliers visit will affect to more income receive, but there will be longer travelling distance which affect to higher transportation cost also.

For the solution, Mixed Integer Programming for a location routing with step–price policy model were formulated. The computational results were indicated the appropriate number of potential collection stations as well as the routing, including number of possible suppliers in each rout in order to maximize profit of the collection system.

2.5.1 Analytical Hierarchy Process (AHP) – Goal Programming (GP) Model

In term of Location selection, AHP-GP model is common use as a tool or technique to make decision effectively and be able to solve complex problems with multiple criteria decision. There are lot of researches which uses GP and LP minimize something and maximize something.. There are a lot of researches that utilize AHP-GP model. First, Ping Ho, Ter Chang, and Yuan Ku (2011) have utilized AHP and multi-choice goal programming (MCGP) to select house for rent from many locations in order to open a coffee. The identified criteria consisted of cost and size, transportation, commercial area, and environment. For alternatives, there were 10 candidate locations and then, criteria and alternatives were compared with the pair-wise and resulted to overall priorities of alternatives and criteria in form of weight scores. After that, goals of location were desired as following.

Goal 1: Min rent cost
Goal 2: Max lot size
Goal 3: Max public transportation
Goal 4: Max parking capacity
Goal 5: Max pedestrian volume
Goal 6: Max size of commercial area
Goal 7: Max extent of public facilities
Goal 8: Min number of competitors
Goal 9: Max landscaping
Goal 10: Max safety

Finally, the alternatives were evaluated to find the optimum place for a coffee shop.

Another research belongs to A. Badri (1998) that intended to make Strategic global facility location-allocation decisions by using AHP-GP model. This research purposed to select the best locations for setting distribution centers oversea which consist of 6 countries (United Arab Emirates, Saudi Arabia, Bahrain, Kuwait, Qatar, and Oman). The criteria were under the condition in political situation of foreign county, global competition and survival, government regulations, and economic related factors. Then, the researcher continued finding location with goal programming by using the weight result from AHP process as the input data in the program. In this goal programming, there were specific goals in minimized fixed cost and unit transportation cost to distribution centers, and maximized production. The result of program was showed as following.

Location alternative	The combined model selection decision ($\boldsymbol{X_j}$)	AHP-only selection decision ($\boldsymbol{W_i^{location}}$)
UAE	Yes (X1=1)	(W1=0.459)
KSA	Yes (X2=1)	(W2=0.158)
BAH	No (X3=0)	(W3=0.033)
KUW	No (X4=0)	(W4=0.200)
QAT	Yes (X5=1)	(W5=0.075)
OMN	Yes (X6=1)	(W6=0.76)

Table 2-3 the AHP-GP model solution and AHP weight solution

Therefore, the United Arab Emirates, Saudi Arabia, Qatar, and Oman were selected to be distribution centers.

2.5.2 Vehicle Routing Problem (VRP)

In the research of vehicle routing problem, Sommut and Sinthuchao (2014) have utilized the VRP to solve the problem about long distance travel by minimizing the total length under the constraint in uncertain demand of customer and limited capacity of vehicle. In order to solve the problem, a Greedy Randomized Adaptive Search Procedure (GRASP) was applied as a heuristic which consists of two phase. The first phase is the initial solution phase which determines the feasible solution. Then, the second phase is to improve a quality of solution using 2-opt, Swap operator and Move exchanges. From the numerical experiment , they found that the heuristic method provide the good solution which can reduce the distance from 154.8 kilometers per day to 120.5 kilometers per day, or approximately 19.25% of distance reduction. Srisuwandee and Pitakaso(2012) have studied the transportation management in the case of Jiaranai drinking water company amphur Warinchamrap Ubonratchathani province. They proposed the algorithm which using the application of Ant Colony Optimization (ACO) and improved the solution using Crossover-Move, 2-Opt, and One-Move heuristics to solve vehicle routing problem (VRP) in this case. They assumed that capacity of vehicle is limited and each customer has uncertain demand. Their experimental results compared to the current vehicle routes show that the proposed ACO with Crossover- Move, 2-Opt, and One-Move heuristics provided good solutions. The total distance could be reduced from 584.25 kilometers to 441.35 kilometers or decreased by 24.46%.

2.6 Method Assumptions

In this research, the critical problem that is surrounding to the factory was focused first. It is a high operation cost in rubber milk collection which the factory needs to close down some collection centres. Then, the group of farmers who used to supply the rubber in the closed collection centres have to be considered next in order to support them a vehicle routing. This is going to be a choice for farmers instead of moving to another collection centres or changing to supply another factory. Therefore, the research' assumptions are categorized into two parts as following.

- Opened-closed collection centers
- Vehicle routing problem

To be a guideline to solve the problem of cost reduction, there is a conceptual idea bellowed to show the process of problem solving.

Stage 1: The decision of closing down some collection centres is started when high operation cost problem in rubber collection activities is faced.

Stage 2: It is a decision process to make criterion for judgment and priority about which collection centre that is supposed to close down first until the last centre. This is called "Analytical Hierarchy Process (AHP)"

Stage 3: It is the process to find the optimum number of collection centre by solving with Linear Programing (LP) under the condition of limited resources and achieved the target cost.

Stage 4: The optimum number of collection centres is shown. The result is divided into 2 groups; opened collection centre and closed collection centre.

Stage 5: In the case of opened collection centre, the collection activity is still continued but there will be group of farmers who have no place to supply in the case of closed collection centres.

Stage 6: "Vehicle Routing Problem (VRP)" is applied in the group of farmer that mention in stage 5 in order to keep number of rubber supplied reduce number of vehicle, make the collected rubber transportation are more efficiency, and reduce transportation cost at the farmer side.

Stage 7: The cost reductions are calculated; there are reduced cost from closing down some collection centres and reduced number of vehicle that use to transport the rubber.

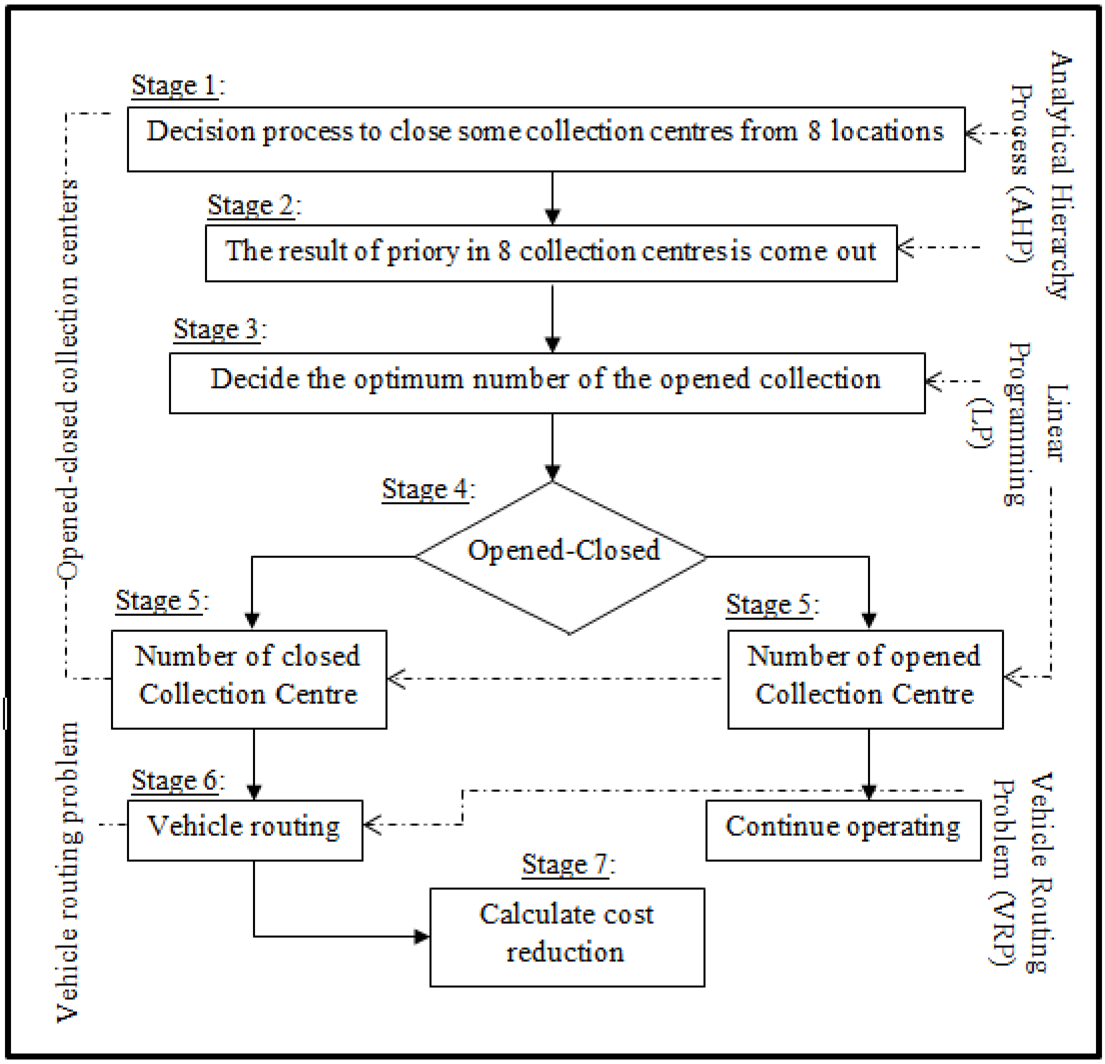

Figure 2-12 Conceptual idea of the research's assumptions

. After that, the numbers of closed collection centres are canceled and the number of suppliers who support these collection centres would deal with vehicle routing problem (VRP).

After that, the last method that responds to the objective is the VRP. There would be routing first to study the road map of the located suppliers. Then, the group of suppliers would be separated into 3 zones which is being cluster by direction and main road. Finally, the vehicle routing problem would be solved by the optimization program (IBM ILOG CPLEX Optimization). The result would show the scheduling of rubber picking up within constrains of vehicle's capacity and time window. In order to be illustrated, there was the linked line of vehicle traveling in displacement form that shows in the graphs and the linked line of vehicle traveling in the reality road that shows in the aerial photographs as well as distance measurement along the road. All of these would be presented as the following chapter.

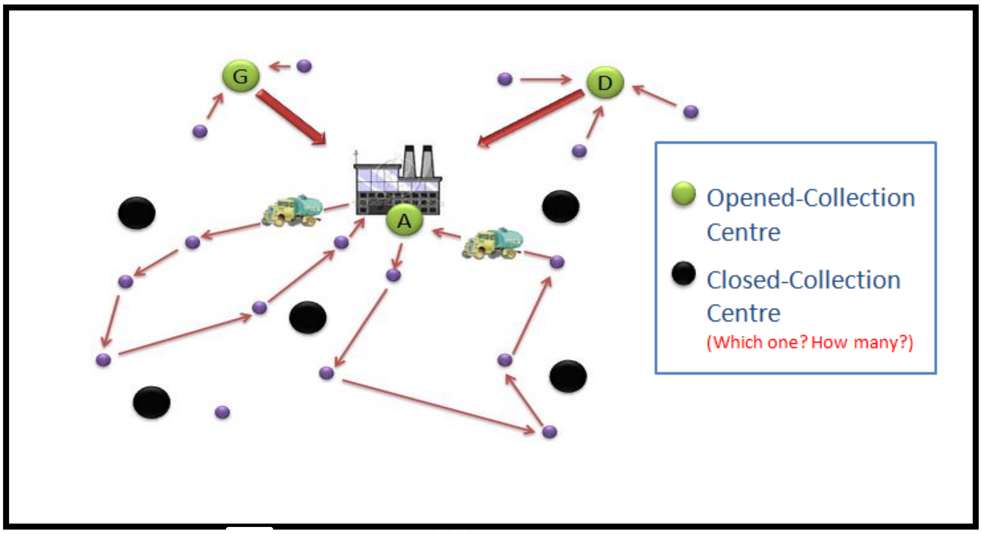

Figure 2-13 Opened-Closed Collection Centers and Vehicle Routing

In conclusion, the research would use vehicle routing that can be combined in to the collection system with AHP and LP model. The new system could view in location planning and transport planning as well that takes into account of reducing cost as figure 2-13.

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CHAPTER 3 DECISION PROCESS OF OPENED – CLOSED COLLECTION CENTRES TO REDUCE COST

According to Chapter 2, the mentioned Analytical Hierarchy Process (AHP) is applied to decide the closing some collection centres. The reason for using AHP because it is fair results that come from to the group brainstorming and it is not too difficult for both farmers and staff in the factory including the executive. This method makes everyone give an opinion to share experiences, exchange information effectively. The method encourages everyone to talk in depth up to the point and make an evaluation by representing in term of score. Finally, the result would come out in the weight priority as number that can make the decision easily.

Analytical Hierarchy Process (AHP) will be presented which is started from weight priority of criterion, weight priority of sub-criterion, and weight priority in alternatives by considering in each sub-criterion. After finished doing these, the result of weight priority in the sub-criterion such as the amount of rubber being received and the operation costs (inbound cost, outbound cost, and fixed cost) would continue use in the linear programming (LP) in order to solve optimum number of the collection centre that should continue operating. In addition, the result of weight priority in the alternatives in every sub-criterion would be overall summary to show the potential priority rank which collection centre is the first should be continued operating and which centre should be closed firstly.

When those results already showed, there would be comparison between the overall priority ranked of alternatives from the AHP and the result of the optimum number of opened collection centre from the LP to show the concordance. Moreover, the LP result is able to show the result of the limited resources that are restricted.

To begin the process, it is started from interviews with authorities in order to collect all relevant information and set criterion for judgment. Then, it follows with the method of AHP model and LP model as following stage.

3.1 Analytical Hierarchy Process (AHP)

Stage 1: All factors that could effect to high operation cost and inconvenient in rubber collection activity are considered.

Stage 2: Hierarchical structure is formed under the goal of cost reduction and decision of closing down some collection centres to achieve the goal.

Stage 3: It is the first pair-wise comparison of criteria to goal. The criteria that were identified in the stage 1 will do priority weights vector. It is estimated by using the eigenvalue method. These will show which criteria is the most and less important by presenting in priority weight percentage. Then, there will be the consistency of the judgments to check the result of the priority weight.

Stage 4: Second pair-wise comparison is sub-criteria to criteria that were also mentioned in the stage 1. It will be priority weight vector between sub-criteria in each criteria and it will be estimated by using the eigenvalue method same as stage 3. These will result the percentage of priority weight of the sub-criteria in such criteria as well as the consistency checking.

Stage 5: Third pair-wise comparison is sub-criteria to alternative. There are 8 collection centres as alternative to decide which one is appropriate to continue or close. It is the same process as stage 3 and 4 to do priority weight vector and the result will be presented by the priority weight percentage including the consistency checked.

Stage 6: After the result of priority weight percentage was shown in stage 5, it is able to do the priority ranking which collection centre that is a low priority weight is supposed to close first and the last collection centres who have a high priority weight is supposed to continue operating.

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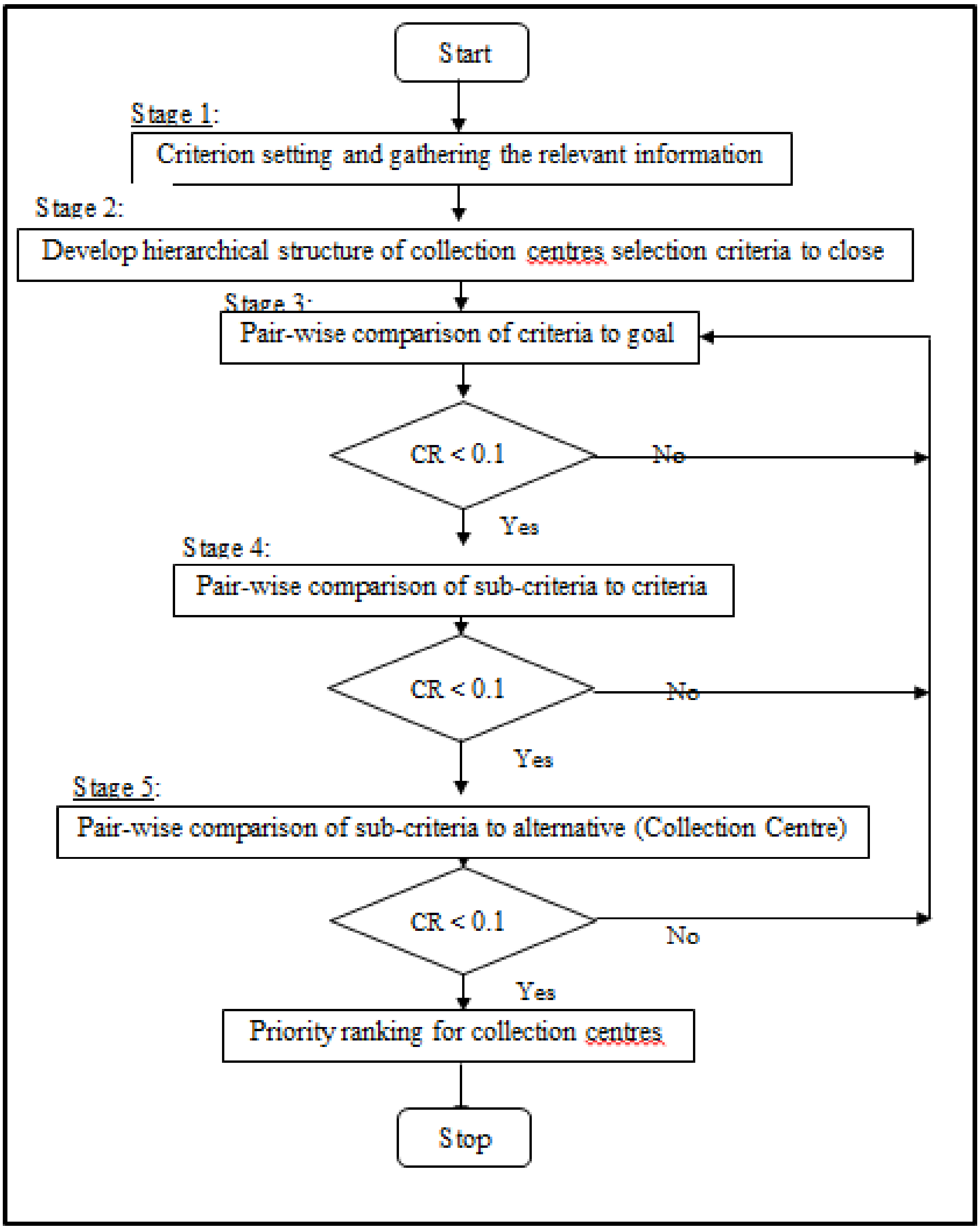

Figure 3-1 Flow chart to make decision by applied Analytical Hierarchy Process (AHP)

3.1.1 Criterion setting and gathering the relevant information of rubber milk collection

Before starting the gathering information, it is important to focus on the factors which are able to affect the rubber collection system in order to identify criterions of opened-closed collection centres. In addition, considering the factors, identifying criterions, and making decision require brainstorming from both side farmers and entrepreneur to make the accurate decision and make sure for both benefits. Apart for the brainstorming, there were 6 concerns who are representative of both farmers and the factory as table 3-1 below.

Position	**Population (people)**	**Experience (year)**
Factory side:		
Chief Executive Officer	1	30
Manager of the board	2	30
Suppliers side:		
Farmers	2	30
Middle man side:		
Specialist (Home Economics Officer)	1	20

Table 3-1 the committees who concern for decision making

Apart from the committee conference, all factors that use to be the criterions in order to make the decision of closing some collection centres are described and there are data collected as following.

Factors / Centres	A	B	C	D	E	F	G	H
Total Length (km)	228.75	27.97	66.12	55.73	109.09	63.3	53.28	16.38
Closeness to the factory (km)	0	6.64	4.2	4.48	6.12	5.88	14.27	2.97
Closeness to the number of planters (km)	228.75	21.33	61.92	51.25	102.97	57.42	39.01	13.41
Number of members	57	7	26	16	17	21	11	8
Amount of Raw-material (kg/month)	22,696	4,736	9,233	6,918	8,984	7,772	5,093	3,301
Inbound Logistic Cost (THB)	59,452	5,543.6	16,093	13,319.8	2,676.1	14,923.4	10,138	3,485
Outbound Logistic Cost (THB)	0	5,390.9	7,629.2	6,155.9	8,093.3	7,194.3	8,145.8	3,211
Fixed Cost (THB)	43,500	17,500	27,500	24,500	27.500	26,000	27,000	17,000

Table 3-2 Historical data from the factors or criterion setting

Location of the collection centres

The reason to locate the collection centre to close the source of materials, factory, and labor is to save cost and time for transportation. Therefore, it can be seen clearly when scale of importance was set as scale to see how many kilometers distance is far and how many kilometers is near. Then, the committees would use this scale in order to score in the process of AHP.

Scale of importance in the collection centre location

Considered Factor	Importance				
	Very High	High	Medium	Low	Very Low
Location of the collection centres					
Close to the factory	Below 2.8 km	2.8 – 5.6 km	5.6 – 8.4 km	8.4 – 14 km	Above 14 km
Close to the number of suppliers (farmers)	Below 40 km	40 – 80 km	80 – 160 km	160 – 200 km	Above 200 km

Table 3-3 Scale of importance in the collection centre location

According to collecting data of the location for all suppliers, collection centres, and the factory as well as distance between each other's, the program ArcGIS 10.1 was used to manage the geographical information to see what the position of suppliers to supply the rubber to their collection centres and what position of collection centres to continue rubber transportation to the factory including of measuring distance between the place

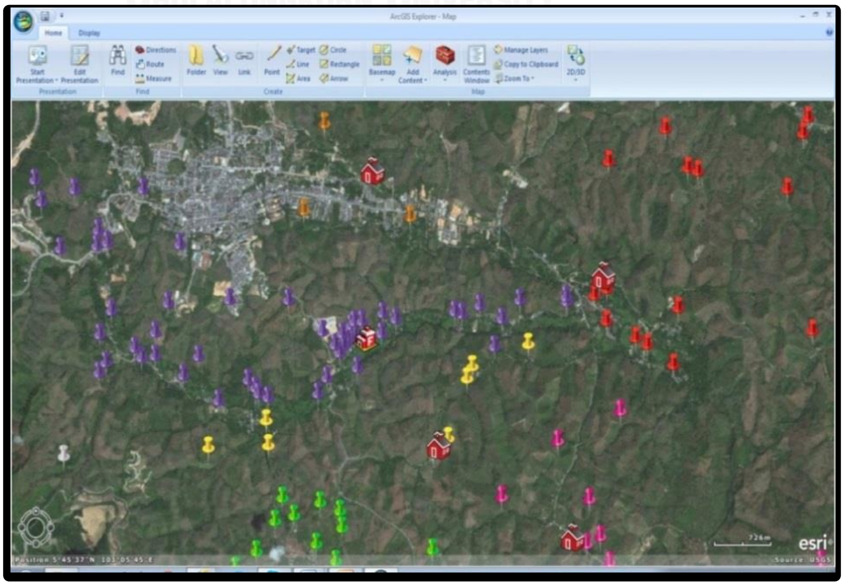

Figure 3-2 ArcGIS 10.1 for Desktop

In addition, mapping the location of suppliers, collection centres, as well as the factory would be stick by pins along the street for transportation at the place where suppliers or farmers use to start for rubber milk transportation, the place that collection center staying to collect rubber milk, and the place that the factory is located. All information of distance between group of suppliers and their collection centres, collection centres and the factory are shown in Appendix A.

Operation cost

<u>Scale of importance in the operation cost</u>

Considered Factor	Importance				
	Very High	High	Medium	Low	Very Low
Inbound Cost	Below 4,000 THB Per month	4,000 – 8,000 THB Per month	8,000 – 12,000 THB Per month	12,000 – 16,000 THB Per month	Above 16,000 THB Per month
Outbound Cost	Below 8,000 THB Per month	8,000 – 16,000 THB Per month	16,000 – 24,000 THB Per month	24,000 – 32,000 THB Per month	Above 32,000 THB Per month
Fixed Cost	Below 10,000 THB Per month	10,000 – 20,000 THB Per month	20,000 – 30,000 THB Per month	30,000 – 40,000 THB Per month	Above 40,000 THB Per month

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Table 3-4 Scale of importance in the operation cost

In order to calculate operation cost, it could be separated into 3 sections which are different of responsibilities in cost and transportation as figure following.

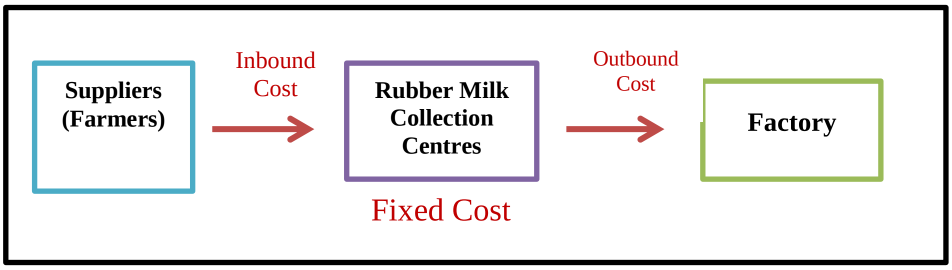

Figure 3-3 Operation cost in rubber milk collection system

- Inbound cost: The farmers would transport the rubber milk from their place to the collection centres which are provided in each area by their own vehicle like motorcycle and the containers that use to contain rubber milk are gallons as the figures below.

Figure 3-4 Operation cost in rubber milk collection system

In general, the limited capacity for transportation by motorcycle is about 100 kilogram (kg) and farmers are able to transport their rubber individually. Therefore, it would be the cost in term of fuel use for round trip and depreciation that take responsibility by farmers as following.

Fuel use: Gasohol 91 is used for the motorcycle which charges 31.18 Bath (THB) per liter (1 liter can run approximately 6.5 km).

Depreciation: It could be calculated as the table 3-3 below.

Equipment	**Depreciation Price**
Wheels	0.44 THB/km
Motor oil/Engine oil	0.23 THB/km
Brake	0.1 THB/km
Battery	0.08 THB/km

Table 3-5 Depreciation cost for motorcycle (available from: http://www.dxplace.com/calc/cost#edit-accs-cost-detail)

Thus, the inbound cost is calculated in monthly rate by counting from 2 times of vehicle scheduling per day, round trip, and 23 days in one month which is shown in Appendix A.

- Outbound cost

After collecting rubber milk, some of chemical (ammonia) is added in order to keep the latex or fluid condition of rubber milk from coagulation before transporting to the factory. Apart from ammonia addition, the amount of ammonia would not affect the total weight of the amount of rubber receiving. In term of transportation, the cars as figure 3-4 below from the factory are run to pick up the rubber from each collection centres with the limited capacity for transportation is about 600 kilogram (kg).

.

Figure 3-5 Vehicles (cars) from the factory to pick up rubber milk

To calculate the outbound cost, it would be price paid for transportation wage about 0.5 THB/kg/km. There also would be the cost of fuel use for round trip and depreciation same as the motorcycle as following.

Fuel use: Diesel is used for the vehicles (4 wheel cars) which charges 28.39 Bath (THB) per liter (1 liter can run approximately 7 km for the empty car and 5.5 km for trucking rubber).

Depreciation: It could be calculated as the table 3-4 below.

Equipment	**Depreciation Price**
Wheels	0.44 THB/km
Motor oil/Engine oil	0.23 THB/km
Brake	0.1 THB/km
Battery	0.08 THB/km

Table 3-6 Depreciation cost for 4 wheels car
(available from: http://www.dxplace.com/calc/cost#edit-accs-cost-detail)

Thus, the inbound cost is calculated in monthly rate by counting from 2 times of 4 wheels vehicle scheduling per day, round trip, and 23 days in one month as same as inbound cost which is shown in Appendix A.

- Fixed cost

The fixed cost is the responsibility of the factory in order to deal with the cost that operates in the rubber milk collection centres which consist of.

→ Ground rental fee
→ Equipment used at the rubber collection centres and Depreciation
→ Expenses such as electricity and public utility
→ Staff salaries/ Wages

Number of suppliers (farmers)

Scale of importance in the number of suppliers

Considered Factor	Importance				
	Very High	High	Medium	Low	Very Low
Number of suppliers (farmers)	Above 40	25 – 40	15 – 25	8 – 15	Below 8

Table 3-7 Scale of importance in the number of suppliers

In each collection centre, there are number of farmer who supplies the rubber milk as a member in order to continue to the production at the factory. A large number of farmers cannot guarantee to large number of the rubber milk output because it depends on number of rubber trees in each farm. Actually, increasing number of farmer means the higher transportation cost as well but it could not affect to farmer due to shared payment. On the other hand, it affect directly to the entrepreneur in term of competitive advantage. The large number of farmer can be benefit to have more production than competitor. If the competitor can gain more rubber milk, there will be more processed rubber which uses to bargain power in order to get the higher sell price when the large amount of the rubber was sold.

Amount of rubber being received

Scale of importance in amount of rubber being received

Considered Factor	Importance				
	Very High	High	Medium	Low	Very Low
Amount of rubber receiving (Monthly)	Above 10,000 kg	8,000 – 10,000 kg	5,000 – 8,000 kg	3,000 – 5,000 kg	Below 3,000 kg

Table 3-8 Scale of importance in amount of rubber being received

Amount of rubber being received is uncontrollable factor due to the weather and seasons. In this case study, the collected data of rubber being received is in the period of April – August (2014) that is during between dry and spring season to started rubber tapping season again after refreshing. The collected rubber milk is considered in term of monthly receiving in order to be the same as cost that is estimated to be a monthly payment and it is convenient to make a criterion with the same standard of monthly consideration. In addition, the amount of rubber being received is an important factor that concerns to generate income of factory because it is used as raw material to do in processed rubber. Therefore, the factory purpose to collect the rubber as much as they can in order to get high amount of processed rubber.

Environment Factors

This factor is in term of qualitative information that uses to be a criterion and it is surveyed from farmers and entrepreneur interviewed. The qualitative information use to analyze in term of logical thinking. It supports the stronger decision of closing the over expenditure in some collection centres. The environment can divided into 2 issues.

Scale of importance in environment factors

Considered Factor	Importance				
	Very High	High	Medium	Low	Very Low
Environment Factors Facilities Acceptable condition for society	Strongly impact	Highly impact	Normal impact	Lowly impact	Lightly impact

Table 3-9 Scale of importance in environment factors

● Facilities

The environment around the located of collection centres are considered such as road quality, closing to the main street, and convenience to travel in and out.

● Acceptable condition for society

It concerns about satisfaction of the farmers to the location of collection centre. For example, is it located near community place like school or hospital or not because it might be annoy when number of vehicle is taken.

3.1.2 Develop hierarchical structure of collection centres selection

To form the hierarchical structure, a complicated decision problem is showed which can be decomposed into several hierarchies according to the related criteria or factor. There are 3 levels of AHP hierarchical structure to show the relationship of the goal, the criteria, and the alternatives from the top to the bottom, corresponding to the first level, second level and third level as show below.

First Level

Goal: To close down some collection centres which are the cause of over expenditure in the rubber collection

Second Level

Criteria 1 (C1): Location of the collection centres
Sub-Criteria 1 (C1-1): Close to the factory
Sub-Criteria 1 (C1-2): Close to the number of suppliers (farmers)

Criteria 2 (C2): Operation Costs
Sub-Criteria 2 (C2-1): Inbound Cost
Sub-Criteria 2 (C2-2): Outbound Cost
Sub-Criteria 2 (C2-3): Fixed Cost

Criteria 3 (C3): Amount of rubber being received

Criteria 4 (C4): Number of suppliers (farmers)

Criteria 5 (C5): Environment
Sub-Criteria 5 (C5-1): Facilities
Sub-Criteria 5 (C5-2): Acceptable condition for society

Third Level

Alternatives: There are 8 collection centres {centre A, B, C, D, E, F, G, and H} which are located in different place.

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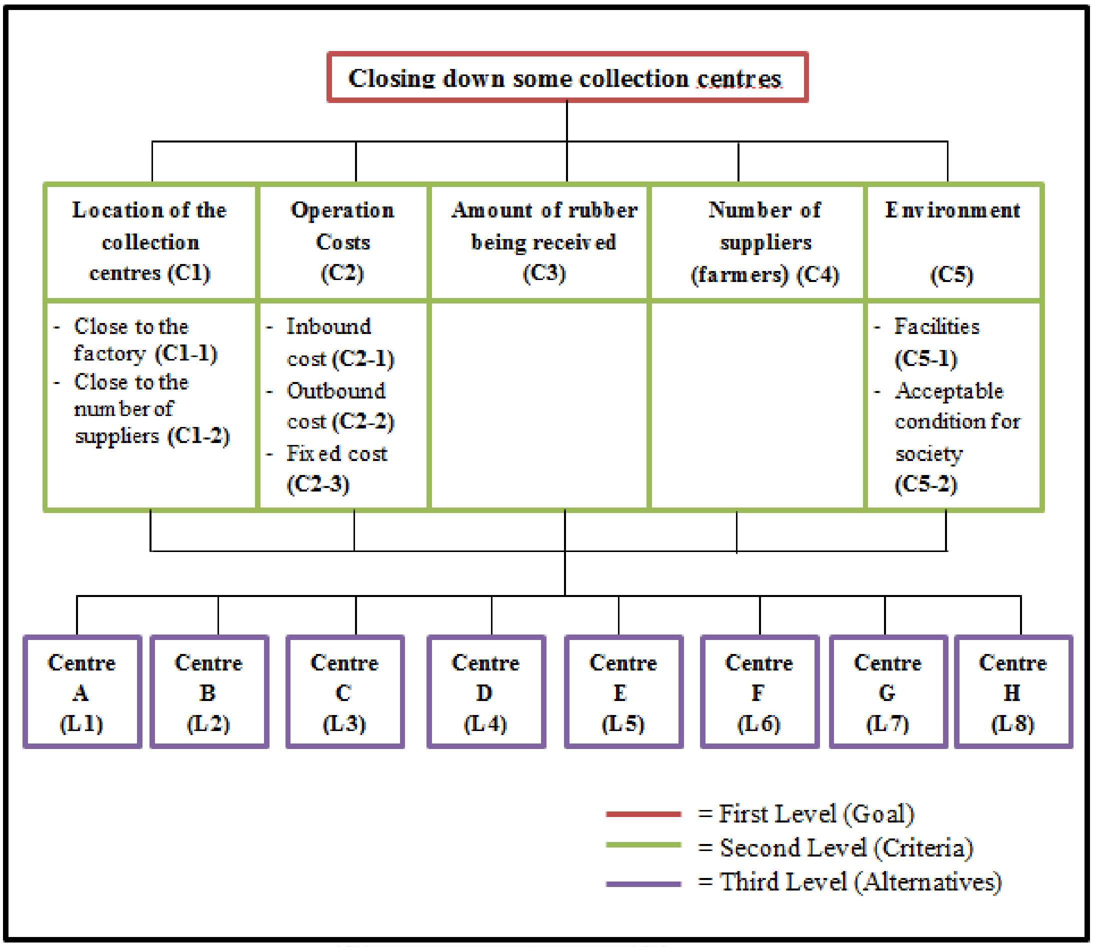

Figure 3-6 the hierarchical structure of collection centres selection

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3.1.3 Score and Scale of Criteria Pair-Wise Comparison

According to figure 3-2, this section is in stage 3 and 4. This is the process to do pair-wise comparison for all criteria in order to see priority weight of each one. All collected information that is shown in Appendix A will used to analyze for decision making process followed the AHP. In order to level the relative preferences for two items (criteria pair-wise), there are various scale to do score in the pair-wise process together with consideration in scale of importance in each criteria that mentioned in 3.2.1 while we are scoring.

Scale of AHP pairwise comparison

Level	Importance	Explanation
1	Equal	The equal contribution of two criteria to the goal
3	Moderate	Experience and judgment slightly favour one criteria over another one
5	Strong	Experience and judgment strongly favour one criterion over another one

7	Very strong	A criteria is favoured very strongly over another; its dominance demonstrated in practise
9	Extreme	The evidence favouring one criteria over another is of the highest possible of affirmation

Table 3-10 Scale of AHP pair-wise comparison

Another Table is to show the pair-wise comparison at the table below.

Criteria 1 (C1)									**Criteria 2 (C2)**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extreme Importance ⟵ Equal Comparison ⟶ Extreme Importance																

Table 3-11 Form for doing scale of AHP pair-wise comparison

<u>Scoring in importance of criteria pair wise comparison</u>

According to 3.2, there were various committees who concern for decision making. Each committee can scale pair-wise comparison criteria to goal with the different aspect. Then, the scoring of 7 judges will be average and continued use in the next step of decision matrix.

Criteria Pairwise Comparison	**More Important**	**Judge 1 Scoring**	**Judge 2 Scoring**	**Judge 3 Scoring**	**Judge 4 Scoring**	**Judge 5 Scoring**	**Judge 6 Scoring**	**Average Scoring**
C1 and C2	C2	5	5	7	5	5	5	5
C1 and C3	C3	9	7	9	9	7	7	8
C1 and C4	C4	3	3	3	1	1	3	2
C1 and C5	C1	5	3	5	5	5	3	4
C2 and C3	C3	5	5	3	7	3	3	4
C2 and C4	C2	3	3	3	1	1	3	2
C2 and C5	C2	9	9	7	9	7	9	8
C3 and C4	C3	7	7	7	7	7	7	7
C3and C5	C3	9	9	9	9	9	9	9
C4 and C5	C4	7	7	5	7	9	9	7

Table 3-12 Score of AHP pair-wise comparison of criteria to goal

At the table 3-8, it can be seen clearly that the scale from the judges various with their own point of view. For instance, there is the information from the interview about criteria pair-wise comparison between C1 (Location of the collection centres) and C2 (Operation cost) explain that C2 are strong importance than C1 (Average scoring is 5). Because of C2 that is criteria of operation cost is more direct to the goal of cost reduction in this analytical hierarchy process.

Decision Matrix:

Criteria	C1	C2	C3	C4	C5
C1	1	0.20	0.12	0.50	4.00
C2	5.00	1	0.25	2.00	8.00
C3	8.00	4.00	1	7.00	9.00
C4	2.00	0.50	0.14	1	7.00
C5	0.25	0.12	0.11	0.14	1

Table 3-13 Score of AHP pair-wise comparison in the table of matrix (1)

After doing the pairwise comparison, all score results will be presented in the table of matrix in order to do eigenvector of the decision matrix as table following. In the table of matrix, C2 is compared to C1 means the result of pairwise comparison (C1 and C2) from table 3-8 (Average scoring is 5) which C2 is more importance criteria. In contrast, when C1 is compared to C2 means the result will invert (the scoring will be 1 divided by 5 equal to 0.20) because C1 is less important than C2. Otherwise, when C1 is compared with C1 together, the result is 1 as same as any criteria when they are compared to themselves.

Calculate the average in each entire column:

There is a total summarize of the score in each column.

Criteria	C1	C2	C3	C4	C5
C1	1	0.2	0.12	0.5	4
C2	5	1	0.25	2	8
C3	8	4	1	7	9
C4	2	0.5	0.14	1	7
C5	0.25	0.12	0.11	0.14	1
Sum	16.25	5.82	1.62	10.64	29

Table 3-14 Score of AHP pair-wise comparison in the table of matrix (2)

Average Matrix:

The result of total summarize will be divided with the score in each column to be average.

Criteria	C1	C2	C3	C4	C5
C1	0.062	0.034	0.074	0.047	0.138
C2	0.308	0.172	0.154	0.188	0.276
C3	0.492	0.687	0.617	0.658	0.310
C4	0.123	0.086	0.086	0.094	0.241
C5	0.015	0.021	0.068	0.013	0.034

Table 3-15 Score of AHP pair-wise comparison in the table of matrix (3)

Calculate priority in term of matrix in each entire row:

The score in each row will be averaged and the result is the priority of eigenvector in the decision matrix.

Criteria	C1	C2	C3	C4	C5	Average
C1	0.062	0.034	0.074	0.047	0.138	0.071
C2	0.308	0.172	0.154	0.188	0.276	0.220
C3	0.492	0.687	0.617	0.658	0.310	0.553
C4	0.123	0.086	0.086	0.094	0.241	0.126
C5	0.015	0.021	0.068	0.013	0.034	0.030

Table 3-16 Score of AHP pair-wise comparison to be the priority weight

Priorities:

These are the resulting weights for the criteria based on the pairwise comparisons below.

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Category		Priority	Rank
1	Locations of Collection Centres (C1)	7.1 %	4
2	Operation Costs (C2)	22 %	2
3	Amount of rubber receiving(C3)	55.3 %	1
4	Number of Suppliers (C4)	12.6 %	3
5	Environment (C5)	3 %	5

Table 3-17 The priority weight of criteria from AHP pair-wise comparison

Calculate Consistency Ratio (CR):

When result of the comparison (priority) come out, it is important to check that the result is consistent or not, by using Consistency Ratio (CR) as formula:

$$CR = \frac{CI}{RI}$$

(CI): Consistency Index and $CI = \frac{\lambda_{\max} - n}{n - 1}$
n: Number of criteria

- Identifying $\lambda_{\max}$

The result of average in each criterion will be multiple with the table matrix of score of AHP pair-wise comparison (Table 3-9) row by row. Then, the result of each row will be averaged to be $\lambda_{\max}$.

C1: ((1)(0.071)+ (0.2)(0.220) + (0.12)(0.553)+(0.5)(0.126) + (4)(0.030))/0.071
= 5.133
C2: ((5)(0.071)+ (1)(0.220) + (0.25)(0.553) + (2)(0.126) + (8)(0.030))/0.220
= 5.49
C3: ((8)(0.071)+ (4)(0.220) + (1)(0.553) + (7)(0.126) + (9)(0.030))/0.553
= 5.701
C4: ((2)(0.071)+ (0.5)(0.220) + (0.14)(0.553) + (1)(0.126) + (7)(0.030))/0.126
= 5.275
C5: ((0.25)(0.071)+ (0.12)(0.220) + (0.11)(0.553)+(0.14)(0.126) + (1)(0.030))/0.030
= 5.035

$\lambda_{\max}$ = (5.133 + 5.490 + 5.701 + 5.275 + 5.035) / 5 = 5.327

●Calculate Consistency Index (CI): $CI = \frac{\lambda_{\max} - n}{n - 1}$

CI = (5.327 – 5) / (5 – 1) = 0.082

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- Calculate Consistency Ratio (CR): CR = CI/RI

RI: Random Index which is provided below.

N	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

In this case, n=5 means RI must be 1.11

CR = 0.082 / 1.11 = 0.074

The results is below 0.1 that means it is consistency

3.1.4 Result and Analysis of Criteria Weight Priority

After doing the Criteria pair-wise comparison and the matrix calculation process, there would result to the priority rank of each criteria.

Category		Priority	Rank
1	Locations of Collection Centres (C1)	7.1 %	4
2	Operation Costs (C2)	22 %	2
3	Amount of rubber receiving(C3)	55.3 %	1
4	Number of Suppliers (C4)	12.6 %	3
5	Environment (C5)	3 %	5

Table 3-18 The priority weight of criteria from AHP pair-wise comparison (1)

From table 3-18, all criterions are derived priority scales and amount of rubber receiving is the most effective with 55.3 % priority to the operation in collection system. The quantity of rubber is the first stage to be considered in order to close the collection centre because it is income generating that is the core business of rubber processed. However, the factory still require a large number of rubber milk but they have to bear in term of collection cost as well which is higher than targeting and there are not the cost-effective for some collection centres to deal with small number of rubber milk receiving.Then, operation cost in rubber milk collection is the second importance with 22% priority that affect to the collection system. Next, it is 12.6 % priority in term of number of suppliers that the factory uses to be criteria. The factory has reasons to keep the number of suppliers to expect more number of rubbers producing but it is not always guarantee that high number of suppliers means more rubber receiving. Moreover, this is the way to prevent in term of competitor that they will have more power for producing. Lastly, there are criterions in locations of collection centres and the environment at the centres which concern to the transportation mainly. It is low effect in term of making decision to close the collection centre but it is the major cause for the high transportation cost which direct to farmers or suppliers who take the responsibility in this term majorly.

3.1.5 Score and Scale of Sub-Criteria Pair-Wise Comparison

According to 5 criteria that were identified, there are 3 criteria that are subdivided (C1, C2, and C5). The process of doing pair-wise comparison is almost the same as criteria pair-wise comparison. Therefore, there is only a sample of criteria 2 to show in this sub – criteria pair wise comparison and otherwise criteria will be presented in Appendix B.

Scoring in importance and priority of sub-criteria (C2) from judges

Scoring in importance of criterion pairwise comparison:

Criteria Pairwise Comparison	More Important	**Judge 1 Scoring**	**Judge 2 Scoring**	**Judge 3 Scoring**	**Judge 4 Scoring**	**Judge 5 Scoring**	**Judge 6 Scoring**	**Average Scoring**
C2-1 and C2-2	C 2-2	3	3	3	3	3	1	3
C2-1 and C2-3	C 2-3	7	7	5	5	5	5	6
C2-2 and C2-3	C 2-3	3	3	3	5	1	3	3

Decision Matrix:

Criteria	C2-1	C2-2	C2-3
C2-1	1	0.33	0.17
C2-2	3	1	0.33
C2-3	6	3	1

Calculate the average in each entire column:

Criteria	C2-1	C2-2	C2-3
C2-1	1	0.33	0.17
C2-2	3	1	0.33
C2-3	6	3	1
Sum	10	4.33	1.5

Average Matrix

Criteria	C2-1	C2-2	C2-3
C2-1	0.1	0.076	0.113
C2-2	0.3	0.231	0.220
C2-3	0.6	0.693	0.667

Calculate priority in term of matrix in each entire row

Criteria	C2-1	C2-2	C2-3	Average
C2-1	0.1	0.076	0.113	0.097
C2-2	0.3	0.231	0.220	0.250
C2-3	0.6	0.693	0.667	0.653

Priorities and Consistency

Category		Priority	Rank
1	Inbound Cost (C2-1)	9.7 %	3
2	Outbound Cost (C2-2)	25 %	2
3	Fixed Cost (C2-3)	65.3%	1

Consistency Ratio (CR) =0.019

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3.1.6 Result and Analysis of Sub-Criteria Weight Priority

After analyzing the criteria, there are sub-criteria that could describe more detail in each criterion to show the priority weight and issue the factor which is supposed to be more consideration in order to close the collection centre. All sub-criteria represent the results as the tables following.

<u>Location of the collection centres</u>

Category		Priority	Rank
1	Close to the factory (C1-1)	25 %	2
2	Close to the number of suppliers (farmers) (C1-2)	75 %	1

Table 3-19 The priority weight of sub-criterion in location

Location of the_collection centres is ranked in number 4 which is quite not important for decision making process but it is a cause which effect directly to the cost in rubber collecting activity in C2 (criteria of operation cost). According to table 4-2, the criteria of collection centre's location is divided into 2 consideration aspects; close to factory and close to number of suppliers. To be advantage, it is better to place the collection centre in order to convince number of farmers to supply the rubber at the collection centre instead to let them go to support another factory. This is win-win situation because the factory target to get the high amount of rubber and it is convenient to farmers to supply their rubber when the centre is placed in their area.

<u>Operation costs</u>

Category		Priority	Rank
1	Inbound Cost (C2-1)	9.7 %	3
2	Outbound Cost (C2-2)	25 %	2
3	Fixed Cost (C2-3)	65.3%	1

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Table 3-20 The priority weight of sub-criterion in operation cost

From the priority weight of criteria in table 4-1, the criteria of operation cost is ranked in the second place which is quite highly effect to the decision of closing the collection centre. The operation cost of rubber collection activity can separate into 3 types; inbound cost, outbound cost, and fixed cost. The first ranked in sub-criteria of operation cost is fixed cost with 65.3%. Because of over expenditure in collection activity, it happens majorly at the collection centre when the expenditures such as ground rental fee, staff salaries, electricity and public utility payment have to deal with low number of farmers supporting the rubber. This is the issue that direct to the problems of this research which to reduce the cost. Next importance sub-criteria in the operation cost is outbound cost. The reason that outbound cost is more important than inbound cost might happen from number of committee. There are only two farmers who have suffrage for scoring in the pair-wise comparison which might lost benefit for their side to get the high weight priority in inbound cost.

<u>Environment</u>

Category		Priority	Rank
1	Facilities (C5-1)	66.7 %	1
2	Acceptable condition for society (C1-2)	33.3 %	2

Table 3-21 The priority weight of sub-criterion in environment

The environment is the less important in the priority weight of criteria with only 3% from 5 criteria setting. This issue is the consideration in term of convenience for traveling and the location of the collection centres that is acceptable for community. In this case, facilities are more important than the acceptable of society because it concern to the access of vehicle to supply the rubber at the collection centre and transport to the factory. All of these affect to the efficiency of rubber collecting which is direct to the research focusing.

3.1.7 Score and Scale of Alternatives Pair-Wise Comparison in Each Criteria

In this process, all criteria including sub-criteria will be considered together with alternatives (collection centre). The 8 collection centre will be compared to each other by focusing on the capacity followed with criteria and sub-criteria that were mentioned. In this case (stage 5 from figure 3-2), the total number of criteria and sub-criteria are 9. Therefore, there is only a sample of criteria 2-3 to show in this alternative and criteria pair wise comparison and otherwise will be presented in Appendix B.

Scoring in importance and priority of collection centres comparing with criteria (C2-3)

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Scoring in importance of centres pairwise comparison in criteria (C2-3):

Centres Pairwise Comparison	More Important	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	3	3	3	3	3	3	3
Centre A and C	A	5	5	5	5	5	5	5
Centre A and D	A	5	5	5	5	5	5	5
Centre A and E	A	5	5	5	5	5	5	5
Centre A and F	A	5	5	5	5	5	5	5
Centre A and G	A	5	5	5	5	5	5	5
Centre A	A	3	3	3	3	3	3	3

and H								
Centre B and C	B	3	3	3	3	3	3	3
Centre B and D	B	1	1	3	3	3	3	2
Centre B and E	B	3	3	3	3	3	3	3
Centre B and F	B	1	1	3	3	3	3	2
Centre B and G	B	3	3	3	3	3	3	3
Centre B and H	H	1	1	3	3	3	3	2
Centre C and D	D	3	3	1	3	1	3	2
Centre C and E	C	1	1	1	1	1	1	1
Centre C and F	F	3	3	1	3	1	3	2
Centre C and G	G	1	1	1	1	1	1	1
Centre C and H	H	3	3	3	3	3	3	3
Centre D and E	D	1	3	1	3	3	3	2
Centre D and F	D	1	1	1	1	1	1	1
Centre D and G	D	1	3	3	1	3	3	2
Centre D and H	H	1	1	1	1	1	1	1
Centre E and F	F	1	3	3	1	3	3	2
Centre E and G	G	1	1	1	1	1	1	1
Centre E and H	H	3	3	3	3	3	3	3
Centre F and G	F	1	3	1	3	3	3	2
Centre F and H	H	1	3	1	3	3	3	2
Centre G and H	H	1	3	1	3	3	3	2

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Decision Matrix

Centre	A	B	C	D	E	F	G	H
A	1	3.00	5.00	5.00	5.00	5.00	5.00	3.00
B	0.33	1	3.00	2.00	3.00	2.00	3.00	0.50
C	0.20	0.33	1	0.50	1.00	0.50	1.00	0.33
D	0.20	0.50	2.00	1	2.00	1.00	2.00	1.00
E	0.20	0.33	1.00	0.50	1	0.50	1.00	0.33
F	0.20	0.50	2.00	1.00	2.00	1	2.00	0.50
G	0.20	0.33	1.00	0.50	1.00	0.50	1	0.50
H	0.33	2.00	3.00	1.00	3.00	2.00	2.00	1

Calculate the average in each entire column

Centre	A	B	C	D	E	F	G	H
A	1	3	5	5	5	5	5	3
B	0.33	1	3	2	3	2	3	0.5
C	0.2	0.33	1	0.5	1	0.5	1	0.33
D	0.2	0.5	2	1	2	1	2	1
E	0.2	0.33	1	0.5	1	0.5	1	0.33
F	0.2	0.5	2	1	2	1	2	0.5
G	0.2	0.33	1	0.5	1	0.5	1	0.5
H	0.33	2	3	1	3	2	2	1
Sum	2.66	7.99	18	11.5	18	12.5	17	7.16

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Average Matrix

Centre	A	B	C	D	E	F	G	H
A	0.38	0.38	0.28	0.43	0.28	0.40	0.29	0.42
B	0.12	0.13	0.17	0.17	0.17	0.16	0.18	0.07
C	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.05
D	0.08	0.06	0.11	0.09	0.11	0.08	0.12	0.14
E	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.05
F	0.08	0.06	0.11	0.09	0.11	0.08	0.12	0.07
G	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.07
H	0.12	0.25	0.17	0.09	0.17	0.16	0.12	0.14

Calculate priority in term of matrix in each entire row

Centre	A	B	C	D	E	F	G	H	Average
A	0.38	0.38	0.28	0.43	0.28	0.40	0.29	0.42	0.361
B	0.12	0.13	0.17	0.17	0.17	0.16	0.18	0.07	0.144
C	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.05	0.051
D	0.08	0.06	0.11	0.09	0.11	0.08	0.12	0.14	0.097
E	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.05	0.051
F	0.08	0.06	0.11	0.09	0.11	0.08	0.12	0.07	0.088
G	0.08	0.04	0.06	0.04	0.06	0.04	0.06	0.07	0.054
H	0.12	0.25	0.17	0.09	0.17	0.16	0.12	0.14	0.153

Priorities and Consistency

Category (Fixed Cost)		Priority	Rank
1	Collection Centre A	36.1 %	1
2	Collection Centre B	14.4 %	3
3	Collection Centre C	5.1 %	7
4	Collection Centre D	9.7 %	4
5	Collection Centre E	5.1 %	7
6	Collection Centre F	8.8 %	5
7	Collection Centre G	5.4 %	6
8	Collection Centre H	15.3 %	2

Consistency Ratio (CR) = 0.02

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3.1.8 Result and Analysis of Alternatives Weight Priority in Each Criteria

Category (Close to factory)		Priority	Rank
1	Collection Centre A	30.2 %	1
2	Collection Centre B	4 %	7
3	Collection Centre C	14.2 %	3
4	Collection Centre D	10.9 %	4
5	Collection Centre E	6.4 %	6
6	Collection Centre F	6.5 %	5
7	Collection Centre G	1.7 %	8
8	Collection Centre H	26.2 %	2

Table 3-22 The priority weight of collection centres comparing with criteria of close to factory

In the case of close to factory, collection centre A is placed at the factory which means it is supposed to be highest priority with 30.2 % priority weight. Apart from centre A, there is collection centre B which is located nearly to the factory. So, it is convenient to travel from the factory to pick up the rubber at the centre and it is ranked to the second place for priority. On the other hand, collection centres F, E, B, and G have low priority weights which mean they are located away from the factory. Therefore, it takes a lot of time for travelling between these centres and the factory that cost too much in term of transportation (outbound cost).

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Category (Close to the number of suppliers (farmers))		Priority	Rank
1	Collection Centre A	1.9 %	8
2	Collection Centre B	27.7 %	1
3	Collection Centre C	7.8 %	6
4	Collection Centre D	12 %	3
5	Collection Centre E	3 %	7
6	Collection Centre F	8.4 %	5
7	Collection Centre G	12 %	3
8	Collection Centre H	27.3 %	2

Table 3-23 The priority weight of collection centres comparing with criteria of close to number of suppliers

According to table 3-23, collection centre B and H are placed in the middle where among of suppliers located which result to the high priority weight at 27.7% and 27.3% respectively. In the case that the collection centre is place nearly the group of suppliers, it is able to save cost for transportation in term of inbound for the supplier side. In addition, collection centre E is located where the places of supplier are sparse. This would result to have a long total distance for supplier travelling to send the rubber at the centre when all suppliers' distances are calculated together. Finally, collection center A is the lowest priority weight because centre A has a large number of suppliers that definitely affect to the sparse location and high total distance calculated for all suppliers travelling.

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Category (Inbound Cost)		Priority	Rank
1	Collection Centre A	1.7 %	8
2	Collection Centre B	25.4 %	2
3	Collection Centre C	6.8 %	6
4	Collection Centre D	10.6 %	4
5	Collection Centre E	3.7 %	7
6	Collection Centre F	9.1 %	5
7	Collection Centre G	14.7 %	3
8	Collection Centre H	27.9 %	1

Table 3-24 The priority weight of collection centres comparing with criteria of inbound cost

In term of inbound cost, the cost depends on number of suppliers and how closing of the collection centre to the number of suppliers. In this case, collection centre H has few numbers of suppliers and the suppliers are located close to the centre. All of these results to the highest priority weight at 27.9 % for the collection centre H. In another way, collection centre A has an inverse result from the centre H because the centre A has a large amount of rubber suppliers that affect to the high inbound cost when the number of supplier are travelling to supply the rubber at the centre A.

Category (Outbound Cost)		Priority	Rank
1	Collection Centre A	38.1 %	1
2	Collection Centre B	13.8 %	3
3	Collection Centre C	5.5 %	5
4	Collection Centre D	8.8 %	4
5	Collection Centre E	3.3 %	7
6	Collection Centre F	5.5 %	5
7	Collection Centre G	3.3 %	7
8	Collection Centre H	21.7 %	2

Table 3-25 The priority weight of collection centres comparing with criteria of outbound cost

Focusing on outbound cost, this issue deepens on the location of the collection centre. The collection centre is supposed to be placed nearly the factory in order to save transportation cost of vehicle that is used for rubber picking up. According to table 3-25, collection centre A has no outbound because the centre is placed at the factory. So, it results to be ranked number 1 at 38.1% priority weight. On the other hand, collection centre E and G are located away from the factory which affect to the high cost of transportation for rubber picking up. So, these would result to have high outbound cost and ranked to be the last place.

Category (Fixed Cost)		Priority	Rank
1	Collection Centre A	36.1 %	1
2	Collection Centre B	14.4 %	3
3	Collection Centre C	5.1 %	7
4	Collection Centre D	9.7 %	4
5	Collection Centre E	5.1 %	7
6	Collection Centre F	8.8 %	5
7	Collection Centre G	5.4 %	6
8	Collection Centre H	15.3 %	2

Table 3-26 The priority weight of collection centres comparing with criteria of fixed cost

In the aspect of fixed cost, the cost is supposed to be relied on the number of suppliers or farmers supplying which cost a lot of expenditure at the collection centre. But in the case of collection centre A, it is exactly placed in the factory and it is quite confident strongly that the centre A is really hard to be closed. Moreover, the centre A has no need to pay for land lord, equipment used, electricity and public utility but it requires a lot of staff to deal with the large number of the suppliers which affect to the highest cost. For these reasons, collection centre A is a special case that raked in number 1 with 36.1% priority weight although they have to pay the high cost. Otherwise, collection centre H is placed as the second ranked because it has to deal with few number of suppliers that requires just few staff and deal with low payment at the collection centre. Lastly, there are collection centre C and E which are ranked in the last place. Both collection centre have to deal with high payment at the collection centre due to high number of supplier.

At the result, it is reasonable that fixed cost is more important than outbound and inbound cost. It is direct to the objective of research that try to reduce the over expenditure for collection centres.

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Category (Amount of rubber receiving)		Priority	Rank
1	Collection Centre A	52.7 %	1
2	Collection Centre B	3.2 %	7
3	Collection Centre C	13 %	2
4	Collection Centre D	6.1 %	5
5	Collection Centre E	10.3 %	3
6	Collection Centre F	7.6 %	4
7	Collection Centre G	4.6 %	6
8	Collection Centre H	2.6 %	8

Table 3-27 The priority weight of collection centres comparing with criteria of amount of rubber receiving

From table 3-17 and 3-18, amount of rubber receiving is the most important criteria that use in decision making process for closing some collection centre with 55.3% priority weight. This criterion could be a strong point to indicate which collection centrre should be continued or closed. According to the result from table 4-10, collection centre A with 52.7 is the most potential centre which is able to collect the rubber around 22,696 kg per month (information available from table 1-1) following with centre C and E which place in the second and third ranked. On the other hand, collection centre B and H are ranked in the last place with the low priority weight. Considering of the highest criteria's priority weight which is more than a half (50%), it could be predicted that collection centre A following with C and E are supposed to be continue operating respectively but collection centre H and B are supposed to be closed due to the low number of rubber collecting.

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Category (Number of suppliers (farmers))		Priority	Rank
1	Collection Centre A	53.2 %	1
2	Collection Centre B	2.7 %	8
3	Collection Centre C	13.7 %	2
4	Collection Centre D	5.6 %	5
5	Collection Centre E	8.1 %	4
6	Collection Centre F	8.8 %	3
7	Collection Centre G	4.7 %	6
8	Collection Centre H	3.2 %	7

Table 3-28 The priority weight of collection centres comparing with criteria of number of suppliers

Number of suppliers is a criteria considered for the decision making process to keep some benefits that already describe in 3.1.1 of chapter 3. According to table 3-28, the result showed is different from table 3-27. This is able to guarantee that large number of farmer does not mean large number of rubber output that mentioned in 3.1.1 as well. In addition, this criteria has a few effective to the decision making due to 12.6% criteria’s priority weight and the result are similar to table 3-27 that collection centre A and C are the top ranked and collection centre H and B are the bottom ranked.

Category (Facilities)		Priority	Rank
1	Collection Centre A	32.5 %	1
2	Collection Centre B	2.6 %	8
3	Collection Centre C	12.1 %	2
4	Collection Centre D	12.1 %	2
5	Collection Centre E	12.1 %	2
6	Collection Centre F	12.1 %	2
7	Collection Centre G	12.1 %	2
8	Collection Centre H	4.6 %	7

Table 3-29 The priority weight of collection centres comparing with criteria of facilities

In the case of facilities, it is low effective to the decision making to close the collection centre due to 3% priority weight in the criteria of environment. From the result, collection centre A is the most conveniences due to located in the centre, close to the main road, and easier for accessing (see the map in figure 3-2). In other way, collection H and B are in the low weight priority because they are located away from number of supplier and it is difficult to send and collect the rubber.

Category (Acceptable condition for society)		Priority	Rank
1	Collection Centre A	16.9 %	3
2	Collection Centre B	7.5 %	4
3	Collection Centre C	7.5 %	4
4	Collection Centre D	7.5 %	4
5	Collection Centre E	7.5 %	4
6	Collection Centre F	25 %	1
7	Collection Centre G	25 %	1
8	Collection Centre H	3.2 %	8

Table 3-30 The priority weight of collection centres comparing with criteria of acceptable condition for society

Due to 3% priority weight in the criteria of environment, acceptable condition for society is also less important for the decision making. In this case, collection centre F and G are the most acceptable for society because it is located in remote communities which are not annoying the people. It is different from collection F, G and A which are placed at the centre of communities.

3.1.9 Priority ranking for collection centres

In the stage 6 from figure 3-1, the criteria that are subdivided (sub-criteria) will be included to be a total priority weight of collection centre under a considered criterion such as C1, C2, and C5. In order to that, the priority weight of sub-criteria will multiply with the priority weight of collection centre in each sub-criterion that is shown below.

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Criteria/ Centre	A	B	C	D	E	F	G	H
C 1-1	0.302	0.040	0.142	0.109	0.064	0.065	0.017	0.262
C 1-2	0.019	0.277	0.078	0.120	0.030	0.084	0.120	0.273
C 2-1	0.017	0.254	0.068	0.106	0.037	0.091	0.147	0.279
C 2-2	0.381	0.138	0.055	0.088	0.033	0.055	0.033	0.217
C 2-3	0.361	0.144	0.051	0.097	0.051	0.088	0.054	0.153
C 3	0.527	0.032	0.130	0.061	0.103	0.076	0.046	0.026
C 4	0.532	0.027	0.137	0.056	0.081	0.088	0.047	0.032
C 5-1	0.325	0.026	0.121	0.121	0.121	0.121	0.121	0.046
C 5-2	0.169	0.075	0.075	0.075	0.075	0.250	0.250	0.032

Table 3-31 the overall priority weight of collection centres from each criterion and sub-criteria from Apendix B

Calculate the overall priority of each criteria

Location of the collection centres(C 1)

Centre A = (0.302 x 0.250) + (0.019 x 0.075) = 0.090 (9 %)
Centre B = (0.040 x 0.250) + (0.277 x 0.075) = 0.218 (21.8%)
Centre C = (0.142 x 0.250) + (0.078 x 0.075) = 0.094 (9.4%)
Centre D = (0.109 x 0.250) + (0.120 x 0.075) = 0.117 (11.7%)
Centre E = (0.064 x 0.250) + (0.030 x 0.075) = 0.039 (3.9%)
Centre F = (0.065 x 0.250) + (0.084 x 0.075) = 0.079 (7.9%)
Centre G = (0.017 x 0.250) + (0.120 x 0.075) = 0.094 (9.4%)
Centre H = (0.262 x 0.250) + (0.273 x 0.075) = 0.270 (27%)

Operation Cost(C 2)

Centre A = (0.017 x 0.097) + (0.381 x 0.250) + (0.361 x 0.653) = 0.333 (33.3 %)
Centre B = (0.254 x 0.097) + (0.138 x 0.250) + (0.144 x 0.653) = 0.153 (15.3 %)
Centre C = (0.068 x 0.097) + (0.055 x 0.250) + (0.051 x 0.653) = 0.054 (5.4 %)
Centre D = (0.106 x 0.097) + (0.088 x 0.250) + (0.097 x 0.653) = 0.096 (9.6 %)
Centre E = (0.037 x 0.097) + (0.033 x 0.250) + (0.051 x 0.653) = 0.045 (4.5 %)
Centre F = (0.091 x 0.097) + (0.055 x 0.250) + (0.088 x 0.653) = 0.080 (8 %)
Centre G = (0.147 x 0.097) + (0.033 x 0.250) + (0.054 x 0.653) = 0.058 (5.8 %)
Centre H = (0.279 x 0.097) + (0.217 x 0.250) + (0.153 x 0.653) = 0.181 (18.1 %)

<u>Amount of rubber receivingAmount of rubber receiving (C3)</u>

Centre A = 0.527 (52.7 %)
Centre B =0.032 (3.2 %)
Centre C =0.130 (13 %)
Centre D =0.061 (6.1 %)
Centre E =0.103 (10.3 %)
Centre F = 0.076 (7.6 %)
Centre G = 0.046 (4.6 %)
Centre H = 0.026 (2.6 %)

<u>Number of suppliers (farmers) (C4)</u>

Centre A = 0.532 (53.2 %)
Centre B =0.027 (2.7 %)
Centre C =0.137 (13.7 %)
Centre D =0.056 (5.6 %)
Centre E =0.081 (8.1 %)
Centre F = 0.088 (8.8 %)
Centre G = 0.047 (4.7 %)
Centre H = 0.032 (3.2 %)

<u>Environment(C 5)</u>

Centre A = (0.325 x 0.667) + (0.169 x 0.333) = 0.273 (27.3 %)
Centre B = (0.026 x 0.667) + (0.075 x 0.333) = 0.042 (4.2 %)
Centre C = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre D = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre E = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre F = (0.121 x 0.667) + (0.250 x 0.333) = 0.164 (16.4 %)
Centre G = (0.121 x 0.667) + (0.250 x 0.333) = 0.164 (16.4 %)
Centre H = (0.046 x 0.667) + (0.032 x 0.333) = 0.041 (4.1 %)

Calculate the overall priority of collection centres

After the overall priority weights of collection centres in each criterion come out, there will be total priority weights of the collection centre which are from the included criteria (C1 to C5). In term of calculation the total priority weights, the overall priority weight of collection centres in each criterion will multiply with the priority weight of criteria from AHP pair-wise comparison.

Criteria/ Centre	A	B	C	D	E	F	G	H
C 1	0.090	0.218	0.094	0.117	0.039	0.079	0.094	0.270
C 2	0.333	0.153	0.054	0.096	0.045	0.080	0.058	0.181
C 3	0.527	0.032	0.130	0.061	0.103	0.076	0.046	0.026
C 4	0.532	0.027	0.137	0.056	0.081	0.088	0.047	0.032
C5	0.273	0.042	0.106	0.106	0.106	0.164	0.164	0.041

Table 3-32 The overall priority weight of collection centres in each criterion

Centre A = (0.090 x 0.071) + (0.333 x 0.220) + (0.527 x 0.553) + (0.532 x 0.126) + (0.273 x 0.030) = 0.446
Centre B= (0.218 x 0.071) + (0.153 x 0.220) + (0.032 x 0.553) + (0.027 x 0.126) + (0.042 x 0.030) = 0.072
Centre C= (0.094 x 0.071) + (0.054 x 0.220) + (0.130 x 0.553) + (0.137 x 0.126) + (0.106 x 0.030) = 0.111
Centre D= (0.117 x 0.071) + (0.096 x 0.220) + (0.061 x 0.553) + (0.056 x 0.126) + (0.106 x 0.030) = 0.073
Centre E= (0.039 x 0.071) + (0.045 x 0.220) + (0.103 x 0.553) + (0.081 x 0.126) + (0.106 x 0.030) = 0.083
Centre F= (0.079 x 0.071) + (0.080 x 0.220) + (0.076 x 0.553) + (0.088 x 0.126) + (0.164 x 0.030) = 0.081
Centre G= (0.094 x 0.071) + (0.058 x 0.220) + (0.046 x 0.553) + (0.047 x 0.126) + (0.164 x 0.030) = 0.056
Centre H= (0.270 x 0.071) + (0.181 x 0.220) + (0.026 x 0.553) + (0.032 x 0.126) + (0.041 x 0.030) = 0.079

Total priority weights of the collection centre

After calculation the overall priority weight of each collection centre, there would be presented in the percentage to show which collection center is supposed to continue if the percentage is high and which collection centre is the first that is supposed to close down if it has low percentage showing as table 3-33.

Category (Collection Centre)		Priority	Rank
1	Collection Centre A	44.6 %	1
2	Collection Centre B	7.2 %	7
3	Collection Centre C	11.1 %	2
4	Collection Centre D	7.3 %	6
5	Collection Centre E	8.3 %	3
6	Collection Centre F	8.1 %	4
7	Collection Centre G	5.6 %	8
8	Collection Centre H	7.9 %	5

Table 3-33 The overall priority weights of collection centres

3.1.10 Analysis of The overall priority ranked of collection centres

After analyzing all 8 collection centres by considering in each criteria and sub-criteria. Next process is doing overall priority ranked of collection centres from all mentioned criteria and sub-criteria in order to get one result of the weight priority ranked of collection centres as table 3-34.

Category (Collection Centre)		Priority	Rank
1	Collection Centre A	44.6 %	1
2	Collection Centre B	7.2 %	7
3	Collection Centre C	11.1 %	2
4	Collection Centre D	7.3 %	6
5	Collection Centre E	8.3 %	3
6	Collection Centre F	8.1 %	4
7	Collection Centre G	5.6 %	8
8	Collection Centre H	7.9 %	5

Table 3-34 The overall priority weights of collection centres (1)

From table 3-34, collection centre A is the most potential place as 44.6 % priority which is located at the factory. There is high number of rubber receiving at centre A as well as free transportation cost in term of outbound but centre A have to deal with high fixed cost and inbound cost which is lower important criteria when comparing with number of rubber receiving. Then, it is following by centre C with 11.1 % priority. Centre C is the second place who gain high amount of rubber and number of supplier. Moreover, it is located nearly the factory and among of farmers group which support to reasonable cost in both term of inbound and outbound. For the remaining centres, it is consider by percentage of the criterion priority same as explanation above in centre A and C and the result are approximately close to each other which is lower 10 % of priority.

3.2 Linear Programming (LP)

3.2.1 Mathematical Model and Computer Simulation Model for Linear Programming (LP)

From table 3-35, Amount of rubber receiving (C3) is the highest weight priority and followed with the operation cost (C2) which is the second highest priority weight. According to these criteria mentioned and priority weight, this information is continued use in Linear Programming (LP) in order to identify the optimum number of rubber milk collection centres with satisfying demand of rubber collecting and minimizing the operation cost as goals by the table following.

Operation Item	Unit Rubber Collecting (kg) and Operation Cost (THB) to Collection Centre								Total Available Monthly Resource Targeted	Ranked resource prioritie (P_K)
	A (X1)	B (X2)	C (X3)	D (X4)	E (X5)	F (X6)	G (X7)	H (X8)		
Rubber Receiving	22,696	4,736	9,233	6,918	8,984	7,772	5,093	3,301	40,000 (kg)	-
Fixed Cost	43,500	17,500	27,500	24,500	27,500	26,000	27,000	17,000	100,000 (THB)	0.653
Outbound Cost	0	5,390	7,630	6,155	8,093	7,194	8,145	3,211	20,000 (THB)	0.25
Inbound Cost	59,452	5,544	16,093	13,320	2,677	14,925	10,139	3,485	85,000 (THB)	0.097

Table 3-35 resource limitations

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In order to do optimization program, the amount of rubber collecting is focused first according to the priority weight of the criteria. The total number of rubber being received is stratifying at 40,000 kg monthly. After number of rubber collecting is already achieved, the minimized cost would be the next target which is limited at 20,000 Thai Bath (THB) for outbound cost, 85,000 (THB) for inbound cost, and 100,000 (THB). All of these are the resource limitations that are from entrepreneur's interview including all committee from the AHP process that will use to be parameter inputs. Next, it is the ranked resources priorities (P_K) that is also use to be parameter input in the LP to show the resource priority in each sub-criteria of operation cost. The information of resource priorities are related to the priorities of sub-criteria (operation cost) In addition, there are no sub-criteria for rubber receiving and it is the first considered criteria which is not important to do the ranked resource priorities. Finally, it is historical data concerned in number of rubber receiving and operation cost concerned in number of rubber receiving and operation cost from each collection centre that is available in table 3-18, 3-19 and shown in Appendix A.

Linear Programming (LP)

Stage 1: Determine weight of resource priorities that is related to sub-criteria priorities weight in order to rank the important of resources and to be a parameter input in the LP.

Stage 2: It is a gathered data process that is directed to the goal such as number of rubber being received, inbound cost, outbound cost, and fixed cost form each collection centres. This information also uses to be a parameter input in the LP.

Stage 3: The goals of collection centre selection are desired and formulated as stage 4 and 5.

Stage 4: The first goal is issued: The number of rubber being received from selected collection centre must exceed to 40,000 kg in a month. If the first goal is achieved, there will be another consideration about cost in the second goal.

Stage 5: In the second goal, there will be a limited in term of cost and it is able to result to the minimized cost and present the optimum number of the collection center selection.

Stage 6: the optimum number of collection centre that should continue operating is presented.

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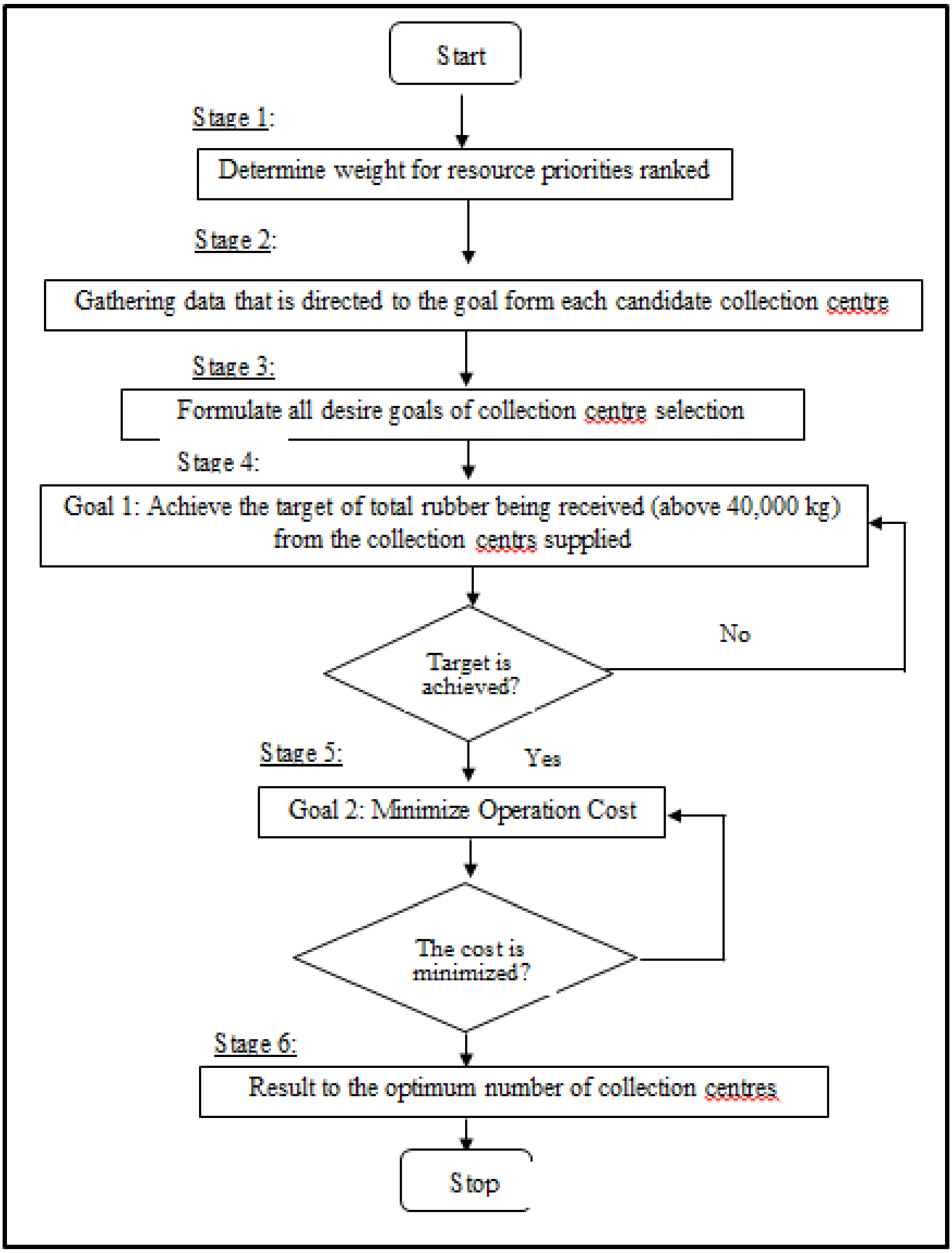

Figure 3-7 Flow chart of Linear Programming (LP) to find the optimum number of collection centres

From figure 3-7, the proposed method of LP are shown as following and it can be solve by optimization program like this case study that use IBM ILOG CPLEX Optimization to solve this problem.

Notation

Indices:

i represents the number of collection centre from A to H = {1, 2, 3, 4, 5, 6, 7, 8}

j represents the number of rank of priority in operation cost = {1, 2, 3}

Parameters:

Q_i represents amount of rubber milk being received per month at centre i

I_i represents inbound cost per month at centre i

O_i represents outbound cost per month at centre i

F_i represents fixed cost per month at centre i

P_j represents priority in each criteria j

RR represents limited overall rubber receiving per month at the factory

FC represents limited overall fixed cost payment per month

OC represents limited overall outbound cost payment per month

IC represents limited overall inbound cost payment per month

Decision Variables:

X_i represents 1 if collection centre € is opened; 0 otherwise

d_1 represents deviations below the limited resource of fixed cost

d_2 represents deviations below the limited resource of outbound cost

d_3 represents deviations below the limited resource of inbound cost

z represents overall minimizing deviations in each limited resource with priority weight

Mathematical Model

Objective:

$$\text{Min } z = P_1 d_1 + P_2 d_2 + P_3 d_3 \quad (1)$$

Subject to:

Demand for amount of rubber collecting

$$\sum_{i=1}^{8} Q_i X_i \geq RR \quad (2)$$

Fixed Cost Limitation

$$\sum_{i=1}^{8}(F_i X_i) - d_1 = FC \quad (3)$$

Outbound Cost Limitation

$$\sum_{i=1}^{8}(O_i X_i) - d_2 = OC \quad (4)$$

Inbound Cost Limitation

$$\sum_{i=1}^{8}(I_i X_i) - d_3 = IC \quad (5)$$

3.2.2 Result of Optimum Number for Opened-Closed Collection Cntres

After finished solving the problem by the linear programming (LP), the result would present by using the optimization program (IBM ILOG CPLEX Optimization) as following.

Index i (collection centre)	Value (Result)
X 1 (A)	1
X 2 (B)	0
X 3 (C)	1
X 4 (D)	0
X 5 (E)	1
X 6 (F)	0
X 7 (G)	0
X 8 (H)	0

Table 3-36 The result of combined AHP-LP model solution

From table 3-36, X1 to X8 would represent the collection centre A to H and the value result is 1 that means that collection centre should be continue operating. The objective of linear programming (LP) is to identify the optimum number of the collection centres and the result of the optimum number is 3 collection centre that should be continued open; collection centre A, C, and E. From the result, it could be seen clearly that the criteria of amount of rubber receiving is the major effective to the decision process with 55.3% weight priority. By comparing with the priority weight of collection centres in the criteria of amount of rubber receiving from table 3-36, the result is similar that collection centre A, C and E are the top three centre which should continue operating.

Deviation in resources limited and minimized cost constraints

Decision Items	Value
d_1	-1500
d_2	-4277
d_3	-6778
Z	-2706.2

Table 3-37 Deviation in resources limited and minimized cost constraints

In term of doing the optimization program, this research is object to minimize cost from the rubber collection process which presents the deviation result by use "z" as decision item for the computer program. Then, criterion in amount of rubber receiving which is the most effective priority from the AHP are used as resource limited constraints in order to ensure the best use. Following with the operation cost, there are different weight priorities in inbound cost, outbound cost, and fixed cost to restrict the resource limited and see how the results are deviation.

At the programming, the total of rubber collecting is expected to exceed monthly 40,000 kilograms (kg). Second, it is to minimize operation cost which can be categorized as 65.3 % priority in fixed cost, 25% priority in outbound cost, and 9.7 % priority in inbound cost. The operation cost is also limited monthly at 100,000 THB (Thai Bath) foe fixed cost, 20,000 THB for outbound cost, and 85,000 THB for inbound cost. After computer program solving, according to rubber collecting operation from 8 collection centres through 162 suppliers, the result of optimum number is 3 collection centre which consist of collection centre A, C, and E through 100 suppliers. This is surly guarantee that the factory will exceed 40,000 kg rubber collecting. Moreover, the operation cost would be minimized that is saved from the expected cost as 1,500 THB (d1) for fixed cost, 4,277 THB for outbound cost (d2), 6,778 THB for inbound cost (d3).

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CHAPTER 4 RUBBER COLLECTING METHOD

In the case study after closing 5 collection centres (centre B, D, F, G, and H), there will be 62 suppliers who have no longer support to rubber collection centre. This is an opportunity to apply the vehicle routing problem (VRP) in order to keep the amount of rubber receiving but the price of rubber receiving has to be negotiated to be lower according to routing cost. Moreover, this method is able to support more the objective of cost reduction in this research. By doing the VRP, this method will make the transportation of rubber collecting is more efficient and reduce number of vehicle and route.

In order to arrange vehicle route by the VRP, the exact approach that mentioned in chapter 2 seems like it is the best solution to get the best result but it will take a lot of time for solving due to the large problem (62 suppliers as nodes). Therefore, it is better to do routing first in order to study a route map to see the farmer or supplier located place. Then, the 62 farmers will be separated in to a zone according to the road map. Finally, it is a scheduling process to divide the route into several sub-routes due to considered capacity of vehicle and time window. All of these are able to describe as a conceptual idea bellow.

Stage 1: It is the stage of collecting data and related information from all 62 suppliers (farmers) about the coordinate where they are place including amount of rubber supplying in each supplier.

Stage 2: By studying the route map of Betong city, all 62 suppliers are able to separate in to a zone according to the main road that they are located.

Stage 3: After finished the clustering, next process is scheduling by applied vehicle routing problem to sequence the number of suppliers who are the first ranked that the vehicles should come and pick up the rubber. These are happened under the constraints in vehicle's capacity and time window.

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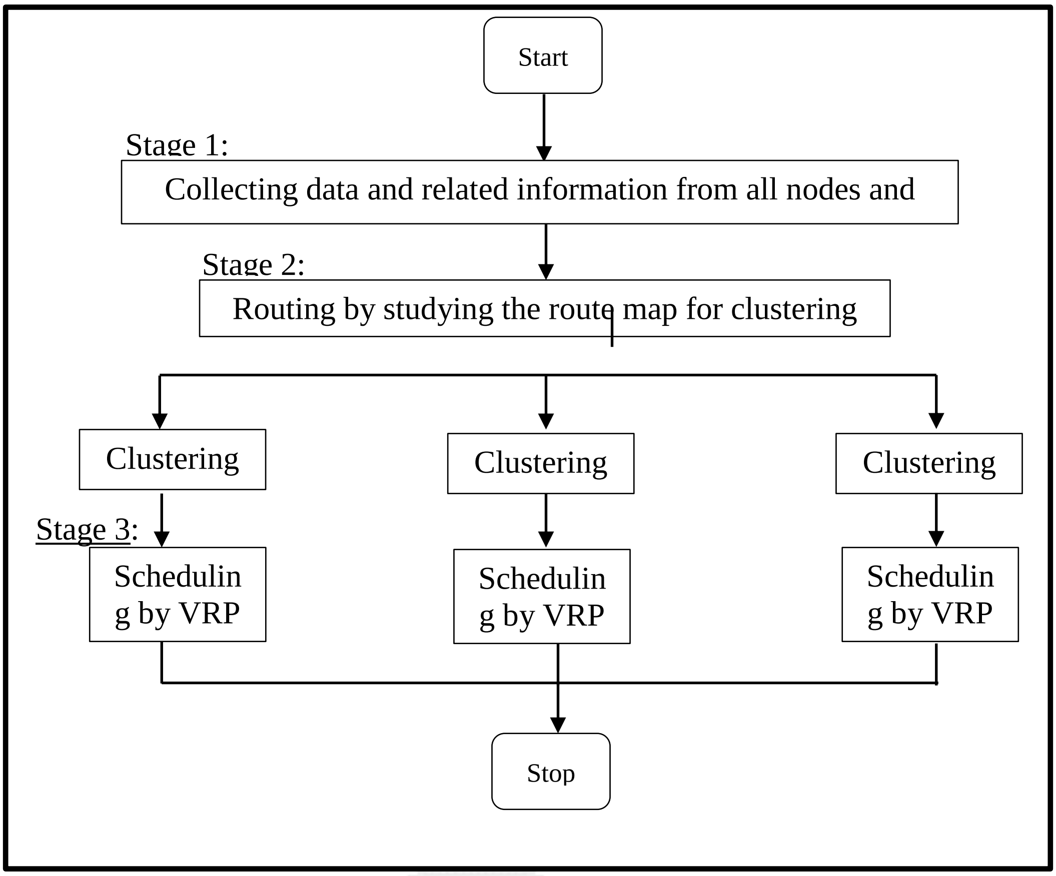

Figure 4-1 conceptual idea of vehicle routing problem (VRP)

4.1 Collecting Data and Related Information

In order to do optimization programming, all parameter inputs are required which consist of the coordinate (x,y) to indicate the position of each suppliers and see how many kilometers they are away from the centre (0,0) by setting the depot (processed rubber factory) at the coordinate (0,0). In this research, ArcGIS 10.1 for Desktop is used to support the mapping by pins to measure the distance in plane x, y which use to be a coordinate to input in the VRP solving. Moreover, amount of rubber supplying from each suppliers also required as a parameter input as well as vehicle capacity which is limited at 500 kg per car and limited time window at 90 minutes per a vehicle traveling.

Apart from the parameter, it is the clustering process which is divided referring to direction and main road of the map. All of these could be described by mapping showed below.

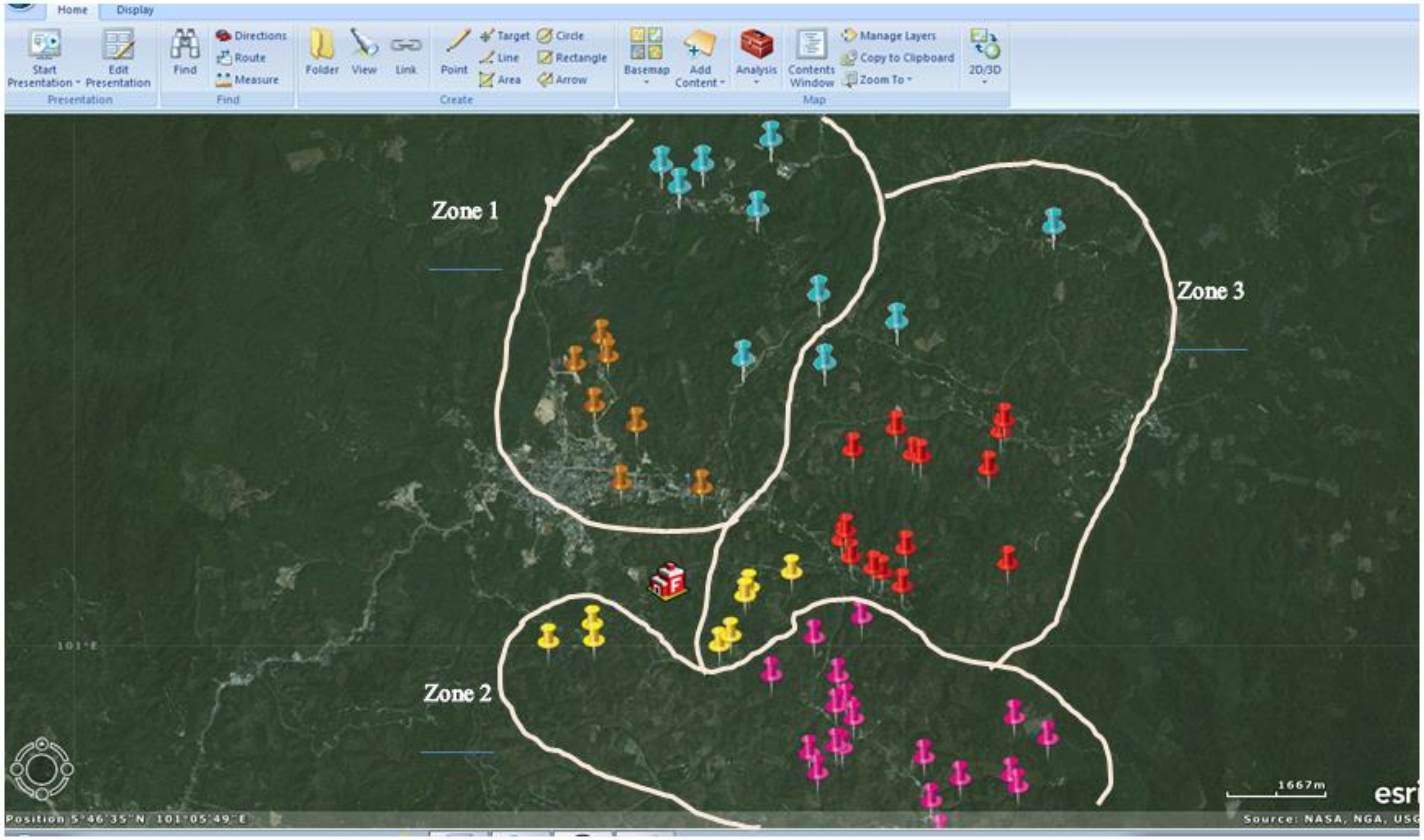

Figure 4-2 The mapping of all 62 suppliers and 1 processed rubber factory with categorized zone

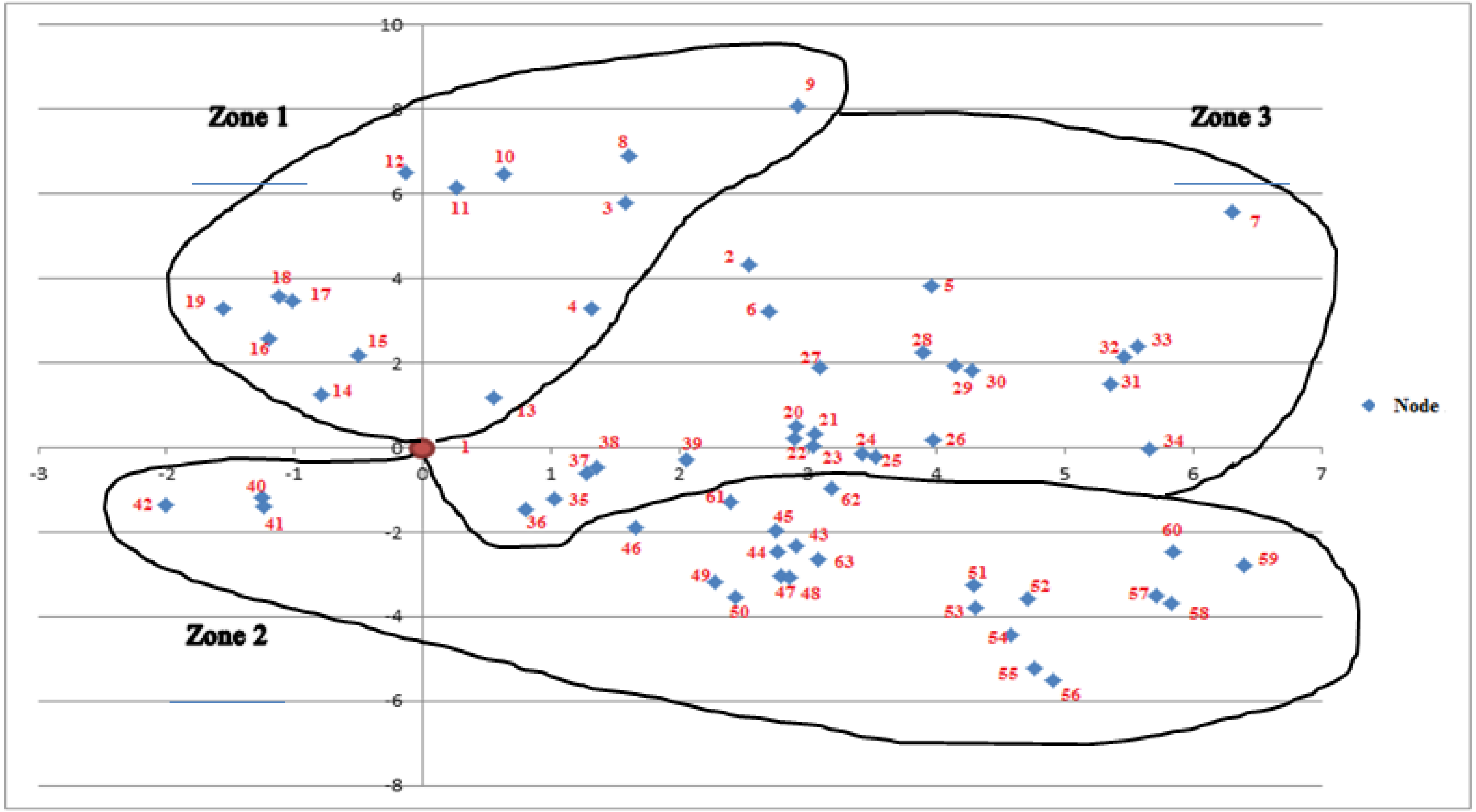

Figure 4-3 Plotted of all 62 suppliers as nodes and 1 processed rubber factor as depot

4.2 Clustering by Mapping

According to figure 4-2 and 4-3, the 62 of nodes or suppliers could be categorized into 3 zones by following.

Zone 1 consist of 15 nodes or suppliers

Zone 2 consist of 24 nodes or suppliers

Zone 3 consist of 23 nodes or suppliers

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Zone 1

Supplier ID	Node Number	Coordinate X	Coordinate Y	Amount of rubber Supplying (kg)
1	1	0	0	0.000
2	2	2.54	4.31	27.406
3	3	1.58	5.78	67.343
4	4	1.31	3.3	23.164
8	5	1.6	6.89	12.556
9	6	2.92	8.08	23.524
10	7	0.63	6.46	39.035
11	8	0.26	6.16	20.044
12	9	-0.13	6.5	12.644
13	10	0.55	1.17	36.270
14	11	-0.79	1.25	124.976
15	12	-0.51	2.18	10.950
16	13	-1.2	2.57	10.855
17	14	-1.02	3.45	30.235
18	15	-1.13	3.56	45.260
19	16	-1.56	3.29	20.066

Table 4-1 The coordinate and amount of rubber supplying of suppliers in zone 1

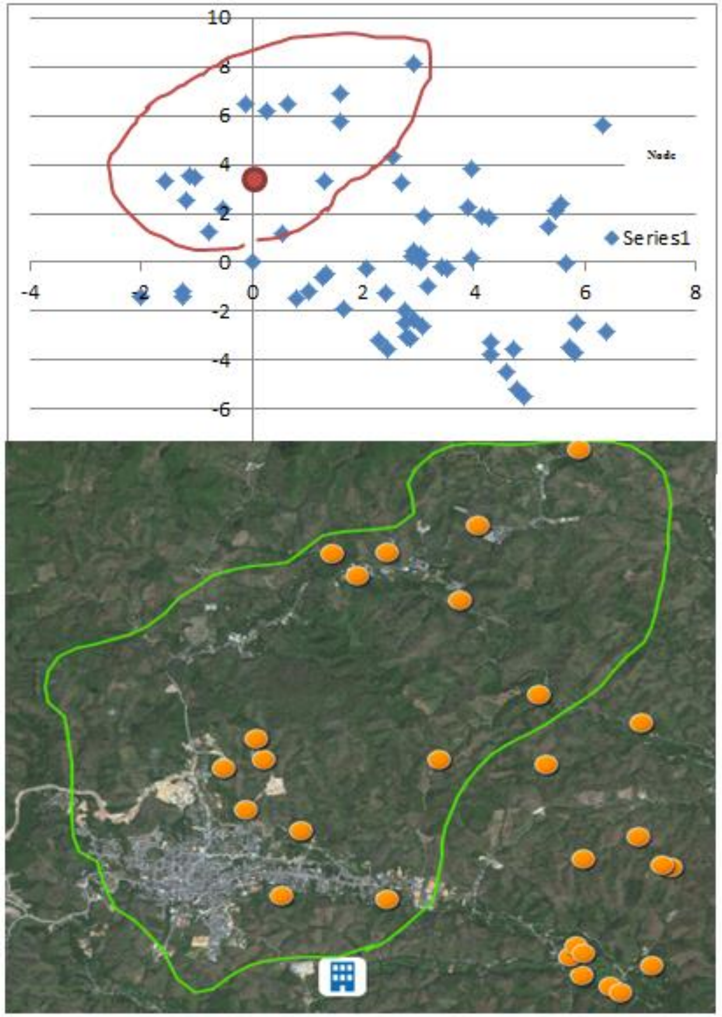


Figure 4-4 Clustering into zone 1

Zone 2

Supplier ID	Node Number	Coordinate X	Coordinate Y	Amount of rubber Supplying (kg)
1	1	0	0	0.000
40	2	-1.25	-1.17	16.079
41	3	-1.24	-1.41	7.783
42	4	-2.01	-1.37	69.319
43	5	2.91	-2.33	12.456
44	6	2.76	-2.48	16.578
45	7	2.75	-1.96	12.784
46	8	1.66	-1.91	14.923
47	9	2.79	-3.05	21.171
48	10	2.85	-3.08	7.904
49	11	2.27	-3.19	15.941
50	12	2.43	-3.55	42.329
51	13	4.29	-3.27	12.200
52	14	4.72	-3.56	13.659
53	15	4.3	-3.78	15.111
54	16	4.58	-4.45	14.089
55	17	4.77	-5.21	20.943
56	18	4.91	-5.49	34.931
57	19	5.71	-3.5	19.568
58	20	5.83	-3.67	31.538
59	21	6.4	-2.79	15.926
60	22	5.85	-2.48	7.918
61	23	2.4	-1.28	13.688
62	24	3.18	-0.95	43.810
63	25	3.08	-2.63	69.729

Table 4-2 The coordinate and amount of rubber supplying of suppliers in zone 2

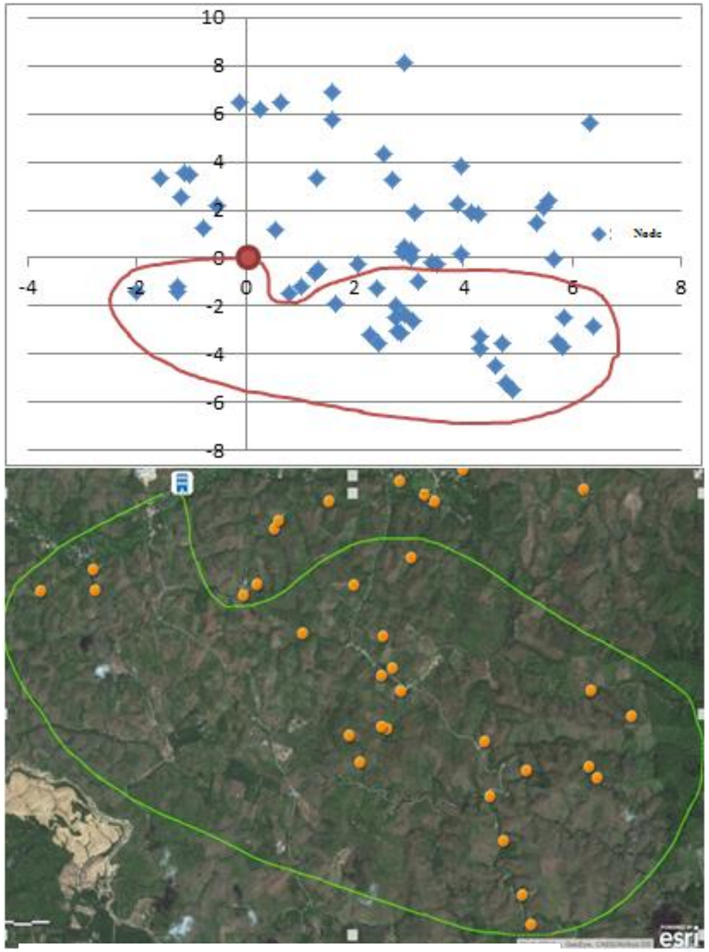
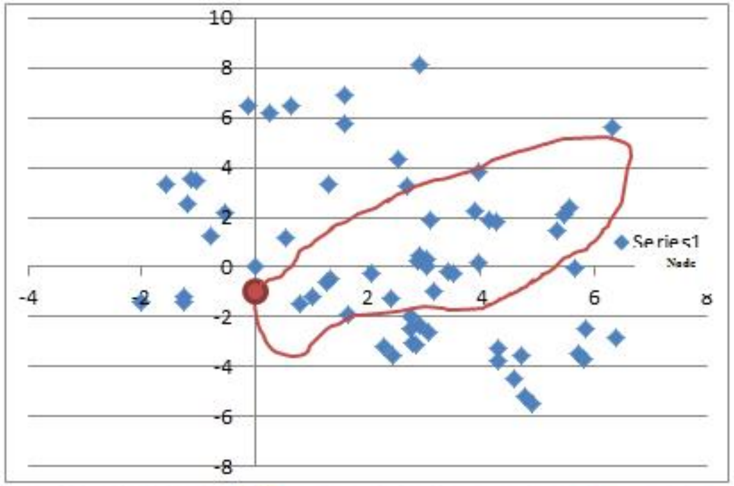


Figure 4-5 Clustering into zone 2

Zone 3

Supplier ID	Node Number	Coordinate X	Coordinate Y	Amount of rubber Supplying (kg)
1	1	0	0	0.000
5	2	3.96	3.83	35.438
6	3	2.7	3.23	16.263
7	4	6.31	5.59	22.230
20	5	2.91	0.49	7.523
21	6	3.05	0.31	39.678
22	7	2.89	0.22	15.869
23	8	3.04	0.03	14.836
24	9	3.42	-0.15	18.198
25	10	3.53	-0.22	60.294
26	11	3.97	0.16	40.619
27	12	3.09	1.89	12.244
28	13	3.9	2.24	12.864
29	14	4.15	1.92	70.558
30	15	4.28	1.83	33.635
31	16	5.36	1.49	23.620
32	17	5.46	2.14	19.473
33	18	5.57	2.41	14.999
34	19	5.66	-0.03	22.584
35	20	1.02	-1.2	28.668
36	21	0.8	-1.47	18.653
37	22	1.28	-0.6	14.295
38	23	1.35	-0.46	8.051
39	24	2.05	-0.27	31.374

Table 4-3 The coordinate and amount of rubber supplying of ers suppliers in zone 3



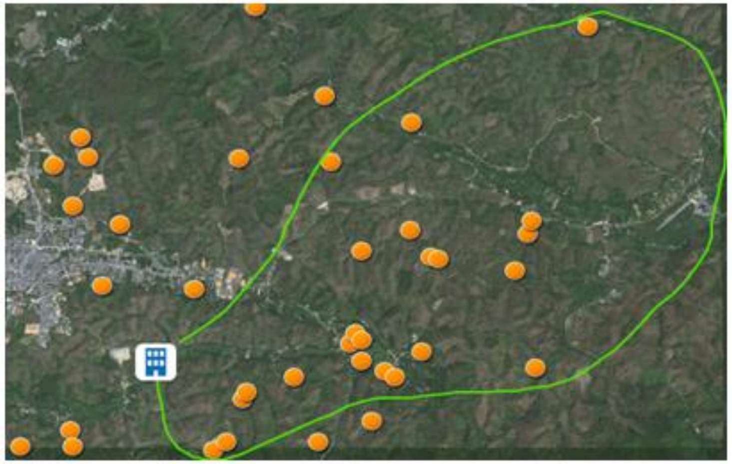


Figure 4-6 Clustering into zone 3

4.3 Mathematical Model and Computer Simulation Model for VRP

The VRP simulation model and mathematical model is stated as follows.

Stage 1: In order to do vehicle routing problem (VRP), all parameter inputs are required which is already provided in each zone from table 3-20, 3-21, and 3-22. The capacity of vehicle is limited to not exceed 500 kg in every as well as limited time window for 2 hours.

Stage 2: The first process is routing for the purpose of studying a map road and following with the clustering and scheduling. In order to set a scheduling of rubber picking up, the vehicles have to be limited capacity of the rubber contained. Then, it is the process to identify the route with the shortest of distance.

Stage 3: It is an evaluation of route stage after doing the VRP optimization programming which proposes to minimize the transportation cost or distance.

Stage 4: From the result of the VRP solving, it would be renew clustering by considering limited capacity of vehicle and time window if the result is not achieve the optimal solutions.

Stage 5: If the result is already achieved the minimized transportation cost or distance, the output best solution set of the result would be represented.

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Simulation Model

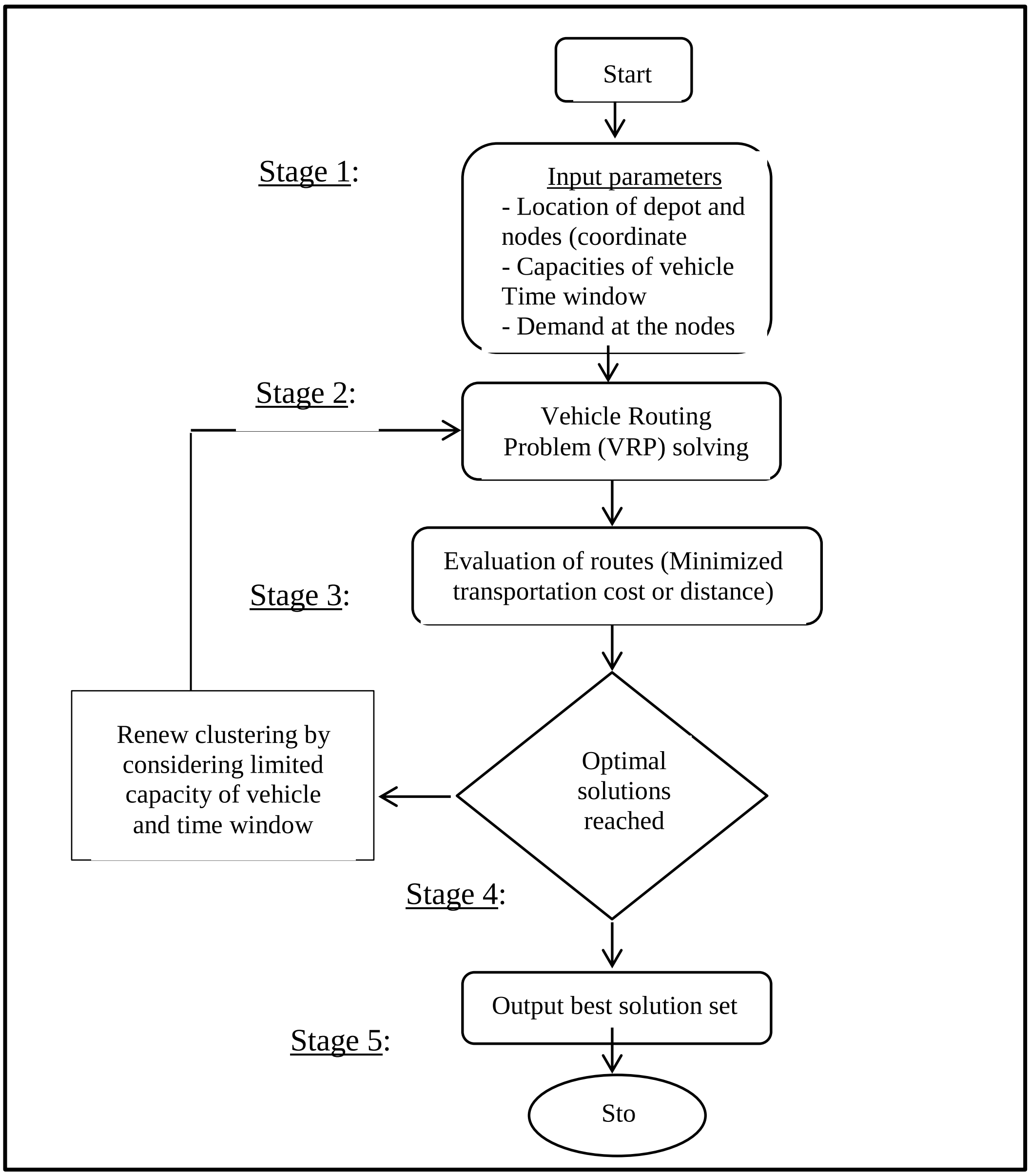

Figure 4-7 The flow chart of the vehicle routing problem (VRP)

From figure 4-7, the proposed method of VRP is shown and it can be solved by optimization program that is called IBM ILOG CPLEX Optimization to solve this problem. The problem solving is presented in mathematical model as following

Notation

Indices:

i, j represents node number or supplier i or j including the factory (i=1); i, j = 1…n

k represents number of vehicle = {1, 2, 3}

n represents total number of suppliers

p represents node number who already have been visited; p = 2…n

Parameters:

D_{ij} represents distance from node i to j

q_i represents amount of rubber milk being received at node i

a_k represents capacity of vehicle k which is not exceed 500 kg

t_{ijk} represents travel time from node i to j by vehicle k

T_k represents time window of vehicle that is not over 90 minutes

t_{ik} represents rubber pick up time at node i (5 minutes)

Decision Variables:

x_{ijk} represents 1 when vehicle k is traveled from i to j; 0 otherwise

y_{ij} represents 1 when the path of node i to node j is traveled; 0 otherwise

u represents decision variable to eliminate the sub tour

z represents minimized distance as well as cost travel from route travelling (node i to j) by vehicle k

Mathematical Model

Objective:

$$\text{Min } z = \sum_{k=1}^{k} \sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij}\ x_{ijk} \qquad (1)$$

Subject to:

Vehicle k must depart from the depot (node i = 1) and arrive to supplier place (node j) at least one.

$$\sum_{j>1}^{n} x_{1jk} \leq 1 \qquad , k = 1\ldots k \qquad (2)$$

To ensure that supplier will be visited only 1 time

$$\sum_{i=1}^{n} x_{ipk} - \sum_{j=1}^{n} x_{pjk} = 0 \qquad , p = 1\ldots n, k = 1\ldots k \qquad (3)$$

To ensure that one supplier or node will be visited by one vehicle

$$\sum_{k=1}^{k} y_{ik} = 1 \qquad , i = 1\ldots n, i > 1 \qquad (4)$$

To limit the capacity of rubber being received for vehicle

$$\sum_{i>1}^{n} q_i\, y_{ik} \leq a_k \qquad , k = 1\ldots k \qquad (5)$$

To limit the time window for vehicle traveling

$$\sum_{i=1}^{n} t_{ik} \sum_{j=1}^{n} x_{ijk} + \sum_{i=1}^{n} \sum_{j=1}^{n} t_{ijk}\, x_{ijk} \leq T_k \ , k = 1\ldots k \qquad (6)$$

To ensure for traveling through node i that a vehicle k have to leave from node j

$$y_{ik} \leq \sum_{j=1}^{n} x_{ijk} \qquad , i = 2\ldots n, k = 1\ldots k \qquad (7)$$

To ensure that nod j will be visited one time which travel from node i by vehicle k

$$\sum_{k=1}^{k} \sum_{i=1}^{n} x_{ijk} \geq 1 \qquad , j = 1\ldots n \qquad (8)$$

To eliminate the sub tour

$$[(u_i - u_j) + (n-1)]x_{ijk} \leq (n-2) \quad , k = 1\ldots k, i = 2\ldots n, j = 2\ldots n \text{ and } j \neq i \qquad (9)$$

After the problem solving from the proposed method of VRP in chapter 3, IBM ILOG CPLEX optimization was used to identified the result which focusing on the minimized distance and effect to minimized cost. In order to solve the problems, 62 suppliers as nodes is quite large scales problem which requires a lot of time to solve. Therefore, it is better to do “Cluster-First Route-Second” as following.

4.4 Result and Analysis of Clustering (Tier 1)

The next process is called “cluster-first route-second” by using sweep method combined with a nearest neighbor search. These method is use to divide the area into 3 zones based on the direction and main road. Then, the result of zone dividing is conclude as following table 4-4 and it could be describe in the picture as figure 4-8 to 4-14.

Zone	Node Number/Supplier ID
1	2 3 4 8 9 10 11 12 13 14 15 16 17 18 19
2	40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
3	5 6 7 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39

Table 4-4 The clustering of all 62 suppliers into 3 zones

After solving with the computer program, the results would show the routing in term of schedule in each zone in order to get the minimize displacement and distance and undthe constraints of vehicle’s capacity and time window. The results are shown as table 4-5 following.

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4.4.1 Results of the vehicle routing problem

Route Number/ Zone	Scheduling	Displacement (km)	Time (minutes)	Distance (km) from the map	Time Window (Max = 90 min)	Capacity (500 kg)
1 (k=1) /Zone 1	1→4→2→3→9→8→10→11→12→18→17→19→16→15→1	21.052	86.052	24.7	89.7	343.081
2 (k=2) /Zone 1	1→13→14→1	4.060	14.060	6.03	16.03	161.246
3 (k=1) /Zone 2	1→46→45→43→44→63→48→47→50→49→41→42→40→1	12.906	72.906	14.73	74.73	306.994
4 (k=2) /Zone 2	1→51→52→53→54→55→56→58→57→59→60→62→61→1	18.545	78.545	25.5	85.5	243.379
5 (k=1) /Zone 3	1→36→35→37→38→39→22→23→24→25→34→26→20→21→1	13.273	78.273	16.7	81.7	320.639
6 (k=2) /Zone 3	1→27→28→29→30→32→31→33→7→5→6→1	18.958	68.958	24.4	74.4	261.321

Table 4-5 The results of the vehicle routing problem (Tier 1)

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According to the results of the vehicle routing problem (VRP) from table 4-5, there are two vehicles used in each zone which is minimized number and get enough capacity for rubber picking up under the controllable time. So, there would be 6 routes in this program solving with the minimize displacement and minimize traveling distance by measuring on the map. All the issues would be discussed route by route as following.

Considering in route 1, the minimize distance for vehicle's travelling is 21.052 km under the constraints restricted that is not over 90 minutes of time window and 500 kg of vehicle's capacity. However, 89.7 minutes of travelling time might be possibly an overtime which effect to quality of the rubber to be coagulated. Focusing in route 2, there is few numbers of suppliers although it achieves the targeted constraints. This is not benefit to deal with the cost of vehicle used and payment for driver in order to get the small amount of rubber from 2 suppliers.

In rout 3, from the result of vehicle routing problem above, there were some disadvantage in route 2, 4 and 6 that is the low number of rubber being received. Moreover, there might be overtime for traveling and rubber picking up in route 3. So, next stage is to improve scheduling by canceling route 2 and 4 and transferring some suppliers in the route including switched suppliers. Then, we will make time window and vehicle capacity are more flexible from 90 minutes to 120 minutes and 500 kg capacity to 600 kg. These will support the new vehicle routing to be more efficient and beneficial which can be seen as table below.

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Result of Routing

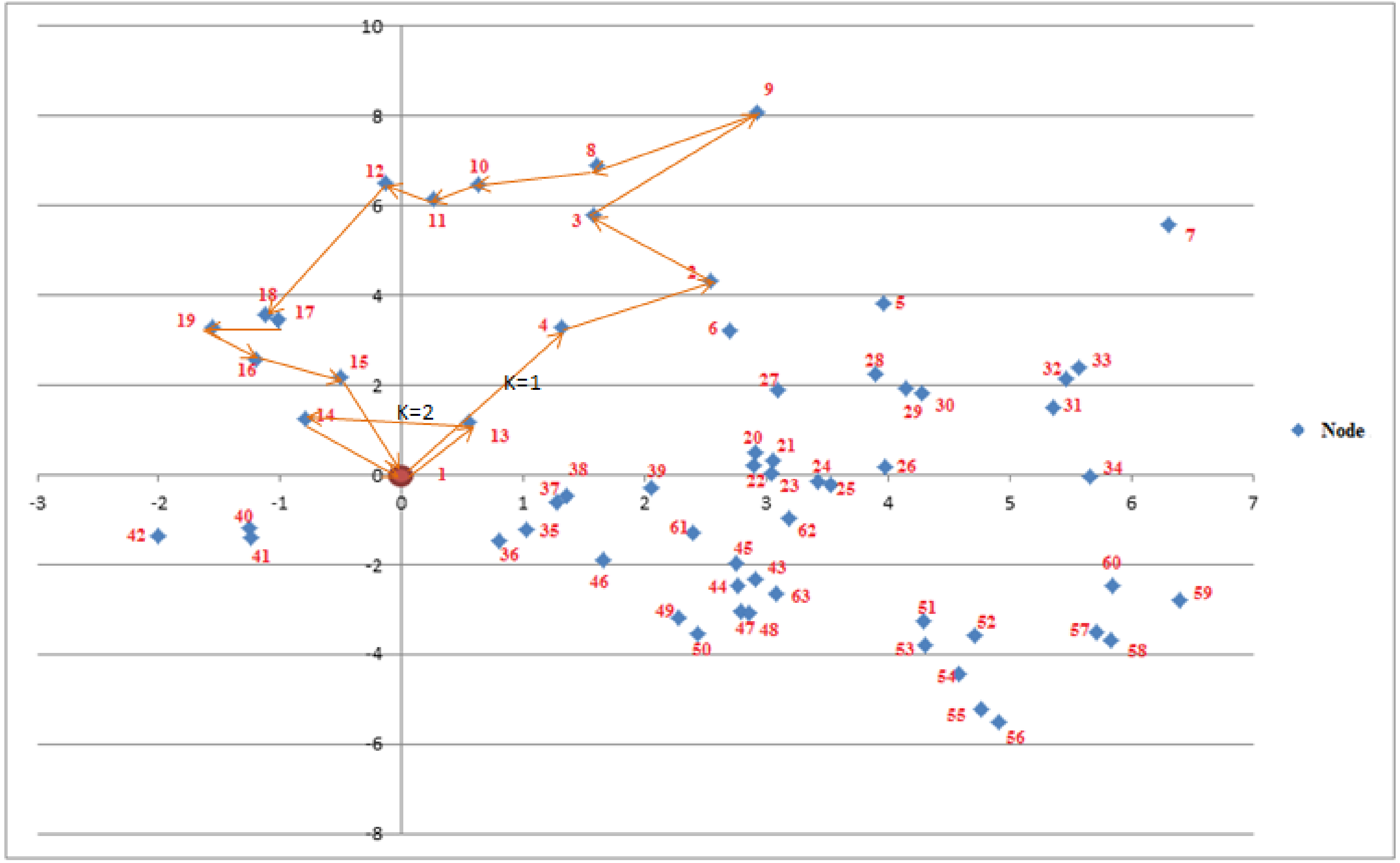

Figure 4-8 Graph of vehicle routing in route 1 (Tier1)

Routing on the map

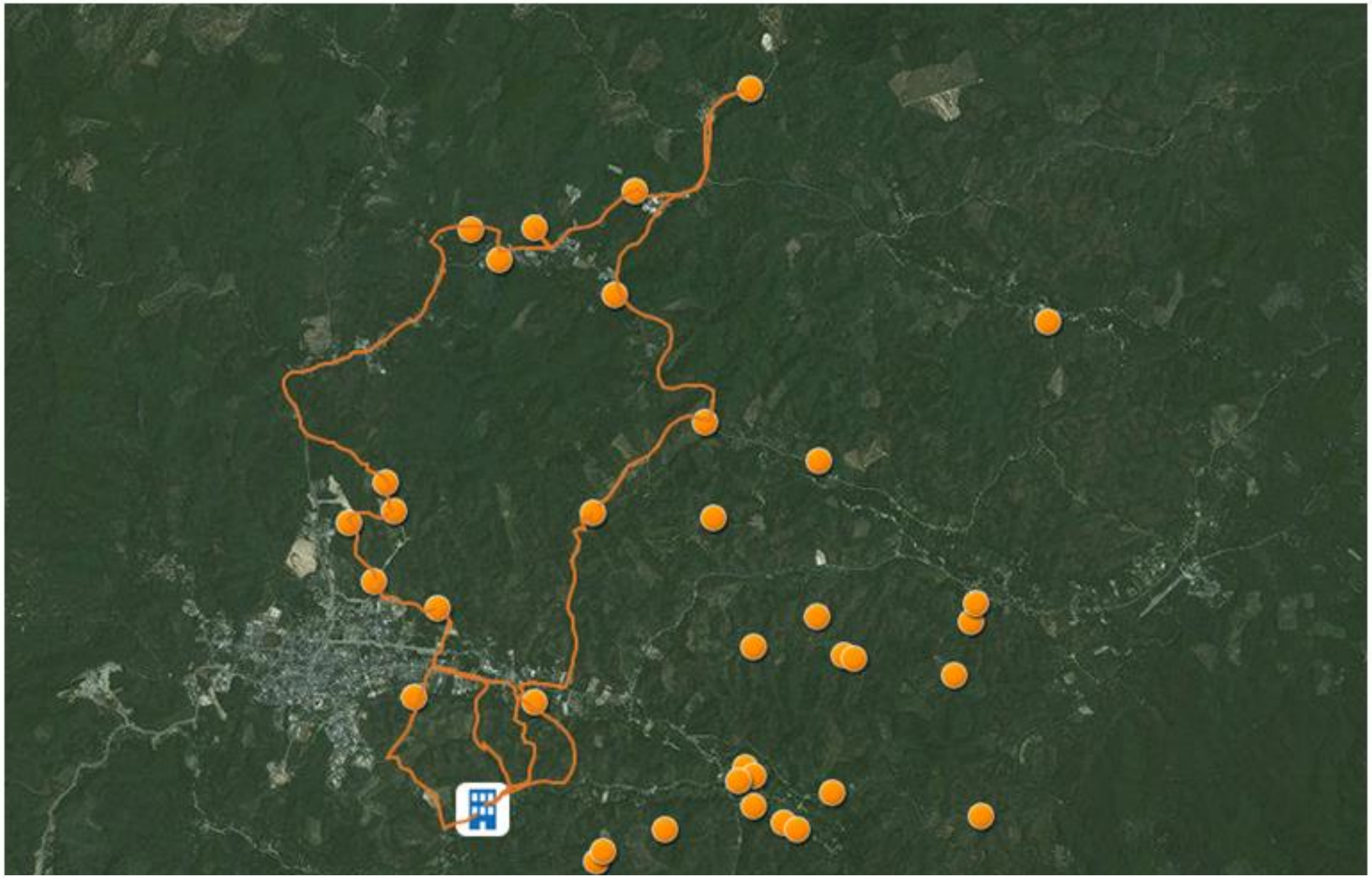

Figure 4-9 Vehicles routing on the map in route 1 (Tier1)

Result of routing

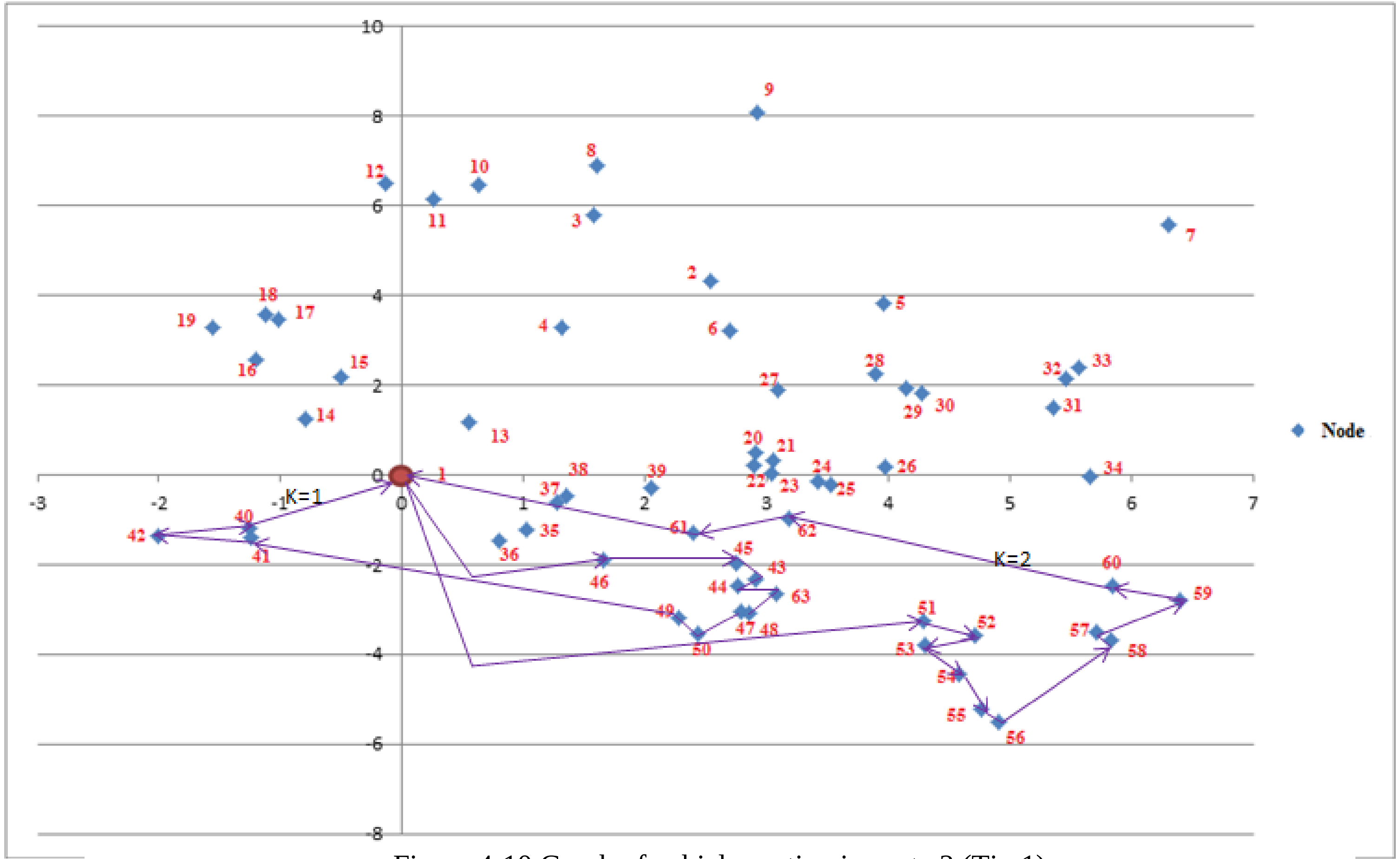

Figure 4-10 Graph of vehicle routing in route 2 (Tier1)

Routing on the map

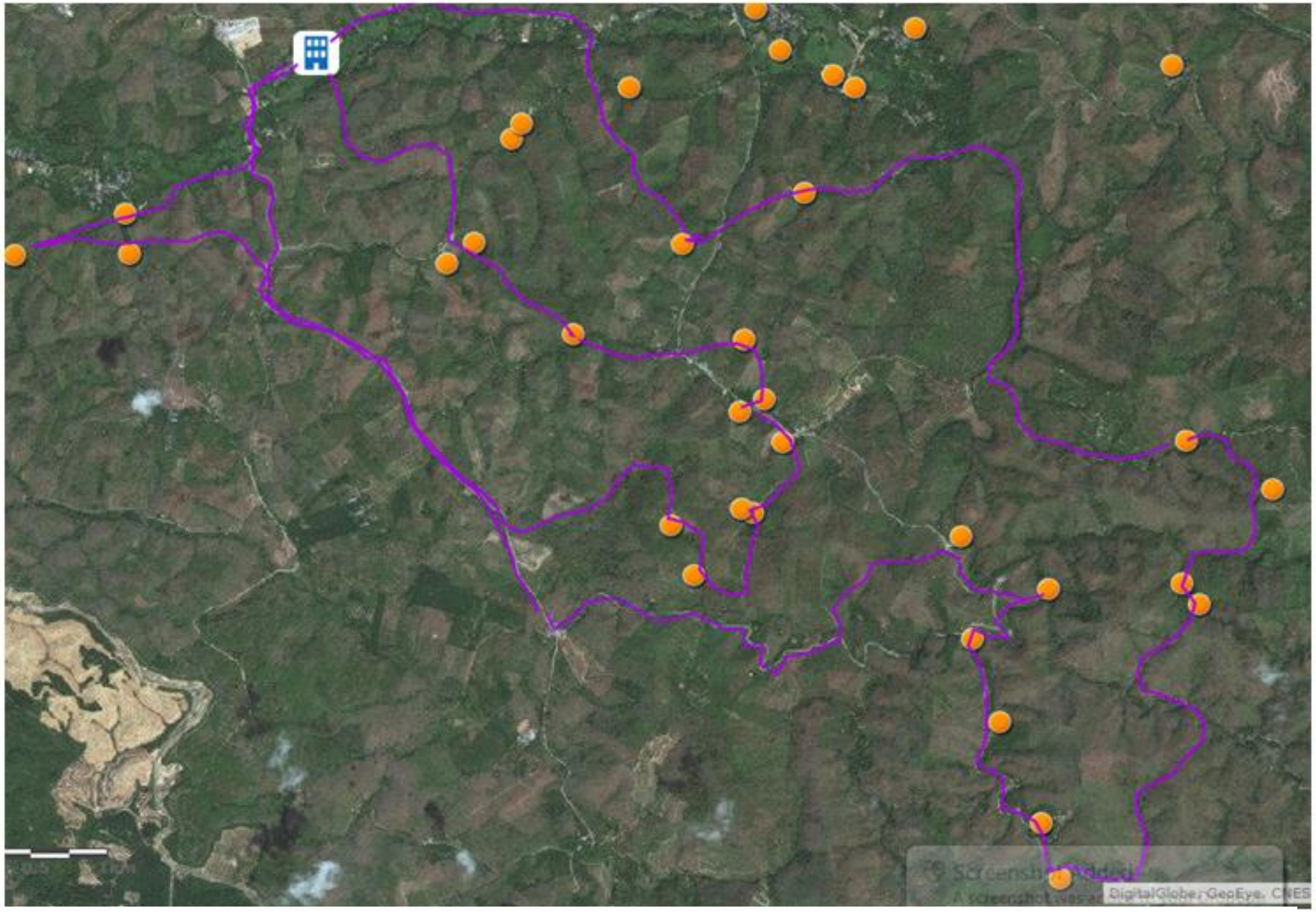

Figure 4-11 Vehicles routing on the map in route 2 (Tier1)

Result of routing

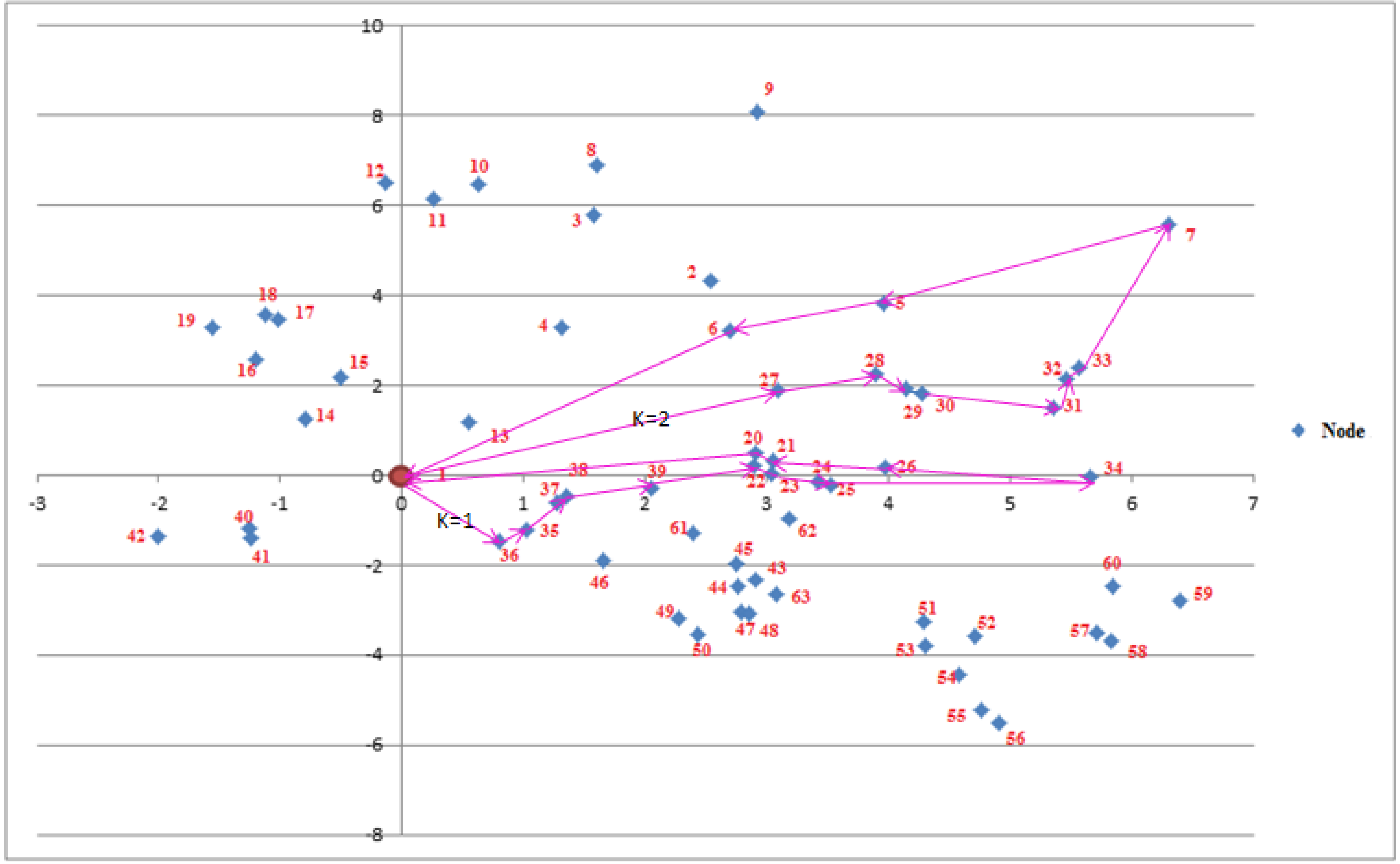

Figure 4-12 Graph of vehicle routing in route 3 (Tier1)

Routing on the map

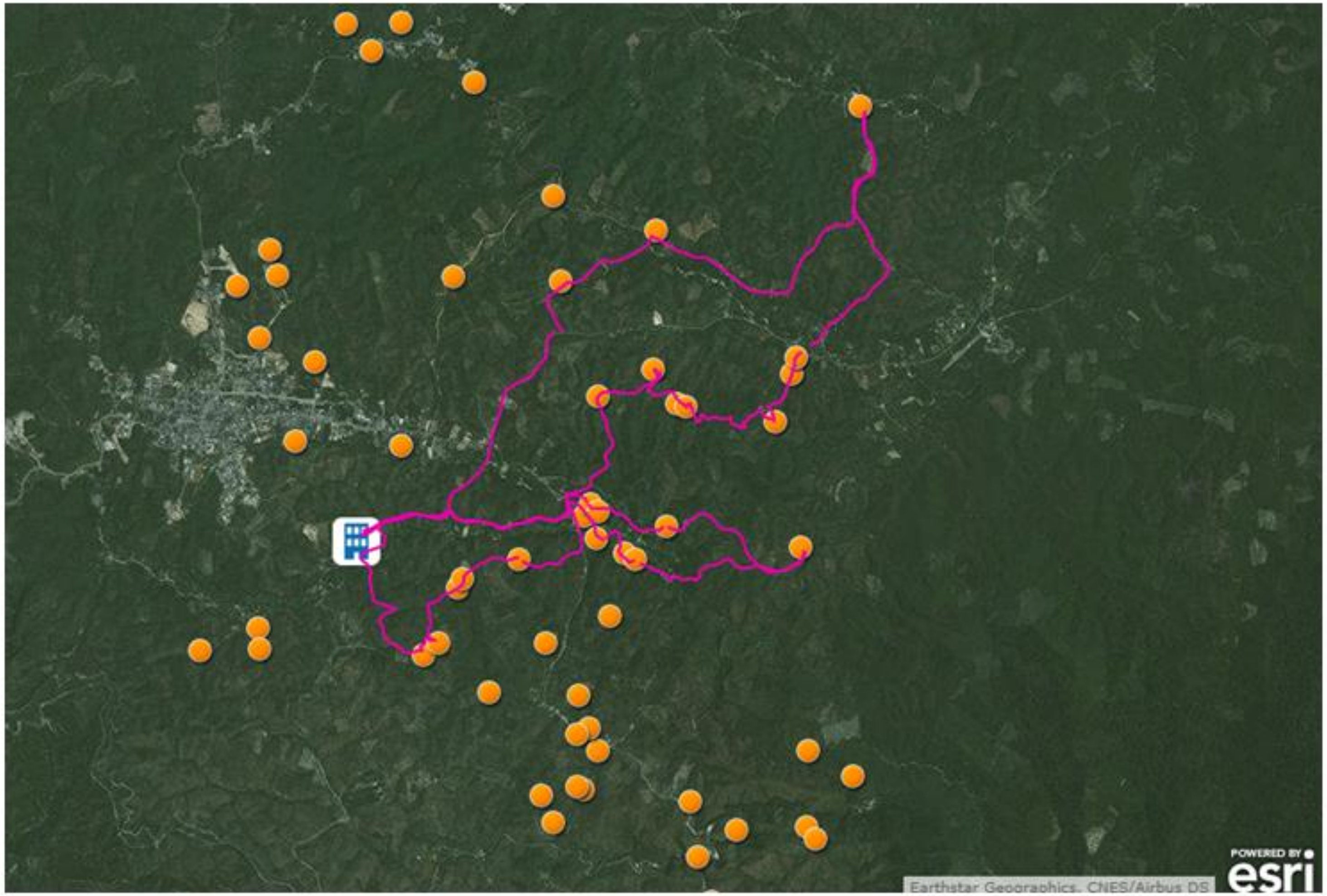

Figure 4-13 Vehicles routing on the map in route 3 (Tier1)

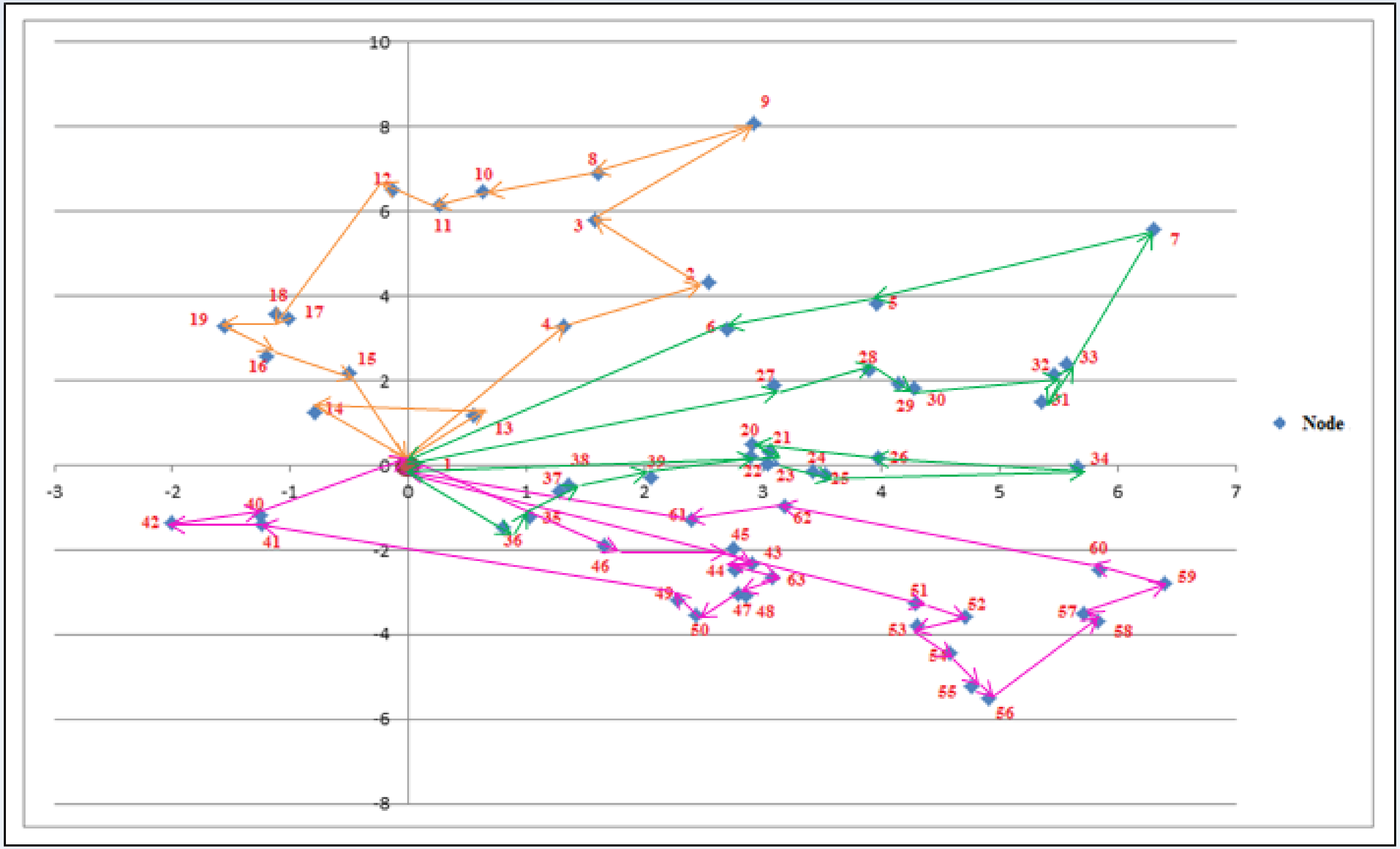

Figure 4-14 Graphs of vehicles routing for clustering into 3 groups

4.5 Result and Analysis of Clustering (Tier 2)

From the overview of vehicle routing problem in figure 4-15, there were some disadvantage in route 2, 4 and 6 that is the low number of rubber being received. Moreover, there might be overtime for traveling and rubber picking up in route 3. So, next stage is to improve scheduling by canceling route 2 and 4 and transferring some suppliers in the route including switched suppliers. Then, we will make time window and vehicle capacity are more flexible from 90 minutes to 120 minutes and 500 kg capacity to 600 kg. These will support the new vehicle routing to be more efficient and beneficial which can be seen as table below.

Route	Node Number/Supplier ID
1	3 8 9 10 11 12 14 15 16 17 18 19 40 41 42
2	43 44 45 47 48 49 50 51 52 53 54 55 56 57 58 59 60 63
3	20 21 22 23 24 25 26 34 35 36 37 38 39 46 61 62
4	2 4 5 6 7 13 27 28 29 30 31 32 33

Table 4-6 New clustering of all 62 suppliers into 4 routes (Tier 2)

After solving with the computer program, the results would show the routing in term of schedule in each zone in order to get the minimize displacement and distance and undthe constraints of vehicle’s capacity and time window. The results are shown as table 4-7 following.

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4.4.2 Results of the vehicle routing problem

Route Number / Zone	Scheduling	Displacement (km)	Time (minutes)	Distance (km) from the map	Time Window (Max = 90 min)	Capacity (500 kg)
1	1→14→15 →3→9→8 →10→11→ 12→18→17 →19→16→ 42→41→40 →1	24.481	99.481	31.3	106.3	510.668
2	1→47→48 →49→50→ 53→54→55 →56→58→ 57→59→60 →52→51→ 63→44→43 →45→1	18.954	108.95 4	27.7	117.7	384.773
3	1→35→36 →46→61→ 62→34→26 →25→24→ 23→21→20 →22→39→ 38→37→1	14.233	94.233	20.2	100.2	393.059
4	1→27→28 →29→30→ 31→32→33 →7→5→2 →6→4→13 →1	20.888	85.888	27.6	92.6	348.161

Table 4-7 The results of the vehicle routing problem (Tier 2)

According to the results of the vehicle routing problem (VRP) from table 4-7, there is a vehicle used in each clustering which is minimized number and get enough capacity for rubber picking up under the controllable time. So, there would be 4 routes in this program solving with the minimize displacement and minimize traveling distance by measuring on the map as shoe in the figure below.

Result of routing

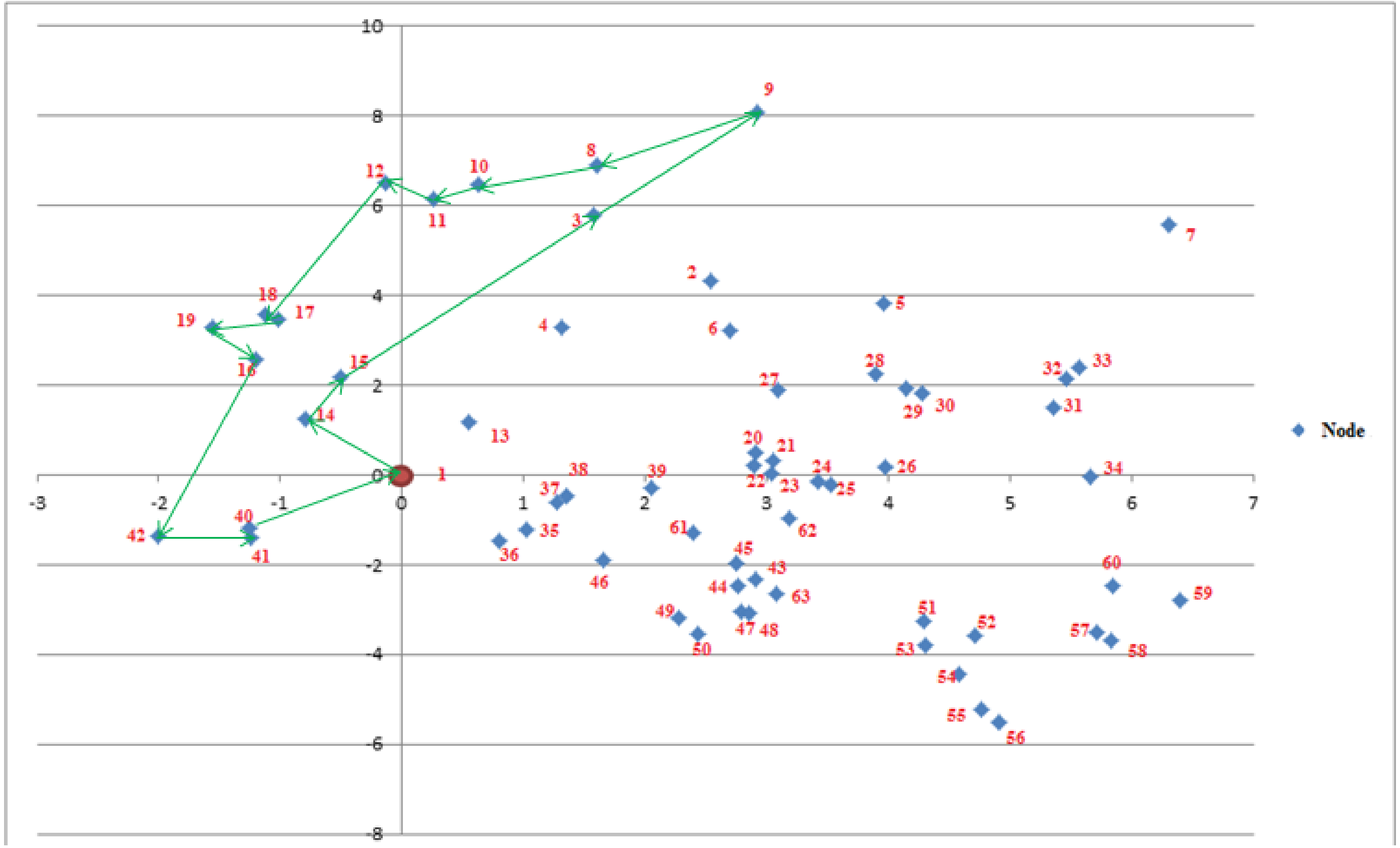

Figure 4-15 Graph of vehicle routing in route 1 (Tier2)

Routing on the map

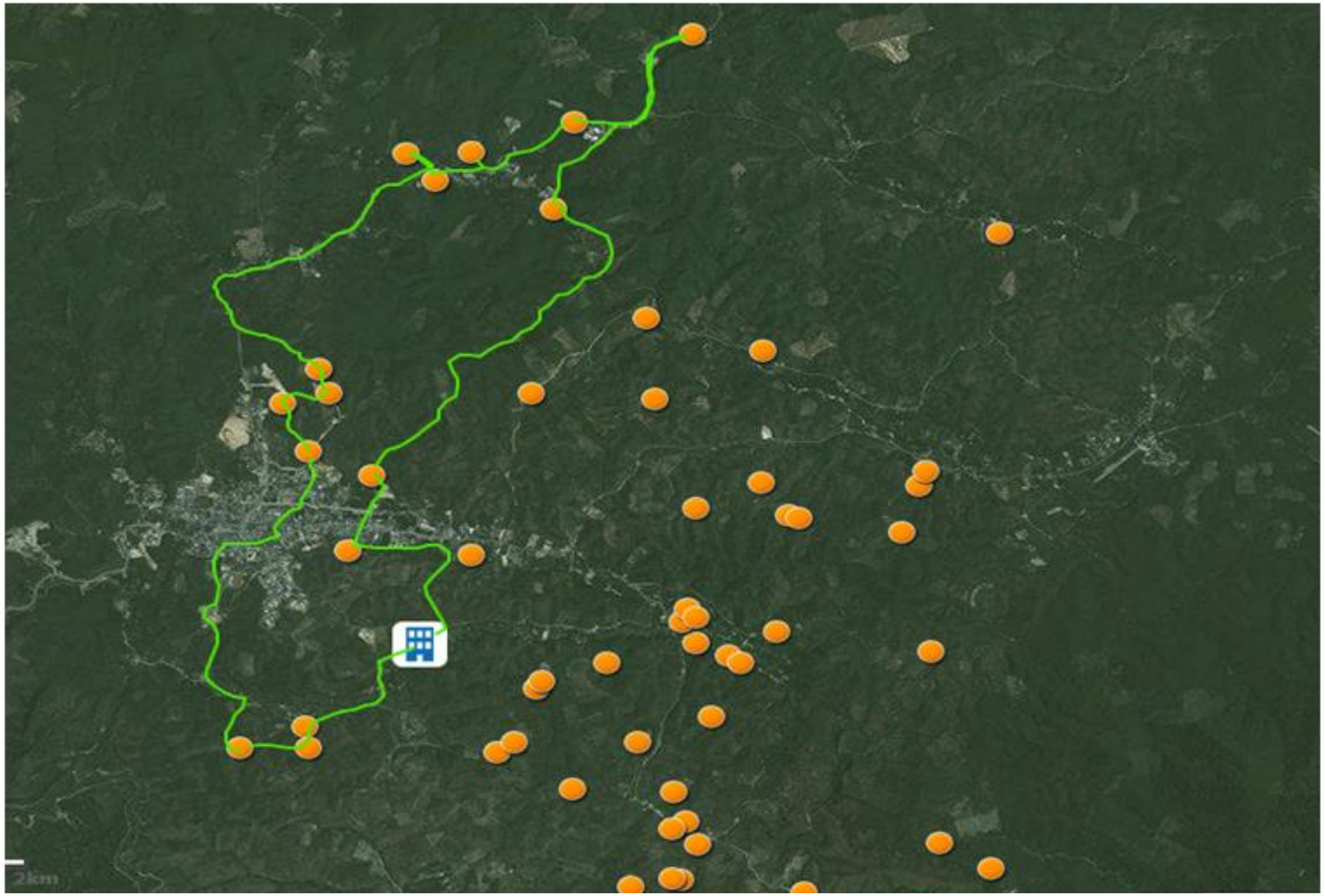

Figure 4-16 Vehicles routing on the map in route 1 (Tier2)

Result of routing

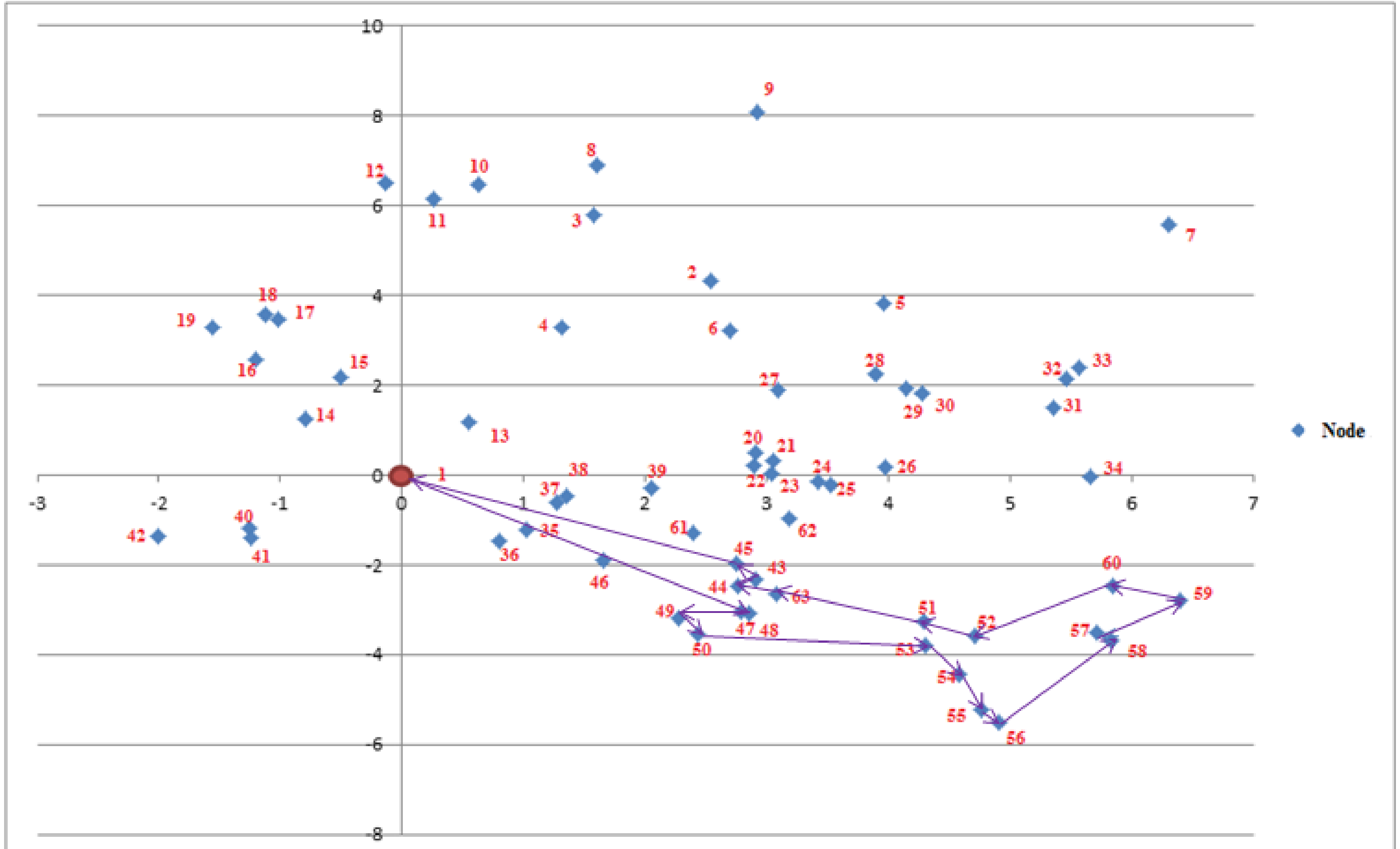

Figure 4-17 Graph of vehicle routing in route 2 (Tier2)

Routing on the map

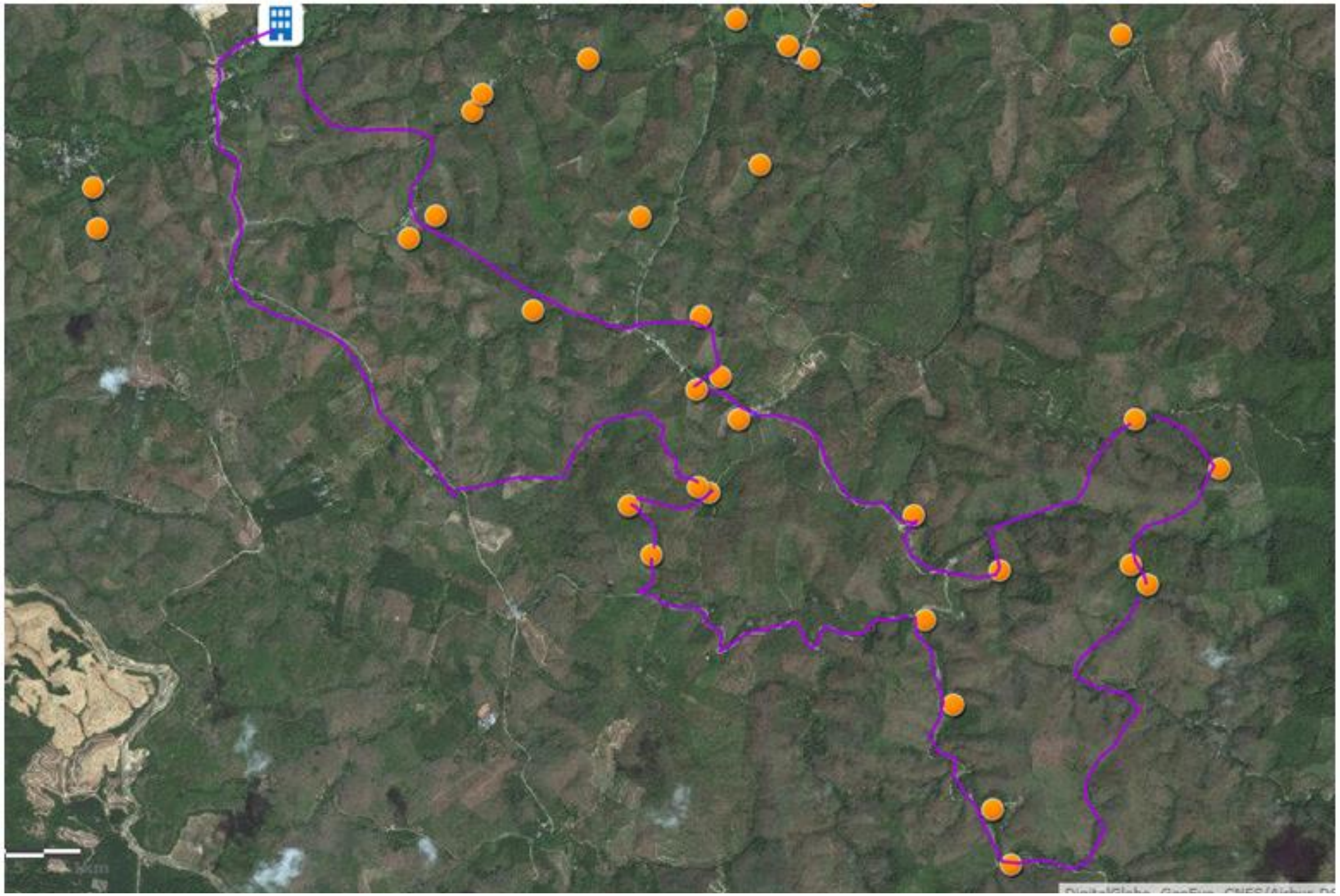

Figure 4-18 Vehicles routing on the map in route 2 (Tier2)

Result of routing

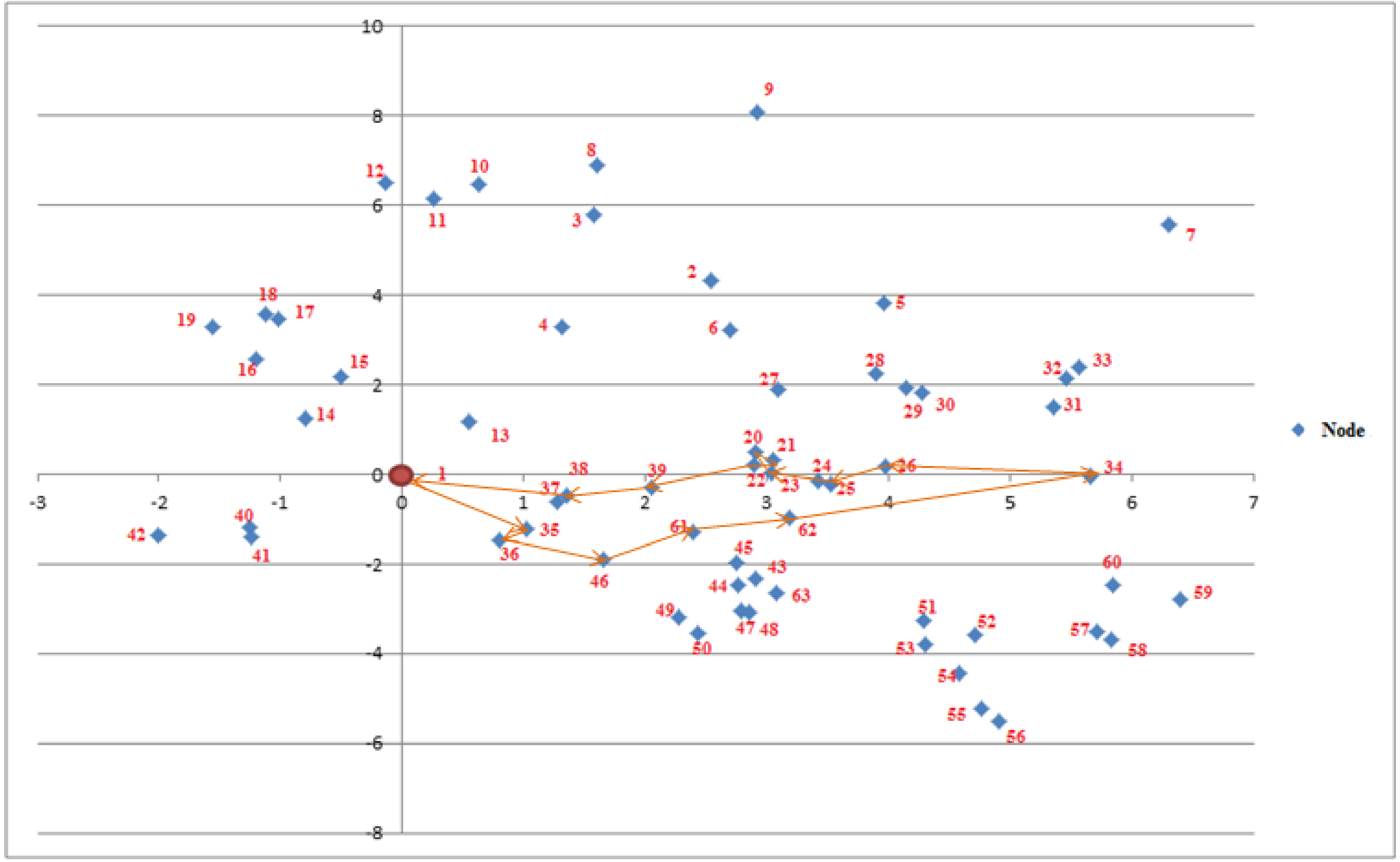

Figure 4-19 Graph of vehicle routing in route 3 (Tier2)

Routing on the map

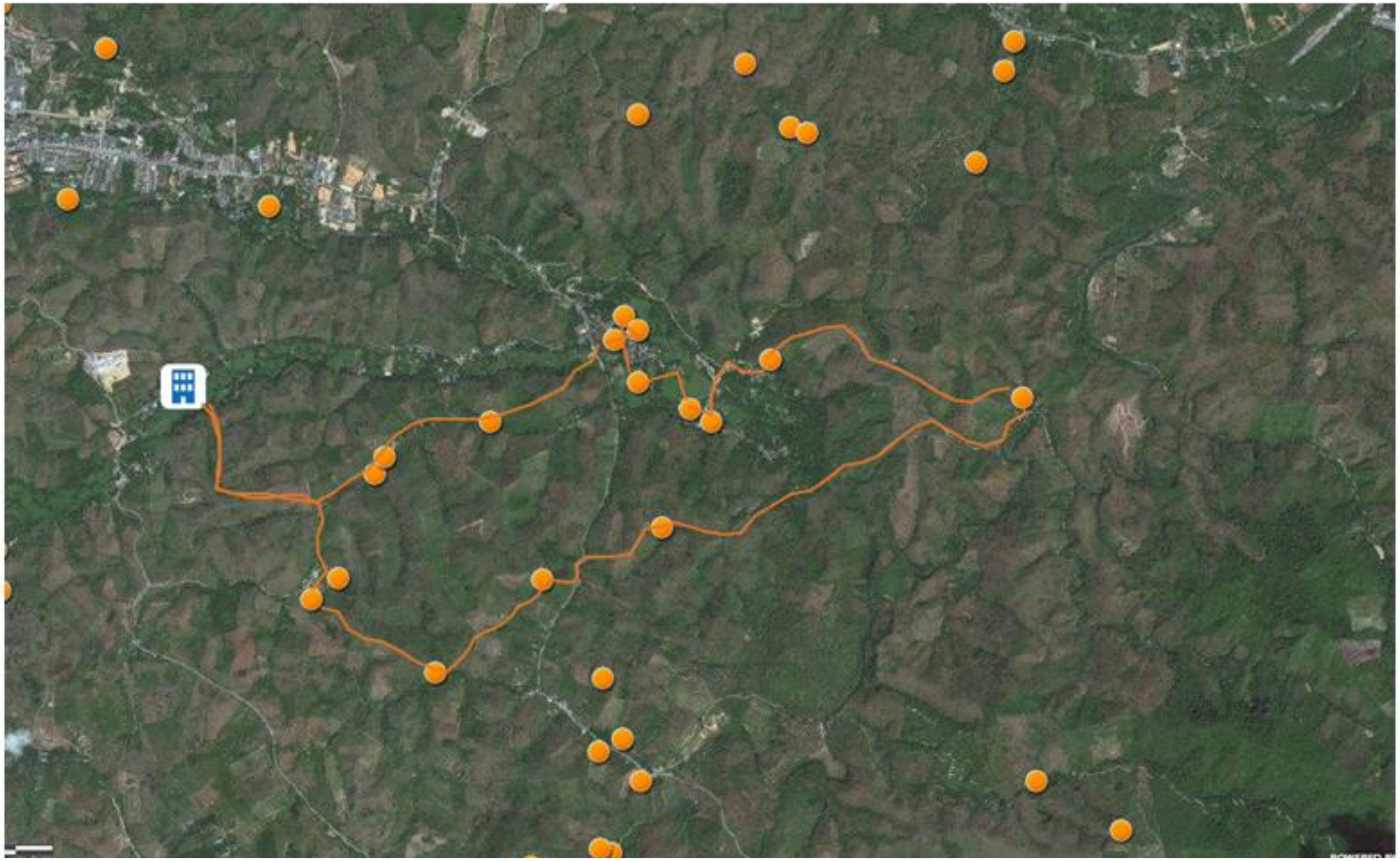

Figure 4-20 Vehicles routing on the map in route 3 (Tier2)

Result of routing

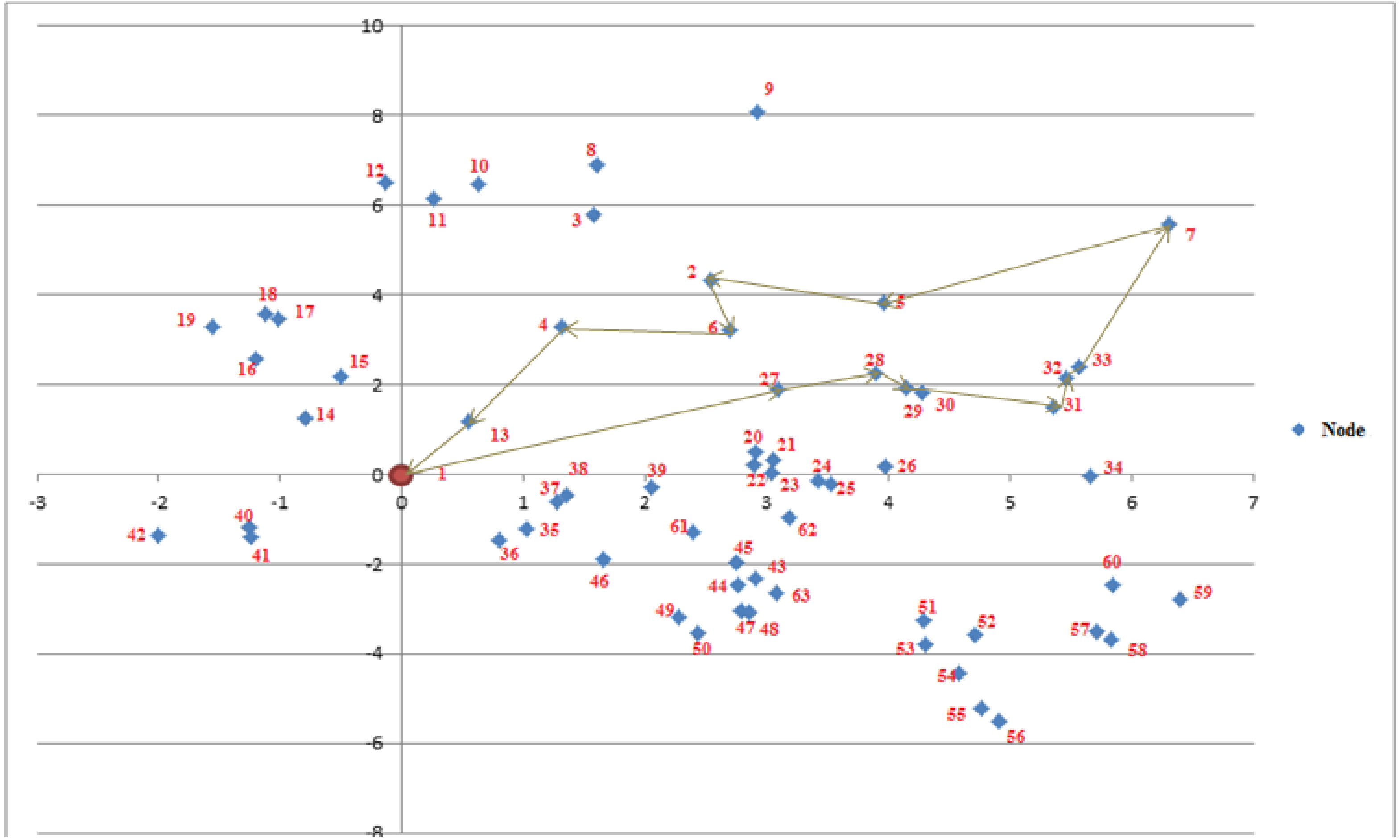

Figure 4-21 Graph of vehicle routing in route 4 (Tier2)

Routing on the map

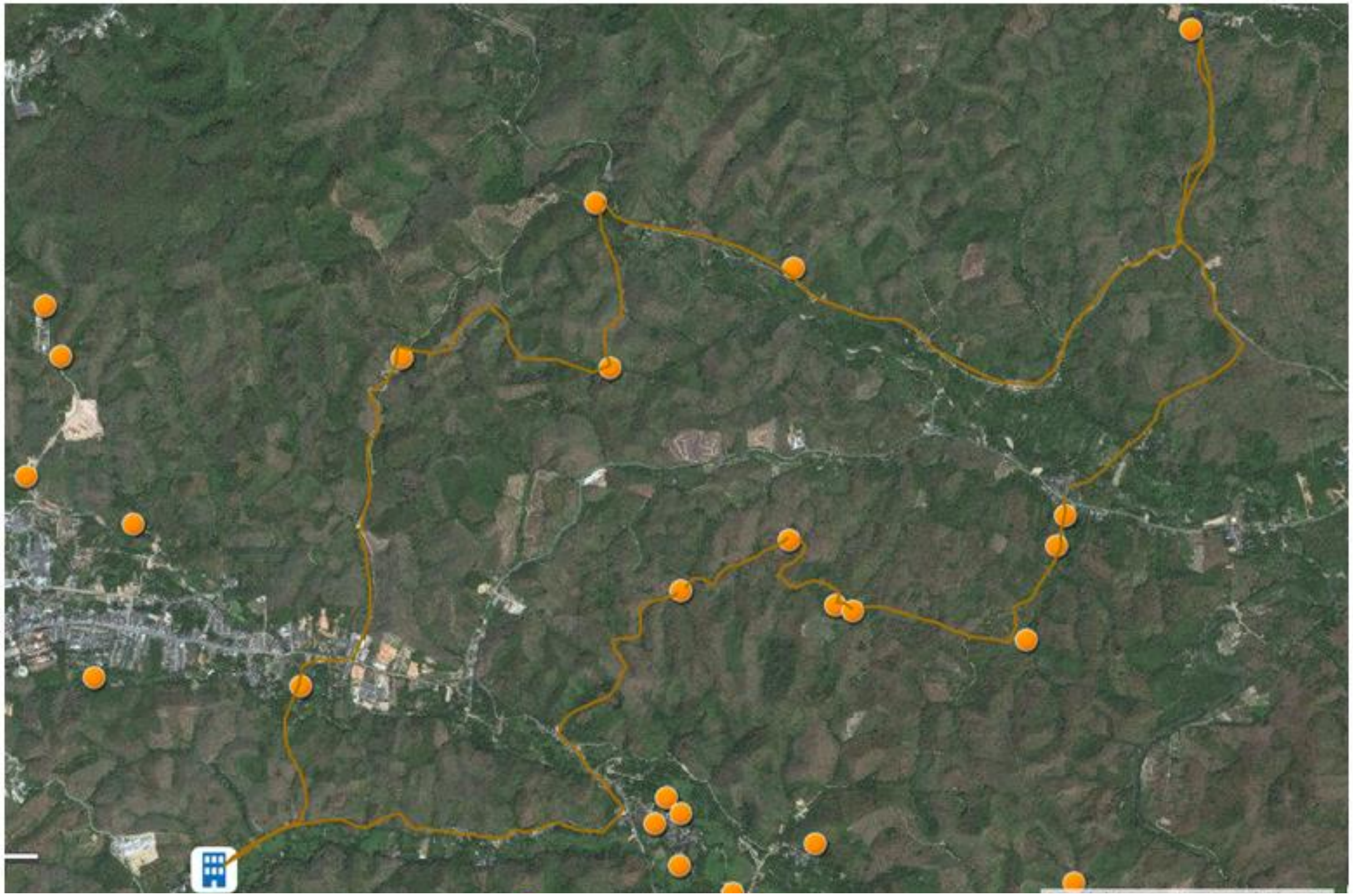

Figure 4-22 Vehicles routing on the map in route 4 (Tier2)

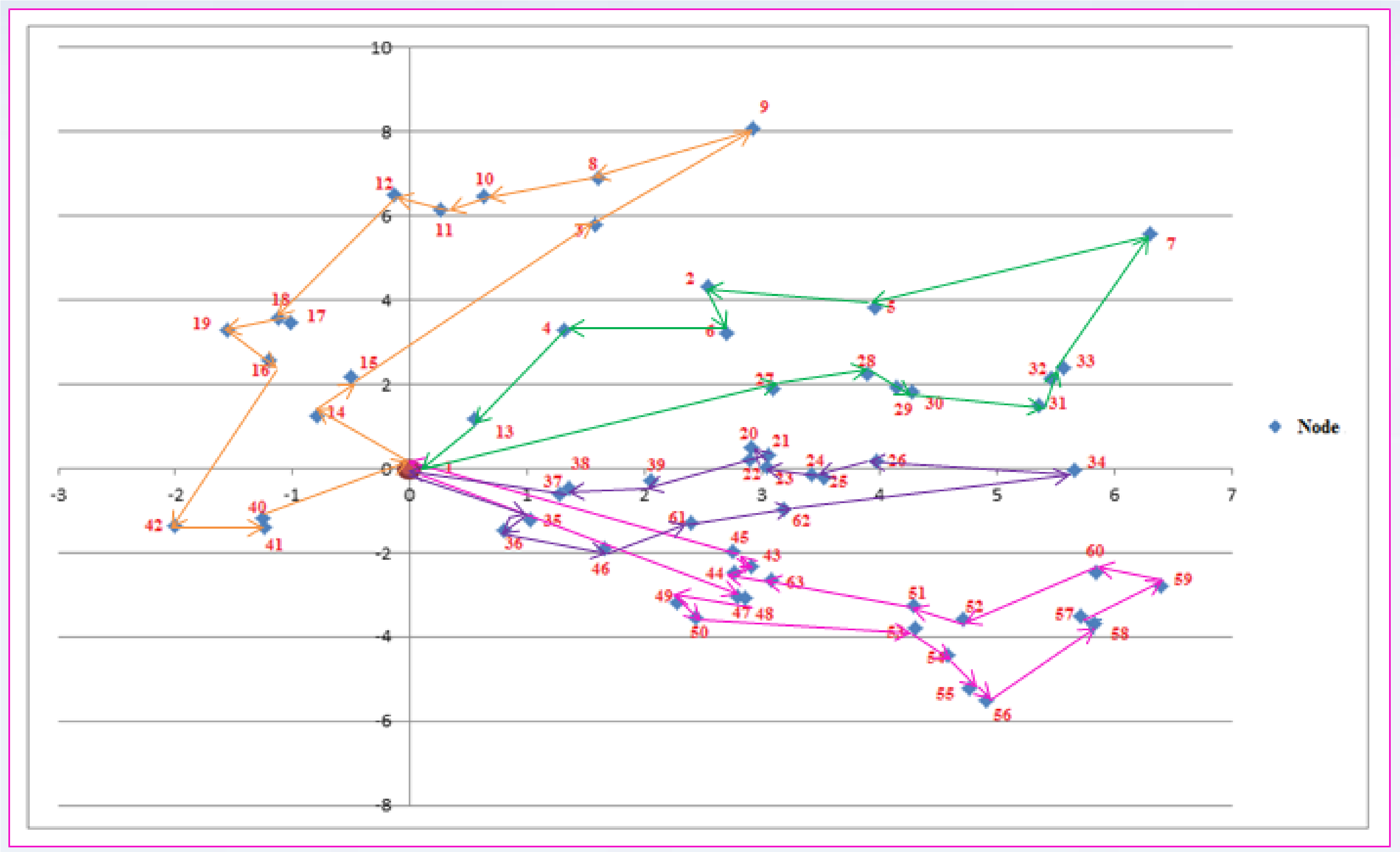

Figure 4-23 Graphs of vehicles routing for clustering into 4 groups

4.6 Result and Analysis of Clustering (Tier 3)

In tier 3, there is new clustering into 5 routes in order to compare with the clustering into 4 routes and 6 routes. Then, the result will compare about which one is more efficient and beneficial especially in term of cost reduction in the next chapter.

Route	Node Number/Supplier ID
1	3 8 9 10 11 12 14 15 16 17 18 19
2	35 37 38 40 41 42 46 47 48 49 50
3	43 44 45 51 52 53 54 55 56 57 58 59 60 63
4	20 21 22 23 24 25 26 34 36 39 61 62
5	2 4 5 6 7 13 27 28 29 30 31 32 33

Table 4-8 New clustering of all 62 suppliers into 5 routes (Tier 3)

After solving with the computer program, the results would show the routing in term of schedule in each route in order to get the minimize displacement and distance under the constraints of vehicle’s capacity and time window. The results are shown as table 4-9 following.

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4.4.1 Results of the vehicle routing problem

Route Number / Zone	Scheduling	Displacement (km)	Time (minutes)	Distance (km) from the map	Time Window (Max = 120 min)	Capacity (600 kg)
1	1→3→9→8→10→11→12→18→17→19→16→15→14→1	20.358	80.36	27.729	87.729	417.488
2	1→40→42→41→49→50→48→47→46→35→37→38→1	13.094	68.09	22.271	77.271	246.463
3	1→45→44→43→63→53→54→55→56→59→58→57→60→52→51→1	20.799	90.799	29.415	99.415	297.43
4	1→36→61→62→34→26→25→24→23→21→20→22→39→1	13.429	73.429	19.991	79.991	327.126
5	1→27→28→29→30→31→32→33→7→5→2→6→4→13→1	20.888	85.888	27.6	92.6	348.161

Table 4-9 The results of the vehicle routing problem (Tier 3)

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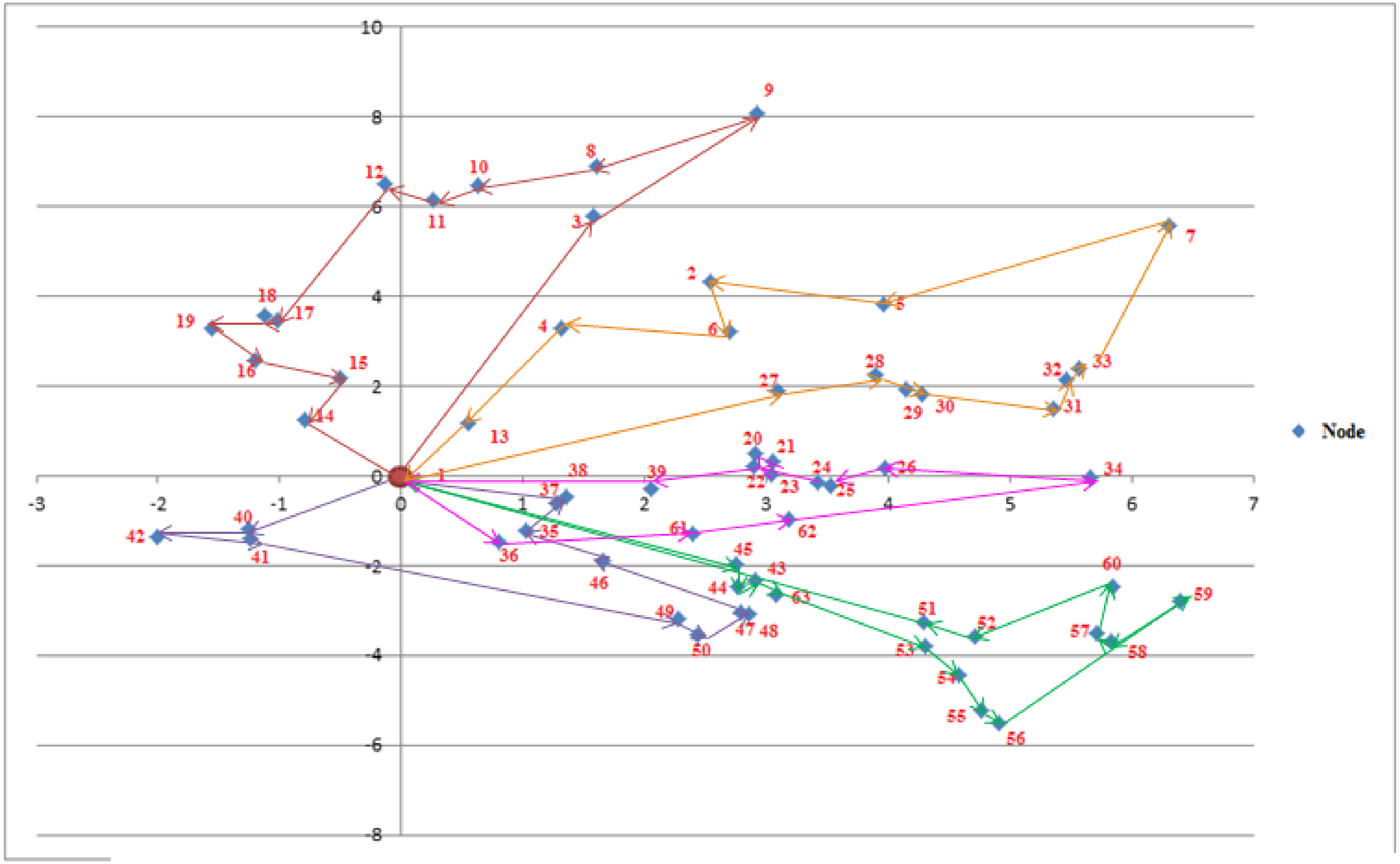

Figure 4-24 Graphs of vehicles routing for clustering into 5 groups

CHAPTER 5 REDUCTION COST CALCULATION

Before going through the decision process by utilizing AHP method, all cost that concern to the rubber collecting are shown and described as table 5-1 in 5.1. Then, the AHP and VRP are applied with the purpose of cost reduction and the result of the reduction is explained in 5.2. Finally, there was the added cost in vehicle routing and there are 3 results to compare the cost reduction (Tier 1, 2, and 3). In term of routing cost, the process of routing is belong to the entrepreneur and factory side, but the benefit are direct to the farmers who have not pay for travelling cost or inbound cost. In order to share the benefit, there would be the negotiation rubber price between entrepreneur and farmers to make it cheaper instead of dealing with inbound cost.

5.1 Total Collecting Cost before Implementation

Collection Centre	Inbound Cost (THB)	Outbound Cost (THB)	Fixed Cost (THB)	Total Collecting Cost (THB)
A	59,452	0	43,500	102,952
B	5,544	5,391	17,500	28,435
C	16,093	7,629	27,500	51,222
D	13,320	6,156	24,500	43,976
E	2,676	8,093	27,500	38,269
F	14,923	7,194	26,000	48,117
G	10,139	8,146	27,000	45,285
H	3,485	3,212	17,000	23,697
				381,953

Table 5-1 Total collecting cost from 8 collection centres

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According the rubber collecting process, there are 3 concerned costs form these actives.

● Inbound cost that is from the travelling cost of the farmers to supply the rubber at the collection centres.

● Outbound cost that is from the travelling cost of the factory's vehicle to pick up amount of the rubber from each collection centre.

● Fixed cost that is from the expenditures in each collection centre.

At the table 5-1, it could be seen clearly that fixed cost is the highest cost for the collecting and it is over expenditure to deal with small number of suppliers in some collection. This is a cause for this research to do the cost reduction by closing some collection centre to reduce the overall cost from 381,953 THB (Thai Bath).

5.2 Total Collecting Cost after Implementation

After applied the AHP method to the process of the rubber collecting, 5 collection centres are closed and 62 suppliers of the closed centres are used to be support the vehicle routing. Then, the result of cost reduction is able to described as following in 5.2.1 and 5.2.2.

5.2.1 Reduction Cost from Closing Some Collection Centres

Due to the AHP process, the optimization program results that 5 collection centre should be closed (Collection centre B, D, F, G, and H). This action would save cost around 189,510 THB (Thai Bath) per month which support the factory to reduce 142,099 THB (Thai Bath) from fixed cost combine with outbound cost. Moreover, the closing down of collection centres would support the farmer to save 47,411 THB (Thai Bath) in inbound cost but there would be the routing cost instead of these transportation costs(Inbound and outbound) and fixed cost which is described later in 4.1.2.2.

5.2.2 Routing Cost

According to the vehicle routing process, 3 result from clustering into 3, 4, and 5 groups respectively as the tables of routing cost calculated below.

<u>Tier 1</u>

Route No.	Total Distance (km)	Vehicle's capacity (kg)	Wage for driver (THB)	Total Cost Monthly (THB)
1	568	343	7,000	12,443
2	138	161	7,000	9,558
3	338	306	7,000	11,871
4	586	243	7,000	10,861
5	384	320	7,000	12,087
6	561	261	7,000	11,146
				67,970

Table 5-2 Routing cost calculated (Tier 1)

Tier 2

Route No.	Total Distance (km)	Vehicle's capacity (kg)	Wage for driver (THB)	Total Cost Monthly (THB)
1	719	510	7,000	18,423
2	637	384	7,000	16,336
3	464	393	7,000	15,102
4	634	348	7,000	15,898
				65,760

Table 5-3 Routing cost calculated (Tier 2)

Tier 3

Route No.	Total Distance (km)	Vehicle's capacity (kg)	Wage for driver (THB)	Total Cost Monthly (THB)
1	637	417	7,000	14448
2	512	246	7,000	12982
3	676	297	7,000	14901
4	459	327	7,000	12369
5	634	348	7,000	15,898
				70,599

Table 5-4 Routing cost calculated (Tier 3)

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From the comparison, 4 vehicles used in Tier 2 is the best result of cost saving to do the vehicle routing. In term of cost calculation, it is calculated in monthly rate (about 23 days operating date) by counting from distance of traveling for 4 wheels vehicle follow the schedule result of rubber picking up queue from the optimization program solving. The calculation also consider about capacity which is able to affect the fuel consumption and includes the cost for driver and depreciation cost.

5.3 Summary of cost reduction

As the result, the factory and farmers has to deal with routing cost for 65,760 THB (Thai Bath) if vehicle routing transportation is replaced and this cost is going to negotiate with farmers to share or use to bargain in term of lower rubber selling price. Therefore, total cost of rubber collecting operation is reduced from 381,953 THB to 258,203THB with 32.4 % reduction as table below.

Cost description	Reduced cost / Cost add in
Previous rubber collecting cost	+381,953 THB
Cost reduction from closing down the collection centres	-189,510 THB
Cost add in from the vehicle routing	+65,760 THB
New implement cost	**258,203 THB**

Table 5-5 Summary of cost reduction

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CHAPTER 6 CONCLUSION

Based on the research conducted about rubber milk collection system, the purpose of this research is to find a tangible way for cost reduction since excessive and unnecessary cost in rubber milk collection activity is the major problem in today's situation. At the view of entrepreneur, the problem cited should be handled with urgency as we have seen that it is possible to close some collection centres which are not really necessary such as some collection centre maintenance especially those centres that only caters few number of farmers or suppliers.

On the other hand, in term of the farmer side, the main cause of wastage in the rubber collection is evident every time all the farmers will have a direct shipping of rubbers from their locations to number of collection centre in their area. The add-up unnecessary cost is happen from numbers of routes taken and number of vehicles use by farmers. In order to improve the transportation, the process called "vehicle routing" could be replaced the old way of transportation but it is not acceptable for many of farmers with following reasons. Firstly, the farmers will instead have their rubber be fetched by a factory in their place and transport it to the factory. Instead of paying for personal vehicle transport and travel series of routes, the farmers will have to pay for the "routing cost" which affect to lower price of rubber for selling. This might not be worth for farmers who are located nearly the collection centre but it is advantage for those who are locating in long distance. Second, there will be a fixed schedule and exact amount of product's weight for supplying. This will result to more systematic approach when the vehicle routing is taken which is described in 6.2.

Therefore, it is better for the research to start of closing some collection centres that are causes of over expenditure first. Then, the vehicle routing could be replaced the method of transportation among the suppliers where there collection centres has been closed. All of these would be explain in 6.1 and there would be shown strength and weakness of result in 6.2 to explain how potential and effect that going to happen when they are implemented. Next, it is a last part of this research to summarize the major point of this research as conclusion in 6.3 and there would be recommendation in order to be actually applied and extend for the further research.

6.1 Summary of Results

First process of cost reduction is to close some collection centres. In order to make decision for closing, there are many concerns in term of qualitative and quantitative factors and it is a hard part of decision maker to analyze what are the factors that influence to rubber milk collection operation. After brainstorming between the entrepreneur side and farmer side, a large number of quantitative factors and qualitative factor are present as criterions which consist of location of the collection centres, Operation costs, amount of rubber receiving, number of suppliers (farmers), and environment factor.In term of decision making process, closing some collection centres is a complex issue which consist of many factors for considering. Moreover, it is important for decision maker to trade off which factors are more influence or more affect to the operation in collection activity and which collection centres should continue operating. Apart from these issues, Analytical Hierarchy Process (AHP) was used as a tool to solve complex situation to be process by process.

At first process, all criterions are derived priority scales and amount of rubber receiving is the most effective with 55.3 % priority to the operation in collection system. The quantity of rubber is the first stage to be considered in order to close the collection centre because it is income generating that is the core business of rubber processed. However, the factory still require a large number of rubber milk but they have to bear in term of collection cost as well which is higher than targeting and there are not the cost-effective for some collection centres to deal with small number of rubber milk receiving.Then, operation cost in rubber milk collection is the second importance with 22% priority that affect to the collection system. Next, it is 12.6 % priority in term of number of suppliers that the factory uses to be criteria. The factory has reasons to keep the number of suppliers to expect more number of rubbers producing but it is not always guarantee that high number of suppliers means more rubber receiving. Moreover, this is the way to prevent in term of competitor that they will have more power for producing. Lastly, there are criterions in locations of collection centres and the environment at the centres which concern to the transportation mainly. It is low effect in term of making decision to close the collection centre but it is the major cause for the high transportation cost which direct to farmers or suppliers who take the responsibility in this term majorly.

Next process is to compare among of collection centres with the mentioned criterions above in order to see the priority. Apart from the result, collection centre A is the most potential place as 44.6 % priority which is located at the factory. There is high number of rubber receiving at centre A as well as free transportation cost in term of outbound but centre A have to deal with high fixed cost and inbound cost which is lower important criteria when comparing with number of rubber receiving. Then, it is following by centre C with 11.1 % priority. Centre C is the second place who gain high amount of rubber and number of supplier. Moreover, it is located nearly the factory and among of farmers group which support to reasonable cost in both term of inbound and outbound. For the remaining centres, it is consider by percentage of the criterion priority same as explanation above in centre A and C and the result are approximately close to each other which is lower 10 % of priority.

Apart from the priority, it is the process of identifying the optimum number of collection centre operation by focusing on criterion in amount of rubber receiving and operation cost which is the most effective priority from the AHP. For determining optimum number of collection centres, there were 2 limited resources that were proposed in order to ensure the best use. First, it is the total of rubber collecting that is expected to exceed monthly 40,000 kilograms (kg). Second, it is to minimize operation cost which can be categorized as 65.3 % priority in fixed cost, 25% priority in outbound cost, and 9.7 % priority in inbound cost. The operation cost is also limited monthly at 100,000 THB (Thai Bath) foe fixed cost, 20,000 THB for outbound cost, and 85,000 THB for inbound cost. After computer program solving, according to rubber collecting operation from 8 collection centres through 162 suppliers, the result of optimum number is 3 collection centre which consist of collection centre A, C, and E through 100 suppliers. This is surly guarantee that the factory will exceed 40,000 kg rubber collecting. Moreover, the operation cost would be minimized that is saved from the expected cost as 1,500 THB for fixed cost, 4,277 THB for outbound cost, and 6,778 THB for inbound cost.

Lastly, it is a stage to deal with group of farmers who have no longer support to the collection centre anymore (62 suppliers). This is a chance to apply the vehicle routing transportation to this group better than let them go and support to other factories. In addition, it could be lighten the load form famers transportation as well as cost. According to do vehicle routing problem, there are large-scales of problem which consist of 63 nodes (number of suppliers and the factory) and it take a long time to solve by computer program. So, it is better to do "route-first cluster-second" based on the direction and main road. After node clustering and computer program solving, the best result is clustering of 4 routes with 4 vehicles (1 route for 1 vehicle) with the time window for 2 hours (star from 7 a.m. to 9 a.m.). When the routing result was compared to the direct shipping, the total distance for transportation is decrease obviously from 433.32 kilometers (km) (inbound and outbound activity) into 106.4 km (routing activity) and number of vehicles also decrease extremely from 62 cars (driving to the collection centre) and 5 cars (driving to pick up the rubber and return to the factory) into 4 cars (driving for routing). This method is going to save much cost for the farmers but it is also be disadvantage in term of selling price and inflexible in time and capacity which is describe in 6.2.

6.2 Strength and Weakness of Results

In this research, there were 2 methods utilized in researching that is combination Analytical Hierarchy Process (AHP) with Linear Programing (LP) for decision making and Vehicle Routing Problem (VRP). When the methods applied in the real situation, there would be some places that suitable with the methods and some are not. The following stages would describe benefit and drawback by categorizing into two methods.

For the AHP method, it was used for making decision in term of brainstorming to share the idea between entrepreneur and farmers including a specialist in this field. So, it is ensuring that the decision would be fair and benefit for both sides. In addition, AHP is flexibility that intuitive appeal to the decision makers and its ability to check inconsistencies. AHP decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here, the importance of each criterion becomes clear. So,It is easier to make decision and it surly includes all factors that affect to closed collection centre decision in the different weight priority.

In other hand, there were only 2 farmers to be a part in group of decision maker that does not cover all preferences from 162 farmers. It is better to represent at least one farmer from each collection centre. Then, the result is not suitable for those who have been close their collection centres. Moreover AHP method is the artificial limitation of the use of the 9−point scale. Sometimes, the decision maker might find difficult to distinguish among them and tell in term of number. In term of VRP method, there would be advantage for the entrepreneur when VRP will be applied. It will be scheduling that is a structured plan for the efficient transportation in order to control the time and number of rubber receiving. It could be useful for some farmers as well because they will not be concern in transportation and the total distance as well as number of vehicles will decrease obviously. These are resulted in lower traveling costs. However, it will not be flexibility for some farmers when they have to follow the scheduling by following reasons. First, it is the term of capacity when they are fixed the amount of supplying rubber. Sometimes, the farmers might able to produce more rubber when the environment and weather conducive to do rubber tapping efficiently. Then, the farmers will have more rubber milk producing in this time but they have to be limited in term of amount rubber supplying. Second, there will be restricted time to do the rubber tapping. Some farmers have a large number of rubber tree and they could not finish tapping on time if they are put in the first order queue for picking up. Lastly, it is a problem of falling rubber price. There will be cutting price in rubber market and other factories as competitor might provide higher price. Therefore, the farmers can possibly change to support others factory all time.

To summarize, According to the AHP and VRP results, both entrepreneur from the factory and farmers are going to have different gain and loss and the farmers who realize on closed collection centre have the most effective in these results as above describing.

6.3 Conclusion and Recommendations

In conclusion, the problem of over operation cost in rubber milk collection system is the main cause of this research. There were 2 different tools to deal with the problem in the different point in order to achieve the same objective of cost reduction. First problem is to close some collection centres that are unnecessary by utilizing AHP method. After solving with linear programming by add in resource limitation, it results to 5 collection centre that should be closed. For doing this, the fixed cost in operating rubber collection is saved with 112,000 THB (Thai Bath) per month. This result of closing decision was planned carefully that is going to minimize impact to farmers and keep appropriate number of rubber receiving for the factory's production within minimum collection.

In the vehicle routing problem, the cost in term of transportation (inbound and outbound) from 5 closed collection centres also disappear at 101,595 THB (Thai Bath) per month. To make it clear, the saved cost are from fixed cost combine with outbound cost that take responsibility by the factory side at 142,099 THB (30,099 THB + 112,000 THB) and inbound cost that take responsibility by farmers who have no longer collection centre to support at 47,411 THB. However, the factory has to deal with routing cost for 65,760 THB (Thai Bath) if vehicle routing transportation is replaced and this cost is going to negotiate with farmers to share or use to bargain in term of lower rubber selling price. Therefore, total cost of rubber collecting operation is reduced from 381,953 THB to 258,203 THB as 32.4 % reduction.

For the result of vehicle routing problem, there were fixed in time for picking up and amount of rubber supplying. In order to make it more flexible, it is possible to make a deal with all farmers in each rout first to ensure the number of farmer, the exactly amount of rubber supplying, and picking up time. Moreover, the issue in term of unfinished to catch up time can be negotiated in order to switch with neighbor in the same route. This issue is able to develop as a program to arrange time and scheduling with the capacity for supplying in each route and this is going to challenge for the further research.

At the end of the research, there were learning points from doing the decision making by AHP methods. AHP can effectively support decision making with regard to complex sustainability issues and can help to recognize and define a problem in detail. However, it quite difficult to uses to deal with large number of people because the problem will get bigger if they allow everyone to take part in the decision making but the decision making is not going to be the best decision as well if the process does not concern decision from everyone. Another learning point from VRP methods is utilizing in transportation management efficiently in order to reduce total distance, number of route, and number of vehicles. In contrary, the result is not flexible to the capacity of rubber supplying and picking up time.

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APPENDIX

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APPENDIX A INPUT PAEAMETERS

There is 1 factory of rubber processed with 8 rubber milk collection centres and 162 suppliers (farmers).

- ID number 1 is Depot (Factory) and the same place as collection centre A
- Collection Centre A has 57 members (ID number 43-99)
- Collection Centre B has 7 members (ID number 13-19)
- Collection Centre C has 26 members (ID number 117-142)
- Collection Centre D has 16 members (ID number 20-34)
- Collection Centre E has 17 members (ID number 100-116)
- Collection Centre F has 21 members (ID number 143-163)
- Collection Centre G has 11 members (ID number 2-12)
- Collection Centre H has 8 members (ID number 35-42)

These is information that used in Computer Simulation Program

Supplier ID	Rubber Daily Supplying (kg)	Distance to Centre (km)	Inbound Cost Monthly (THB)	Collection Centre	Distance to Centre (km)	Total Inbound Cost (THB)	Fixed Cost Monthly (THB)	Outbound Cost (THB)
2	27.40625	0.54	140.346	G	14.27	10138.7	27000	8145.885
3	67.3425	2.83	735.517	G				
4	23.16375	2.22	576.978	G				
5	35.4375	1.28	332.672	G				
6	16.2625	1.3	337.87	G				
7	22.23	5.98	1554.202	G				
8	12.55625	4.67	1213.733	G				
9	23.52375	6.96	1808.904	G				
10	39.035	4.15	1078.585	G				
11	20.04375	4.43	1151.357	G				
12	12.64375	4.65	1208.535	G				
13	36.27	4.24	1101.976	B	6.64	5543.667	17500	5390.994
14	124.9763	3.53	917.447	B				
15	10.95	1.15	298.885	B				
16	10.855	2.21	574.379	B				
17	30.235	3.23	839.477	B				
18	45.26	3.53	917.447	B				
19	20.06625	3.44	894.056	B				
20	7.5225	2.22	576.978	D	4.48	13319.88	24500	6155.918
21	39.6775	2.22	576.978	D				
22	15.86875	2.22	576.978	D				
23	14.83625	2.01	522.399	D				
24	18.1975	1.55	402.845	D				
25	60.29375	1.26	327.474	D				
26	40.61875	1.24	322.276	D				

27	12.24375	4.6	1195.54	D				
28	12.86375	4.69	1218.931	D				
29	70.5575	3.07	797.893	D				
30	33.635	2.95	766.705	D				
31	23.62	6.77	1759.523	D				
32	19.4725	6.76	1756.924	D				
33	14.99875	6.74	1751.726	D				
34	22.58375	2.95	766.705	D				
35	28.6675	0.15	38.985	H	2.97	3485.259	17000	3211.729
36	18.6525	0.32	83.168	H				
37	14.295	0.69	179.331	H				
38	8.05125	0.86	223.514	H				
39	31.37375	1.69	439.231	H				
40	16.07875	2.93	761.507	H				
41	7.7825	3.1	805.69	H				
42	69.31875	3.67	953.833	H				
43	7.26125	0.04	10.396	A	0	59452.13	43500	0
44	18.31875	0.17	44.183	A				
45	17.205	0.18	46.782	A				
46	14.29375	0.26	67.574	A				
47	34.05625	0.33	85.767	A				
48	18.5625	0.31	80.569	A				
49	28.825	0.34	88.366	A				
50	35.285	0.46	119.554	A				
51	15.90375	0.36	93.564	A				
52	16.51	0.36	93.564	A				
53	18.81125	0.21	54.579	A				
54	19.2225	0.63	163.737	A				
55	26.81875	0.72	187.128	A				
56	30.69875	0.74	192.326	A				
57	2.365	0.49	127.351	A				
58	28.06625	0.25	64.975	A				
59	22.775	1.95	506.805	A				
60	4.30125	1.95	506.805	A				
61	43.585	1.71	444.429	A				
62	16.2875	2.05	532.795	A				
63	17.66375	2.24	582.176	A				
64	12.32125	2.87	745.913	A				
65	15.7075	2.86	743.314	A				
66	30.9675	3.16	821.284	A				
67	12.72375	5.91	1536.009	A				
68	30.17625	0.89	231.311	A				

69	23.84875	1.21	314.479	A				
70	10.37	1.16	301.484	A				
71	9.07625	8.6	2235.14	A				
72	23.64125	8.38	2177.962	A				
73	24.0525	8.39	2180.561	A				
74	27.07	8.33	2164.967	A				
75	19.21875	8.1	2105.19	A				
76	11.69125	7.79	2024.621	A				
77	17.01875	7.45	1936.255	A				
78	55.26125	6.98	1814.102	A				
79	18.545	6.83	1775.117	A				
80	23.09	6.83	1775.117	A				
81	35.3725	6.5	1689.35	A				
82	38.93875	6.5	1689.35	A				
83	10.24625	7.08	1840.092	A				
84	19.05375	6.22	1616.578	A				
85	37.7675	6.08	1580.192	A				
86	26.1575	5.26	1367.074	A				
87	22.34375	5.32	1382.668	A				
88	32.00875	7.4	1923.26	A				
89	71.5775	7.96	2068.804	A				
90	26.3825	6.3	1637.37	A				
91	33.9675	7.8	2027.22	A				
92	23.1325	7.8	2027.22	A				
93	39.08875	7.47	1941.453	A				
94	19.09375	3.94	1024.006	A				
95	8.18125	4.12	1070.788	A				
96	8.47375	2.95	766.705	A				
97	45.72375	1.23	319.677	A				
98	13.26625	8.46	2198.754	A				
99	22.7175	8.87	2305.313	A				
100	25.29125	0.34	88.366	E	6.12	2676.19	27500	8093.318
101	34.0825	0.96	249.504	E				
102	20.515	0.96	249.504	E				
103	10.60375	2.03	527.597	E				
104	33.3775	1.6	415.84	E				
105	61.02375	2.14	556.186	E				
106	24.455	3.53	917.447	E				
107	109.3562	4.3	1117.57	E				
108	26.83	5.77	1499.623	E				
109	24.6625	6.02	1564.598	E				
110	23.7425	6.42	1668.558	E				

111	27.15875	3.04	790.096	E				
112	11.37875	3.71	964.229	E				
113	31.1425	13.79	3584.021	E				
114	19.64	15.37	3994.663	E				
115	37.4075	16.21	4212.979	E				
116	7.8225	16.78	4361.122	E				
117	40.26875	1.48	384.652	C	4.2	16093.01	27500	7629.25
118	39.66125	1.91	496.409	C				
119	12.40625	0.53	137.747	C				
120	25.96125	1.21	314.479	C				
121	39.37625	1.35	350.865	C				
122	14.17125	1.5	389.85	C				
123	22.41	1.63	423.637	C				
124	32.42125	2.21	574.379	C				
125	24.9675	1.99	517.201	C				
126	11.66625	2.17	563.983	C				
127	12.50375	2.64	686.136	C				
128	6.44375	2.64	686.136	C				
129	10.05125	3.03	787.497	C				
130	5.87625	2.48	644.552	C				
131	16.54625	3.55	922.645	C				
132	9.7325	3.72	966.828	C				
133	46.7625	3.51	912.249	C				
134	15.6575	3.85	1000.615	C				
135	8.79	4.23	1099.377	C				
136	6.5475	4.63	1203.337	C				
137	12.80875	5.37	1395.663	C				
138	42.17875	0.84	218.316	C				
139	4.31375	1.18	306.682	C				
140	38.175	1.53	397.647	C				
141	25.57375	0.69	179.331	C				
142	17.85375	2.05	532.795	C				
143	12.45625	0.41	106.559	F	5.88	14923.46	26000	7194.351
144	16.5775	0.33	85.767	F				
145	12.78375	1.92	499.008	F				
146	14.9225	0.5	129.95	F				
147	21.17125	1.29	335.271	F				
148	7.90375	1.27	330.073	F				
149	15.94125	1.96	509.404	F				
150	42.32875	2.05	532.795	F				
151	12.2	2.07	537.993	F				
152	13.65875	3.17	823.883	F				

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153	15.11125	3.01	782.299	F				
154	14.08875	3.89	1011.011	F				
155	20.9425	5.02	1304.698	F				
156	34.93125	5.5	1429.45	F				
157	19.5675	4.67	1213.733	F				
158	31.5375	4.7	1221.53	F				
159	15.92625	5.98	1554.202	F				
160	7.9175	5.24	1361.876	F				
161	13.6875	0.98	254.702	F				
162	43.81	1.25	324.875	F				
163	69.72875	2.21	574.379	F				
						125632	210500	45821.44

- Suppliers or farmers have to deal with inbound cost about 125,632 Bath (THB) per month
- Entrepreneur or factory has to deal with fixed cost and outbound cost about 256,321.44 Bath (THB) per month

Total cost in rubber milk collection system is around 381,953 Bath (THB)

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APPENDIX B ANALYTICAL HIERACHY PROCESS (AHP)

Criteria and sub-criterions for Decision Making

Location of the collection centres (C1)

- Close to the factory (C1-1)
- Close to the number of suppliers (farmers) (C1-2)

Operation Costs (C2)

- Inbound Cost (C2-1)
- Outbound Cost (C2-2)
- Fixed Cost (C2-3)

Amount of rubber receiving (C3)

Number of suppliers (farmers) (C4)

Environment (C5)

- Facilities (C5-1)
- Acceptable condition for society (C5-2)

Scoring in importance and priority of criteria from judges

Scale of AHP pairwise comparison

Level	Importance	Explanation
1	Equal	The equal contribution of two criteria to the objective
3	Moderate	Experience and judgment slightly favor one criteria over another one
5	Strong	Experience and judgment strongly favor one criteria over another one
7	Very strong	A criteria is favored very strongly over another; its dominance demonstrated in practise
9	Extreme	The evidence favoring one criteria over another is of the highest possible of affirmation

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Scoring in importance of criterion pairwise comparison

Criteria Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
C1 and C2	C2	5	5	7	5	5	5	5
C1 and C3	C3	9	7	9	9	7	7	8
C1 and C4	C4	3	3	3	1	1	3	2
C1 and C5	C1	5	3	5	5	5	3	4
C2 and C3	C3	5	5	3	7	3	3	4
C2 and C4	C2	3	3	3	1	1	3	2
C2 and C5	C2	9	9	7	9	7	9	8
C3 and C4	C3	7	7	7	7	7	7	7
C3and C5	C3	9	9	9	9	9	9	9
C4 and C5	C4	7	7	5	7	9	9	7

Priorities and Consistency

Category		Priority	Rank
1	Locations of Collection Centres (C1)	7.1 %	4
2	Operation Costs (C2)	22 %	2
3	Amount of rubber receiving (C3)	55.3 %	1
4	Number of Suppliers (C4)	12.6 %	3
5	Environment (C5)	3 %	5

CR = 0.086 / 1.11 = 0.074

Scoring in importance and priority of sub-criteria (C1) from judges

Scoring in importance of criterion pairwise comparison

Criteria Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
C1-1 and C1-2	C 1-2	5	3	3	1	3	3	3

Priorities and Consistency

Category		Priority	Rank
1	Close to the factory (C1-1)	25 %	2
2	Close to the number of suppliers (farmers) (C1-2)	75 %	1

Consistency Ratio (CR) = 0.0

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Scoring in importance and priority of sub-criteria (C2) from judges

Scoring in importance of criterion pairwise comparison

Criteria Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
C2-1 and C2-2	C 2-2	3	3	3	3	3	1	3
C2-1 and C2-3	C 2-3	7	7	5	5	5	5	6
C2-2 and C2-3	C 2-3	3	3	3	5	1	3	3

Priorities and Consistency

Category		Priority	Rank
1	Inbound Cost (C2-1)	9.7 %	3
2	Outbound Cost (C2-2)	25 %	2
3	Fixed Cost (C2-3)	65.3%	1

Consistency Ratio (CR) = 0.019

Scoring in importance and priority of sub-criteria (C5) from judges

Scoring in importance of criterion pairwise comparison

Criteria Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
C5-1 and C5-2	C 5-1	3	1	1	3	3	1	2

Priorities and Consistency

Category		Priority	Rank
1	Facilities (C5-1)	66.7 %	1
2	Acceptable condition for society (C1-2)	33.3 %	2

Consistency Ratio (CR) = 0.0

Scoring in importance and priority of collection centres comparing with criteria (C1-1)

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Scoring in importance of centres pairwise comparison in criteria (C1-1)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	5	7	7	5	5	7	6
Centre A and C	A	3	3	3	3	5	3	3
Centre A and D	A	3	3	3	3	5	3	3
Centre A and E	A	5	5	5	5	5	5	5
Centre A and F	A	5	5	5	5	5	5	5
Centre A and G	A	9	9	9	9	9	9	9
Centre A and H	A	3	3	3	1	1	3	2
Centre B and C	C	3	3	5	5	3	5	4
Centre B and D	D	3	3	5	3	3	5	4
Centre B and	E	3	3	3	3	3	3	3

E								
Centre B and F	F	3	3	1	3	3	3	3
Centre B and G	B	5	7	7	5	5	5	6
Centre B and H	H	7	7	7	5	5	5	6
Centre C and D	C	3	1	1	1	1	1	1
Centre C and E	C	3	3	5	3	5	5	4
Centre C and F	C	3	3	5	5	5	3	4
Centre C and G	C	7	7	7	7	7	7	7
Centre C and H	H	3	3	3	1	3	3	3
Centre D and E	D	3	3	1	1	1	3	2
Centre D and F	D	3	3	1	3	1	3	2
Centre D and G	D	5	5	5	5	5	5	5
Centre D and H	H	3	1	3	3	3	3	3
Centre E and F	F	1	1	1	1	3	1	1
Centre E and G	E	7	7	7	5	5	5	6
Centre E and H	H	5	5	5	5	5	3	5
Centre F and G	F	7	7	7	7	7	7	7
Centre F and H	H	7	7	7	7	5	5	6
Centre G and H	H	9	9	7	9	9	9	9

Priorities and Consistency

Category (Close to factory)		Priority	Rank
1	Collection Centre A	30.2 %	1
2	Collection Centre B	4 %	7
3	Collection Centre C	14.2 %	3
4	Collection Centre D	10.9 %	4
5	Collection Centre E	6.4 %	6
6	Collection Centre F	6.5 %	5
7	Collection Centre G	1.7 %	8
8	Collection Centre H	26.2 %	2

Consistency Ratio (CR) = 0.067

Scoring in importance and priority of collection centres comparing with criteria (C1-2)

Scoring in importance of centres pairwise comparison in criteria (C1-2)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	B	9	9	7	7	9	7	8
Centre A and C	C	5	7	7	5	5	5	6
Centre A and D	D	7	5	7	7	7	7	7
Centre A and E	E	3	3	3	3	3	3	3
Centre A and F	F	5	7	7	5	5	5	6
Centre A and G	G	7	7	7	7	7	5	7
Centre A and H	H	9	9	9	9	9	9	9
Centre B and C	B	5	5	3	3	5	5	4
Centre B and D	B	3	3	3	3	3	3	3
Centre B and E	B	7	9	9	9	9	7	8
Centre B and F	B	5	5	3	3	3	5	4
Centre B and G	B	3	3	3	3	3	3	3
Centre B and H	H	3	1	1	1	1	1	1
Centre C and D	D	1	1	1	3	3	3	2
Centre C and E	C	5	3	5	3	3	5	4
Centre C and F	F	1	1	3	1	1	1	1
Centre C and G	G	1	1	1	3	3	3	2
Centre C and H	H	3	3	3	3	5	5	4
Centre D and E	D	3	3	5	5	5	5	4
Centre D and F	D	3	3	3	1	1	3	2
Centre D and G	G	1	1	1	1	1	1	1
Centre D and H	H	3	3	3	3	3	3	3
Centre E and F	F	5	7	5	5	5	5	5
Centre E and G	G	3	5	3	5	5	5	4
Centre E and H	H	9	9	9	9	9	7	9
Centre F and G	G	3	1	1	3	3	3	2
Centre F and H	H	3	3	3	3	3	3	3
Centre G and H	H	3	3	3	3	3	3	3

Priorities and Consistency

Category (Close to Close to the number of suppliers (farmers))		Priority	Rank
1	Collection Centre A	1.9 %	8
2	Collection Centre B	27.7 %	1
3	Collection Centre C	7.8 %	6
4	Collection Centre D	12 %	3
5	Collection Centre E	3 %	7
6	Collection Centre F	8.4 %	5
7	Collection Centre G	12 %	3
8	Collection Centre H	27.3 %	2

Consistency Ratio (CR) = 0.033

Scoring in importance and priority of collection centres comparing with criteria (C2-1)

Scoring in importance of centres pairwise comparison in criteria (C2-1)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	B	7	9	9	9	9	9	9
Centre A and C	C	5	7	7	7	5	7	6
Centre A and D	D	5	7	7	7	5	7	6
Centre A and E	E	7	5	5	5	5	5	5
Centre A and F	F	5	7	7	5	5	7	6
Centre A and G	G	7	7	7	9	7	7	7
Centre A and H	H	9	9	9	9	9	9	9
Centre B and C	B	3	3	5	5	3	3	4
Centre B and D	B	3	3	3	3	3	3	3
Centre B and E	B	5	7	7	7	7	7	7
Centre B and F	B	3	3	5	5	5	3	4
Centre B and G	B	3	3	3	3	3	3	3
Centre B and H	H	3	3	1	1	3	3	2
Centre C and D	D	3	3	3	3	3	3	3
Centre C and E	C	3	5	5	5	5	5	5
Centre C and F	F	5	3	5	3	3	3	3
Centre C and G	G	3	3	3	3	3	3	3

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Centre C and H	H	5	5	5	5	5	5	5
Centre D and E	D	1	3	1	3	3	3	2
Centre D and F	D	1	3	1	3	1	3	2
Centre D and G	G	1	1	3	1	3	3	2
Centre D and H	H	3	3	3	3	3	3	3
Centre E and F	F	3	3	3	3	3	5	3
Centre E and G	G	5	5	5	5	5	5	5
Centre E and H	H	7	7	7	7	7	7	7
Centre F and G	G	5	5	3	3	3	3	2
Centre F and H	H	5	3	3	3	3	3	3
Centre G and H	H	1	1	3	3	3	3	2

Priorities and Consistency

Category (Inbound Cost)		Priority	Rank
1	Collection Centre A	1.7 %	8
2	Collection Centre B	25.4 %	2
3	Collection Centre C	6.8 %	6
4	Collection Centre D	10.6 %	4
5	Collection Centre E	3.7 %	7
6	Collection Centre F	9.1 %	5
7	Collection Centre G	14.7 %	3
8	Collection Centre H	27.9 %	1

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Consistency Ratio (CR) = 0.071

Scoring in importance and priority of collection centres comparing with criteria (C2-2)

Scoring in importance of centres pairwise comparison in criteria (C2-2)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	B	5	5	3	3	5	3	4
Centre A and C	C	5	5	7	7	7	7	6
Centre A and D	D	5	5	3	5	5	5	5
Centre A and E	E	7	7	7	7	7	7	7
Centre A and F	F	5	7	5	7	7	7	6
Centre A and G	G	7	7	7	7	7	7	7

Centre A and H	H	3	3	3	3	3	3	3
Centre B and C	B	3	3	3	3	3	3	3
Centre B and D	B	1	3	3	1	3	3	2
Centre B and E	B	3	5	5	5	5	5	5
Centre B and F	B	3	3	5	3	3	3	3
Centre B and G	B	5	5	5	5	5	5	5
Centre B and H	H	1	3	3	3	3	3	3
Centre C and D	D	1	1	3	3	3	1	2
Centre C and E	C	3	3	1	3	3	1	2
Centre C and F	F	1	1	1	1	3	1	1
Centre C and G	C	3	3	1	3	3	1	2
Centre C and H	H	3	3	5	5	3	5	4
Centre D and E	D	3	3	3	3	3	3	3
Centre D and F	D	3	1	1	1	3	3	2
Centre D and G	D	3	3	3	3	3	3	3
Centre D and H	H	3	3	3	3	3	5	3
Centre E and F	F	3	3	1	1	3	3	2
Centre E and G	E	1	1	1	1	1	1	1
Centre E and H	H	5	5	7	5	5	5	5
Centre F and G	F	3	1	1	3	3	3	2
Centre F and H	H	3	5	3	5	5	5	4
Centre G and H	H	5	7	5	5	5	5	5

Priorities and Consistency

Category (Outbound Cost)		Priority	Rank
1	Collection Centre A	38.1 %	1
2	Collection Centre B	13.8 %	3
3	Collection Centre C	5.5 %	5
4	Collection Centre D	8.8 %	4
5	Collection Centre E	3.3 %	7
6	Collection Centre F	5.5 %	5
7	Collection Centre G	3.3 %	7
8	Collection Centre H	21.7 %	2

Consistency Ratio (CR) = 0.026

Scoring in importance and priority of collection centres comparing with criteria (C2-3)

Scoring in importance of centres pairwise comparison in criteria (C2-3)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	3	3	3	3	3	3	3
Centre A and C	A	5	5	5	5	5	5	5
Centre A and D	A	5	5	5	5	5	5	5
Centre A and E	A	5	5	5	5	5	5	5
Centre A and F	A	5	5	5	5	5	5	5
Centre A and G	A	5	5	5	5	5	5	5
Centre A and H	A	3	3	3	3	3	3	3
Centre B and C	B	3	3	3	3	3	3	3
Centre B and D	B	1	1	3	3	3	3	2
Centre B and E	B	3	3	3	3	3	3	3
Centre B and F	B	1	1	3	3	3	3	2
Centre B and G	B	3	3	3	3	3	3	3
Centre B and H	H	1	1	3	3	3	3	2
Centre C and D	D	3	3	1	3	1	3	2
Centre C and E	C	1	1	1	1	1	1	1
Centre C and F	F	3	3	1	3	1	3	2
Centre C and G	G	1	1	1	1	1	1	1
Centre C and H	H	3	3	3	3	3	3	3
Centre D and E	D	1	3	1	3	3	3	2
Centre D and F	D	1	1	1	1	1	1	1
Centre D and G	D	1	3	3	1	3	3	2
Centre D and H	H	1	1	1	1	1	1	1
Centre E and F	F	1	3	3	1	3	3	2
Centre E and G	G	1	1	1	1	1	1	1
Centre E and H	H	3	3	3	3	3	3	3
Centre F and G	F	1	3	1	3	3	3	2
Centre F and H	H	1	3	1	3	3	3	2
Centre G and H	H	1	3	1	3	3	3	2

Priorities and Consistency

Category (Fixed Cost)		Priority	Rank
1	Collection Centre A	36.1 %	1
2	Collection Centre B	14.4 %	3
3	Collection Centre C	5.1 %	7
4	Collection Centre D	9.7 %	4
5	Collection Centre E	5.1 %	7
6	Collection Centre F	8.8 %	5
7	Collection Centre G	5.4 %	6
8	Collection Centre H	15.3 %	2

Consistency Ratio (CR) = 0.02

Scoring in importance and priority of collection centres comparing with criteria (C3)

Scoring in importance of centres pairwise comparison in criteria (C3)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	9	9	9	9	9	9	9
Centre A and C	A	7	9	9	7	7	9	8
Centre A and D	A	7	9	9	9	9	9	9
Centre A and E	A	7	9	9	9	7	9	8
Centre A and F	A	7	9	9	9	7	9	8
Centre A and G	A	7	9	9	9	9	9	9
Centre A and H	A	9	9	9	9	9	9	9
Centre B and C	C	5	3	3	5	5	3	4
Centre B and D	D	3	3	3	3	3	3	3
Centre B and E	E	5	3	3	5	3	3	4
Centre B and F	F	3	3	3	3	3	3	3
Centre B and G	G	1	3	3	3	3	1	2
Centre B and H	B	1	3	3	3	3	1	2
Centre C and D	C	3	3	3	3	3	3	3
Centre C and E	C	1	1	3	3	3	1	2
Centre C and F	C	3	1	3	3	3	1	2
Centre C and G	C	3	3	3	3	3	3	3
Centre C and H	C	5	5	5	3	5	3	4

Centre D and E	E	3	1	3	1	3	3	2
Centre D and F	F	3	1	1	1	3	3	2
Centre D and G	D	1	1	3	1	3	3	2
Centre D and H	D	3	3	3	3	3	3	3
Centre E and F	E	1	3	1	3	3	3	2
Centre E and G	E	3	3	3	3	3	3	3
Centre E and H	E	5	5	3	5	3	3	4
Centre F and G	F	1	3	1	3	3	3	2
Centre F and H	F	3	3	3	3	3	3	3
Centre G and H	G	3	3	3	3	3	3	3

Priorities and Consistency

Category (Amount of rubber receiving)		Priority	Rank
1	Collection Centre A	52.7 %	1
2	Collection Centre B	3.2 %	7
3	Collection Centre C	13 %	2
4	Collection Centre D	6.1 %	5
5	Collection Centre E	10.3 %	3
6	Collection Centre F	7.6 %	4
7	Collection Centre G	4.6 %	6
8	Collection Centre H	2.6 %	8

Consistency Ratio (CR) = 0.05

Scoring in importance and priority of collection centres comparing with criteria (C4)

Scoring in importance of centres pairwise comparison in criteria (C4)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	9	9	9	9	9	9	9
Centre A and C	A	7	9	7	7	9	9	8
Centre A and D	A	9	9	9	9	9	9	9
Centre A and E	A	9	9	9	9	9	9	9
Centre A and F	A	7	9	7	9	9	9	8
Centre A and G	A	9	9	9	9	9	9	9
Centre A and H	A	9	9	9	9	9	9	9

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Centre B and C	C	5	5	5	5	5	5	5
Centre B and D	D	3	3	3	3	3	3	3
Centre B and E	E	3	3	3	3	3	3	3
Centre B and F	F	5	5	5	5	5	5	5
Centre B and G	G	5	3	5	3	3	3	2
Centre B and H	H	1	1	1	1	1	1	1
Centre C and D	C	3	3	3	3	3	3	3
Centre C and E	C	3	3	3	3	3	3	3
Centre C and F	C	1	1	3	3	1	3	2
Centre C and G	C	5	3	3	3	3	3	3
Centre C and H	C	5	3	3	3	3	3	3
Centre D and E	E	1	1	1	1	1	1	1
Centre D and F	F	1	3	3	1	1	3	2
Centre D and G	D	1	1	1	1	1	3	1
Centre D and H	D	1	1	1	3	3	3	2
Centre E and F	E	1	3	1	3	3	3	2
Centre E and G	E	1	3	3	3	1	3	2
Centre E and H	E	3	3	3	3	3	3	3
Centre F and G	F	3	3	3	3	3	3	3
Centre F and H	F	3	3	3	3	3	3	3
Centre G and H	G	1	3	1	3	3	3	2

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Priorities and Consistency

Category (Number of suppliers (farmers))		Priority	Rank
1	Collection Centre A	53.2 %	1
2	Collection Centre B	2.7 %	8
3	Collection Centre C	13.7 %	2
4	Collection Centre D	5.6 %	5
5	Collection Centre E	8.1 %	4
6	Collection Centre F	8.8 %	3
7	Collection Centre G	4.7 %	6
8	Collection Centre H	3.2 %	7

Consistency Ratio (CR) = 0.051

Scoring in importance and priority of collection centres comparing with criteria (C5-1)

Scoring in importance of centres pairwise comparison in criteria (C2-2)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	7	7	7	7	7	7	7
Centre A and C	A	3	3	3	3	3	3	3
Centre A and D	A	3	3	3	3	3	3	3
Centre A and E	A	3	3	3	3	3	3	3
Centre A and F	A	3	3	3	3	3	3	3
Centre A and G	A	3	3	3	3	3	3	3
Centre A and H	A	7	7	7	7	7	7	7
Centre B and C	C	5	5	5	5	5	5	5
Centre B and D	D	5	5	5	5	5	5	5
Centre B and E	E	5	5	5	5	5	5	5
Centre B and F	F	5	5	5	5	5	5	5
Centre B and G	G	5	5	5	5	5	5	5
Centre B and H	H	3	3	3	3	3	3	3
Centre C and D	C	1	1	1	1	1	1	1
Centre C and E	C	1	1	1	1	1	1	1
Centre C and F	C	1	1	1	1	1	1	1
Centre C and G	C	1	1	1	1	1	1	1
Centre C and H	C	3	3	3	3	3	3	3
Centre D and E	D	1	1	1	1	1	1	1
Centre D and F	D	1	1	1	1	1	1	1
Centre D and G	D	1	1	1	1	1	1	1
Centre D and H	D	3	3	3	3	3	3	3
Centre E and F	E	1	1	1	1	1	1	1
Centre E and G	E	1	1	1	1	1	1	1
Centre E and H	E	3	3	3	3	3	3	3
Centre F and G	F	1	1	1	1	1	1	1
Centre F and H	F	3	3	3	3	3	3	3
Centre G and H	G	3	3	3	3	3	3	3

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Priorities and Consistency

Category (Facilities)		Priority	Rank
1	Collection Centre A	32.5 %	1
2	Collection Centre B	2.6 %	8
3	Collection Centre C	12.1 %	2
4	Collection Centre D	12.1 %	2
5	Collection Centre E	12.1 %	2
6	Collection Centre F	12.1 %	2
7	Collection Centre G	12.1 %	2
8	Collection Centre H	4.6 %	7

Consistency Ratio (CR) = 0.01

Scoring in importance and priority of collection centres comparing with criteria (C5-2)

Scoring in importance of centres pairwise comparison in criteria (C5-2)

Centres Pairwise Comparison	More Importance	Judge 1 Scoring	Judge 2 Scoring	Judge 3 Scoring	Judge 4 Scoring	Judge 5 Scoring	Judge 6 Scoring	Average Scoring
Centre A and B	A	3	3	3	3	3	3	3
Centre A and C	A	3	3	3	3	3	3	3
Centre A and D	A	3	3	3	3	3	3	3
Centre A and E	A	3	3	3	3	3	3	3
Centre A and F	F	3	3	3	3	3	3	3
Centre A and G	G	3	3	3	3	3	3	3
Centre A and H	A	5	5	5	5	5	5	5
Centre B and C	B	1	1	1	1	1	1	1
Centre B and D	B	1	1	1	1	1	1	1
Centre B and E	B	1	1	1	1	1	1	1
Centre B and F	F	3	3	3	3	3	3	3
Centre B and G	G	3	3	3	3	3	3	3
Centre B and H	B	3	3	3	3	3	3	3
Centre C and D	C	1	1	1	1	1	1	1
Centre C and E	C	1	1	1	1	1	1	1
Centre C and F	F	3	3	3	3	3	3	3
Centre C and G	G	3	3	3	3	3	3	3

Centre C and H	C	3	3	3	3	3	3	3
Centre D and E	D	1	1	1	1	1	1	1
Centre D and F	F	3	3	3	3	3	3	3
Centre D and G	G	3	3	3	3	3	3	3
Centre D and H	D	3	3	3	3	3	3	3
Centre E and F	F	3	3	3	3	3	3	3
Centre E and G	G	3	3	3	3	3	3	3
Centre E and H	E	3	3	3	3	3	3	3
Centre F and G	F	1	1	1	1	1	1	1
Centre F and H	F	5	5	5	5	5	5	5
Centre G and H	G	5	5	5	5	5	5	5

Priorities and Consistency

Category (Acceptable condition for society)		Priority	Rank
1	Collection Centre A	16.9 %	3
2	Collection Centre B	7.5 %	4
3	Collection Centre C	7.5 %	4
4	Collection Centre D	7.5 %	4
5	Collection Centre E	7.5 %	4
6	Collection Centre F	25 %	1
7	Collection Centre G	25 %	1
8	Collection Centre H	3.2 %	8

Consistency Ratio (CR) = 0.027

Overall priority and criterion for decision making

Criteria/ Centre	A	B	C	D	E	F	G	H
C 1-1	0.302	0.040	0.142	0.109	0.064	0.065	0.017	0.262
C 1-2	0.019	0.277	0.078	0.120	0.030	0.084	0.120	0.273
C 2-1	0.017	0.254	0.068	0.106	0.037	0.091	0.147	0.279
C 2-2	0.381	0.138	0.055	0.088	0.033	0.055	0.033	0.217
C 2-3	0.361	0.144	0.051	0.097	0.051	0.088	0.054	0.153
C 3	0.527	0.032	0.130	0.061	0.103	0.076	0.046	0.026
C 4	0.532	0.027	0.137	0.056	0.081	0.088	0.047	0.032
C 5-1	0.325	0.026	0.121	0.121	0.121	0.121	0.121	0.046

C 5-2	0.169	0.075	0.075	0.075	0.075	0.250	0.250	0.032

Calculate the overall priority of each criteria

Location of the collection centres (C 1)
Centre A = (0.302 x 0.250) + (0.019 x 0.075) = 0.090 (9 %)
Centre B = (0.040 x 0.250) + (0.277 x 0.075) = 0.218 (21.8%)
Centre C = (0.142 x 0.250) + (0.078 x 0.075) = 0.094 (9.4%)
Centre D = (0.109 x 0.250) + (0.120 x 0.075) = 0.117 (11.7%)
Centre E = (0.064 x 0.250) + (0.030 x 0.075) = 0.039 (3.9%)
Centre F = (0.065 x 0.250) + (0.084 x 0.075) = 0.079 (7.9%)
Centre G = (0.017 x 0.250) + (0.120 x 0.075) = 0.094 (9.4%)
Centre H = (0.262 x 0.250) + (0.273 x 0.075) = 0.270 (27%)

Operation Cost (C 2)
Centre A = (0.017 x 0.097) + (0.381 x 0.250) + (0.361 x 0.653) = 0.333 (33.3 %)
Centre B = (0.254 x 0.097) + (0.138 x 0.250) + (0.144 x 0.653) = 0.153 (15.3 %)
Centre C = (0.068 x 0.097) + (0.055 x 0.250) + (0.051 x 0.653) = 0.054 (5.4 %)
Centre D = (0.106 x 0.097) + (0.088 x 0.250) + (0.097 x 0.653) = 0.096 (9.6 %)
Centre E = (0.037 x 0.097) + (0.033 x 0.250) + (0.051 x 0.653) = 0.045 (4.5 %)
Centre F = (0.091 x 0.097) + (0.055 x 0.250) + (0.088 x 0.653) = 0.080 (8 %)
Centre G = (0.147 x 0.097) + (0.033 x 0.250) + (0.054 x 0.653) = 0.058 (5.8 %)
Centre H = (0.279 x 0.097) + (0.217 x 0.250) + (0.153 x 0.653) = 0.181 (18.1 %)

Amount of rubber receiving Amount of rubber receiving (C3)
Centre A = 0.527 (52.7 %)
Centre B = 0.032 (3.2 %)
Centre C = 0.130 (13 %)
Centre D = 0.061 (6.1 %)
Centre E = 0.103 (10.3 %)
Centre F = 0.076 (7.6 %)
Centre G = 0.046 (4.6 %)
Centre H = 0.026 (2.6 %)

Number of suppliers (farmers) (C4)
Centre A = 0.532 (53.2 %)
Centre B = 0.027 (2.7 %)
Centre C = 0.137 (13.7 %)
Centre D = 0.056 (5.6 %)
Centre E = 0.081 (8.1 %)
Centre F = 0.088 (8.8 %)
Centre G = 0.047 (4.7 %)
Centre H = 0.032 (3.2 %)

Environment (C 5)
Centre A = (0.325 x 0.667) + (0.169 x 0.333) = 0.273 (27.3 %)

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Centre B = (0.026 x 0.667) + (0.075 x 0.333) = 0.042 (4.2 %)
Centre C = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre D = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre E = (0.121 x 0.667) + (0.075 x 0.333) = 0.106 (10.6 %)
Centre F = (0.121 x 0.667) + (0.250 x 0.333) = 0.164 (16.4 %)
Centre G = (0.121 x 0.667) + (0.250 x 0.333) = 0.164 (16.4 %)
Centre H = (0.046 x 0.667) + (0.032 x 0.333) = 0.041 (4.1 %)

Calculate the overall priority of collection centres

Criteria/Centre	A	B	C	D	E	F	G	H
C 1	0.090	0.218	0.094	0.117	0.039	0.079	0.094	0.270
C 2	0.333	0.153	0.054	0.096	0.045	0.080	0.058	0.181
C 3	0.527	0.032	0.130	0.061	0.103	0.076	0.046	0.026
C 4	0.532	0.027	0.137	0.056	0.081	0.088	0.047	0.032
C5	0.273	0.042	0.106	0.106	0.106	0.164	0.164	0.041

Centre A = (0.090 x 0.071) + (0.333 x 0.220) + (0.527 x 0.553) + (0.532 x 0.126) + (0.273 x 0.030) = 0.446
Centre B = (0.218 x 0.071) + (0.153 x 0.220) + (0.032 x 0.553) + (0.027 x 0.126) + (0.042 x 0.030) = 0.072
Centre C = (0.094 x 0.071) + (0.054 x 0.220) + (0.130 x 0.553) + (0.137 x 0.126) + (0.106 x 0.030) = 0.111
Centre D = (0.117 x 0.071) + (0.096 x 0.220) + (0.061 x 0.553) + (0.056 x 0.126) + (0.106 x 0.030) = 0.073
Centre E = (0.039 x 0.071) + (0.045 x 0.220) + (0.103 x 0.553) + (0.081 x 0.126) + (0.106 x 0.030) = 0.083
Centre F = (0.079 x 0.071) + (0.080 x 0.220) + (0.076 x 0.553) + (0.088 x 0.126) + (0.164 x 0.030) = 0.081
Centre G = (0.094 x 0.071) + (0.058 x 0.220) + (0.046 x 0.553) + (0.047 x 0.126) + (0.164 x 0.030) = 0.056
Centre H = (0.270 x 0.071) + (0.181 x 0.220) + (0.026 x 0.553) + (0.032 x 0.126) + (0.041 x 0.030) = 0.079

Priorities of the collection centre

Category (Collection Centre)		Priority	Rank
1	Collection Centre A	44.6 %	1
2	Collection Centre B	7.2 %	7
3	Collection Centre C	11.1 %	2
4	Collection Centre D	7.3 %	6
5	Collection Centre E	8.3 %	3
6	Collection Centre F	8.1 %	4
7	Collection Centre G	5.6 %	8
8	Collection Centre H	7.9 %	5

APPENDIX C LINEAR PROGRAMMING (LP) AND DECISION MAKING

The objective of linear programming (LP) is to identify the optimum number of rubber milk collection centres with satisfying demand of rubber collecting and minimizing the operation cost as the table following.

The objective of linear programming (LP) is to identify the optimum number of rubber milk collection centres with satisfying demand of rubber collecting and minimizing the operation cost as the table following.

Operation Item	Unit Rubber Collecting (kg) and Operation Cost (THB) to Collection Centre								Total Available Monthly Resource Targeted	Ranked resource priority (P_K)
	A (X1)	B (X2)	C (X3)	D (X4)	E (X5)	F (X6)	G (X7)	H (X8)		
Rubber Receiving	22,696	4,736	9,233	6,918	8,984	7,772	5,093	3,301	40,000 (kg)	-
Fixed Cost	43,500	17,500	27,500	24,500	27,500	26,000	27,000	17,000	100,000 (THB)	0.653
Outbound Cost	0	5,390	7,630	6,155	8,093	7,194	8,145	3,211	20,000 (THB)	0.25
Inbound Cost	59,452	5,544	16,093	13,320	2,677	14,925	10,139	3,485	85,000 (THB)	0.097

In order to do optimization program, all parameter inputs are required which generate from top criterion priority in the AHP process.

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Notation

Indices:

i represents the number of collection centre from A to H = {1, 2, 3, 4, 5, 6, 7, 8}

j represents the number of rank of priority in operation cost = {1, 2, 3}

Parameters:

Q_i represents amount of rubber milk being received per month at centre i

I_i represents inbound cost per month at centre i

O_i represents outbound cost per month at centre i

F_i represents fixed cost per month at centre i

P_j represents priority in each criteria j

RR represents limited overall rubber receiving per month at the factory

FC represents limited overall fixed cost payment per month

OC represents limited overall outbound cost payment per month

IC represents limited overall inbound cost payment per month

Decision Variables:

X_i represents 1 if collection centre i is opened; 0 otherwise

d_1 represents deviations below the limited resource of fixed cost

d_2 represents deviations below the limited resource of outbound cost

d_3 represents deviations below the limited resource of inbound cost

z represents overall minimizing deviations in each limited resource with priority weight

Mathematical Model

Objective: $$\text{Min } z = P_1 d_1 + P_2 d_2 + P_3 d_3 \quad (1)$$

Subject to:

Demand for amount of rubber collecting

$$\sum_{i=1}^{8} Q_i X_i \geq RR \quad (2)$$

Fixed Cost Limitation

$$\sum_{i=1}^{8} (F_i X_i) - d_1 = FC \quad (3)$$

Outbound Cost Limitation

$$\sum_{i=1}^{8} (O_i X_i) - d_2 = OC \quad (4)$$

Inbound Cost Limitation

$$\sum_{i=1}^{8} (I_i X_i) - d_3 = IC \quad (5)$$

Computer program solving (IBM ILOG CPLEX Optimization **Code)**

```
/*********************************************
 * OPL 12.6.0.0 Model
 * Author: KRIWUT
 * Creation Date: Mar 12, 2015 at 8:56:27 PM
```

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```
 *********************************************/
//Indices
{int} index_i =...;
{int} index_j =...;

//Input Parameter
float Q[index_i]=...;
float I[index_i]=...;
float O[index_i] =...;
float F[index_i] =...;
float P[index_j] =...;
float RR=...;
float FC=...;
float OC=...;
float IC=...;

//Decision Variable
dvar boolean X[index_i];

dvar float d1;
dvar float d2;
dvar float d3;
dvar float z;

//objective
minimize z;
{
z == P[1]*d1+P[2]*d2+P[3]*d3;

//subject to
//Demand for amount of rubber collecting
sum(i in index_i)Q[i]*X[i] >= RR;

//fixed cost
sum(i in index_i)F[i]*X[i]-(d1) == FC;

//Outbound cost
sum(i in index_i)O[i]*X[i]-(d2) == OC;

//Inbound cost
sum(i in index_i)I[i]*X[i]-(d3) == IC; }
```

Information input in computer program solving

Index i (collection centre)	Rubber Receiving (kg) monthly	Fixed Cost (THB) monthly	Outbound Cost (THB) monthly	Inbound Cost (THB) monthly
X 1 (A)	22,696	43,500	0	59,452
X 2 (B)	4,736	17,500	5,390	5,544
X 3 (C)	9,233	27,500	7,630	16,093
X 4 (D)	6,918	24,500	6,155	13,320
X 5 (E)	8,984	27,500	8,093	2,677
X 6 (F)	7,772	26,000	7,194	14,925
X 7 (G)	5,093	27,000	8,145	10,139
X 8 (H)	3,301	17,000	3,211	3,485
Limited Resources	More than 40,000	100,000	20,000	85,000
Ranked resource priorities (P_K)	-	0.653	0.25	0.097

Solution of Decision Variables

Index i (collection centre)	Value (Result)
X 1 (A)	1
X 2 (B)	0
X 3 (C)	1
X 4 (D)	0
X 5 (E)	1
X 6 (F)	0
X 7 (G)	0
X 8 (H)	0

Decision Items	Value
d_1	-1500
d_2	-4277
d_3	-6778
z	-2706.2

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APPENDIX D VEHICLE ROUTING PROBLEM (VRP)

After closing 5 collection centres (centre B, D, F, G, and H), there will be 62 suppliers who have no longer support to rubber collection centre and the factory where the routings are started and finished. The following information is data input that use to indicate position of 63 nodes (62 suppliers and the factory) and use to be parameter input in the computer programming.

Supplier ID	Coordinate X	Coordinate Y	Amount of rubber Supplying (kg)
1	0	0	0.000
2	2.54	4.31	27.406
3	1.58	5.78	67.343
4	1.31	3.3	23.164
5	3.96	3.83	35.438
6	2.7	3.23	16.263
7	6.31	5.59	22.230
8	1.6	6.89	12.556
9	2.92	8.08	23.524
10	0.63	6.46	39.035
11	0.26	6.16	20.044
12	-0.13	6.5	12.644
13	0.55	1.17	36.270
14	-0.79	1.25	124.976
15	-0.51	2.18	10.950
16	-1.2	2.57	10.855
17	-1.02	3.45	30.235
18	-1.13	3.56	45.260
19	-1.56	3.29	20.066
20	2.91	0.49	7.523
21	3.05	0.31	39.678
22	2.89	0.22	15.869
23	3.04	0.03	14.836
24	3.42	-0.15	18.198
25	3.53	-0.22	60.294
26	3.97	0.16	40.619
27	3.09	1.89	12.244
28	3.9	2.24	12.864
29	4.15	1.92	70.558
30	4.28	1.83	33.635
31	5.36	1.49	23.620
32	5.46	2.14	19.473

33	5.57	2.41	14.999
34	5.66	-0.03	22.584
35	1.02	-1.2	28.668
36	0.8	-1.47	18.653
37	1.28	-0.6	14.295
38	1.35	-0.46	8.051
39	2.05	-0.27	31.374
40	-1.25	-1.17	16.079
41	-1.24	-1.41	7.783
42	-2.01	-1.37	69.319
43	2.91	-2.33	12.456
44	2.76	-2.48	16.578
45	2.75	-1.96	12.784
46	1.66	-1.91	14.923
47	2.79	-3.05	21.171
48	2.85	-3.08	7.904
49	2.27	-3.19	15.941
50	2.43	-3.55	42.329
51	4.29	-3.27	12.200
52	4.72	-3.56	13.659
53	4.3	-3.78	15.111
54	4.58	-4.45	14.089
55	4.77	-5.21	20.943
56	4.91	-5.49	34.931
57	5.71	-3.5	19.568
58	5.83	-3.67	31.538
59	6.4	-2.79	15.926
60	5.85	-2.48	7.918
61	2.4	-1.28	13.688
62	3.18	-0.95	43.810
63	3.08	-2.63	69.729

The next process is called “cluster-first route-second” by using sweep method combined with a nearest neighbor search. These method is use to divide the area into 3 zones based on the direction and main road. Then, the result of zone dividing is shown as following.

In order to do vehicle routing problem (VRP), all parameter inputs are required. Then, VRP mathematical model is stated as follows

Notation

Indices:

i, j represents node number or supplier i or j including the factory (i=1); i, j = 1…n

k represents number of vehicle = {1, 2, 3}

n represents total number of suppliers

p represents node number who already have been visited; p = 2…n

Parameters:

D_{ij} represents distance from node i to j

q_i represents amount of rubber milk being received at node i

a_k represents capacity of vehicle k which is not exceed 500 kg

t_{ijk} represents travel time from node i to j by vehicle k

T_k represents time window of vehicle that is not over 90 minutes

t_{ik} represents rubber pick up time at node i (5 minutes)

Decision Variables:

x_{ijk} represents 1 when vehicle k is traveled from i to j; 0 otherwise

y_{ij} represents 1 when the path of node i to node j is traveled; 0 otherwise

u represents decision variable to eliminate the sub tour

z represents minimized distance as well as cost travel from route travelling (node i to j) by vehicle k

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Mathematical Model

Objective: $$\text{Min } z = \sum_{k=1}^{k} \sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij}\ x_{ijk} \quad (1)$$

Subject to:

Vehicle k must depart from the depot (node i = 1) and arrive to supplier place (node j) at least one.

$$\sum_{j>1}^{n} x_{1jk} \leq 1 \qquad , k = 1 \ldots k \quad (2)$$

To ensure that supplier will be visited only 1 time

$$\sum_{i=1}^{n} x_{ipk} - \sum_{j=1}^{n} x_{pjk} = 0 \qquad , p = 1 \ldots n, k = 1 \ldots k \quad (3)$$

To ensure that one supplier or node will be visited by one vehicle

$$\sum_{k=1}^{k} y_{ik} = 1 \qquad , i = 1\ldots n, i > 1 \qquad (4)$$

To limit the capacity of rubber being received for vehicle

$$\sum_{i>1}^{n} q_i\, y_{ik} \leq a_k \qquad , k = 1\ldots k \qquad (5)$$

To limit the time window for vehicle traveling

$$\sum_{i=1}^{n} t_{ik} \sum_{j=1}^{n} x_{ijk} + \sum_{i=1}^{n} \sum_{j=1}^{n} t_{ijk}\, x_{ijk} \leq T_k \ , k = 1\ldots k \qquad (6)$$

To ensure for traveling through node i that a vehicle k have to leave from node j

$$y_{ik} \leq \sum_{j=1}^{n} x_{ijk} \qquad , i = 2\ldots n, k = 1\ldots k \qquad (7)$$

To ensure that nod j will be visited one time which travel from node i by vehicle k

$$\sum_{k=1}^{k} \sum_{i=1}^{n} x_{ijk} \geq 1 \qquad , j = 1\ldots n \qquad (8)$$

To eliminate the sub tour

$$[(u_i - u_j) + (n-1)]x_{ijk} \leq (n-2) \ , k = 1\ldots k, i = 2\ldots n, j = 2\ldots n \text{ and } j \neq i \qquad (9)$$

Computer program solving (IBM ILOG CPLEX Optimization **Code)**

```
/*********************************************
 * OPL 12.6.0.0 Model
 * Author: KRIWUT
 * Creation Date: Mar 12, 2015 at 9:42:21 PM
 *********************************************/
//Indices
int n=...;
range cities=1..n;
{int} index_i =...;
{int} index_j =...;
{int} index_k =...;
{int} index_p =...;

//input parameter
float D[index_i][index_j]=...;
float q[index_i]=...;
float a[index_k]=...;
float t[index_i][index_k]=...;
float t[index_i][index_j][index_k]=...;
float T[index_k]=...;

//decision variable
```

```
dvar boolean x[index_i][index_j][index_k];
dvar boolean y[index_i][index_k];
dvar float+ u[2..n];
dvar float z;

//objective
minimize z;
subject to
{z== sum(i in index_i,j in index_j, k in index_k)D[i][j]*x[i][j][k];

//subject to cons
//2
forall (k in index_k)
sum(j in index_j: j>1)x[1][j][k]<=1;

//3
forall (p in index_p, k in index_k)
sum(i in index_i)x[i][p][k]-sum(j in index_j)x[p][j][k]==0;

//4
forall (i in index_i: i>1)
  sum(k in index_k)y[i][k]==1;

//5
forall (k in index_k)
  sum(i in index_i,j in index_j)q[i]*y[i][k]<=a[k];

  //6
forall (k in index_k)
  sum(i in index_i: i>1)t[i][k]*x[j][i][k]+t[i][j][k]*x[j][i][k]<=T[k];

//7
forall (i in index_i: i>1, k in index_k)
  y[i][k]<=sum(j in index_j)x[j][i][k];

//8
forall (j in index_j)
  sum(k in index_k,i in index_i)x[i][j][k]>=1;

//9
  forall (k in index_k,i in index_i : i>1, j in index_j : j>1 && j!=i)
  u[i]-u[j]+(n-1)*x[i][j][k]<=n-2;
}
```

This program was used to solve vehicle routing problem in each zone following the method of sweep combined with a nearest neighbor search.

VITA

Kriwut Yanawimuti was born in Songkhla, Thailand. After he finished his high school diploma in 2007, he continued his studies in Aeronautical Engineering at Suranaree University of Technology, Nakhon Ratchasima, Thailand. While he was still completing his Bachelor’s degree, he had the opportunity to do internship in the maintenance department as trainee student and engineer assistant for 5 months at Thai Aviation Industries Co., Ltd. Bangkok, Thailand. Then, he graduated the Bachelor's degree in 2011 and continued his Master's degree in 2012. He joined the postgraduate dual-degree programme in the Master of Engineering in Engineering Management from Chulalongkorn University, Bangkok Thailand, and Master of Science degree from the University of Warwick, Coventry, United Kingdom. In 2015, he started his job at Sumitomo Electric Hardmetal (Thailand) Ltd. Bangkok, and he is currently working as a technical support engineer.

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