A STUDY OF INBOUND LOGISTICS TO REDUCE COST AND WAITING TIME USING LOADING SERVICE STATION IN SUGAR INDUSTRY: AN APPLICATION OF MATHEMATICAL PROGRAMMING AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

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(INDUSTRIAL ENGINEERING)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2014

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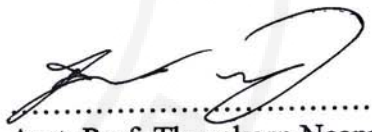

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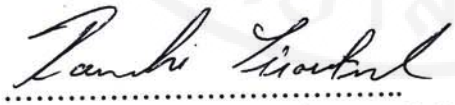

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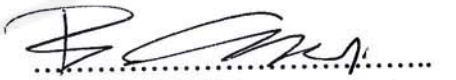

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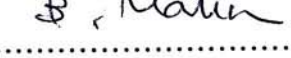

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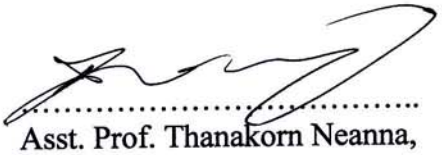

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Attakorn Jaruthien

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ABSTRACT

The problem facing the sugar industry in Thailand is the low quality of product as a result of sugar production efficiency, lengthy transportation distances due to poor transportation management, and other factors involved in the production process. This research is aimed to study the inbound transportation logistics management system needed to improve the value and productivity of sugar cane production. GIS (Geographic Information System) is used in designing and selecting the suitability area as a hub-and-spoke system for distribution. VRP (Vehicle Routing Problem) and mathematical models are used to find the optimal transportation cost and capacity for operational planning. New transportation models with appropriate hub locations derived from k-mean clustering and vehicle routing technique can improve overall sugar cane inbound transportation system. The number of trips reduced from 1,200 in the traditional transportation method to 279 and 800 trips for new model 1 and 2, respectively. The queuing time was drastically reduces from 28 hours in the traditional method to 6.5 hours and to 10.5 hours in the new model 1 and 2, respectively. Additionally, the transportation distances and costs were reduced by 27% and 25.6%, respectively, in the new transportation model 1 and reduced to 20% and 18%, respectively, in model 2.

KEY WORDS: INBOUND OF TRANSPORTATION AND LOGISTICS /
CAPACITY OF VEHICLE ROUTING PROBLEM / GIS /
SUGAR CANE INDUSTRY / K-MEANS CLUSTERING

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การศึกษารูปแบบการลดต้นทุนและเวลารอคิวอ้อยของโลจิสติกส์ขาเข้าในอุตสาหกรรมน้ำตาลด้วยสถานีบริการขนถ่ายอ้อยโดยการใช้โปรแกรมคณิตศาสตร์และระบบภูมิศาสตร์สารสนเทศ

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บทคัดย่อ

งานวิจัยนี้มุ่งศึกษาการจัดการโลจิสติกส์ขาเข้าตั้งแต่ในไร่จนถึงโรงงานผลิตเพื่อปรับปรุงให้เกิดคุณค่าและประสิทธิภาพในการผลิตอย่างสูงสุด โดยนำระบบภูมิศาสตร์สารสนเทศมาใช้ในการวิเคราะห์ข้อมูลเชิงพื้นที่ ในการเลือกหาตำแหน่งที่เหมาะสมในการตั้งสถานีขนถ่ายอ้อย และตรวจสอบความถูกต้องเหมาะสมด้วยโปรแกรมคณิตศาสตร์เพื่อหาต้นทุนค่าขนส่งอ้อยที่ประหยัด เพื่อการวางแผนระบบดำเนินการขนส่งอ้อยเข้าสู่โรงงานที่มีตำแหน่งสถานีขนถ่ายอ้อยที่ได้จากการใช้ K-Mean ในการจัดกลุ่มไร่อ้อยและเทคนิค VRP ในการปรับปรุงการขนส่งอ้อยขาเข้าโรงงาน ทำให้การขนส่งอ้อยเข้าโรงงานด้วยวิธีการสร้างสถานีขนถ่ายอ้อยสามารถลดจำนวนรถบรรทุกที่ต้องมาจอดรออยู่หน้าโรงงานลงจาก 1,200 เที่ยวในแบบดั้งเดิมลงได้ถึง 279 เที่ยวในการขนส่งอ้อยโมเดลที่ 1 และลดลงถึง 800 เที่ยวในการขนส่งอ้อยโมเดลที่ 2 เวลาการรอคอยคิวของรถบรรทุกอ้อยแต่ละเที่ยวก็ลดลงจาก 28 ชั่วโมงในแบบดั้งเดิม เหลือ 6.5 ชั่วโมงในการขนส่งอ้อยโมเดลที่ 1และ 10.5 ชั่วโมงในการขนส่งอ้อยโมเดลที่ 2 ระยะทางการขนส่งและต้นทุนการขนส่งก็ลดลงร้อยละ 27 และ 25.6 ตามลำดับ ในการขนส่งอ้อยเข้าโรงงานโมเดลที่ 1 และลดลงร้อยละ 20 และ 18 ตามลำดับในการขนส่งอ้อยเข้าโรงงานโมเดลที่ 2

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CHAPTER I
INTRODUCTION

1.1 Background.

Sugar and sugar cane industry has been an important agricultural industry where it is one of the five most important agricultural industries in the Kingdom of Thailand. In addition, using its own sugar cane resource supplies, Thailand is considered as one of the top two sugar exporting countries after only Brazil (Office of the Cane and Sugar Board) (Table 1.1 International statistics: the world of sugar year runs from October to September) with an increasing trend to a record high of sugar exporting in 2013 and sugar production in 2014 (Foreign Agricultural Service, United Stated Department of Agriculture) (figure 1.1 and table 1.2). Thailand was projected to be on top raking sugar production and exporting country of the world for the next ten years (Koo and Taylor, 2013). Therefore, sugar industry is an important industry which can help solving the economic problem in Thailand.

Table 1.1 International statistics: the world of sugar year runs from October to September

2011/12 estimate	Production million tons	Exports million tons	Export ranking	Population millions	Per capita consumption (kg/person)
Brazil	39.014	27.590	1	203	61
India	27.837	2.911	4	1 263	19
EU	18.549	2.174	5	499	35
China	12.184	–	-	1 383	10
Thailand	11.347	8.520	2	70	38
United States	7.257	–	–	321	30
Mexico	5.467	1.000	8	113	34
SADC	5.435	1.960	6	263	13
Australia	5.167	3.061	3	22	49
Pakistan	5.109	–	–	196	21

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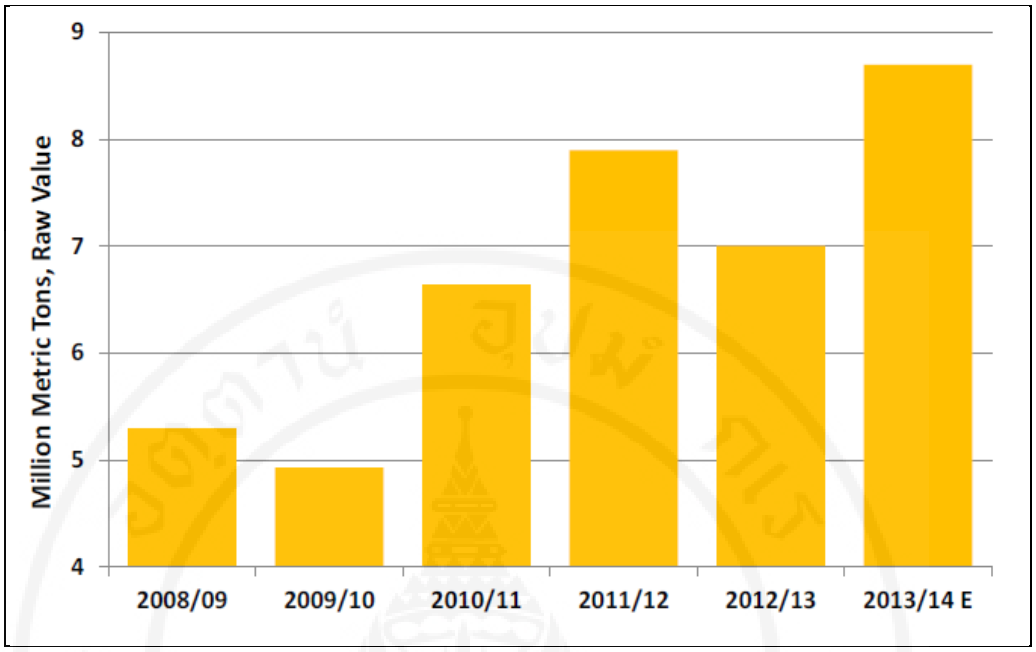

Figure 1.1 Thailand sugar export value from 2008 to 2014

(U.S. Department of Agriculture, 2013)

Table 1.2 World Centrifugal Sugar: Imports and Exports (1,000 Metric Tons, Raw Value)

	2009/10	2010/11	2011/12	2012/13	2013/14	May 2014/15
Production						
Brazil	36,400	38,350	36,150	38,600	37,800	36,800
India	20,637	26,574	28,620	27,337	27,045	27,900
EU	16,897	15,939	18,320	16,655	16,100	16,300
China	11,429	11,199	12,341	14,001	14,346	13,700
Thailand	6,930	9,663	10,235	10,024	11,390	11,000
Other	61,075	60,215	66,500	70,869	69,022	69,889
Total	**153,368**	**161,940**	**172,166**	**177,486**	**175,703**	**175,589**
Export						
Brazil	24,300	25,800	24,650	27,650	26,200	25,250
Thailand	4,930	6,642	7,898	6,693	7,500	8,300
Australia	3,600	2,750	2,800	3,100	3,190	3,300
Mexico	751	1,557	985	2,090	2,543	2,158
Guatemala	1,815	1,544	1,619	1,911	1,950	1,950
Other	12,936	15,564	17,028	13,046	14,530	14,283
Total	**48,332**	**53,857**	**54,980**	**54,490**	**55,913**	**55,241**

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Source: Foreign Agricultural Service, United States Department of Agricultural, May 2014

Sugar cane can be considered as a "3 F's" product: Food, Feed, and Fuel. Not only can sugar cane be used as food for the people, but it can also be used to as feeds for domestic animals. Moreover, sugar cane can be used as alternative fuel for automobiles.

The quality of the product can be calculated by the sweetness of sugar cane (Commercial Cane Sugar, CCS). This is still an issue because the quality of sugar cane is still low based on the sweetness, which results in low productivity. If farms are able to increase the quality through the improvement of agricultural practices, transportation, and zone separation, they will able to be effectively better the quality of sugar canes.

An important setback in the production of sugar is due to the low sugar cane quality coming from farms. Many times the low productivity is caused from long-distanced transportation from farms to factories (Acharawan, 1996). Besides this, the quality of sugar cane affects the price and factories are willing to pay for the product.

Since the majority of the price is a result of the cost of the product itself. The cost of sugar cane is 70% of the total cost. It is evident that the sugar industry benefits the country of Thailand. The sugar industry along with related industries hires more than 600,000 workers. There are 47 sugar factories located all over Thailand; the amount of sugar cane during crushing season is approximately 63,797,807.576 ton (Office of the Cane and Sugar Board). The sugar cane farming area involves 6,516,376 Rai. Even though the government tries to closely intervenes using laws and other restrictions by using the power and authority of the Office of the Cane and Sugar Board (OCSB). The Ministry of Industry plays in role in a three parties committee between sugar cane farmers, factories, and government in order to move the industry forward steadily. Nevertheless, from following the industry's news (Siam Business, 2008), many research papers (Kromkit, 2007; Prasit, 2006; Pronchai, 2000; Khonkean University; Virapat, 2008; Virapat and group, 2008; Saran, Wanchai, 2008, Chamber of Commerce, 2006a, 2006b, 2006c; Arun 2008), each presents the information that point to a similar direction. They claim that the sugar industry has been still contained many flaws and challenges, mainly the process by which the administration operates. In other words, the focuses are on the upstream and downstream methods. The upstream process refers to the sugar cane production, starting in the farms. The downstream process refers to the completion of the sugar processing procedures and handling sugar cane as processed sugar to customers. The problems occur throughout the process, especially in the transportation of sugar cane from farms to factories, or what is well-known as inbound logistics. The most essential flaws fall in the production cost, and excess transportation trucks' waiting time during the journey. While the average waiting time at the factory is 15 hours, the maximum waiting time at the factory is as high as 42 hours and the minimum is 6 hour and 43 minutes (The Completed Paper, The

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Project of Relating Logistics and Sugar Agricultural Industry, 2006). The unpredictable length of the waiting time influences sugar cane's weight and quality. Farmers are unable to prepare for sugar cane harvest. Thus, the unpreparedness results in other major problems such as the organization of sugar cane transportation and labor placement. The cost of transportation contributes to a major fraction relative to other procedures in the industry. The causes of the problem stem from many factors such as the lack of farmers' knowledge and skills to organize effective transportation. As a result, many trucks are backed up by the sugar factory's parking and loading garage. Furthermore, there is a problem of transporting sugar cane from long distances. In other words, farmers are willing to drive long distances in order to sell sugar cane to another factory rather than save on transportation costs and sell to the nearest sugar factory in their area. This is due to uncertain causes. Information from sugar cane farmers demonstrates that the dispersion of sugar cane harvest, some of which is farther away from a main sugar recipient. Farmers who are part of a larger cooperation quota suffer from long distanced transportation costs. Sometimes factories compete for sugar cane across districts.

Many research papers suggest that farmers should be prohibited to transporting goods over a given distance (Khonkean University, 2006, Virapat, 2008, Virapat and group2008) because it results in unnecessary increased in production cost. A research study (Khonkean University, 2006) suggests for an implementation of strict consequences on both sugar cane farmers and factories that accept sugar canes from different districts. There have been proposals for limitation for sugar cane transportation into factories. In other words, it is ideal to set up district collectors for sugar cane in each of the areas so that farm representatives do not have to travel more than 100 kilometers during a normal sugar cane season. In case of a high-producing season, the limit on travel distance should be set at no more than 80 kilometers from farms (Khonkean University, 2006). If there is a strict execution of the law with consistent disciplinary actions for those who fail to abide by the laws, how this set of laws will be benefit? How can we know that each sugar cane buyer in the district is not going to use this power to take advantage of the farmers? If maps are created to restrict farmers and buyer, does the buyer have sufficient funds to purchase all the sugar cane in a high-producing season? If the factory is unable to buy the total amount of sugar cane in its given district (disregarding the reason behind this incapability, whether it is lower than average production or temporary pause of machines due to breakage), there should be further discussion to whether or not that an additional sugar factory can be built in that same particular region1. How can we make sure that the radius around which farmer can sell to which factory can be effective for more than one year? In addition, can this particular map be used in other parts of Thailand without renewal of the map each year? If this is all possible, what is the method most

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effectively used in order to organize sugar cane distribution within a region so that it is acceptable for both the sugar cane providers and recipient.

The Office of the Cane and Sugar Board (OCSB) is determined to raise the bar higher for competition in the sugar industry by increasing the quality of sugar cane to increase the ratio of amount per produced goods per farm and increase the weight of sugar. Its efforts can be shown in the support for a high quality sugar cane species farming in suitable environments, encouragement of sugar cane farming departments, and the use of internationally quality-controlled trading policy in Thailand. Most importantly, a research study that relates logistics to agricultural practices suggests that the most effectively solution is to reduce production costs from transportation flaws. However, the results from that research only expresses information about amount and quality, not about characteristics of the location using graphics and maps, which would aid better understanding of the idea. The graphics and maps would be able to facilitate the three parties committee in understanding and developing a solution to the crisis.

The appropriate mapping of the main routes of transportation of sugarcane and sugar shows a network of transport and route maps. The map demonstrates the map of main roads used to travel from farms to factory warehouse and from the warehouse to modern retailers, industrial customers, and exported throughout the Kingdom of Thailand. The alternative route to transport sugar cane and sugar can be calculated based on information such as maps of the route, forms of transport, types of trucks. Comparisons between the cost of transportation of each alternative of geo-political, economic, social, and cultural factors that might pose problems and concerns should be made. They can influence the routing and transportation of sugar cane. Map of sugarcane plantations is based on regular production of sugar cane in that area or in regions where the sugar cane crops are planted as part of a cycle including other crops. Sugar cane varies according to cultivated area by map / cost of C.C.S. The map is also based from average yield of sugarcane per Rai. A proposed policy has the target on conversion of policy into action.

This project takes the issue of sugar and sugar cane transportation from farm to factory across the region to be studied seriously. The effects of transportation failures on productivity and competitiveness of the sugar industry are obvious. The sugar industry tries to create a system of sugar cane transportation that is effective for reducing raw material costs. Keys Logistics Co., Ltd., which is one of the ten businesses under Thai Roongruang Sugar Company, is responsible for managing the logistics and supplying proper management in the sugar industry. Therefore, Keys Logistics Co., Ltd volunteered itself to support the project as controlled by the Office of the Cane and Sugar Board (OCSB) in order to apply the research

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results to the sugar businesses. The company wishes to help improve the quality and organization of sugar cane and sugar from the company. In addition, research study about the limitation of district based on sugar cane purchase is important information required to invest in Contract Farming in the future. The proper distance around a certain factory to set up as district depends on observations and analyses of transportation procedure from farms to warehouses.

1.2 Objectives.

The objectives of this research are the followings:

1. In order to study and analyze the condition of sugar cane transportation from its provider to sugar factory, including location of the sugar factory, the procedures in which the sugar cane is transported, the type of vehicle used, the distance from sugar cane farms to factory, the amount of time needed for transportation, and the transportation of sugar cane to another district.

2. In order to analyze and set up an appropriate amount of land to place in a single sugar cane district.

1.3 Scope of the research.

Since there are more than 4,000 sugar cane farmers that subscribe to sugar factories and there are a total of 47 sugar factories scattered all over Thailand, it is impossible under given budge and time constraints to study the entire industry. Therefore, the study uses a cane fields and sugar mills in the central region of Thailand as a case study for the research. This region covers mainly sugar cane plantations in Saraburi, Lopburi, and Nakornrachasima Province. However, the following research study can be adapted to use for other sugar factories in other regions of Thailand without any complications. The scope of this research is as follows:

1. Conduct a study on three provinces in the central region of Thailand: Saraburi, Lopburi, and Nakornrachasima. These provinces are included in the Office of the Cane and Sugar Board's annual report.

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2. The application of Geo-Informatics tools for this study includes the use of Remote Sensing, Geographic Information Systems (GIS), and Global Positioning System. Remote Sensing is used to pin point and check position of sugar cane farms in each area. GIS is used in the analysis of relevant and irrelevant information. In addition, Global Positioning System is used to compute the amount of sugar and location in each district. The information is taken from the control of location and time of plantation. Thus, when sugar cane is harvest, information on the sweetness of sugar cane can be analyzed.

1.4 Expected results.

The expected results from this research are:

1.4.1 To collect the total amount of sugar cane effectively. This information is based on the Saraburi sugar factory's sugar cane buyer district.

1.4.2 To propose a new and effective way to define an area around the radius of a sugar factory for suitable purchase in the future.

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CHAPTER II
LITERATURE REVIEW

The application of Geo-Informatics for sugar cane and sugar industry in the eastern region of Thailand has information and proposal of theory as follows:

1. Sugar cane plantation
    - 1.1 The nature of sugar cane
    - 1.2 Sugar cane planting season.
    - 1.3 The cultivation of sugar cane as a crop
    - 1.4 Factors that associate with growth of sugar cane
2. Purchasing system
    - 2.1 Trading system
    - 2.2 The system of quotas and additional factors
    - 2.3 The system of revenue sharing
3. A System that protects the interests of farmers
4. Sugar industry's organization
    - 4.1 Sugar cane supply
    - 4.2 The style of sugar cane transactions
5. Geo-Informatics
    - 5.1 Information from Remote Sensing
    - 5.2 Geographic Information System (GIS)
    - 5.3 Global Positioning System (GPS)
6. The supply chain and logistics in the sugar industry
7. Research works in related fields in the inbound logistics of the sugar industry
8. Sugar cane harvest
9. The harvest procedure and sugar cane transportation system
10. Concepts and theories about lead time
11. Concepts and theories about transportation
    - 11.1 General aspects of transportation
    - 11.2 Land transportation routes

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12. Equations and mathematical modeling of transportation system
    12.1 Theories about the problems of bus line
    12.2 Theories about the separation of zones or groups
    12.3 Type of Clustering
    12.4 Analysis form of transportation route organization problem
    12.5 Mathematical formula for solving transportation problems
13. Related research
    13.1 Research about the harvest and transport of sugar cane.
    13.2 The future of Thailand's sugar industry
    13.3 Survey the cost of sugar cane production
    13.4 Explore the cost of sugar cane production
    13.5 Study the partnership in order to manage cost of shipping by truck
    13.6 Research on the costs of harvesting sugar cane

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2.1 Sugar Cane Plantation.

2.1.1 The Nature of Sugar Cane.

Sugar cane is a crop that is grown in tropical areas and in areas which has high exposure to sunshine. It is grown at an average temperature of 25-35◦C on blended land condition. An ideal amount of rainfall is approximately 1500 mm, throughout the year. When soil is let dry, there is only 2% mineral content present. Before the start of a seven to eight month period, water and resources are important to farming. There should be agricultural water supply storage because sugar cane is often harvested after low rainfall reason.

Sugar cane has a growing pattern similar to that of rice. The initial growth stage includes the development from a seedling into a tree. The sweetness of sugar cane depends on the cultivation and protection process until its optimal growth stage. The environment and the soil play a huge role in the sweetness of sugar cane.

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2.1.2 Sugar cane planting season.

The 80% of the productivity of sugar cane depends on the rainfall rate. Thus, the planning of the crop is dependent on the rain condition and rainy season:

Planting before the rainy season: In general, this season begins in April and ends in June. Farmers who cultivate crops during this period of time will not be able to harvest before the end of the season.

Planting after the rainy season or during non-rainy season: Cultivation starts during October and ends around January. Farmers can be sure that there will be no rainfall during this period of time. Since the soil surface is not as soaked in water as that of the rainy reason, which affects the growth process of sugar cane, farmers should plan ahead and use blended soil.

From comparing sugar cane cultivation process and the season in which it is planted, it shows that sugar cane quality is the best if planted during the rainy season and during a drought. Sugar canes from these seasons have a higher sugar concentration in sugar cane relative to other seasons. Moreover, it saves the farmer's cost of plantation.

2.1.3 Cultivation of Sugar Cane.

Sugar cane planted for use in sugar factories need to be sweeter than sugar cane for chewing. Sugar cane can have sweetness of up to 20 Brix, fiber of 13.14%, and longer in shape. There are more than 400 species of sugar cane grown in Thailand. Transportation is essential in the sugar industry because sugar cane needed to be transformed into sugar. Farmers and sugar factories are to follow a set of procedures as controlled by the Office of Sugar Cane Board.

Famers can register for sugar cane planting license through the governmental office in the neighborhood. This process is beneficial in many ways due to the support from the government. For example, farmers are able to get loans with low interest rates, cheap fertilizer, and the confidence that the government will protect the safety and interests of the farmers.

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Farmers should contact with the factory close to the plantation in order to create an interconnected system of quotas for the purchase of sugar cane. This is so that the farm can sell sugar cane to the factory in a proper price and get assistance in

terms of fertilizer and other help from the factory. To improve the use of fertilizers, the amount of chemicals should be as follows: Urea (40-0-0), Aluminum Sulfate (21-0-0), Triple Super Sulfate (0-46-0), Single Super Sulfate (0-(21-22)-0) and Potassium Chloride (0-0-60) in the formula or appear as 15-15-15, 25-7-7, 28-28-0. 16-20-0 is used for the cultivation depending on the ratio of fertilizer to the characteristics of soil. Generally, farmers apply one set of fertilizer (50kg) per one Rai and use Nitrogen by Ammonium Sulfate (21-0-0) or apply 25-50 kg with Urea (40-0-0) to the soil surface.

Usually approximately 4-5 workers are needed for the cultivation and harvest of sugar cane per land area of 10 Rai. However, the rate of employment is higher during the cultivation process to plant sugar cane, apply fertilizer, and crop collection. More workers might be hired due to higher amount of sugar cane product in a particular season.

In order to apply knowledge and skills to one's own farm, farmers need to study from other experienced or successful farmers. Moreover, farmers should take action in research theories from books, research studies, and tour of the other's plantations.

2.1.4 Factors that affect sugar cane growth.

Physical factor such as weather, water temperature, sunlight, moister, and soil condition affects sugar cane growth. Similarly, biological factors such as natural disasters, insects, pests, and many other issues influence sugar cane growth.

Sugar cane plantation is most successful in areas high sunlight until harvest date. The productivity is lower in areas lack of sufficient sunlight, including under shades or dense areas. Sugar cane is able to produce sugar from carbon dioxide the same way as other species of plants.

Sugar cane crop requires high temperature of more than 30°C during its 8-month period of growth. During growth, sugar cane stores sugar in order to nourish leaves and stem. After that, sugar is kept in its roots, which should be at 18-22 °C for the next 2-3 months. The sweetness is at its peak during harvest time. However, the amount of sugar is different depending on each sugar cane species.

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The amount of water or moister is the most important factor in sugar cane planting. Areas that have sufficient amount of water would yield a better result than

that of little water. If there is an insufficient amount of water, the condition would affect the quality and amount of sugar cane that can be produced, especially during sugar cane growth period. In particular, more water is required during growth as the crop ages. Lac of water and nitrogen during the 5-6 month period will result in shorter stem, and therefore, less sugar amount.

Characteristics of soil used for cultivation depends on the amount of minerals in the soil, water, oxygen stored in an area of land, pH of around 5-6.5, air, and microorganisms. The amount of organic matter in the soil should not exceed 2%.

Natural enemies that come along with high levels of sweetness in sugar cane are virus, bacteria, fungi, and cytoplasma. They can be seen on the plant roots, leaves, and shoots. The most dangerous enemy of sugar cane is caused by cytoplasma (the threat of white leaves). Farmers should maintain and care for crops regularly.

Insects in this case do not refer all types of insects. However, only some insects are considered as sugar cane pests, which can destroy sugar cane. Farmers must consider a way to prevent pests from harm sugar cane.

Other animals that might be considered harmful to sugar cane plantations are rats, wild boar, and wild elephants.

Farmland that produces the largest quantities and high quality of sugar cane result in higher profits. Sugar cane farmers are required to manage and control the factors that affect productivity. Farmers can apply methods of pesticides and insecticides application. In addition, sugar cane farmers should consider other factors that might affect cultivation such as the amount of labor and farming tools.

2.2 Procurement Systems (The Office of the Cane and Sugar Board, 2000)

In the past, the domestic sugar market is independent. The government only determines the amount of sugar factories could produce so that it is enough for consumption. The price of sugar has been set at a high price to protect the consumers and prevent business owners to over-charge based on the Consumer Protection Act (1966). The Act has changed in again in 1974. The actual price and the amount of sugar cane distributed depend on the mechanism of the market. The purchasing system in year of 1982/1983 agreement occurs between farmers and factories. The problem is

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caused when the two sides cannot agree on the price given by the world's sugar cane market. Farmers encounter problems due to uncertainties and insecurities of the price of crop per Rai. The government has to step in every year to solve the problem, as well as give financial assistance to farmers in need. However, the problem still cannot be solved efficiently.

The issue arises from the annual allocation of sugar. The Ministry of Industry has established a policy in 1982/1983 to study from systems in Australia and South Africa in order to set up a proper price. Systems from abroad can be researched and applied to that of Thailand's.

The distribution systems of sugar are composed with three parts call quota A, B and C

1. Quota A is the production that has a white color or pure sugar for domestic consumers.

2. Quota B is the production that will be exported after processing. This requires coordination between farmers, factories, and government in order to export to foreign countries.

3. Quota C is the production for export and distribution of sugar by the factory.

Sugar cane farmers need to understand the pricing system in the world market based on the three quotas. In addition, farmers need to learn about the details of quota B, the price of raw sugar in each season to fit in with the standard price of distribution and quota C in order to compute revenues (Office of Cane and Sugar Board, 2000).

Benefit-sharing system has been used since the production season of 1982/1983. The system of sugar distribution within the country has changed into one that is more controlled. It has set up a central office to distribution sugar to act as an intermediary. The brown sugar will be sold to users such as in the soft drink, sweetened condensed milk, canned foods, and wholesalers (or Yor Pua Sugar) factories. The process of sale, delivery, production, and storage of refined white and brown sugar must be in accordance with the regulations of the central committee and anti-monopoly pricing control. This procedure is from the Price Fixing and Anti-Monopoly Act of 1979. Later, the central committee that distribute white sugar transferred under the Department of Sugar (1984) and changed into a control center

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for the production and sale of sugar as known as The Cane and Sugar Board, Ministry of Industry (October, 21, 1985). Then, it is given the responsibility of the sale control committee, Thai Sugar Cane and Sugar company (June 1, 1986). This committee is later moved back under the Division of Sugar Cane and Sugar and was renamed as Division of Sugar Cane Distribution and Control (October, 1, 1994). Based on this new system, the Office of the Cane and Sugar Board controls sugar cane and sugar production process and marketing. This is so that sugar cane farmers can receive money from the sale of sugar. Moreover, the net income from sales is used to pay production and distribution facilities of governmental factories. There are measures to control the sugar yield for sale in order to repay farmers and factories (except the production of Molasses, which is a byproduct). This is done by separating sugar produced in each season. Quota A is the product of white sugar and sugar. The Office of the Cane and Sugar Board determines that sugar factories can produce for domestic consumption based on the amount that the Office of the Cane and Sugar Board limits in each season. Sugar in quota B is raw sugar that the Office of the Cane and Sugar Board orders to be transferred to Thailand's Sugar Cane and Sugar Company Limited to export to foreign countries. Sugar in quota C is raw sugar or refined pure white sugar that the Office of the Cane and Sugar Board orders the factory to produce for export after the completion of quota A and B, as shown by the amount of sugar quota from the year 1998-2009.

2.2.1 Price System

The shared ratio computed from the three quota system used to determine a reasonable price. The final ratio of profit shared between farmers and the sugar factory is 70:30. A formula of this calculation is below:

$$PC = \frac{0.7(R_1 + R_2)}{QC}$$

PC = sugar prices (Baht/ton)

0.7 = sugar cane farmers' share

R_1 = net return from the distribution of sugar in the domestic market

R_2 = net return from the distribution of sugar in the international market

QC = quantity of sugar processing in factory

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In addition to the 70:30 ratio of distribution between farmers and factories, the amount of money is based on the comparison of initial estimated price of sugar and the actual value of sugar. After the crushing season, profit distribution need to be recalculated. The actual price should not be less than 80% of the initial estimated price. After September 30, in this case, the final price is greater than the estimated price, so farmers receive a greater share of the profit. If, on the other hand, the final price is less than 80% of the initial estimated price, profit needs to be recalculated and readjusts.

In the last 17 years, farmers have an increased level of security in the production of sugar cane, as well as improved productivity in the Thailand's sugar cane and sugar industry.

2.2.2 Quota System and Other Factors

There is a management and support system in terms of transportation to the factory. In fact, sugar factories use sugar cane as a raw material for production. Farmers who cultivate and sell crops to the factory need to contact the factory and sign a contract for sale quota purposes. The factory will evaluate the productivity of cultivation in specific plantation. Famers will give information about the location of their plantation and the amount of product send to factories as support detail and advice. When farmers need to withdraw an amount of money for planting, the factory will be able to refer back to this information and consider whether it is necessary.

Thai farmer can directly sell their sugar cane if to the factory if they are able to supply sugar cane at the contract amount or sell their sugar cane through quota head as indicated in figure 2.1 (Arjchariyaartong, 2006)

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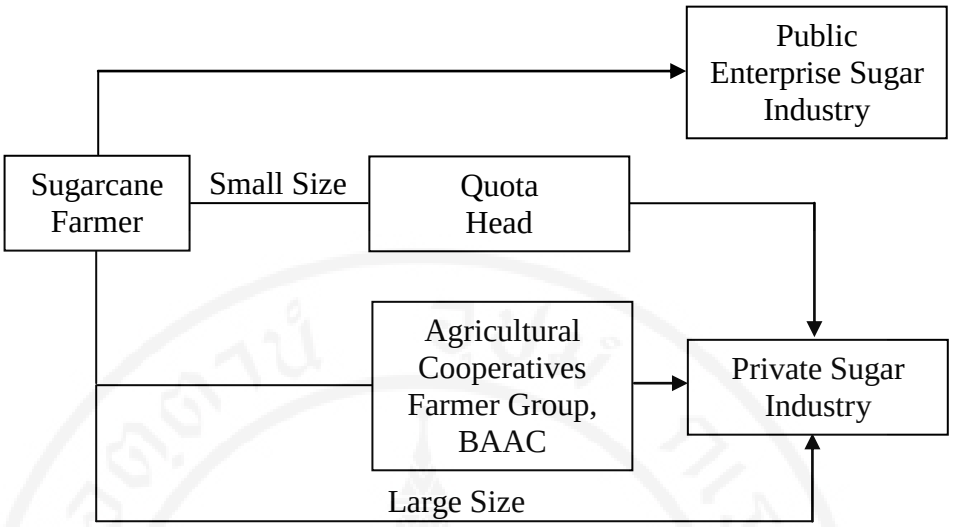

Figure 2.1 Market channel of sugar cane in Thailand

2.2.3 Revenue Sharing System

The rise in the sugar industry comes along with uncertainties and lack of the government's ability to carry out policies. Moreover, these policies change every year. The problem is with the lack of no long-term development of a single policy. The trading system of sugar cane has been somewhat unstable, which creates dissatisfaction among both buyers and sellers. The sugar industry's industrial management system is unclear. As a result, the study of system of revenue sharing can resolve this crisis. There had been success in Australia, the Philippines, and South Africa after using this same method.

On September 28, 1982, the Ministry of Industry set a policy used in the trading of raw sugar cane. In account for the revenue is calculated from the net income of sugar distribution in the domestic and international market. The split ratio is 70% for farmers and 30% for sugar factories. Figure 2.2 show the management of revenue sharing system (Arjchariyaartong, 2006).

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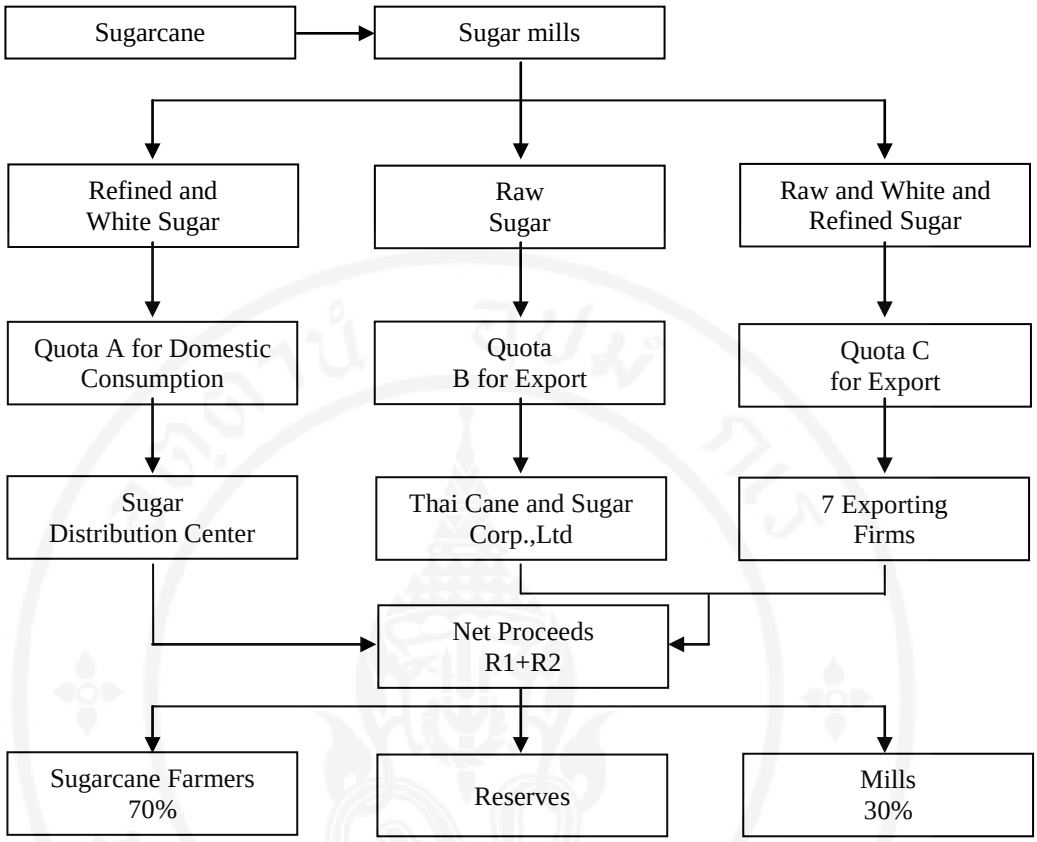

Source: OCSB(1990a)

Figure 2.2 Thailand Sugar Revenue Sharing System

2.3 Protection of Farmers' interests

The intention is to protect the farmers' interests and act as the sugar cane farmers' representative to take care of transportation of sugar cane to the factory and value of CCV. The Office of the Cane and Sugar Board is part of the Ministry of Industry that is responsible for the following sections.

- Offer guidance and policy administration of systems in the sugar industry in order to improve sugar's quality and create fairness among sugar cane farmers, factories, and consumers.
- Monitor and make sure farmers and factories are obey regulations created by the Office of the Cane and Sugar Board.

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- Promote and support the efficient development of sugar industry continuously and conduct research studies relating sugar and sugar cane to apply this new knowledge to increase productivity, create value, and reduce costs.
- Serve as the information center to support the management and alarm sugar industry of harmful occasions regularly.

The Office of the Cane and Sugar Board will collect and explore data such as raw material, quality, sugar cane processing, and lab research work done in form of CCS to standardize trials in each factory.

2.4 Sugar industry's organization

2.4.1 Sugar cane supply

The sugar factory's purchasing system is managed by a factory's manager who has no experience in the field of sugar cane and does not own a farm oneself. The manager has two options in supplying the mill with sugar cane. The first option is to self-cultivate, while the second is to buy fresh sugar cane from farmers. Figure 2.3 illustrates the possibility of choice. This is different from that of sugar factories that own sugar cane farms because they are able to buy from their own land or buy more land to plant more sugar cane. Moreover, they also have the choice to buy from other farmers.

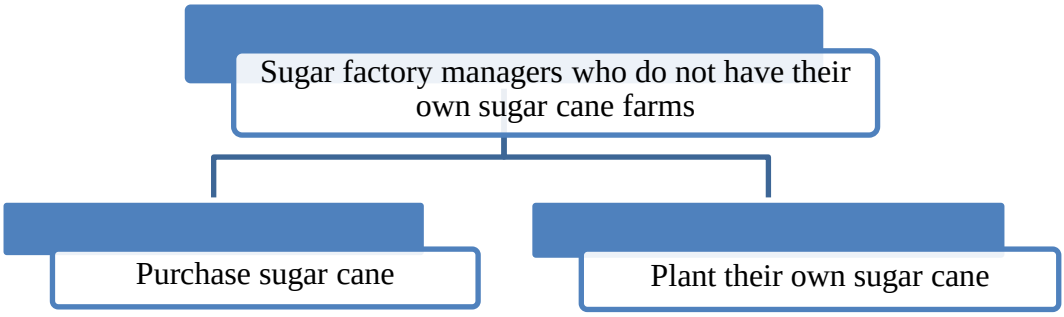

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Figure 2.3 The manager's choices of purchasing sugar cane

Studies in the past show that most managers choose to purchase sugar cane from farmers. Managers are unlikely to cultivate on their own because of higher cost and higher risk. Thus, till today, factories still buy its raw materials from sugar cane farmers.

2.4.2 Business Style and Sugar cane Transactions

The business style in the sugar industry is often the purchase of sugar cane from local sugar cane farmers. Factories try to find the cheapest, most efficient, and the most risk-free method to transfer sugar cane from the farms to the factory. In other words, farmers would pick the transportation route that would safest and yield the most benefits.

The factory has two options in the business with sugar cane farmers. The first option is to create a distribution center, while the second option is to make the purchase in advance. The advance purchase of sugar cane must consider whether or not to pre-determined sugar cane price. Figure 2.4 shows the alternatives sugar factories have.

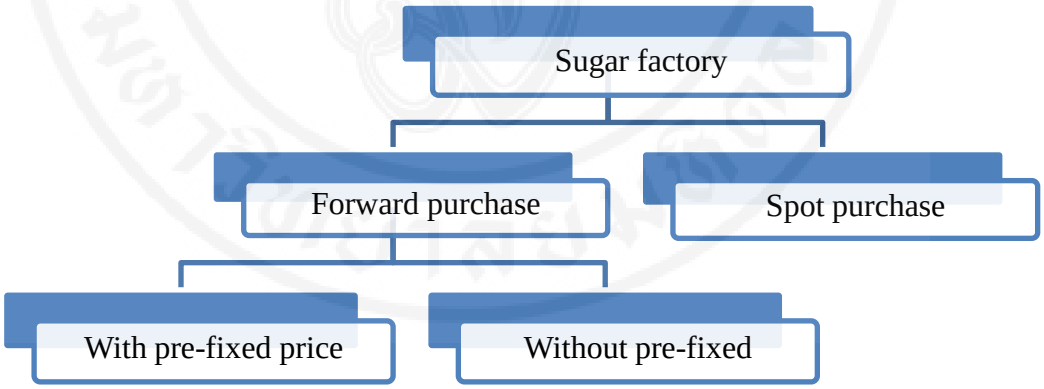

Figure 2.4 The choice of sugar cane factory's type of transaction

2.5 Geo-Informatics

The current technology information plays a role in management planning, administration, and decision making. Geo-Informatics technology is a type of technology that is known and used more frequently in the present both in public and private organizations. A common and seemingly easy question: what is the definition

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of Geo-Informatics System? However, the answer is not quite as simple as the question. It is hard to describe or explain in a short phrase or sentence.

Thailand came up with a mast plan project to create GIS by the Faculty of Engineering, Chulalongkorn University. The project is presented to the Department of Space Technology and Development (Public Organization). In 2002, this innovative technology is defined in as "Geographic Information System." The general term means "all types of directional information, including verbal and mathematical terms (Digital) or are derived from any other processes or methods." Therefore, by this meaning, Geographic Information System refers to aerial maps, satellite images, vector data, and numerical terrain models. GIS deals with survey data of all kinds, including conventional survey or contemporary ways using satellite signals such as that of GPS.

The given definition of Geographic Information Systems (GIS) is associated with a technology that can collect, store, manage, and analyze information in terms of location. In addition, the definition covers Global Positioning Systems (GPS) for the determination of exact location on Earth with satellite, Remote Sensing (RS) for photogrammetric and mapping technologies. Therefore, Geographic Information Systems need to study these information thoroughly because the technology is used starting from the initial stage of data collection to the end, which is the planning process using computers. The combined term of Geo-Informatics Systems Technology is a mixture of technology and GIS.

2.5.1 Information from Remote Sensing

Lillesand T.M. and Kieffer R.W. (1993) defined Remote Sensing as something that is used in both scientific and artistic models to analyze a specific location or occurrence from gathered informational data. It is tool that is able to find a certain thing, location, or phenomenon under investigation.

Jeffery Star and John Estes (1990) defined Remote Sensing as a process that passes on information by searching and detecting the object or phenomenon of interest.

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Long distanced detecting is a form of investigation from afar without direct contact between the tool and the object of interest. This type of object detection

is done by setting up cameras in areas of higher altitude such as airplanes, hot air balloons, rockets, or satellites. The process uses electromagnetic field or reflection from the pin pointed object as a method of measurement. This type of measurement is used for more general area. This method collects data that has a lot of information in wider areas of the field. Because the tool does not need to be in direct contact with the object of interest, it can be on airplanes and can observe a wider range of data from an airplane or satellite.

When it comes to remote sensing technology, a couple of elements to consider are:

Electromagnetic Waves Acts as a media that connect the instrument of detection to the object you want to explore.

Measurement tools Determines the electromagnetic waves used in the measures as well as the nature of the data being measured.

Instruments used to set up remote sensing technology Determines the distance between each detection tool and the object of interest, amount of area being covered, and the time of measurement

Interpretation of the data obtained from the measurements is the process of transforming the information intensity and the form of electromagnetic waves being measured, which will need to be further measured in another step.

Remote sensing tool can be used to study the theories, properties, and interaction of electromagnetic waves. Moreover, one can study the electromagnetic waves' ability to reflect off of objects on the Earth's surface. Then, researchers can study the types and characteristics of satellite remote sensing. Since each remote sensing satellite has a slightly different detection mechanism, the qualities of recorded information differ as well. After gathered information, the data is entered in a process of information preparation such as Radiometric Correction and Geometric Correction. While radiometric correction deals with inaccuracies of waves, geometric correction attempts to adjust in terms of geometry in order to standardize the data. Then, we improve the information using Image Enhancement. For example, this method includes the mixing of colors so that data from the satellite shows exact color of the object. As a result, we can determine each object on the Earth's surface more accurately. This following process is called Image Classification. Image classification

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represents types such as separation of objects by bare eyes or computers. The results of classification are then combined to create a map, calculate area, and check for accuracy and reliability of the classified information.

The data obtained from remote sensing satellite has been widely applied, especially in the exploration of natural resources. Similarly, the technology is used to monitor and plan the management of society in terms of the environment: water and forest conditions. It can also be used to track and manage the growth of a city. In addition, it can assess the impact or damage caused by natural disasters such as that of tsunamis and forest fires.

2.5.2 Geographic Information System (GIS)

Geographic Information System (GIS) is a process associated with directional and geographical computer system that uses geographic information that relates to relative positions such as address that is coordinated with longitudinal and latitudinal information. The database in GIS is an information system in terms of spatial data. The forms and relations in the spatial data will be analyzed with GIS to make meaningful changes in relation to time, such as the spread of epidemics or invasions of diseases that destroy a settlement, movement, or changes in land use. When this information appears on the map, it is not only possible to interpret and convey significant meaning, but it is also easy to use.

GIS is a systematic process of information that is stored on computers, but it is able to translate and link conditions to the geographical area of working conditions related to the ratio of distance to space on the map. The difference between GIS and MIS lies in the characteristics of data. GIS uses information in terms of spatial data that shows graphic and map that is linked to attribute data or database. It allows users to show both types of database simultaneously. For example, one can find the location of black smoke and white smoke checkpoint by specifying the name of the checkpoint. Alternatively, one can inquire details about that certain checkpoint from the selected checkpoints. On the other hand, MIS is only able to display image due to the lack of connection to the database linked to particular images. For instance, there is only image in Computer Aid Design (CAD). However, maps in GIS are related to the position in terms of geographic area which is exact coordinate on Earth. The

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information in GIS, both geographical and analytical, is able to refer directly and indirectly to an actual location on Earth by using Geocode. For example, the location of buildings and roads are considered an actual location. Indirect information is home address, including house number, district, city, zip code, and so on. From existing data, we can find out where on Earth this house is located because no two houses can be located in the same exact place.

The main components of GIS are divided into 5 major components: Hardware, Software, Methods, Data, and People. Details about each of the components are as follows:

Computer Tools. Computer tools include computer and its parts such as digitizer, scanner, plotter, printer, and so on to import information, analyze, process, and display the results of the work produced.

Program. The program is a complete set of orders, such as Arc/Info and MapInfo which consists of a work function and other tools essential for the import and manipulation of data. These tools function to manage, retrive, anayze, and simulate the image and database.

Information. The information to be used in a GIS system is stored and taken care of in the database. The database management system, or DBMS, is part of an important component besides people.

People. Workers are the ones who are involved in the GIS as data technicians, administrators, and database experts for analysis. Executives need the information to make decisions. Workers are the most important element in GIS. Without workers, the tremendous amount of data is valueless. Data becomes useless if not being used or analyzed due to lack of workers.

Method. The method is the process in which an organization uses the GIS system different units of that particular organization. Each unit in a big cooperation is unique. Therefore, executives need to choose appropriate solutions for each problem in each unit.

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2.5.3 Global Positioning System (GPS)

Global Positioning system is a system that searches and directs to an object or place based on the satellite navigation systems. It consists of 24 satellites that orbit

around the Earth twice per day. As a result, the GPS signal receiver on the Earth's surface detects 4 satellites per day. Because of this, the GPS receiver is able to calculate the position of a given object or place 24 hours a day in all types of weather and condition on the Earth's surface or at the atmospheric level. GPS is an automatic and accurate system depending on the quality of the GPS receiver and the method used to measure.

Satellite Positioning System on Earth contains three parts. First, the Space Segment which consists of 24 satellites orbiting around the Earth. These are divided into six orbits, each contains 4 GPS satellites. The satellites are located 20,200 km above the Earth's ground level. Each satellite takes 12 hours to travel across the globe. The satellites are controlled on Earth at the control stations in the Control Segment. This segment functions to control different characteristics of a satellite such as speed, time, location, and altitude of the given GPS satellite. These measurements need to be accurate at all times because coordinates may be shifted tens to hundreds of meters. These parameters are converted into signals to send to the correct satellite. Then, the signals are transferred to the User Segment. This segment is the where GPS users, or consumers receive the signal. The user's receiver converts the signals received from satellites. Then, the receiver calculates the coordinates of that specific location. In addition to the coordinates, the user's receiver device is able to calculate other information such as time of sunrise, time of sunset, the distance, and the time needed for travel.

2.6 The supply chain and logistics in the sugar industry.

The supply chain in the sugar industry can be considered as well studied through many case studies and research studies. The aim of these studies is to organize and manage the performance and cost of production. Generally, the logistics in the sugar industry focus on the cooperation of farmers and factories ranging from harvest, transport, and stocking process (Strohm, 199; Grunow et al, 2007). Lukesch (2005) has studied the issue from the process of seed selection, crop cultivation, and selection of an appropriate location for planting. The study examines the differences in price of on time, early, and late transportation (Grunow et al, 2007). Some articles study

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transportation schedules and the addition of efficiency (Higgins et al, 2007). In terms of harvest and transportation in the sugar industry, there are many opportunities for development in logistics of the sugar industry. Figure 2.5 illustrates that the supply chain of the sugar industry in Thailand.

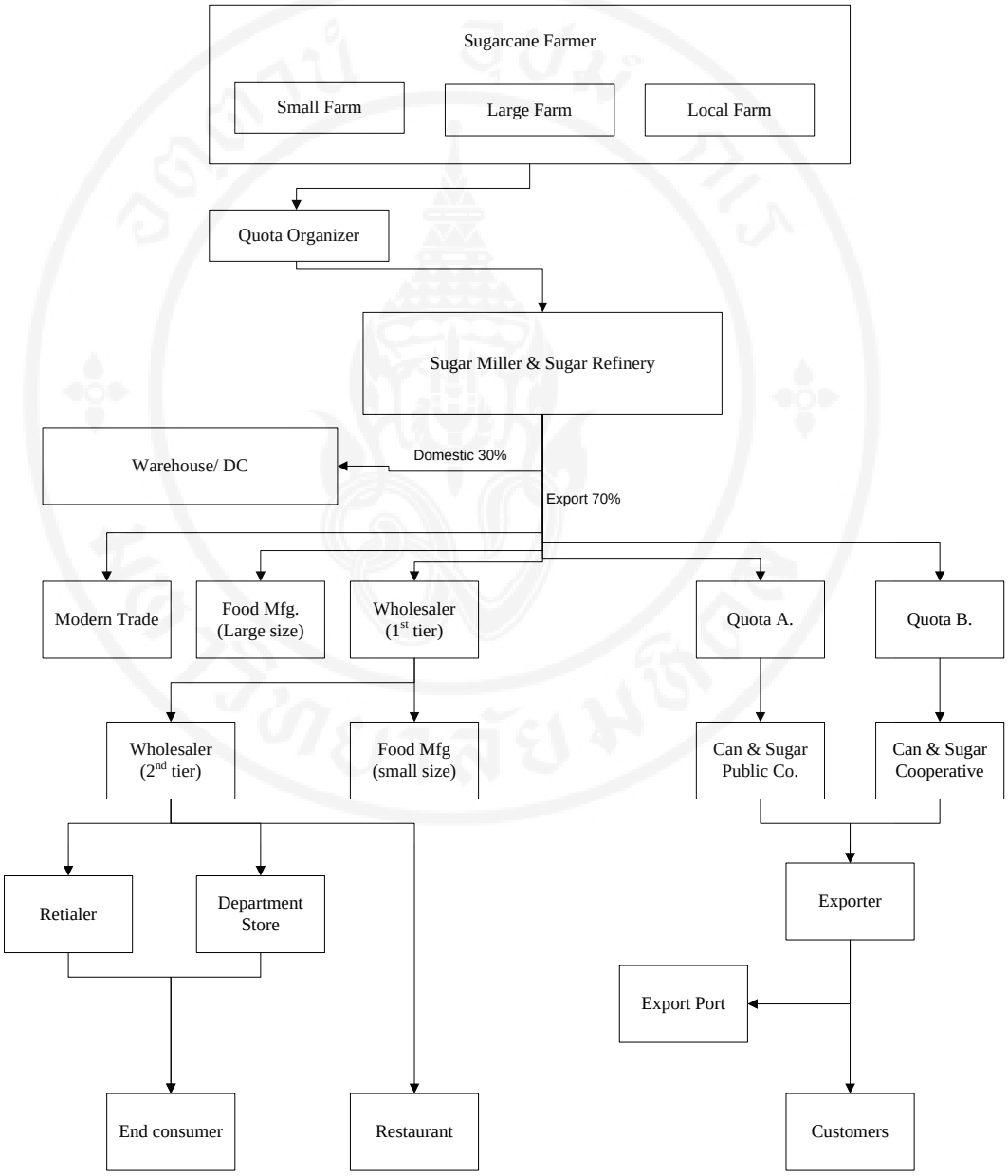

Figure 2.5 Supply chain: the relationship between upstream and downstream model

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Figure 2.5 demonstrates the relationship between sugar cane and sugar industry from upstream to downstream method in Thailand. In the upstream part, farms that are close to factories sign an agreement to set a quota for the sugar cane to

be sent to factories. This agreement needs to be approved by the Office of the Cane and Sugar Board so that sugar factories know the amount of sugar cane that will be entering the factory. Sugar factories need this information to perform production planning. In the mid-stream part, the factory produce refined sugar from sugar cane. In the downstream part, the sugar factory separates the amount of sugar depending on the quota limited by the Thai government. Generally, 30% of the total amount of sugar produced is for domestic use or storage in the sugar factory's warehouse. The other 70% is to export to foreign countries. Figure 2.6 illustrates detail inbound logistics from farm to factory.

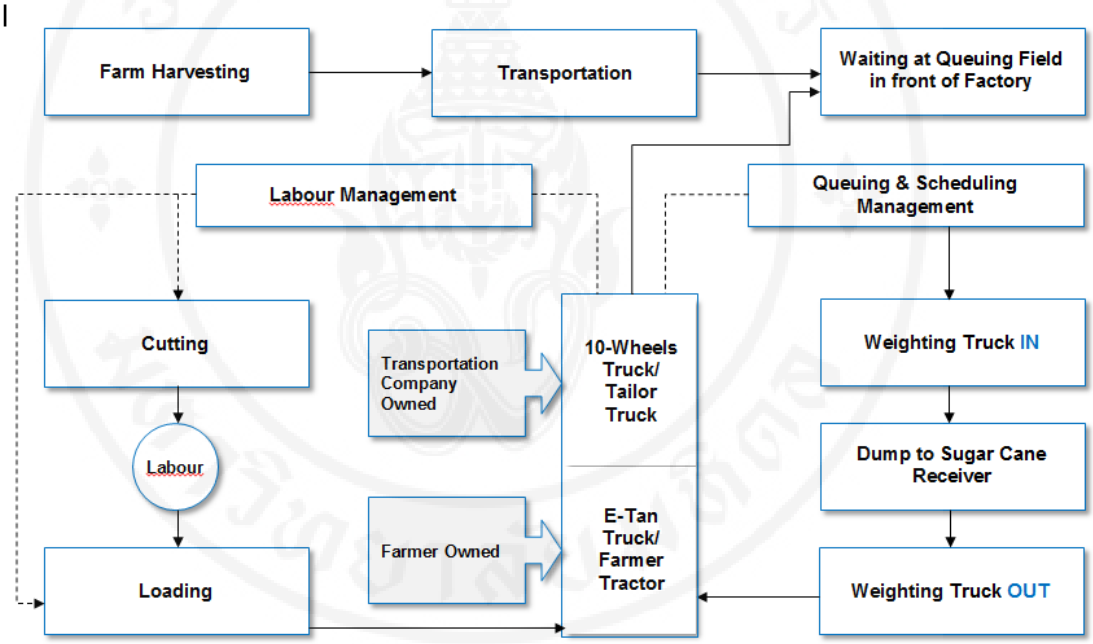

Figure 2.6 The traditional inbound logistics from sugar cane farm to factory

2.7 Research works in related fields in the inbound logistics of the sugar industry.

The most cases when talking about the logistics of the sugar industry, input is often thought of as transportation from farm to sugar factory. In Cuba, there is a study using a simulation analysis of road transportation to transport sugar cane (Diaz and Perez, 2000) Moreover, the study explores the development and mathematical equations to analyze the logistics in Cuba. Lopez Milan et al conducted a study on

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transportation in several forms, starting from truck in the warehouse and transportation using train. The study does not consider the transit time of truck.

In Thailand, sugar industry is mostly a family business. The analysis is done on a random selection basis in order to learn about appropriate amount of sugar cane from farms. The analysis of lead time and the amount of sugar cane for transport are uncertain in the Supsomboon and Yosnual (2004) study. It uses the total equation to study the transportation of sugar cane to the sugar factory through different types of vehicles and methods. Prichanont et al (2005) have used a sample situation to assess the number of trucks used to transport from the factory. The timing of trucks entering the factory corresponds to available parking spaces and the capability of machines effect the overall efficiency of sugar production. Improvements based on these factors will decrease the trucks' queuing time and the amount of time with machines not properly functioning. This is difficult to accomplish because during harvest time, there are tremendous amount of sugar caring andne entering the sugar factory. It is not quite logical for the factory to increase the amount or capability of machine only during harvest season, nor is it possible to limit the amount of sugar cane from the farmers (Higgins, 2006).

Dowling and Jessadachat (1978) studied the supply response in Thailand's sugar industry. They try to find the key of flexible response to price chances. However, the results are inconclusive because the limitations of information. Nevertheless, results from the model can help researchers find a satisfactory result. This can help to create a detailed analysis of the entire system. Many researchers study studied the process of ordering and delivering as a case study, such as Koster et al (2007). In addition, Geotschalckx and Ashayen (1989) did a similar study that has an aim to analyze the ordering and storage system so that it can reach its highest level of service. There are limitations to the optimization of service, such as workers and machinery. Furthermore, other related factors include mean and variance of the time delivery, honesty and accuracy, relationship between buyer and seller, and level of service. A good relationship can facilitates the process, making it faster and less bothersome for both the factory and customers. If an order cannot be scheduled, the customers need to wait until the next harvest round (Chaiadamrong and Kawtummachai, 2008). By studying related articles, most of the researches are

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conducted to study the supply chain. The tools used in the supply chain have limitations according to date and time because the sugar supply chain has complicated production and management systems as studied by Chaiadamrong and Kawtummachai (2008).

The problem of sugar cane transportation from farms to factories depends on the amount and time management. In the case of an overabundance of sugar cane, the sugar factory does not have the capability to process the amount of sugar cane. Yorthnual (2005) analyzes the uncertainty of transportation time and amount of goods by the stochastic method. Long waiting times during delivery in the parking lot of might be caused by the imbalance of trucks that enter the sugar factories throughout the day. This can be divided into two scenarios. The first one is a type of transportation on the basis of first come first serve to analyze an appropriate the amount of input in the sugar factory. The second scenario is to decrease waiting time by modeling case scenarios.

2.8 Sugar cane harvest.

Since sugar cane is an important raw material in the sugar industry, the harvest must correspond with the conclusion of a sugar crushing season. The goal is to harvest when sugar cane is highest level of sweetness and have enough to send to sugar factories continuously. Farmers and factories need to cooperate in order to benefit both parties. They need to both plan and manage systematically. For instance, farmers should know the quota of sugar cane set by sugar factories and farm in areas approved by the Ministry of Agriculture. Generally, farms should be located within 50 kilometers of a sugar factory because farmers that exceed this distance will need to pay more for transportation. The ministry needs to observe and approve the soil quality and weather to determine which species of sugar cane to grow. The correct species will yield results that are in perfect timing for sugar crushing season. Moreover, sugar cane at its peak of ripeness will yield greater sweetness, and thus, higher in quality. The harvest of sugar cane at its peak is usually between November and May. Farmers need to plan to harvest sugar cane section per section. This type of harvest is called crop cycle. The time of harvest depends on sugar cane species or

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ripeness so that it has the highest level of sweetness throughout crushing season. The harvest is scheduled for each week or fortnight because the amount of sugar cane needs to satisfy a factory's intake by the number of quotas. The main goal is to sync sugar cane maturation with sugar factory's demand.

Sugar cane should be harvested when it is at its highest maturation. One can determine whether a sugar cane is ripe or not by looking at its flower. If the flower did not bloom, one can look at the set of leaves at the shoot. The leaves will have a yellowish green, signifying that it has a nitrogen deficiency. Farmers should start to collect starting from sugar cane with flowers because the quality and yield will rapidly decrease after time. Typically, sugar cane that is almost at its peak ripeness will not grow in height. Cooler weather conditions, dry environment, and lack of nutrients such as nitrogen cause sugar cane to become ripe at a faster rate. When the amount of growth in the stem decreases in sugar cane, sucrose sugar storage starts to rise. Farmers stop giving sugar cane water one month before its harvest date to increase the sucrose sugar storage within the stem. The process causes more reducing sugar to transform into sucrose sugar. When sugar cane is at its peak of ripeness, sucrose increases while fructose and glucose decreases.

The best method to check sugar ripeness is the analysis of sucrose amount by randomly selecting 8-10 sugar canes from 1 Rai. Then, sugar canes are separated into three groups by eye. The three groups are the bottom, middle, and upper section. Farmers poke each section and withdraw a couple drops of liquid on the hand refractometer to read and compare each section. If the three parts are similar, it shows that that particular sugar cane is fully ripe. Even though this is a good method, it wastes time, crops, and costs. Therefore, it is not popular for farmers to use this method.

Before cutting sugar cane, farmers need to detach the leaves and stem with a knife or shovel. Because the sweetness is at the bottom of sugar cane crop, it is ideal to cut the stem as close to the ground as possible. Moreover, cutting close to the ground increases sugar cane weight. The small stem leftover will sprout into a bigger and stronger sugar cane plant. After cutting off the stem, farmers cut off the top of the shoot to eliminate extra length. The top section has some type of power that contains carbohydrate. These compounds cause difficulty in chewing crystallized sugar. If a

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sugar factory uses CCS as a standard to measure sugar cane, long sugar cane top section length is a disadvantage to the farmers. This is because the weight of the top section is not of value. It is not recommended to burn sugar cane if not necessary because the quality decreases. Slow harvest causes rapid decrease in weight and quality of sugar cane.

Sugar cane harvest machines, which are uncommon in Thailand, can be used to harvest crops. Although it has high efficiency, there are many disadvantages that come with it. One of the faults is that it is unable to completely cut sugar cane, especially when sugar cane is wet. The tractors sometimes pull the whole crop from the ground, which cause sugar cane to be contaminated with dirt and other unsanitary compounds. This causes sugar cane to have a low level of purity. Dirt that stick to sugar cane cause the sugar refining machine to break down over time. As a result, the sugar factory might need to waste more time and money to stop and fix the machines. With machines, there are fewer opportunities for jobs creation in the sugar industry. This might increase unemployment rate.

Sugar cane that has been cut should be send to sugar factories immediately because weight and quality rapidly decrease over time. High amount of waiting time is one of the reasons that cause low sweetness and amount of sugar cane produced. This waiting time could be at the farm or during transportation. This could be fixed by the communication between farmers and factories to plan the most time efficient method.

2.9 The harvest procedure and sugar cane transportation system.

There are various methods for sugar cane harvest, transportation, and sugar crushing system in Thailand. (Sukhothai Thammathirat, 2539:237-242).

2.9.1 Method of sugar cane harvest.

There are two methods for sugar cane harvest in Thailand. These are harvesting by manual labor and by tools.

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The use of manual labor is a system used for a long time. It must have workers to cut sugar cane and to transfer them on the truck. In general, workers will cut 1 to 1.5 tons of cane per day, or about 100-150 bundles, each approximately 10

sugar cane per bundle. It depends on the size and length of sugar cane, as well as the difficulty of cutting sugar cane. Usually, 4 workers are able to throw sugar cane to fill 1 truck, or about 25 ton within 8 hours. They will receive money based on the amount thrown per day. In addition, the cutting system is based on ton of sugar cane cut. Workers are paid based on the number of tons cut or thrown per day as agreed. Cutting sugar cane workers receive 60-80 Baht per ton, while throwing workers receive 20-30 Baht per ton. Thus, the average wage of these workers is 80-110 Baht per ton.

The use of tools. Machines facilitate sugar cane harvest. This system was created because there is a shortage of sugar cane cutting workers. There are two types of machines. The first is machine of larger scale which cut and transfers sugar cane into trucks in large quantity at the same time. Te second type of machine cut sugar cane on the ground and transfers to trucks in two steps. Harvest machines in Thailand are identified in the following.

(a) The harvest machine cut sugar cane and arranges it on the ground in order to be transfer to trucks' trunk. This method has not been made popular. Moreover, it is not so successful because farmers need to burn sugar cane before using the harvest machine; therefore, losing sweetness and quality. The Department of Agricultural Engineering has produced a prototype of the harvest machine that follows a farmer. This way, a machine is able to burn and harvest 5-6 tons per hour. An approximate price for such machine is 120,000 Baht and the cost of harvest per ton is 30 Baht.

(b) In some areas that still lack sugar cane cutting workers, farmers use machines to cut and transfer sugar cane to trucks. It is a popular method among provinces in the north of Thailand such as Kamphaengphet province. The method of hiring workers to cut sugar cane and machines to clamp bundles of sugar cane into trucks has wages that is based on the length of sugar cane. The wage is 1.50-2.00 Baht per meter of sugar cane. Therefore, farmers pay 390-520 per Rai to get about 8 ton of sugar cane. This method has advantages in that it is fast. Sugar cane can be send to factories in little time. It uses a small amount of manual workers so it is fit for areas in need of workers. Workers, moreover, receive high wages. The disadvantages are that it is expensive for the farmers to buy clamping machine, which costs around 1 million Baht. Also, farmers need to plant sugar cane in high density. This method becomes

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more and more common. In Thailand, more than 200 clamping machine tractors are used in sugar cane fields.

(c) Another type of machine is one that cuts sugar cane into smaller pieces and transfers into trucks. This type of machine is big in size and is able to cut fresh sugar cane into around 20-25 centimeters-long pieces. It has a fan that blows debris and leaves away to remain clean. It sprays off residue left on the ground and lifts sugar cane into trucks at the same time. Generally, this type of machine is imported from Australia, the United States, and Germany. It is worth around 4-5 million Baht. Today, more than 200 machine tractors have been imported into Thailand.

2.9.2 System of Sugar Cane Transportation

Managing and improving transportation system so that it becomes more efficient is one of the factors that help reduce costs. It is related to the area in which sugar cane is planted and distance from farms to sugar factories. Another major factor in transportation is the amount of workers. It is ideal to keep the amount of workers at its most productive number. This is to prevent having excess cut sugar cane lying around without transporting it to sugar factories. High waiting time decreases sweetness and quality of sugar cane. To transport sugar cane in Thailand, the following vehicles are used.

1) Ten-wheels truck can carry up to 20 tons of sugar cane. This type of vehicle is the most common.

2) Six-wheels truck can carry around 6-10 tons of sugar cane. It is often found used in the Northeast provinces of Thailand.

3) Tractor trailers with another tractor following it can carry 5-6 tons of sugar cane.

4) E-Tan cars can carry 1-4 tons of sugar cane.

Australia has a sugar cane transportation system that uses trains to transport sugar cane. Sugar factories invest in the transportation system along with the conversion of sugar cane to sugar in mills.

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2.9.3 System of Sugar Crushing

According to the Cane and Sugar Act in 1984, sugar cane farmers need to transport sugar cane at sugar factories. Therefore, there must be a way to transport sugar cane as follows.

1) Farmers bring sugar cane packed trucks to sugar factories. There is a staff member that checks documents of delivery, name of farmer, sugar cane species, and location of plantation.

2) When sugar cane farmers report their names and details, sugar factories will report queue for delivery.

3) When sugar factories call for a queue, farmers need to weigh sugar cane at weighing room in order to enter the process of production. After this process, it is considered that farmers have already transferred sugar cane to sugar factories. Farmers will receive documents about weighing details as evidence of delivery.

4) Farmers' sugar cane will have a tag number. When the carton is stored for sugar cane juice analysis for sweetness, this measurement is used along with weight to determine price of sugar cane.

2.10 Concepts and theories about lead time.

Lead Time is the length of time required for a single business. It is the amount of time, from the point of view of customers, is needed for product to be delivered. Typically, the production capacity in a period of time and amount of time for delivery determine lead time. There are several terms about time in logistics. Queuing Time is the length of waiting time before work begins. Setup Time is the period of preparation for the work. Running Time is the duration of work. Waiting Time is the length of waiting time after work ends. Moving Time is the transportation time during work.

In this study, lead time is calculated using the formula below:

$$Lead\ Time = Processing\ Time + Waiting\ Time + Transportation\ Time$$

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When, Processing Time is the amount of time in the process of sugar cane storage. Waiting Time is the amount of time before sugar cane entered the process. And Transportation Time is the amount of time in sugar cane transportation to sugar factory and back to farms.

2.11 Concepts and theories about transportation.

2.11.1 General aspects of transportation.

Transportation as defined by Jakkrit Duangpustra (2000) is the movement of people, animal, and things with energy saving devices from one location to another. This also includes the loading, unloading, moving people, and moving products from one place to another. Concepts such as place utility and time utility arise from the system of transportation.

In addition, Sunil Chopra (2003) provides the definition of transportation as the movement of goods from one location to another in order to create a route from starting point of supply chain to ending point at the consumers, who has an important role in all supply chains. Consumers are the major source of income in the supply chain. The Thai law, as specified by the fourth Act of Land Transport Act in 1979, states that “transportation is the transport of people, animals, or things by land with an automobile”. Therefore, freight transportation is a type of transportation that moves goods from one location to another which causes the utility of time. This adds value to products.

Chatterjee, Staley and Sullivan (1989) divided the form of land transportation by starting location and ending location in four different types:

1. Transportation within the city (Internal – Internal: I:I) is when the point of origin and destination is in urban areas. The form of this type of transportation demonstrates the economic characteristics of the area. The observation is made from the type of vehicle used to transport goods, location of transportation, and variety of products.

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2. Shipping outside the city (External – External: E:E) is when the point of origin and destination is not in urban areas.

3. Shipping between the city and rural areas (Internal-External: I:E, External – Internal : E:I) is also known as the transportation between cities and regions which have either starting point or destination in the city area. This form of transportation uses large trucks to carry sugar cane in order to reduce costs of long distance travel. This type of transportation has a capability to transfer greater amounts of goods in one load.

4. The transportation through the city area as known as through movement has neither starting point nor destination in the city. However, the route travels through the city in this type of transportation. This system has no relation to the economy of the region, but it has an effect on safety and environment. It can be solved by changing the shipping route and avoiding the city area.

The Department of Highways set a maximum weight for each type of vehicle. This is an important factor that affects cost and road transport because it is a factor that controls the amount of goods carried on each flight. The government has to be adjusted to suit the evolution of transportation and the economic growth in the past. The law limits that trucks are able to carry 16 tons of goods. This law is later amended and changed to 21 tons in the beginning of 1975. The law is significant because it increased the truckload of ten-wheelers to 26 tons. It lasts until December 31, 2005. On January 13, 2006, the Ministry of Transportation issued a notification No. 8/2549 that declared truck load permanently. This rule is effective since January 13, 2006. The weight allowed on trucks and other vehicles to run on highways are as follows:

1. four-wheels automobile with two axles weighing 9.5 tons
2. six-wheels automobile with four axles weighing 15 tons
3. ten-wheels automobile with three axles weighing 25 tons
4. twelve-wheels automobile with four axles weighing 30 tons
5. eighteen-wheels trucks, semi-trailers, with 5 axles weighing 45 tons
6. twenty-two-wheels trucks, semi-trailer, with 6 axles weighing 50.5 tons
7. eighteen-wheels trailers with 5 axles weighing 47 tons
8. twenty-two-wheels trailers with 6 axles weighting 53 tons (declared as a special case for a period of one year).

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Patchanop Tonpichai (2544) discussed on the overview of freight transportation by truck and divided it into four different types based on the characteristics of the route and distance.

1. Long-distance transportation is for example, the transfer of goods to rural areas. In this case, it might be product transfer to small shops directly or to distribution centers that will later deliver to shops. Truckload is fixed on the main road. The average running speed is high because trucks drive on main roads.

2. Short-distance transportation is usually the type of transportation between shops. Since distribution center is set in the suburban areas, closer to the small shops, the majority of time is spend in the shops because it takes time to unload the products.

3. Transit transportation typically is a type of long-distance transportation that has many stops on the way. Trucks stop to deliver goods or load new products from distribution centers before reaching the final destination.

4. Transportation through more than one province in one round is the case in which there are not enough products for one province to fill one truckload. Therefore, managers organize two different orders in two different provinces to fill the truck with goods.

2.11.2 Land transportation routes.

Land transportation uses the highway to transfer goods as the main route in transportation within the country. The system of transportation using highway is divided into 6 types according to the Highway Act of 1992.

1. Special highway route, or motorway, is designed espeically for fast traffic. The government announced the opening of motorway and the Ministry of Highways build and maintain the motorway.

2. Ground highways or the main highways that connect different regions, provinces, countrys, and many significant locations.

3. Concession Highway is a highway in which the government has given legal concession to a private concessionaire.

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4. Highway public corporations is the highway in the municipality. Government officer working in the municipality district will operate to build and maintain the highway in their areas.

5. Sanitation Highway is the highway in which located in the sanitation areas and government officers working at sanitation will operate to build and maintain the highways in their district.

6. Rural highways or highways outside of municipality and sanitation is build and maintain by Provincial Public Works Department or the Office of Accelerated Rural Development.

The main highway route that is used in the land transportation system in Thailand is ground highway. It is the one that connects many provinces. It can be divided into four types as follows:

1. The main National Highway has total distance of 7,340 kilometers. There are four main National Highways that connect different provinces these are "Ground highway number 1" (Pahonyothin Road: Bangkok – Chiangrai), "Ground highway number 2" (Mitraphap Road: Saraburi – Hnongkai), "Ground highway number 3" (Sukhumwit Road" Bangkok – Tlad) and "Ground highway number 4" (Phetkaseam Road: Bangkok –.Sadao and Songkla).

2. Secondary ground highway has a total distance of 11.368 kilometers.

3. Province route of ground highway has a total distance of 32,900 kilometers.

4. Special highways, or motorways, between cities has a total distance of around 303 kilometers.

In the present, 88 percent of all goods transportation within Thailand occurs on land. Most of the goods are raw materials for different industries in Thailand, especially construction industry and agricultural industry. Sugar cane is one of the most common goods that is transported throughout the country of Thailand using land transportation. Busy months for sugar cane transportion lasts from the beginning of December to the end of April. Main highways are used in sugar cane transportation. This is significant because sugar factories are located ajacent to main highway roads. Therefore, it is easier and more convenient to transport sugar cane to sugar factories. Another major raw material that is often transported is rice.

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Nevertheless, the most common routes includes main highways and important roads toward the sea. Important routes such as Lamchabang port are often used. If we analyze traffic jams based on density capacity of a road, the main highway that connects Bangkok to Northern, Northeastern, and Southern regions of Thailand are dense. Moreover, routes that is used to enter and exit ports in Bangkok and ports in the Chonburi and Rayong provinces also experiences traffic jams. Lamchabang port, Siracha harbor, and Mabtaput port are considered as conjested routes. These are important routes in sugar cane transportation. Farmers usually transport sugar cane during the beginning of December through the end of April.

2.12 Equations and mathematical modeling of transportation system.

In the study of the form and system of transportation along with logistics system, it is difficult to analyze and make a decision about problems because the systems are very complicated. Generally, we need to know the best possible and appropriate result in order to hope for highest productivity, high profit, low initial costs, and low management costs. There are two forms of decision making in business and logistics. First is the problems of decision making in order to use in work process and hope for best result in terms of quality and costs. And the second is the problems of decision making techniques in order to use in the process of palnning and testing management proposals of the company.

2.12.1 Theories about the problems of bus line.

Kluawan Jampayern (2004) studies ”the improvement of decision making support system in managing and organizing transportation routes.” The study analyzes product shipment date, the most appropriate route of transportation, and the representation of the plan of transportation in numerical form to help with decision making. Decision making support system is developed from the process of problem solving or Heuristics. It is divided into two different analysis steps. The first step is the analysis of product shipment date by problem solving process of Heuristics. This is done by taking into account the number of trucks used, the amount of customers, and the amount of time available. The second step is the analysis of the best appropriate

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route of transportation that will be able to deliver goods on time. The comparison of results from step one and step two of the new and improved decision making support system with the original transportation system reveals that the new system works better in the real world. In addition, it is also better in terms of goods delivery and planning. In conclusion, the new decision making support system helps with management of transportation routes. It is effective in managing delivery system and cutting costs of fuels.

Forms of Transportation Route Problems has a basis on the demand of each area and will be serviced with transportation trucks without any limitations. Lowering costs of transportation and using the most effective route will solve the problems of time wasted in delivery and amount of delivery service. These changes will benefit operation research in many ways.

The Traveling Salesman Problem (TSP) is a form of traveling problem of one salesman. One limitation is that the salesman need to travel through all cities and travel back to the original starting point in the shortest distance.

The Chinese Postman Problem (CPP) is a form in which the shortest route is used by running through at least one city connection route. This problem can be solved with a method call Polynomially-Bounded Algorithms

The M-Traveling Salesman Problem (TSP-M) is a form of problem that is developed from the traveling salesman problem. It is a problem of M amount of salesman. This form best represents problems in the real world.

The Single Depot, Multiple Vehicle, Node Routing Problem (Classical Vehicle Routing Problem, VRP) is a form of problem that mentions sets of routes being used by transportation vehicles to deliver goods from one place to different locations. The delivery should have a certainty (Deterministic) of having the least total distance route.

The Multiple Depot, Multiple Vehicle, Node Routing Problem is a problem developed from The Single Depot, Multiple Vehicle, Node Routing Problem (Classical Vehicle Routing Problem, VRP) with stocks of goods in different places.

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The Single, Depot, Multiple Vehicle, Node Routing Problem with Stochastic Demands is a form of problem that is developed from The Single Depot, Multiple Vehicle, Node Routing Problem (Classical Vehicle Routing Problem, VRP).

However, the demand in different areas is unknown (uncertainty) for example, the demand distribution in the form of Poison.

The Capacitated Chinese Postman Problem is a form of problem that is developed from The Chinese Postman Problem (CPP). It has an indirect structure for transportation web.

2.12.2 Theories about the separation of zones or groups.

Clustering is the organization of information into smaller groups. Data in the same cluster group have similar characteristics. Figure 2.7 represents sample of the information clustered into two, four and six groups.

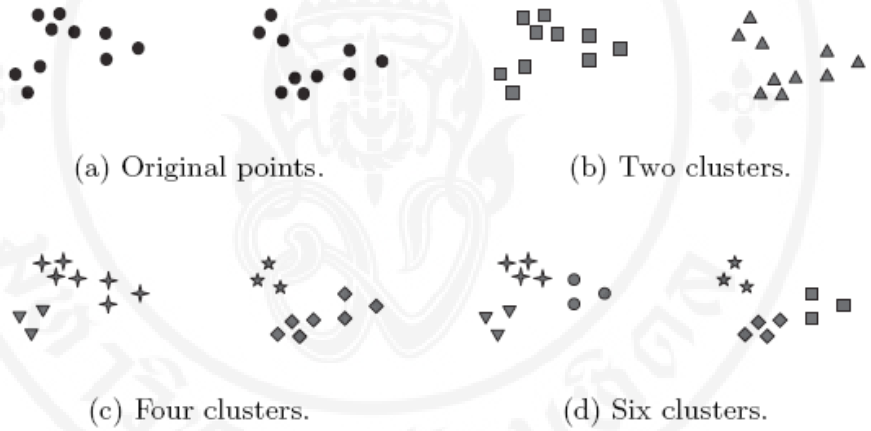

Figure 2.7 Samples of Information Clustering

Clustering is used in statistical and logistical terms. It has the purpose of dividing customers into smaller groups for easy route planning. Routing and clustering are normally used in conjunction to each other. There are two methods as follows:

Cluster First – Route Second is the grouping in which the final delivery destination is considered before the organization of transportation route in that group.

Route First – Cluster Second is the grouping in which the organization of transportation route is considered before the grouping of customers' delivery stations.

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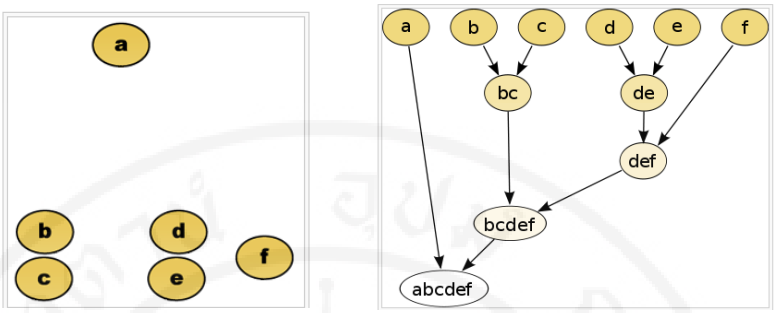
2.12.3 Type of Clustering

Hierarchical is a type of Clustering that organizes step by step based on time, before and after, in order to separate information into different steps. Both top-

down and bottom-up form is possible. Example for Hierarchical Clustering was presented in Figure 2.8.



(a) Before Clustering (b) After Clustering

Figure 2.8 Hierarchical Clustering

Center of Gravity. Analysis with the Center of Gravity is in order to find the center of transportation in each zone. In other words, the purpose is to find the densest area of transportation. To find transportation center location in each zone, enable by calculating from the following formula.

$$X^* = \sqrt{\frac{\sum X_i V_i}{\sum V_i}} \quad \text{and} \quad Y^* = \sqrt{\frac{\sum Y_i V_i}{\sum V_i}}$$

when X^* is the location at the X-axis

Y^* is the location at the Y-axis

x_i is the location of i at the X-axis

y_i is the location of i at the Y-axis

v_i is the amount of goods delivered from location i

Partitioned clustering. Partitioned clustering is separated into two methods, *K-means* clustering and Fuzzy *c*-means clustering

"K-means clustering" is a type of Clustering information with the shortest distance by comparing the distance between centroids of each group and other centroids. Centroid is the average distance from every point in a cluster group. The sample for *"K-means clustering"* is depicted in figure 2.9.

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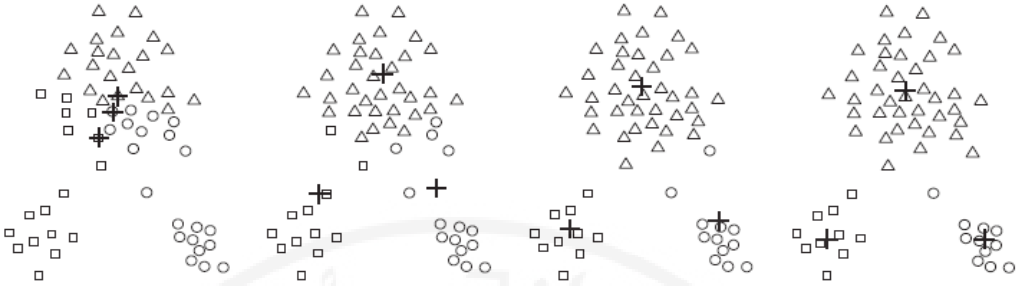

Figure 2.9 k-means clustering procedure

The purpose of K-mean clustering is to find the lowest value of objective function with the equation below:

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^j - c_j \right\|^2$$

When $\left\| x_i^j - c_j \right\|^2$ as a value from the measured distance between the data center and appropriate sharing spot.

"*Fuzzy c-means clustering"* is a type of clustering that member has an importance or that the weight of information is unbalanced. Characteristics of algorithm to find the centroid of this cluster are the same as k-means clustering method.

DBSCAN is a type of clustering by considering the density of information location by the border of each cluster. There are three main section as follows:

- Section with the highest information density (core point).
- Section with sparse density of information (border point).
- Section with density information close to border point, in between border and core point, or could be core point or border point of the next cluster.

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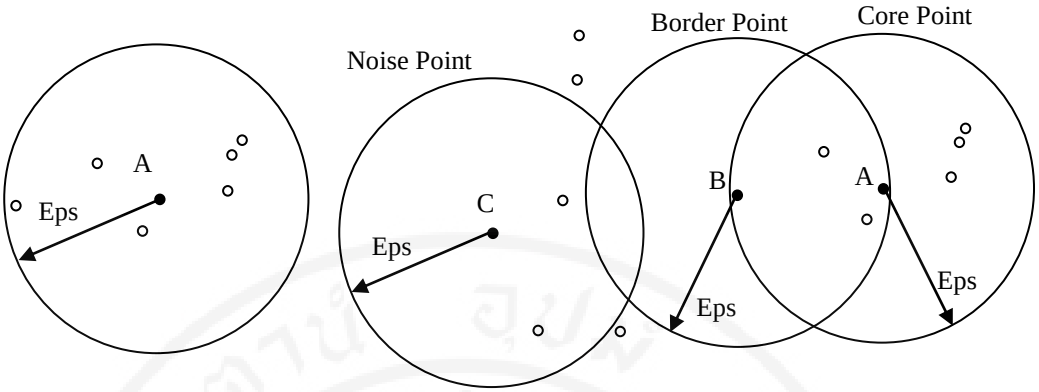

Figure 2.10 DBSCAN clustering method

Overlapping Clustering is a way of grouping customers for delivery and cash collection. Each customer is able to be a member of many cash distribution centers at the same time. Nevertheless, it depends on distance of delivery and frequency of delivery of each customer route. To better understand the concept, overlapping clustering can be demonstrated in the figure 2.11 below.

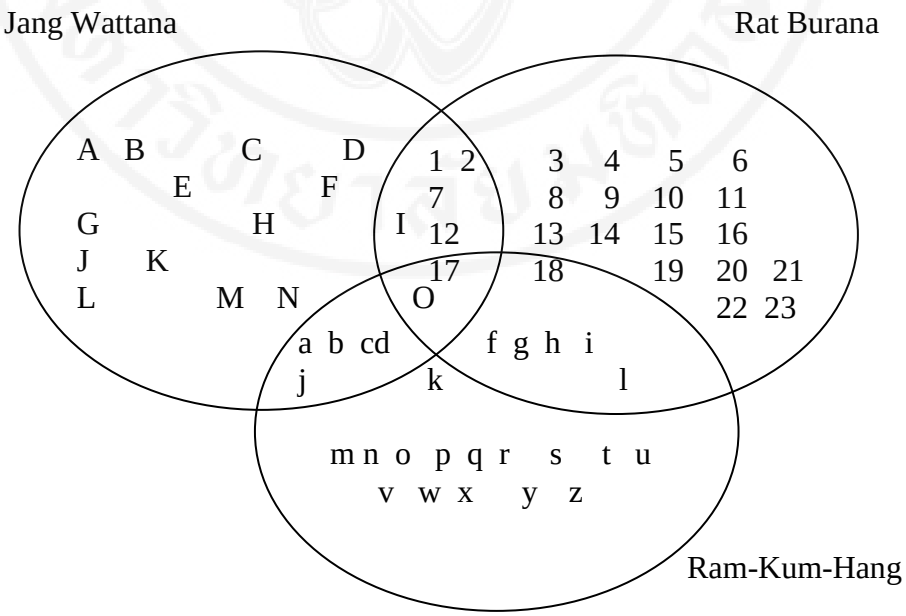

Figure 2.11 Overlapping Clustering for 3,000 ATM stands

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This method can be used to find the highest number of members in each cluster. Moreover, it can find the greatest distance each cluster can be apart with

algorithm that is used to manage clustering. There are two steps for Overlapping Clustering. First step is the organization of similar members in one cluster depends on characteristics such as frequency of cash add, amount of cash used, and amount of time used in each cashing process. Next step is the normalizing distance between locations that need money in between the two places.

$$d_{ij} = \sqrt{(x_i^1 - x_j^1)^2 + (x_i^2 - x_j^2)^2 + ... + (x_i^P - x_j^p)^2}$$

With $x_1, x_2 \ldots . x_n$ as the amount of member of information n. $x_i^1, x_i^2, \ldots .$, x_i^p are the characteristics of member x_i and d_{ij} is the distance between x_i and x_j. If (x_1-x_2) or (x_3-x_4) have value of zero, the distance between two locations is great. If (x_1-x_2) or (x_3-x_4) is one, the two location have the same characteristics in all respects.

Method to Find Answers using Sweep Algorithm Method

The process is similar to the method of Route-First-Cluster-Second. The difference between angles is measured to organize areas. The advantage of Route-First-Cluster-Second is the not complicated. The disadvantage is that it is not appropriate for every problem such as locations being too far apart (Burim and Pongchai, 2007). Analysis is done with the following techniques:

- Count the amount of goods delivered to each customer
- Grouping by combining goods of each customer. It is done by drawing circles of customers from characteristics clockwise or counterclockwise until the amount is not greater than one truckload. If it is greater than one truckload, a new route can be set from distribution center.
- Testing of newly set transportation route
- Check the amount of goods in each day by standardized documents
- Transport and distribute goods according to previously set routes

2.12.4 Capacitate Vehicle Routing problem (CVRP)

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The first generation of studies on transportation is during 1959 by Dantzig and Ramser. There are proposals to solve problems of the transportation of oil from

warehouses to gas stations. The purpose is to reduce costs and increase transportation efficiency with conditions as follow:

- Goods are transported from initial location to destination by one truck.
- The customers' needs shall not exceed carrying capacity of a truck.
- The quantity of goods that need to be delivered needs to meet the demands of customers.
- Transportation trucks depart from the distribution center (Depot) and return after shipment completion.

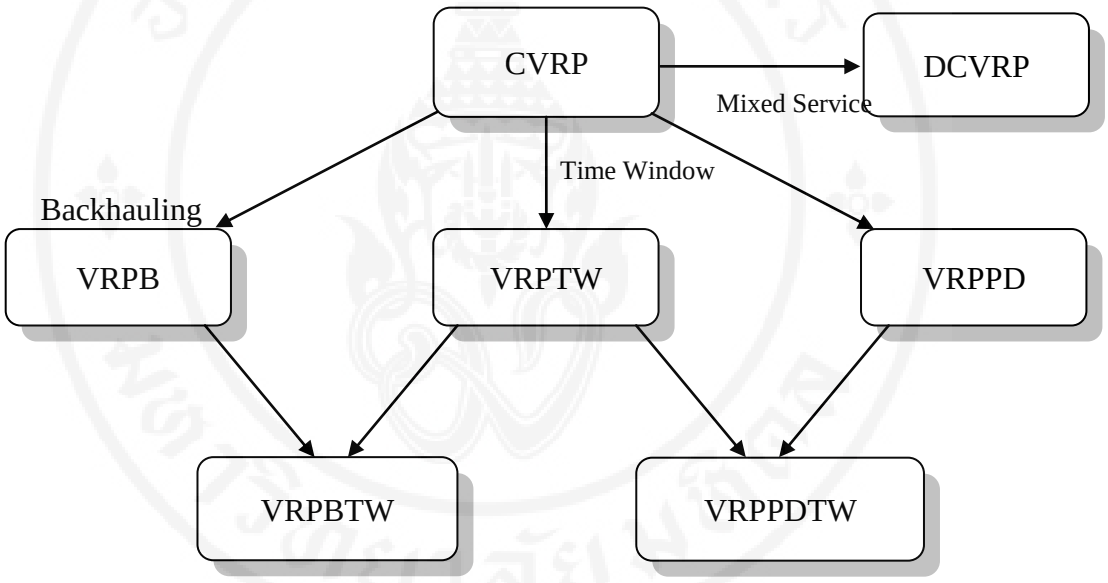

Figure 2.12 Form of basic VRP and related forms of problem-causing VRP

Distance–Constrained Vehicle Routing Problem (DCVRP) is a transportation problem that is similar to the conditions of DVRP. The difference is the addition of transportation time. The purpose is to find the minimum cost and the shortest distance of transportation. Another factor to consider is the least walking distance. The amount of time spent travelling consists of two parts: travel time and service time (such as unloading). The purpose of DCVRP is to find a solution that will result in greatest distance in limited time.

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Vehicle routing Problem with Time Window (VRPTW) is the study of transportation problems that is developed from CVRP. It takes the amount of transportation time into account. That amount of time affects arrival time of goods. If

trucks arrive before allotted time, time will be wasted due to the increase in waiting time. For instance, some service deliver goods before employees start working in the morning. Thus, the transport is not successful because no worker is there is receive goods. In the same way, trucks that deliver beyond working hours at night cannot successfully deliver goods because workers are already out of work for the day. The specification of deliver time is in the born of [ai , bi]. The word "ai" is defined as the fastest amount of time transportation trucks can reach destination. On the other hand, the word "bi" is the slowest amount of time transportations trucks will reach destination. There conditions are as follows:

- Transportation trucks depart the distribution center (Depot) and return after shipment completion
- Each customer will receive goods in only one truck
- The sum of demands shall not exceed carrying capacity of the vehicle.
- Customers must be served within a specified period of time [ai,bi] and delivery vehicles arrive at the time Si.

VRP with Backhauls (VRPB) is the study of transportation problems that is developed from CVRP by dividing customers into two groups. The first group consists of customers who organize product shipment (Linehaul customers) according to the amount the customer wants. The second group consists of customers who want to organize product shipment on the backward way (Backhaul customer). The concept is illustrated in figure 2.13.

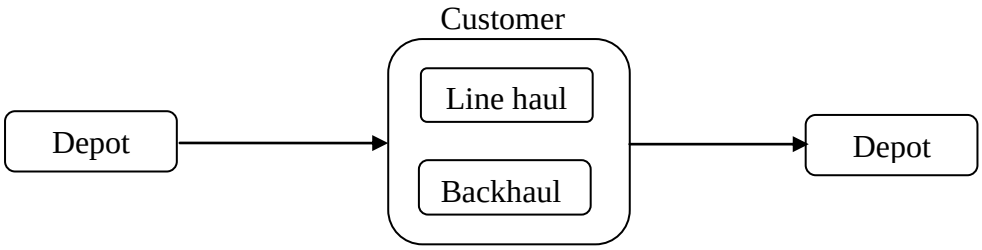

Figure 2.13 Transportation in the form of VRPB with goods from Depot will be send to customers (Linehaul) first and receive products (Backhaul) back to Depot.

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Terms for the VRPB form are the conditions between two types of transportation, Linehaul and Backhaul. The two types are forms of customer service that ship goods from distribution center to the customer first, then receive goods from

customers back to the distribution center. The demands from Linehaul customers or Backhaul customers have a value equal to di. Conditions for VRPB form of transportation are as follows:

- Transportation trucks depart the distribution center (Depot) and return after shipment completion
- Each customer will receive goods in only one truck
- The sum of demands of Linehaul and Backhaul customers shall not exceed the carrying capacity of the vehicle.
- Transportation in the form of Linehaul before Backhaul

In addition, VRPB is finding the minimum amount of cars (K) in order to response to transportation form of VRPB. K_L and K_B represent Linehaul and Backhaul forms of transportation, respectively. The value of K that will be used to limit the amount of car cannot be less than the minimum amount of cars that can be used in service. In other words, $K \geq \max (K_L , K_B)$.

TSP with Backhaul (TSPB) is another case of VRPB model that consists of one truck (K=1) with the condition that the customers' highest demands shall not exceed the carrying capacity of the vehicle ($C \geq \max (d (L), d (B))$). With the condition of delivery within a specified time, the transportation in the form of VRPB is called VRPB with Time Window (VRPBTW).

VRP with Pickup and Delivery (VRPPD) is the study of transportation service in the form of Mix Service as shown in figure 2.14.

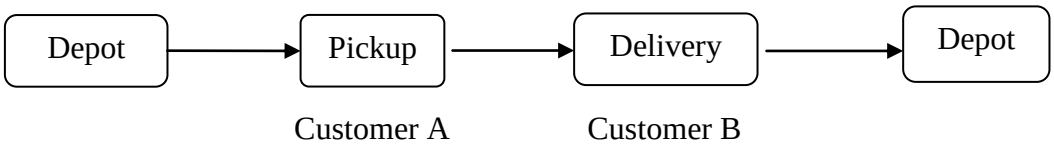

Figure 2.14 Transportation in the form of VRPPD

Transportation begins with departure from Depot in order to transport goods received from customer A to customer B. Then, trucks are to return to Depot. The transportation problem VRPPD has the purpose of finding the number of trucks needed to carry lowest weight in tons. VRPPD conditions are as follows:

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- All vehicles have starting point at the Depot
- Customers are serviced with only one truck
- Transportation trucks need to first receive products from customer A. Then, deliver those goods to customer B. The amount of goods shall not exceed carrying capacity of the vehicle.

With the limitation of specified time of goods' arrival and goods' shipment, the problem is called VRP with Pickup and Delivery and Time Windows (VRPPDTW).

2.12.5 Mathematical formula for solving transportation problems

Mathematical formula for solving transportation problem has the form as follows:

With V as set of node

$\{0\}$ as distribution center (cash)

c_{ij} as cost of transportation from node i to node j

$V \setminus \{0\}$ as set of Node without distribution center (cash)

S as set of routes (arc)

k as members of the amount of automobiles K

K as total amount of automobiles used in transportation

x_{ij} as automobiles that run from node i to node j

x_{ijk} as automobile k that runs from node i to node j

a_i as the fastest time transportation automobile can reach destination

b_i as the slowest time transportation automobile can reach destination

Mathematical basic form in the management of transportation (VRP)

Min $$\sum_{i \varepsilon V} \sum_{j \varepsilon V} c_{ij} x_{ij} \quad (1.1)$$

Subject to $$\sum_{i \varepsilon V} x_{ij} = 1 \qquad \forall j \in V \setminus \{0\}, \quad (1.2)$$

$$\sum_{j \varepsilon V} x_{ij} = 1 \qquad \forall i \in V \setminus \{0\}, \quad (1.3)$$

$$\sum_{i \varepsilon V} x_{i0} = K, \quad (1.4)$$

$$\sum_{j \varepsilon V} x_{0j} = K, \quad (1.5)$$

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$$\sum_{i \notin S} \sum_{j \varepsilon S} x_{ij} \geq r(S) \qquad \forall S \subseteq V \backslash \{0\}, S \neq \varnothing, \tag{1.6}$$

$$x_{ij} \in \{0,1\} \qquad \forall i, j \in V. \tag{1.7}$$

From above, c_{ij} is the cost of transportation. The main objective of Equation (1.1) is to find the lowest cost in the transport. Equation (1.2) and (1.3) is under the condition that only one truck can travel the route from one point to another point. Equation (1.4) and (1.5) is the condition of the amount of vehicles that enter and exit from starting point has to be equal to K. Equation (1.6) is the condition that the amount of vehicles used cannot be less than transportation demand for delivery. Equation (1.7) is the condition that variables that must be answered are integers.

Mathematical basic farm in the management of transportation (VRPTW)

Min $$\sum_{k \in K} \sum_{(i,j) \in A} c_{ij} x_{ijk} \tag{2.1}$$

Subject to $$\sum_{k \in K} \sum_{j \in \Delta^+(i)} x_{ijk} = 1 \qquad \forall i \in N, \tag{2.2}$$

$$\sum_{j \in \Delta^+(0)} x_{0jk} = 1 \qquad \forall k \in K, \tag{2.3}$$

$$\sum_{j \in \Delta^-(j)} x_{ijk} - \sum_{j \in \Delta^+(j)} x_{ijk} = 0 \qquad \forall k \in K, j \in N, \tag{2.4}$$

$$\sum_{j \in \Delta^-(n+1)} x_{i,n+1,k} = 1 \qquad \forall k \in K, \tag{2.5}$$

$$x_{ijk}(w_{ik} + s_i + t_{ij} + w_{jk}) \leq 0 \qquad \forall k \in K, (i,j) \in A, \tag{2.6}$$

$$a_i \sum_{j \in \Delta^+(i)} x_{ijk} \leq w_{ik} \leq b_i \sum_{j \in \Delta^+(i)} x_{ijk} \quad \forall k \in K, i \in N, \tag{2.7}$$

$$E \leq w_{ik} \leq L \qquad \forall k \in K, i \in \{0, n+1\}, \tag{2.8}$$

$$\sum_{i=N} di \sum_{j \in \Delta^+(i)} x_{ijk} \leq C \qquad \forall k \in K, \tag{2.9}$$

$$x_{ijk} \geq 0 \qquad \forall k \in K, (i,j) \in A, \tag{2.10}$$

$$x_{ijk} \in \{0,1\} \qquad \forall k \in K, (i,j) \in A. \tag{2.11}$$

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Equation (2.2) is the condition that limits one truck to one route. Equation (2.3)-(2.5) represents transportation for trucks amount k. Equation (2.6)-(2.9) shows that the management of delivery schedule need to fit within the specified time window and the amount of goods cannot exceed the carrying capacity of the vehicle.

Mathematical basic farm in the management of transportation (VRPPD)

Min $\sum_{k\in K}\sum_{(i,j)\in A_k} c_{ijk}x_{ijk}$ (3.1)

Subject to $\sum_{k\in K}\sum_{j\in N_k\cup\{d(k)\}} x_{ijk}=1 \quad \forall i\in P$ (3.2)

$\sum_{j\in N_k} x_{ijk}-\sum_{j\in N_k} x_{j,n+i,k}=0 \quad \forall k\in K, i\in P_k,$ (3.3)

$\sum_{j\in P_k\cup\{d(k)\}} x_{0(k),j,k}=1 \quad \forall k\in K\ ,$ (3.4)

$\sum_{i\in N_k\cup\{o(k)\}} x_{ijk}-\sum_{i\in N_k\cup\{o(k)\}} x_{j,i,k}=0 \ \forall k\in K, j\in N_k,$ (3.5)

$\sum_{i\in D_k\cup\{o(k)\}} x_{i,d(k),k}=1 \quad \forall k\in K,$ (3.6)

$x_{ijk}(T_{ik}+s_i+t_{ijk}-T_{jk})\le 0 \quad \forall k\in K,(i,j)\in A_k,$ (3.7)

$a_i\le T_{ik}\le b_i \quad \forall k\in K, i\in V_k,$ (3.8)

$T_{ik}+t_{i,n+i,k}\le T_{n+i,k} \quad \forall k\in K, i\in P_k,$ (3.9)

$x_{ijk}(L_{ik}+\ell_j-L_{jk})=0 \quad \forall k\in K,(i,j)\in A_k,$ (3.10)

$\ell_i\le L_{ik}\le C_k \quad \forall k\in K, i\in P_k,$ (3.11)

$0\le L_{n+i,k}\le C_k-\ell_i \quad \forall k\in K, n+i\in D_k,$ (3.12)

$L_{0(k),k}=0 \quad \forall k\in K,$ (3.13)

$x_{ijk}\ge 0 \quad \forall k\in K,(i,j)\in A_k,$ (3.14)

x_{ijk} binary $\quad \forall k\in K,(i,j)\in A_k.$ (3.15)

Equation (3.2)-(3..3) reflects the delivery demand that only requires one truck. Equation (3.4)-(3.6) represents the condition of transportation truck leaving from distribution center o(k) to customer d(k). Equation (3.7) illustrates the

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relationship between the needs of customers and time schedules. Equation (3.8) shows the condition of time window. Equation (3.9) demonstrates the condition that trucks need to receive goods before delivering to another point. Equation (3.10) shows the condition of the ability to unload the truck. Equation (3.11)-(3.12) represents the ability of each truck to pick up and deliver at each point. Equation (3.13) reflects the condition of the truck when it starts.

Mathematical basic farm in the management of transportation (VRPB)

$$\text{Min} \quad \sum_{(i,j)\in\bar{A}} c_{ij}x_{ij} \tag{4.1}$$

$$\text{Subject to} \quad \sum_{i\in\Delta_j^-} x_{ij} = 1 \qquad \forall j \in \bar{V} \setminus \{0\}, \tag{4.2}$$

$$\sum_{j\in\Delta_i^+} x_{ij} = 1 \qquad \forall i \in \bar{V} \setminus \{0\}, \tag{4.3}$$

$$\sum_{i\in\Delta_0^-} x_{i0} = K, \tag{4.4}$$

$$\sum_{j\in\Delta_0^+} x_{0j} = K, \tag{4.5}$$

$$\sum_{j\in S}\sum_{i\in\Delta_j^-\setminus S} x_{ij} \geq r(S) \;\; \forall S \in F, \tag{4.6}$$

$$\sum_{i\in S}\sum_{j\in\Delta_i^+\setminus S} x_{ij} \geq r(S) \qquad \forall S \in F, \tag{4.7}$$

$$x_{ij} \in \{0,1\} \qquad \forall (i,j) \in \bar{A}. \tag{4.8}$$

Equation (4.2)-(4.5) shows terms of transportation between starting point and ending point. Equation (4.6)-(4.7) reflects the amount of entrance and exit of transportation from initial point to customers.

1. The search will end when the solution received is only 5% or 10% from the best solution. From using this method, we can set Branch-and-bound method to stop work. The solution is guaranteed to be within 5% difference from the best solution.

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2. Beam search technique is somewhat useful when memory is limited. This method is possible by setting the upper limit in the amount of Node to be

analyzed in memory unit of a computer such as 1000 Node. If the amount of Node is equal to 1000 Node, we can order the computer to prioritize Node according to the lower limit. The method of Branch-and-bound considers only 1000 Node that has the best lower limit. This act helps in greatly reducing the computer's memory unit used. However, a consequence from this act is that we cannot prove that the solution is the best because the Node not considered has the possibility of being the Node of the best result.

2.13 Related research.

The study program to relate logistics and the sugar industry was conducted by Khonkean University under the administrators of sugar cane and refined sugar committee. In the year 2006, the process of sugar transportation from processes of production, storage in the factory's warehouse, and delivery outside (to public or factory's warehouses). The purpose of storage as stock is for delivery to customers.

Public storage warehouse mean private warehouse that has been approved by product management center, selling center, and refined sugar's transportation. According to sugar cane and refined sugar Act in 1984, warehouses that belongs to sugar companies are not only to serve a company's own circle of factories, but are also for other sugar factories. Generally, product warehouses store raw sugar in order to prepare to shipment. Public storage warehouses are divided into two types. The first type is when head office is in charge of arranging transportation for every factory in the company group. It is called the Combined Management Center method. Results show that 55 or 35 percent of factories out of 46 use this method. Another method is when head office negotiate price and select loading helpers. The head office also control and manage the process follow the company's proposal. Sugar factories are in charge of informing the head office of the amount of shipment and trucks needed per day. It is a way to distribute power throughout the company and sugar factories under that company. The process of searching for loading helpers and drivers requires the negotiation between truck Transportation Company and Sugar Company. Big sugar factories use the method of biting while medium and small size factories usually use the same truck transportation company because they made an agreement with that

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single company. Moreover, sugar factories are more likely to trust one truck transportation company to complete a job.

There are big and small transportation companies that serve in loading and transporting sugar from sugar factories. Big transportation companies might have trailers, tanks, or semi-trailers for transportation. Small transportation companies, however, might have transportation trucks. Sometimes they can contact other transportation companies in Thailand to serve sugar factories in Thailand. Group of sugar companies might use representative domestic transportation company. This might greatly reduce initial transportation costs if transportation company effectively. This is because the distributions of goods make goods always available. It is the matching between different types of goods.

The shipment of goods in the transportation process is grouped according to the type of customers into two cases. The first case is delivery in the country such as big groups of businessmen, contemporary group of stores, and industrial group of customers. In 2005/2006, most of the sugar from factories and warehouses are delivered to industrial group of customers (49 percent of all deliveries). The second most common group of delivery is to big groups of businessmen (44 percent of all deliveries). Another 7 percent of deliveries are to contemporary group of stores.

The total export of sugar to foreign countries in 2005/2006 is 3.02 million ton in weight. There are two methods of delivery. (1) Delivery by using big ships. This method is the shipment of large amounts of sugar at the same time. One round of shipment can deliver thousands of tons. (2) Delivery by packing sugar into containers.

Information from Product Management Center, Selling Center, and Sugar Transportation Center shows that in 2006, there are 19 checkpoints scattered throughout the region for the export of white sugar contained in sacks. The percentage of all border exports to neighboring countries are as follows: 75 percent of all border exports of sugar takes place at Khlong Yai checkpoint, Trat province. The next most common checkpoint used is 10 percent of all border exports at Mukdahan checkpoint. Other popular checkpoints are Tah Pae in Nong Khai province and Aranprathet deep canal with 6 and 4 percent of the exports, respectively. The rest of sugar exports at other checkpoints combined make up around 5 percent.

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In 2006, phase two of the logistics cost reduction programs supported by the sugar cane industry analyzed the logistics of initial cost in the crushing season of 2007/2008 in order to study ways to reduce initial costs for sugar cane factories. Results show that distance between sugar cane farms and sugar factories determine the type of vehicle needed to transport goods. If the distance is less than 5 kilometers, it is fit to use smaller cars in the transportation of sugar cane. Distance of between 5 and 30 kilometers is fit to use six-wheel or ten-wheel trucks. Distance of between 31 to 60 kilometers is fit to use ten-wheel trucks or semi-trailers. For distance of over 60 kilometers, it is recommended to use trailers. There are two appropriate methods for the logistics of sugar cane delivery to sugar factories. (1) Farmers cooperate in the area to transport using small and medium agricultural trucks that fit with the distance between farms and factories. There is also another option of delivering sugar cane to sugar cane buying center in the area within 25 kilometers from the farms. E-tan cars can be used to delivery if the distance does not exceed 1-5 kilometers. Six-wheel trucks can be used if delivery does not exceed 20 kilometers. (2) The collaboration of farmers to use transportation outside of the area. It is the grouping big and small farms with farther away from sugar factories. The distance between the farms and factories is more than 25 kilometers. Therefore, medium and large trucks are fit for this job. If the distance does not exceed 20 kilometers, six-wheel trucks can be used. However, if the distance is more than 50 kilometers, trailers and ten-wheel trucks are used (p.175-176).

2.13.1 Research about the harvest and transport of sugar cane.

Nittaya Surinan (2522) studies the transportation of sugar cane from plantation to sugar factories in the Southern region of Thailand. The purpose is to study methods and processes of transportation in detail. The study includes the analysis of the process, profit, and costs. This study uses both informative and mathematical reasoning to calculate starting cost of transportation. Most of the information and data are from interviews and surveys of sugar cane farmers, head quota of sugar factories, and transportation truck drivers conducted between December 1976 and November 1977. The conclusion is that the costs of transportation of sugar cane to sugar factories are divided into two types: constant (including semi-variable cost) and variable cost.

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Semi-variable cost is variable cost that does not change according to amount of goods needed to be delivered. This type of cost is different from constant cost in that if there is no shipment, this cost is equal to zero. It includes costs of tires, truck drivers, and truck driver assistants.

Variable cost is the cost that changes according to amount delivered. In a case of transportation value is zero; variable cost depends on the number of rounds and distance of transportation. It includes factors such as gas, fuel, lubricant, repair, and maintenance. Moreover, other variable costs include toll charges, taxable expenses, compensation management or other miscellaneous expenses. Transportation expenses are for example, compensation for workers' services and food for drivers. These expenses are not present in every occasion so it is considered as variable costs.

The method of sugar cane delivery has a condition resulted from the sugar cane marketing. Sugar cane is sold through an intermediate or head of quota who is the one who made an agreement with sugar factories. These individuals are the ones who have the permission to transport sugar cane to sugar mills. Farmers of small sugar cane plantations do not grow enough sugar cane to directly sell sugar cane to factories. Therefore, they sell through these head of quotas. Farmers not only need to pay for the contract, but they also need to pay the head of quota for managing the sugar cane transportation process.

The study found that using large trucks to transport sugar cane is a proper way to deliver goods. However, there are still problems of wasting time and slow delivery. Moreover, large trucks are useless during non-sugar cane season. The cost of sugar cane transportation is high compared to the transportation of other products. The transportation of sugar cane contributes to the head quota's main source of income. In addition to the money received according to the number of ton of sugar cane based on the contract, the rise of amount of sugar cane because of the expansion of sugar cane plantation due to increased demands cause higher demands for sugar cane delivery. The increase in demand results in the increase in price of transportation. The increase in rate of sugar cane transportation was not added to the price index for transport. So, the revenue from the transportation of sugar cane yields exaggerated amount of profit for the carrier.

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Results from the study concluded that the transportation method of sugar cane in the present should be able to change some aspects of the process, such as reducing the minimum quota. This will create opportunities for farmers of smaller plantations to directly communicate with sugar factories without contacting an intermediate. Therefore, the queues at the sugar mill will be reduced. If the factory manages to unload sugar cane as soon as delivery truck arrives to weigh sugar cane, it will increase efficiency of the process and improve sugar cane quality. Moreover, it is a way to reduce the amount of trucks used. If a truck is able to deliver goods in less amount of time, those trucks are able to complete more deliveries per day. The transportation cost might slightly decrease, which will result in lower marketing costs for sugar factories. However, there is yet to be a solution for the current process of sugar cane transportation. This is because the prices of sugar cane delivered to sugar mills are set by the government. Sugar factories are unable to buy sugar cane at a cheaper price than previously agreed. Therefore, there is no incentive for the sugar factories to change the terms and conditions to another method of sugar cane transportation. The study of sugar cane transportation analyzed in terms of the private companies as the focus. There should be additional studies based on the social costs so that we understand the transportation process in detail.

2.13.2 The future of Thailand's sugar industry.

Thailand Development Research institute (1993) studied the Thai sugar cane and sugar industry with the objective to study the changing trends and factors that caused changes in the sugar cane and sugar industry. The production of sugar cane includes the production cost of harvesting and transporting sugar cane. By studying the changing trends in the sharing of benefits from the production in 1983/1984 onwards and predict future changes until production year of 2001/2002, researchers concluded that there is an increase in cutting and loading workers' wages. The increase has yet to taken into account the search for workers, transportation of workers, workers' housing, electric bills, water bills, health insurance, and celebration in different special occasions. Researchers also found that the use of machines to cut and load sugar cane onto trucks results in lower amounts of sugar cane delivered in

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each round as compared to that of labor. This causes higher costs of transportation per ton of sugar cane.

Day by day the lacking of the cutting sugar cane labor problem has been increasing. It was found that the large-scale sugar cane farmers are likely to use new technology of agricultural equipments to handle in the cutting and harvesting the sugar cane process in the future. The reason behind is that finding and controlling the number of labors are far beyond of the control as needed. Besides, the replacing of new technology of agricultural equipments is cheaper than the cost of the labors. The equipments work faster and can be used as needed matching to the crashing season. Those farmers who disagree with the idea of replacing the harvest labors with the equipment have the explained that the new technological equipments are too expensive to purchase, do not have enough money to buy. Other reasons are that the expenses of using the machines will be higher than using labors. Land is not appropriate to use the machines. Some farmers said that don't know there is a machine to cut sugar cane. Some said that they don't know the pros and cons of the machine and some thinks that the sugar cane varieties are not appropriate to use such machines.

2.13.3 Survey the cost of sugar cane production.

Wariya Akkarapan (2541) surveyed the sugar production cost in 1993/1997 with the aim to determine the cost of production in the country to use as a baseline data in pricing as well as the policies and guidelines for the development of the country's sugar cane production. Information from data gathering Information is gathered from many plantations across the country of Thailand. Data are from a total of 43 provinces, 11 provinces in Northern region, 12 provinces in Central region, 15 provinces from Northeastern region, and 5 provinces from Eastern region. The survey was conducted in 1997 from farmers who registered as sugar cane farmers. There are a total of 1,500 households of farmers. The three sizes of plantations are 1-59 Rai, 60-199 Rai, and more than 200 Rai.

A survey of the production cost of sugar cane in 1996/1997. The average cost of production is equal to 4,299.30 Baht per Rai. The Eastern region has the lowest production cost of 3,694.30 Baht per Rai. The Northeastern region has an average production cost of 3,985.42 Baht per Rai. The Northern region has an average

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production cost of 4,077.36 Baht per Rai. Lastly, the Central region has an average production cost of 4,632.83 Baht per Rai. When calculated as production cost per ton of sugar cane, Thailand has an average production cost of 439.87 Baht per ton. Average production costs of Northern and Northeastern are 474.11 and 484.04 Baht per ton, respectively. The highest average production costs is in the Central region of Thailand, where it is as high 501.39 Baht per ton.

When considering the cost of transportation, researchers found that both the total transportation cost per ton is 103.39 Baht. The average transportation cost all over Thailand is 587.25 Baht/ton. Northeastern region has lowest average investment cost of 550.00 Baht/ton when include transportation cost of 110.33 Bath/ton. Northern region has a higher average investment cost of 572.95 Baht/ton when include transportation cost of 98.43 Baht/ton. Eastern region has average investment cost of 597.95 Baht/ton when include transportation cost of 113.91 Baht/ton. The region with the highest average cost is Central region; the average investment cost is 602.33 Baht/ton after include transportation cost of 100.94 Baht/ton.

After analyzing average investment cost, costs can be separated into constant and variable investment costs. The average variable investment cost per Rai is 4,038.84 Baht, or 94%. The average constant investment cost is 260.45 Baht per Rai, or 6%. By observing activities that cause variable costs, researchers found that cost of labor in developing land and harvest including loading onto trucks is 1,787.48 Baht. Moreover, the cost of material is 1,227.40 per Rai. Other miscellaneous costs amount to 1,023.97 per Rai. In percentage, the costs are 44.26, 30.39, and 25.39 percent of total variable costs, respectively. In terms of wages, 55% is for harvest and loading workers and 45% is for planting workers. From material costs, 36% is the cost of sugar cane species, 18% is the cost of pesticides and weed removal, 14% is the cost of water, 3% is the cost of agricultural tools, 2% is the cost of gas/fuel, and 1% is the cost of oil and lubricant.

Wuttipong Arjchariyaartong (2006) studies the production of sugar cane in the process of analyzing the profitability of sugar cane production. The study of the profitability was made in comparison with other 4 crops which are rice, pineapple, cassava, and maize. The study summarized that the cost of sugar cane production is slightly different between regions where farm located in central area has higher

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production cost of 4,245 Bath per Rai while farm in Northeastern area has lower production cost of 4,130 Bath per Rai. The calculation of sugar cane production is showed in table 2.1. However, in actual calculation of the study, the calculation was done leaving some cost factors and grouped the production cost into 2 categories; Cash cost and Non-Cash cost. The study also survey and analyze break-even of sugar production in 3 regions of Thailand to summarize the policy suggestion and area for improvement along sugar production supply chain.

Table 2.1 Sugar Cane's Production Cost Calculation

Item			Calculation
Total Revenue	=		Sugarcane yield x Sugarcane Price
Total Variable Costs	=	+	Seed
		+	Fertilizer
		+	Plant Protection
		+	Variable Machinery Costs
		+	Contractor (Land Preparation, Planting, Harvest, Loading and Transportation Costs)
		+	Labour (Permanent and seasonal labour)
		+	Irrigation (Energy, Maintenance/repairs and fees)
		+	Insurance (Tractors and Trucks)
		+	Fees (Growers Associations)
		+	Loading and Transport Costs
		+	Other Costs
		+	Interest (Circulation Capital)
Total Fixed Costs	=	+	Depreciation (Machinery and Buildings)
		+	Land rent
		+	Taxes (Land, Trucks, Tractors and others)
		+	Insurances (Tractors, trucks and social insurances for labour)
		+	Other farm overheads)
		+	Interest (Fixed assets)
Total costs	=	+	Total Variable Costs
		+	Total Fixed Costs
Opportunity Costs	=	+	Calculated labour costs (Farm own labour)
		+	Calculated land rent (Farm own land)
		+	Calculated interest (Farm own capital)
Economic costs	=	+	Total cost
		+	Opportunity costs

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Table 2.1 Sugar Cane's Production Cost Calculation (cont.)

Item			Calculation
Gross Margin	=	+	Total revenue
		-	Total variable costs
Accounting Profit	=	+	Gross Margin
		-	Total Fixed Costs
Economic Profit	=	+	Accounting Profit
		-	Opportunity costs

Source: Nott, Betz and Schwab (2006)

2.13.4 Explore the cost of sugar cane production.

Kritha Julanon (2006) studies ways to increase income in rounds of empty trucks from Transportation Company of Thailand. The objective is to improve transportation service to its utmost capabilities. Moreover, it will increase profit for the transportation industry in every round of delivery. Other than increasing profit, the objective is to reduce problems of excess usage of fuel and energy in each round of empty running trucks. The focus is on the improvement of structure of proper usage of tractors in transportation industry.

The analysis of empty running trucks shows at 21 million Baht per year of 94% of total transportation cost can be attributed to trucks running without goods or trucks traveling back from a delivery. Income from returning trip is 8 million Baht per year. Investment cost of these trucks is 20 million Baht per year. This amount of money is literally lost by the transportation company without added value of shipment in any way. The investment struck adapted to improve the tractor usage so that it accommodates different kinds of goods on its return trip. Margin is calculated after cost deduction of returning trip to the company. Cost is around five hundred thousand Baht per vehicle for the transportation of rubber on the returning trip. Without deduction of costs of the returning trip, this method is capable of making 1 million Baht revenue per vehicle. Therefore, not only is this proposal able to reduce consumption of fuel and energy, but it can also increase the company's net income with little additional cost.

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2.13.5 Study the partnership in order to manage cost of shipping by truck.

Kunakorn Sipirom (2006) studied the cooperation in the transportation cost to manage the logistics cost by truck for household electrical appliances and to find ways to deliver goods by truck in case if there is a little amount of goods left over from normal delivery. So the logistics will be able to match with the period of the order and cover with the order of the dealer as much as possible. By collaborating in the delivery with its partners' companies to gather goods together as a whole is the comparison performance study between before the improvement and after the improvement of the case study. The results of the study concerning logistics cost can be reduced both in the case study and its allies. Therefore the approach used in this study indicated that the logistics management can manage the delivery of the rest of the regular delivery and can increase the efficiency in the delivery of the company's from 90.23 percent to 99.78 percent. Nevertheless, the company and its partners' companies can also reduce operating costs for the cargo as well.

2.13.6 Research on the costs of harvesting sugar cane.

Viramon Tamjalern (2008) conducted research on various aspects of data costing from the cost of producing sugar cane survey on the part of the harvest cost and transportation cost to use as guidelines in the study. She introduced the concept about the cost of transporting sugar cane as the direct costs which included the fixed costs, semi-variable costs, and variable costs to deploy in an interview. She also reported the cost of harvesting and transporting sugar cane including problems and obstacles found during administrative research by improving the format of costing. In the part of logistics research, she brought the information from the truck logistics management costing in order to achieve the ultimate goal. The purpose is find ways to increase capacity for competition.

2.13.7 Survey on logistics cost of Truck Transportation in Thailand

Thailand Development Research Institute (TDRI) (2011) prepared special report on transportation cost of Bus and Truck transportation in Thailand. The survey study cost factors of the transportation using bus and truck were separated into five major factors; depreciation cost (investment cost), labor cost, fuel cost, maintenance

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cost, and other cost. The first four factors account for more than 95% of unit cost of transportation per kilometer.

Table 2.2 Cost Structure of Truck Transportation

Cost factor	Description	% of Total Cost
Investment Cost	Depreciation	5.85
Labour cost	Driver	20.21
	Driver Assistance	4.93
	Support Staff	2.36
Fuel Cost	Fuel Cost	27.49
Maintenance Cost	Lubricant	1.25
	Tires	3.78
	Preventive Maintenance	22.94
	Cleaning	2.02
	Other	2.00
Other Cost	Other Cost	3.31
Total		100.00

The survey does not only summarize cost per kilometer of each type of bus and truck but also provide sensitivity information on the effect on overall transportation cost when each cost factor change which can be summarized as table 2.3 below

Table 2.3 Cost Effect Index of each Truck Transportation Cost factor

Cost factor	**Cost Effect Index**	**% increase in Transportation Cost if 10% increase**
Depreciation cost	0.098	0.98%
Labor cost	0.267	2.67%
Fuel Cost	0.409	4.09%
Maintenance Cost	0147	1.47%

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Paitoon Chetthamrongchai, Aroon Auansakul, and Decha Supawan (2001) study transportation cost in order to assess the transportation problem of the sugar cane industry in Thailand. In this study, transportation cost indicated refer to survey done by the Office of the Cane and Sugar Board, Ministry of Industry, Thailand carried out during 1999/2000-2001 as shown in table 2.4. The survey indicates that the transportation cost is 85 baht per ton.

Table 2.4 Average Cost of Sugar Cane Production in the North-east region, 1999-2000

Items	**Average cost of cane production over 3-year period (baht per rai)**	**Percentage of total production costs**
1. Total labor costs	1,472.35	44.70
2. Materials	1,015.34	30.83
3. Other variable costs	246.92	7.50
Total variable costs	**2,734.61**	**83.03**
1. Depreciation of agricultural tools	193.30	5.87
2. Land rental	365.92	11.11
Total fixed costs	**559.25**	**16.98**
Production costs	**3,293.86**	**100.00**
Average cutting and loading costs (baht/ton)	85.00	13.00 - 14.00
Average other costs	340.14	53.00 - 56.00
Cost of production (baht/ton)	425.14	66.00 - 70.00
Transportation costs (baht/ton)	180.00 - 220.00	30.00 - 34.00
Total costs (baht/ton)	**606.14 - 646.14**	**100**

2.13.8 Survey on Commercial Cost Sugar

Singhanart Icecim and Supak Payakbut (2012) study sugar cane transportation using time slot scheduling technique. In this study, one factor that was considered is CCS and decreasing rate of CCS for green cut sugar cane and burnt cut sugar cane. Figure 2.15 and 2.16 show decreasing rate of each type of sugar cane after

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cut. This study indicated that CCS for green cut sugar cane will decrease at the rate of 0.8 CCS per day while CCS of burnt cut sugar cane will decrease at the higher rate of 1.4 CCS per day.

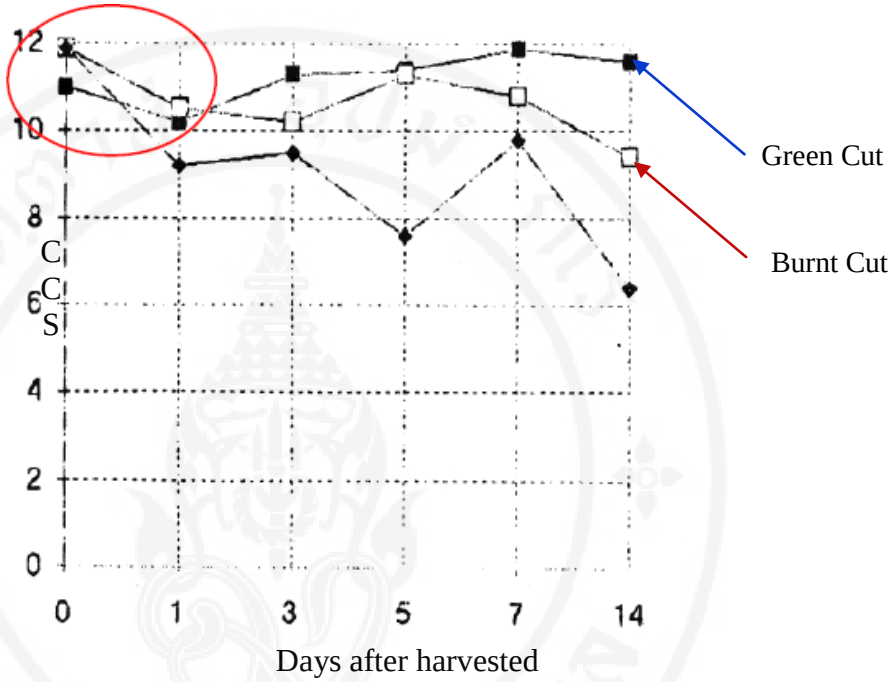

Figure 2.15 CCS decreasing rate of green cut and burnt cut sugar cane

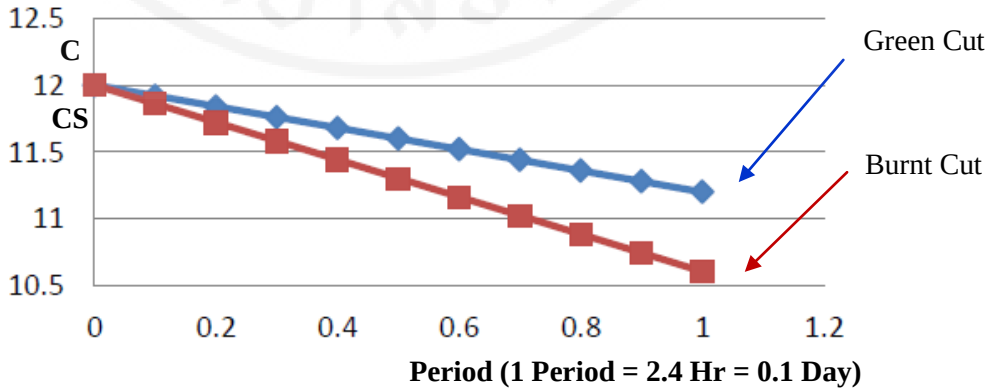

Figure 2.16 CCS decreasing rate of green cut and burnt cut sugar cane in one day

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CHAPTER III
RESEARCH METHODOLOGY

Chapter 3 is the setting of the methodology and procedures in the study. In order to guide the study to target the objectives, there are steps to follow as the following order.

3.1 Population

The population using in this study is that the sugar cane farmer population including the location and quantity of the cultivation of the sugar cane farmers in the years 2009-2010. The total numbers of farmers are 1,807 members in which there are the numbers of areas planted as 300,273 plants under commitment contracted with Saraburi Sugar Factory.

3.2 Method of Data Gathering and Analysis

To explore the harvest area, as well as statistics collected from the factory, the sugar cane transportation from farm-to-plant observation is also possible. In which the transportation information including the data of sugar cane truck entering to the factory each truck has been recorded in a database of plants in the form of Microsoft Access Files (see the Appendix A). The plant has analyzed the area of agriculture by using GIS to help in verifying the amount of area farmers.

In this study the transportation system was analyzed by using mathematical equations to help solve the problem of transportation issue. The analysis is divided separately into three following aspects.

- The study of traditional transportation systems.
- The study of transportation system by using mathematical equations.
- The model of studying from a new transportation system.

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3.2.1. A study of traditional transportation systems.

The study of such system the data is used from the transportation from farm to factory directly and using the coordinated information from the GIS area, which has come to find the distance occurring during the transportation. It was compared with the actual shipping cost. The use of Closest Facility ARCGIS version 9.3, as well as the use of comparison of the OD-Cost Matrix to determine the distance between farm and factory was implemented. Then analyze the distance and transport costs that incurred.

3.2.2 Study of transportation system by using mathematical equations.

In the analysis as mentioned using the equation in the analysis with the following steps.

(i) Gathering of geographical and statistical information of plantation area and characteristic in the area of study using GPS and GIS. Database and digital map was later prepared using ArcGIS.

(ii) Analyzing of the existing transportation form

(iii) Analyzing of the spatial data with Geographic Information System (GIS)

(iv) Analyzing and proposing the new transportation form by identifying the appropriate hub locations using K-Mean clustering technique. Using the k-mean clustering analysis equation to identify the location of the Sugar cane Service Station. This station will be used as the collecting and weighing point including the allocation of sugar cane from each field in order to prepare the transportation to the plant efficiently. In such study it was analyzed that each station has the ability to allocate up to 200 tons per day. New Transportation Model 1 is proposed.

(v) Formulating model to find optimum routing from farms through each hub location using Capacitate Vehicle Routing problem.

(vi) Calculating transportation route and distance between source farms and destination factories using ArcGIS

(vii) Analysis and finding solution of new model transportation distance and cost.

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(viii) Comparing the result of traditional transport with proposed new transportation form.

The formulated equation is as following:

Objective Function: Min. Cost = $Min \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}Q_{ij}$ (1)

Subject to: $\sum_{i=1}^{m} Q_{ij} \le b_j$ (2)

$\sum_{j=1}^{n} Q_{ij} \le a_i$ (3)

$\sum_{i=1}^{m} a_i \le \sum_{j=1}^{n} b_j$ (4)

$Q_{ij} \ge 0$ (5)

Where:

Q_{ij} = The amount of sugar cane transported from farm i to factories j (ton)

C_{ij} = Unit Transportation cost from farm i to factory j (Thai Bath per ton)

$C_{ij} = 85.00 + 2.67D$ (6)

D = Distance between farm i and destination factory j (km.)

b_j = Amount of sugarcane, factory j is capable of buying during each season (ton)

a_i = Capacity of sugar cane in i

i = Sugar cane plantation farm in central region in study area = 1, 2, 3, …., m

j = Sugar factory (Saraburi Sugar factory)

m = Total plantation area in collecting location

Details of this model:

- Sugar cane can only be delivered to the closest factory (cross-factory transportation is not allowed).

- Transportation is done using farmers tractor or standard 10-weel trucks.

- Calculation accuracy and reliability of the result is based on 1:50,000 map scale.

- The capacity of each Loading Service Station = 200 tons/day

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- Sugar cane carriage with long distance between plant-area to collecting location will use major highway. While for the short distance will use road in farm.

- Cost for sugar cane transportation comprise of “cutting and loading cost” and “transportation cost”. When transportation cost is the cost of sugar cane transportation from farm to loading service station and from loading service station to factory which includes 4 major factors; Depreciation Cost, Fuel Cost, Labor Cost, and Maintenance Cost (including parts and consumables).

- The increase in each transportation cost factor effect overall transportation cost as following (TDRI 2010).

Table 3.1 Cost effect index of each transportation cost factor.

Cost Factor	**Cost Effect Index**	**% increase in Transportation Cost if 10% increase**
Depreciation cost	0.098	0.98%
Labor cost (Driver/Assistance)	0.267	2.67%
Fuel Cost	0.409	4.09%
Maintenance Cost	0.147	1.47%

It includes the use of Closest Facility Program of ARCGIS version 9.3 in order to compare routes. It also uses OD-Cost Matrix in order to analyze distance between farms and factories. Then, we can analyze the distance and transportation costs incurred.

3.2.3 The model of studying from a new transportation system.

By increasing the restrictions on the investment improve the conditions of sugar cane service station. Conducted the study by increasing conditions of an establishment of sugar cane service station was made. By consideration it was concluded the investment of various resources in order to give an alternative to the sugar factories to be able to select an appropriated choice for the investment.

The input data including the distance metrix between farms and factory and the volume of sugar cane in each farm is analyzed in 2 scenarios. First scenario is the analysis of Traditional Transportation Method; direct transportation from farm to factory. Second scenario is the analysis of proposed new transportation model which sugar cane transportation routing is from farms through collecting hub locations to

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sugar factory. The collecting hub locations shall collect more amount of sugar cane while performing additional primary process of leaf cutting and sugar cane crushing. Processed sugar cane shall then be transported to sugar factory for milling process.

Due to the fact that locating a lot of collecting hubs may not suitable in real situation, additional transportation model is proposed called New Transportation Model 2. With this new transporation model 2, limited number of larger hub locations called Loading Service Stations are proposed. In this model, fixed-investment cost of locating each loading service station is introduced. Distance, D, is calculated using Closest Facility and OD-Cost Matrix.

The Formulation of the New Trasportation Form 2 is as following

Objective Function:

$$Min \quad \sum_{k=1}^{p} F_k U_k + \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}Q_{ij} + \sum_{i=1}^{m}\sum_{k=1}^{p} C_{ik}Q_{ik} + \sum_{k=1}^{mp}\sum_{j=1}^{n} C_{kj}Q_{kj} \quad (7)$$

Subject to:

$$\sum_{i=1}^{m} Q_{ik} \leq S_k U_k \quad (8)$$

$$Q_{ik} \leq min\{a_i, S_k\}U_k \quad (9)$$

$$\sum_{j=1}^{n} Q_{ij} + \sum_{k=1}^{p} Q_{ik} \leq a_i \quad (10)$$

$$\sum_{j=1}^{n} Q_{ij} + \sum_{k=1}^{p} Q_{kj} \leq b_j \quad (11)$$

$$\sum_{i=1}^{m} Q_{ik} - \sum_{j=1}^{n} Q_{kj} \geq 0 \quad (12)$$

$$Q_{ij}, Q_{ik}, Q_{kj} \geq 0 \quad (13)$$

Where:

Q_{ij} = Amount of sugar cane transported from farm i to factories j (ton)

Q_{ik} = Amount of sugar cane transported from farm i to loading service station k (ton)

Q_{kj} = Amount of sugar cane transported from loading service station k to factory j (ton)

C_{ij} = Unit Transportation cost from farm i to factory j (Thai Baht/ton)

C_{ik} = Unit Transportation cost from farm i to loading service station k (Thai Baht/ton)

C_{kj} = Unit Transportation cost from loading service station k to factory j (Thai Baht/ton)

$$C_{ij} = 85.00 + 2.67D_{ij} \quad (6.1)$$

$$C_{ik} = 85.00 + 2.67D_{ik} \quad (6.2)$$

$$C_{kj} = 85.00 + 2.67D_{kj} \quad (6.3)$$

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D_{ij} = Distance between farm i and destination factory j (km.)

D_{ik} = Distance between farm i and loading service station j (km.)

D_{jk} = Distance between loading service station k and factory j (km.)

b_j = Amount of sugar cane that factory j is capable of buying during each season (ton)

a_i = Capacity of sugar cane of farm i (ton)

F_k = Cost of locating Loading Service Station at location k

U_k = Logical variable = 1 if and only if loading service station is located at k, and 0 otherwise.

S_k = Capacity of loading service station k

i = Sugar cane plantation farm in central region in study area = 1, 2, 3, …, m

j = Sugar factory (Saraburi Sugar factory)

k = Loading service station = 1, 2, 3, ….., k

m = Total plantation area in collecting location

Details of this model:

Condition of the Model:

- Loading Service Stations to be opened located within set of hub locations (result from New Transportation Model 1).

- Fix Investment Cost of opening each Loading Service Station is equal to 4,500,000 THB/stations.

- The capacity of each Loading Service Station = 3,000 tons/day.

- Transportation is done using farmers tractor or standard 10-wheel trucks.

- The calculating of the accuracy and reliability of the result is based on 1:50,000 map scale.

- Sugar cane carriages which have long distance between the plant area to collecting location, will use major highway except carriage is close collecting location use road in farm.

- Cost for sugar cane transportation assumption comprise of “cutting and loading cost” and “transportation cost” from farm to Loading Service Station and from Loading Service Station to Factory which includes 4 major factors; Depreciation Cost, Fuel Cost, Labor Cost, and Maintenance Cost (including parts and consumables).

- The increase in each transportation cost factor effect overall transportation cost is the same as indicated in New Transportation model 1.

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3.3 The Process of this Research.

3.3.1 Preparation of Research and Research Related Literature Review.

Related researches and theses are studied, including topics of management of production of sugar cane and sugar, mathematical models, knowledge management, and geographic information. This information must be searched through papers in national and international level. Information can be found in complete theses and related articles. The search is to conduct a study that is not identical to one that has already been done in the past. Moreover, the search reveals types of research and technology of research in detail.

3.3.2 Planning of Data Storage in the Field.

Data storage is studied and planned to provide sufficient storage space for research. In addition, it saves time in the analysis if raw data is appropriate for mathematical model. Moreover, it is easy to check for mistakes. From the case study, data are collected from Saraburi sugar factory. It is the study of transportation of sugar cane from farms to sugar factory to increase speed and efficiency. There is a collection data of management of inbound transportation.

3.3.3 Exploration and Collection of Locations and Characteristics of Sugar Factories and Sugar Cane Farmers in Area of Case Study.

In this study, there is a collection and storage of data in both geographical and statistical forms of raw data. The consideration of sugar cane purchase in the central region of Thailand and the zoning of the purchase of sugar cane are divided into 3 parts:

- The economy of the cane and sugar industry in central region of Thailand
- The environment of the cane and sugar industry in central region of Thailand
- The combination of economic and environmental factors of the cane and sugar industry in central region of Thailand

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From the study, there is an application physical, environmental, economical, and societal factor on economic modeling and sample analysis of Geographic Information System as shown in figure 3.1.

In the study of sugar factories, it is important to use statistical data such as total production capacity and ability to weigh. Moreover, the study uses geographical information, which details will be explained in the chapter of case study. In part of the sugar cane farm and farmers' information, it is necessary to statistical data and storage.

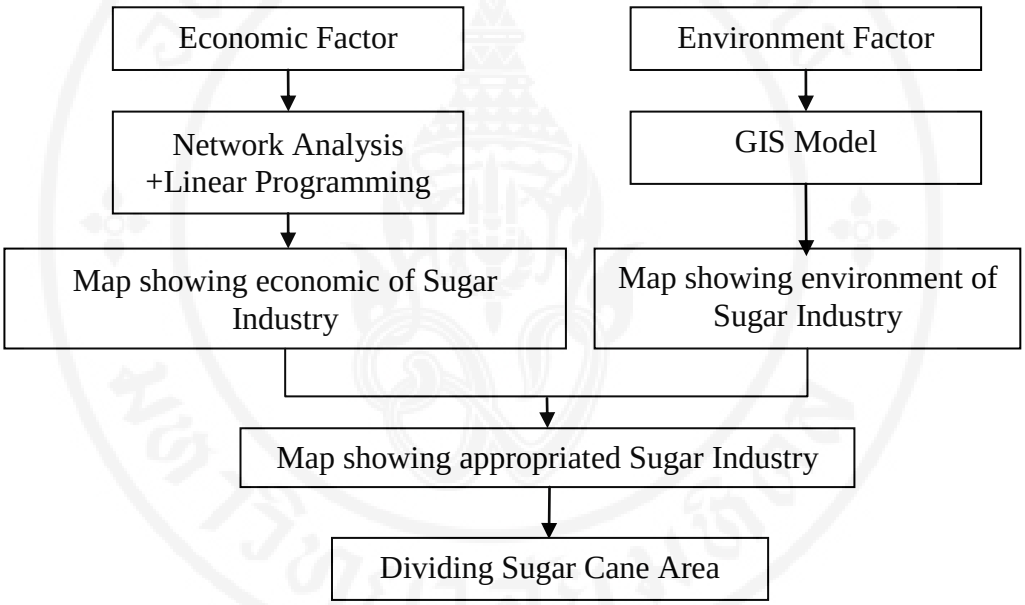

Figure 3.1 Steps of agricultural area analysis in the sugar industry

3.3.4 Field data collection of sugar cane transportation.

In the case study, it is analyzed from statistical data collected by the factory, including data from observation. Generally, ten-wheel trucks are used to transport goods from farms to factories. These trucks have the ability to carry 20 ton per car. In real working conditions, some farmers need to wait for head quota with ten-wheel trucks. This is because there is a shortage of trucks compared to amount of production in the area. The amount of waiting time for carrying trucks can be as long as many days.

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In the case study of the new method, farmers can use small-sized tractors with carrying capacity of a few tons in transporting goods to station in order to reduce waiting time.

The study analyzes the location of factory, area of contracted farmers' sugar cane plantation of each sugar factory, road network, level of road service, and route of sugar cane transportation to sugar factories. The purpose is to prepare a system of transportation by using Closest Facility Program by ARCGIS version 9.3 in order to compare routes. Moreover, OD-Cost Metric is used to analyze and find distance from farms to factory or from farms to sugar cane service station and then to factory.

3.3.5 Development and synthesis of statistical data on the current form of transportation.

The current form of transportation is analyzed in order to know the structure, distance, and cost of transportation. Moreover, it is used as a guide to improve new forms of transportation.

The formula of transportation and choice of sugar cane service station location are analyzed. The analysis is divided into two parts.

1. To determine the location of sugar cane service station by using k-mean clustering. Then, distance of delivery and investment of creation of service station are analyzed. Vehicle Routing Problem form of equation is used to calculate the least distance of transportation and investment of service station. It determine that each service station have the capability of 200 tons per day.

2. The analysis of another form of sugar cane service station locator by creating equation from Linear Programming. The purpose is to find the least amount of investment and the shortest distance by Vehicle Routing Problem as equation mentioned above.

3.3.6 Analysis of each forms of transportation and create appropriate sugar cane service station.

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The results from the calculation with mathematical equations for each form of transportation are analyzed. This is to find the proper amount and coordinate

of service station. Moreover, the objective is to find an appropriate distance and value of transportation.

Results are compared from analysis. Results are then summarized to write a complete research report.

3.4 Areas of Study.

The researcher has studied the sugar cane industry in the area around the central region of Thailand, using GIS systems. Nowadays Sugar industries in Thailand are totally 46 factories. (Office of the Cane and Sugar, 2009) Saraburi Sugar factory is located at Wang Kapi, City District, Saraburi. The capacity of production is about 28,000 tons of sugar cane per day. Contracts with sugar cane farmers are about 1,807 contracts. The area harvesting of sugar cane farmers covered about 300,273 Rai during the year of 2007/2008. By most of the contracting farmers located in 3 provinces in the area of Saraburi, Lop Buri and Nakhon Ratchasima. Farmers mostly are in the radius not exceeding 90 kilometers around the factory. There is one sugar factory as a competitor in the area of Saraburi province. The crashing season starts in the month of November and ends at the end of March, depending on the amount of sugar cane entering the mill.

In a study using the Geo-Informatics system, it was explored the cane and sugar industry in the central part of Thailand, in order to consider the station to transport sugar cane including dividing area for purchasing sugar cane in the central region of Thailand. The divided area is determined by various factors, including physical, biological, economic, social and legal, the analysis using models for consideration by the Geographic Information System.

Currently, the technology of Geographic Information (GIS) used for management, in particular, the supply of sugar cane department or raw material purchasing department. The ARCGIS software packages were used for the preparation of spatial database. Also the specific programs are developed. By dividing the area into six zones to promote the sugar cane supply officers take the responsibility of zoning authorities. Each of which covers the promotion of sugar cane for each district in each province as follows.

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In the province of Lopburi; there are 6 districts which are Ta Luong, Khok Sum Roog, Lum Sui Ti, Muang District, Sra Boat, and Pattananikom

In the province of Saraburi; there are 10 districts which are Wang Muang, Nong Saeng, Nong Kae, Kang Khoi, Muang District,Nong Don, Soun Hai, Moung Lake, Pha Put Tha Baht and Chalaemprakiet

In the province of Nakornrajchasrima; there are 3 districts which are Pak Chong, Sri Quaen and Dan Khun Thot.

The space used in the study area to transport the sugar crop and get the proper zoning shown in figure 3.2.

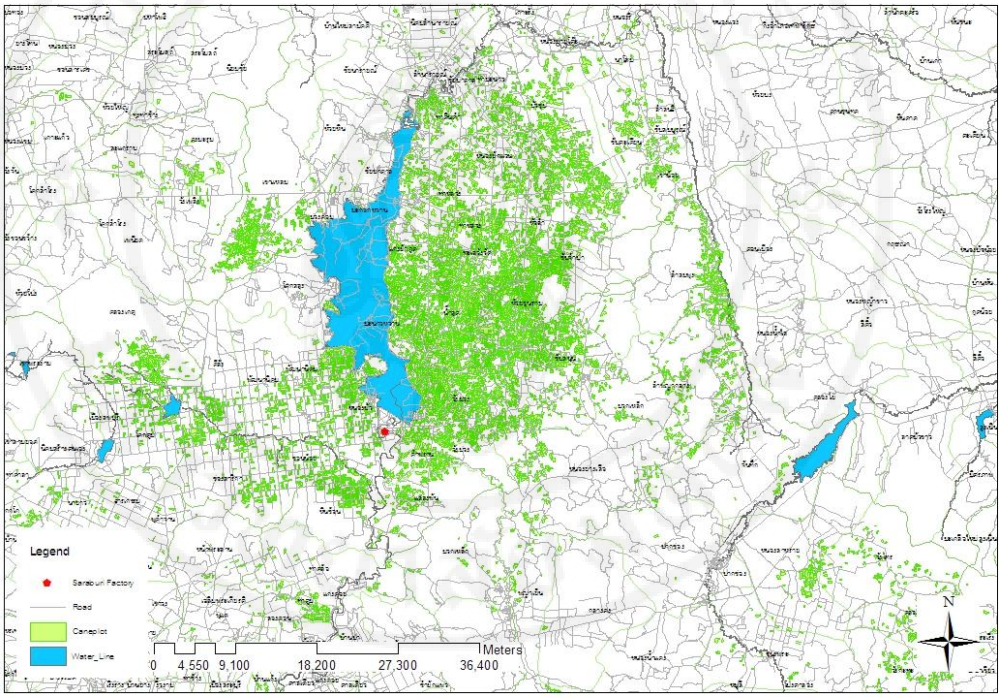

Figure 3.2 Area used in the research study to implement an appropriate form of sugar cane transportation and collection method

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Figure 3.3 Map of sugar cane plantations in the district area of the case study sugar factory

Figure 3.4 Research team enter Saraburi Sugar Company Limited
in order to gather data at this case study sugar factory

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CHAPTER IV
RESEARCH RESULTS

This research has the purpose of creating a mathematical sample size in order to help the web of sugar factories to decide and solve problems caused by high waiting time in transportation. The waiting time occurs during the delivery of sugar cane as raw material for sugar production. High waiting time affects sugar's sweetness and freshness. The purpose is also to reduce the amount of trucks parked inside the factory. Excess trucks should be used to transport goods instead of idly parking in the sugar factory.

5.1 Results from the Analysis of Present Transportation Form.

Through the harvesting season, volumes of sugarcane delivered to the plant by 113,355 flights of vehicle have been recorded. The daily amount of sugarcane transported was presented in figure 4.1. The number of trucks entered the factory in each day were presented in figure 4.2.

It was found that the amount of trucks that entered to the plant exceed the capacity of the plant to be obtained. So the trucks have to take a long time waiting for deliver (the waiting time was presented in figure 4.3). The plenty of trucks exceed the capacity of the parking lot and have to make a queue on the street outside the factory. This will affect to the traffic congestion in the area. The plant needs to reduce the amount of parking trucks which creates congestion traffic in front of the plant by not reducing the efficiency and the amount of sugarcane delivering to the plant. The results from the analysis of ARCGIS 9.3 Network Analyst tool determine the distance of transportation in its current form. The total distance in transportation during the harvesting season is 105,844,644.54 kilometers where the expenses of the transportation as high as 731,344,152.92 baht of the observed harvesting season. This

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figure could compare as 28% of the total of sugarcane value purchasing of this case study plant at 2,611,185,936.41 baht.

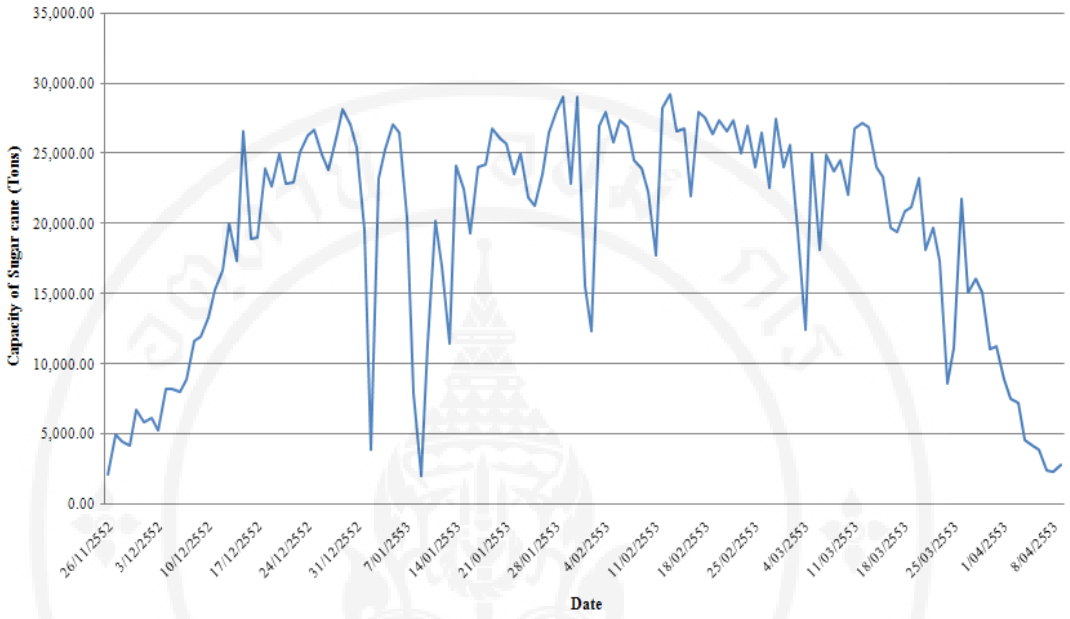

Figure 4.1 The amount of sugar cane transported into the sugar factory each day during harvest season 2009/2010 (in the case study sugar factory).

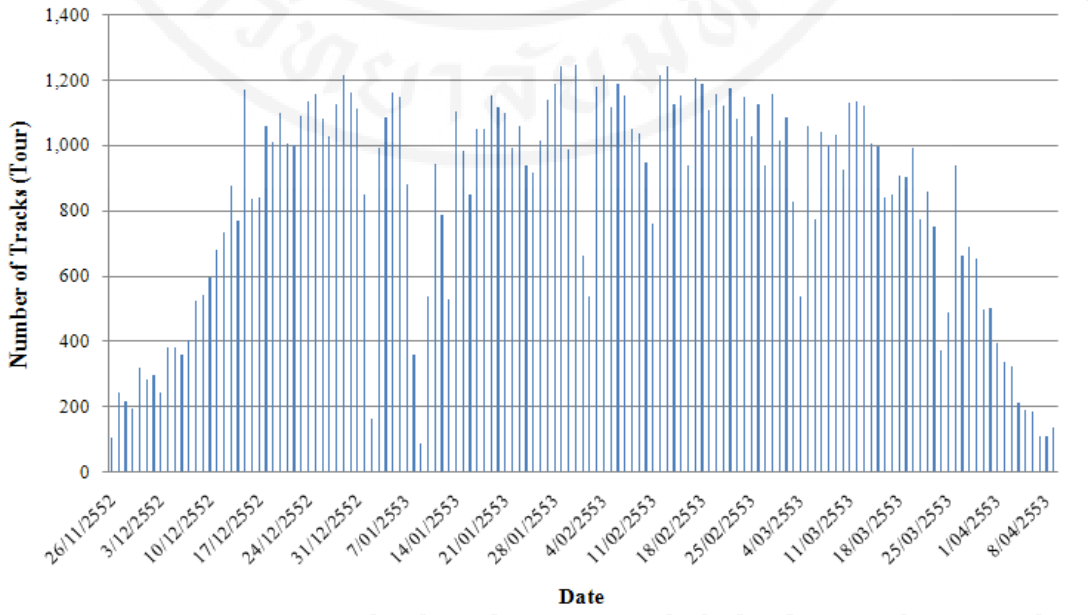

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Figure 4.2 The amount of trucks that enter the sugar factory each day (the case study sugar factory) in the original method of transportation.

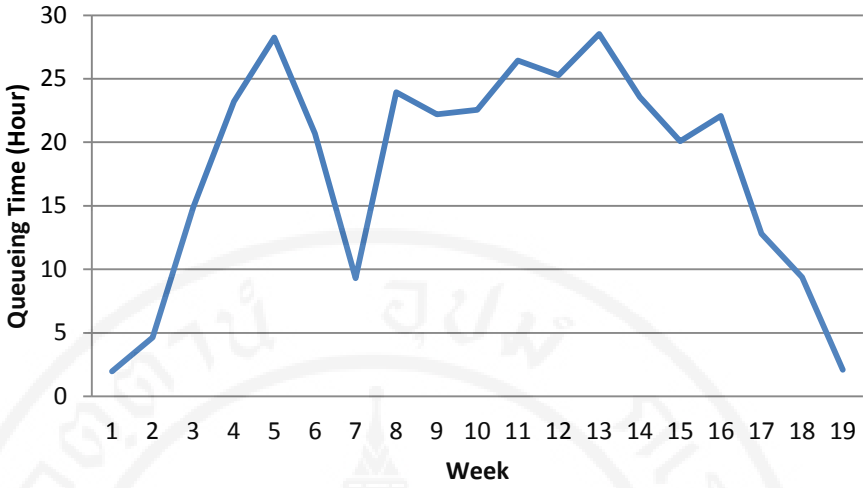

Figure 4.3 Number of hours, trucks spent waiting each day on average.

5.2 Results from the Analysis of New Transportation Form 1.

From the search for product gathering station by K-mean Clustering was shown in figure 4.4 and in Appendix A.

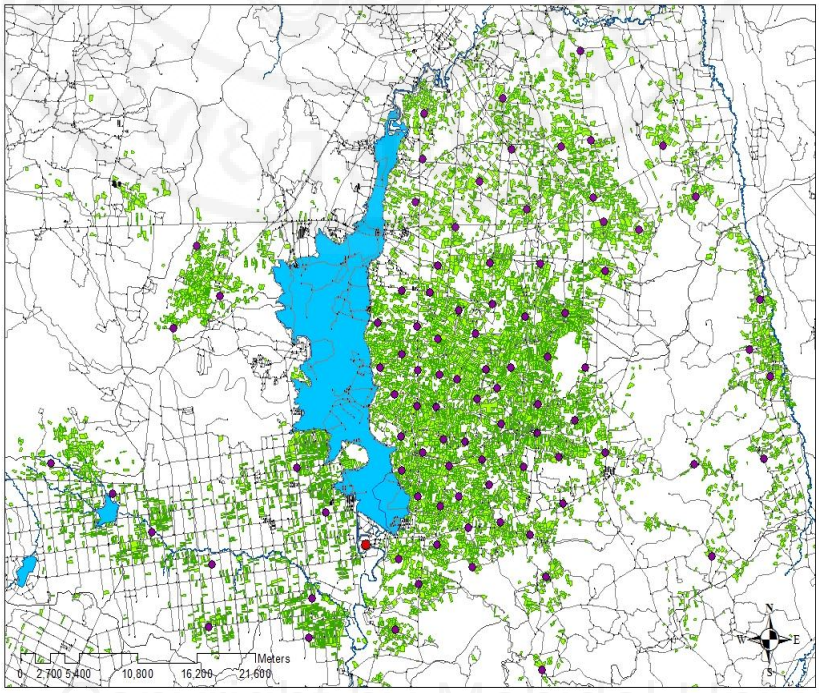

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Figure 4.4 Location of factory and sugar cane collection station in each district from the analysis of K-mean Clustering.

Figure 4.4 shows the location of each purchasing sugarcane point area. By the analysis of the K-mean Clustering, replacing value of the quantity of sugarcane purchased each day to 200 tons per day, regardless of the value of investments which occurs from the establishment of sugar cane services station during the harvest season. From the picture, there will be a number of purchasing sugarcane areas of 91 points. The investment cost will be 45.5 million baht. Each point will be responsible to purchase and weight sugarcane for each quota that delivering to the factory. Gathering and scheduling sugarcane according to the amount of purchase and capacity of the factory in each day. This will manage the amount of sugarcane that needed to deliver to the factory properly.

The results by analysis were calculated with the equation modeling the transport of traffic with a Linear Programming collected in each area of the Sugar Cane in Saraburi Plant. The analysis to find the patterns of transportation from farm to the collection point in each area are estimated about 18 points depending on the volume density of the cultivated area in each point. After that the analysis to determine the distance of each collection point of the sugarcane to the factory will use the tool in Closest Facility in Network Analyst of ARCGIS 9.3 to determine the distance as shown in Figure 4.5.

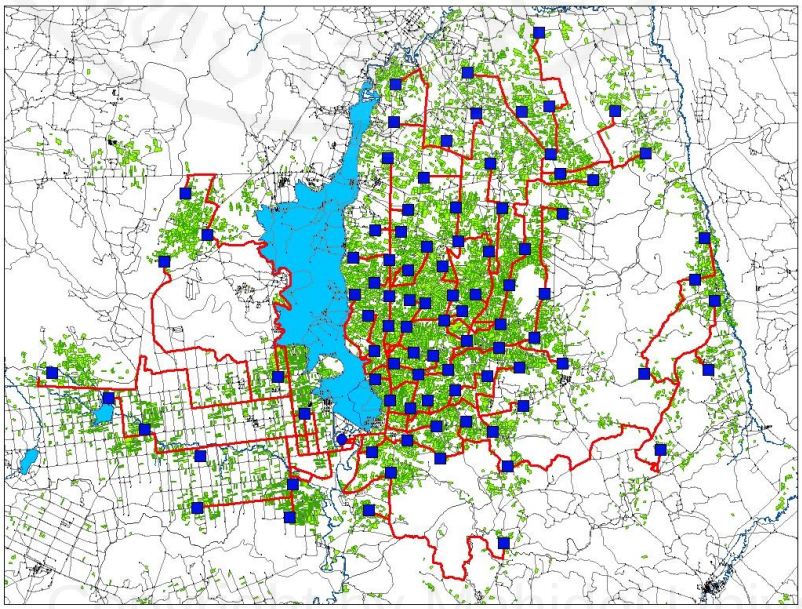

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Figure 4.5 Analysis of the distance from collection center to sugar factories using Closest Facility from Net Analyst.

Figure 4.5 shows the path of transport from each point of purchasing sugarcane to the factory. The results of the analysis indicated that the amount of trucks entering the premises of the factory should not exceed 279 flights per day, approximately (figure 4.6) from normal day, some days entering to the factory up to 1,200 vehicles per day. This will reduce the waiting time at the front of the truck to the sugar mills, only a day not more than 6 hours. (figure 4.7), normally it will take time for the trucks to wait in front of the plant up to 28 hours.

By reducing the transportation distance to just only 77,266,590.51 kilometers, it reduces down from the previous transportation distance up to 28,578,054.03 kilometers during the whole harvest season of the year 2009/2010 and can reduce the cost of transportation up to 142,224,103.10 Baht to reach at only 589,120,049.77 Baht.

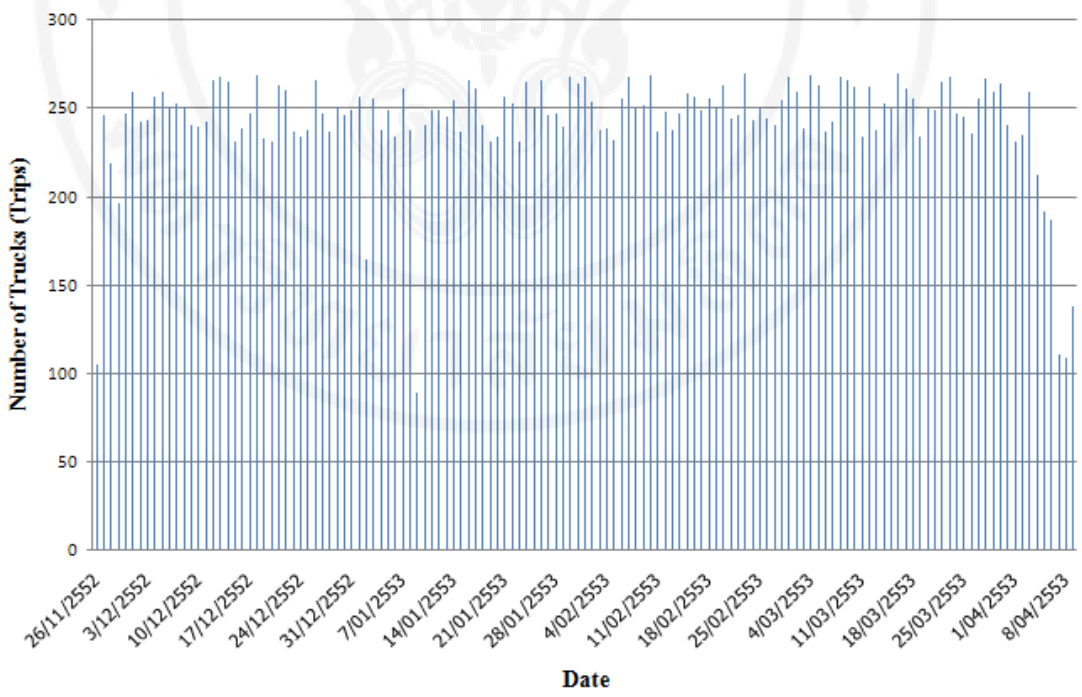

Figure 4.6 The number of trucks transporting sugar cane in front of sugar factory after using the new method of transportation #1

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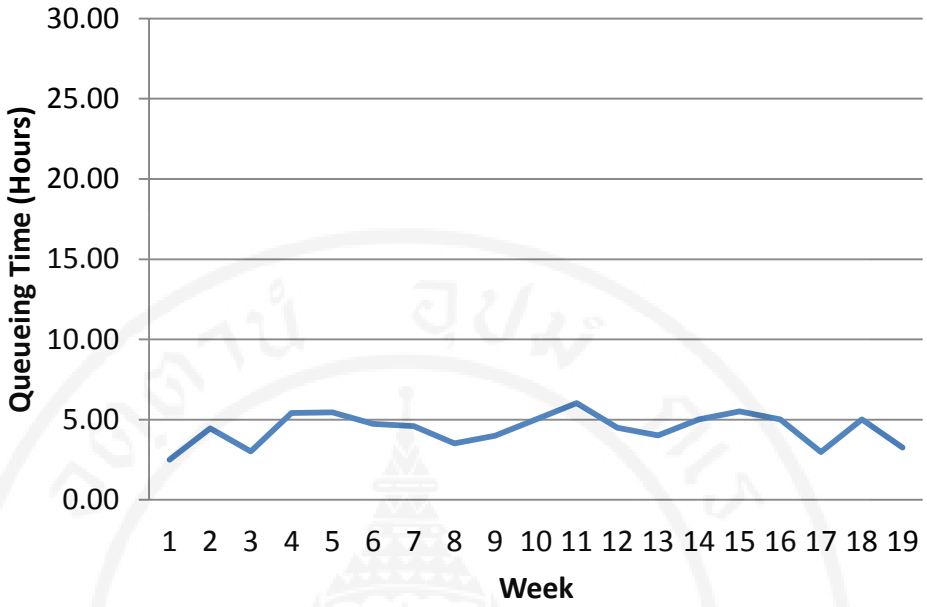

Figure 4.7 The graph shows the number of hours trucks spent waiting in front of the sugar factory after using the new method of transportation #1

5.3 Results from the Analysis of New Transportation Form 2.

Results from the Analysis of New Transportation Form 2: from the search for product gathering station by Linear Programming found location as shown in figure 4.8 and index Table in Appendix A.

Figure 4.8 shows the locations of the purchasing sugar cane points of each area. By using the analysis of Linear Programming, replacing value follows the additional conditions equation. The analysis includes the cost of establishing Sugar Cane Services Stations during the sugarcane harvest season. According to the picture above, we will have a total area of sugarcane purchased by 9 points. Each point will be responsible to purchase and weight the sugarcane of each quota, the transport collection of each cane to the factory. Gathering and scheduling the transportation of sugarcane collected by traffic volume and capacity of the plant each day. This will allow the plant to be able to manage the amount of sugar cane delivering to the mills properly. The ability to handle the amount of sugar cane in each center has up to 3,000 tons per day.

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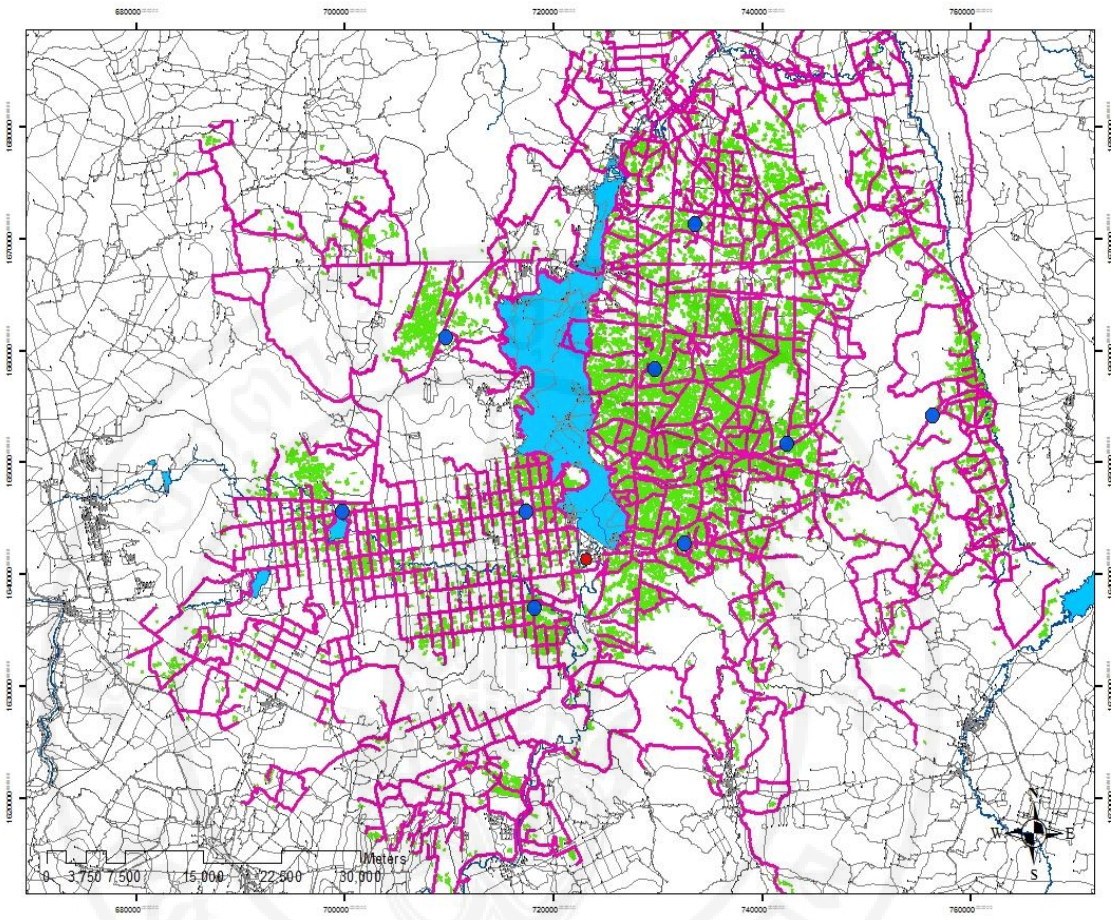

Figure 4.8 Linear Programming shows the position of the sugar factories and the collection point in each area

The results by analysis were calculated with the equation modeling the transport of traffic with a Linear Programming collected in each area of the Sugar Cane in Saraburi Plant. The analysis to find the patterns of transportation from farm to the collection point in each area are estimated about 18 points depending on the volume density of the cultivated area in each point. After that the analysis to determine the distance of each collection point of the sugarcane to the factories will use the tool in Closest Facility in Network Analyst of ARCGIS 9.3 to determine the distance as shown in figure 4.9.

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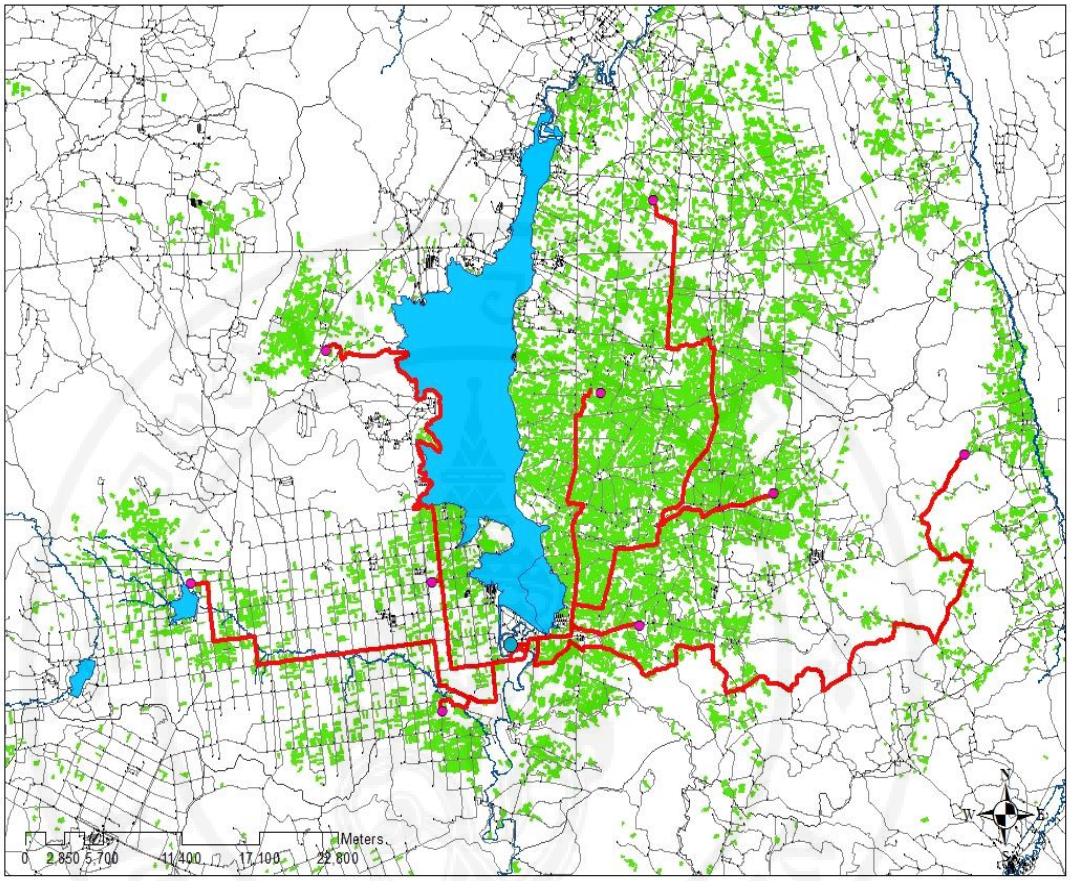

Figure 4.9 Analysis of the distance from the point of purchase (Sugar Cane Service Station: SCSS) to the factory using Closest Facility under Network Analyst

Figure 4.9 illustrates the routes of transportation from each buying center location (Sugar Cane Service Station: SCSS) to sugar factory. By the analysis, the amount of trucks that enter factory area was reduced to an average of 800 rounds per day (as figure 4.10). The number of truck rounds is as much as 1,200 trucks per day in the original method of transportation. The new method reduces waiting time in front of sugar factory to less than ten and a half hours each day (as figure 4.11) from the normal 28 hours.

In the case, researcher studies the investment of sugar cane service station in each location. Results show that there are 9 locations with investment value of 4,500,000 Baht initial investment. Costs in following years will only include workers' wages and maintenance, which are less than initial investment. Results from the equation has the ability to reduce transportation distance to only 84,744,951.27

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kilometers, which is significantly less than the original distance of 21,099,693.27 kilometers during harvest season of 2009/2010. Moreover, 133,629,494.03 Baht is reduced in transportation to a final cost of only 597,714,658.89 Baht.

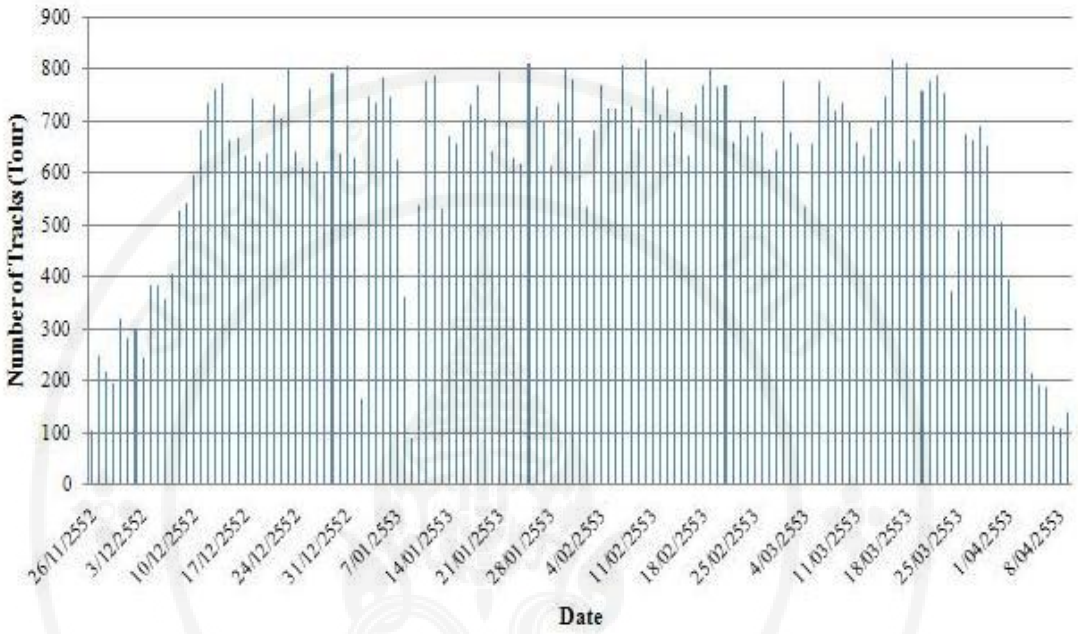

Figure 4.10 Number of trucks waiting at the Factory: New Model Transportation Model 2.

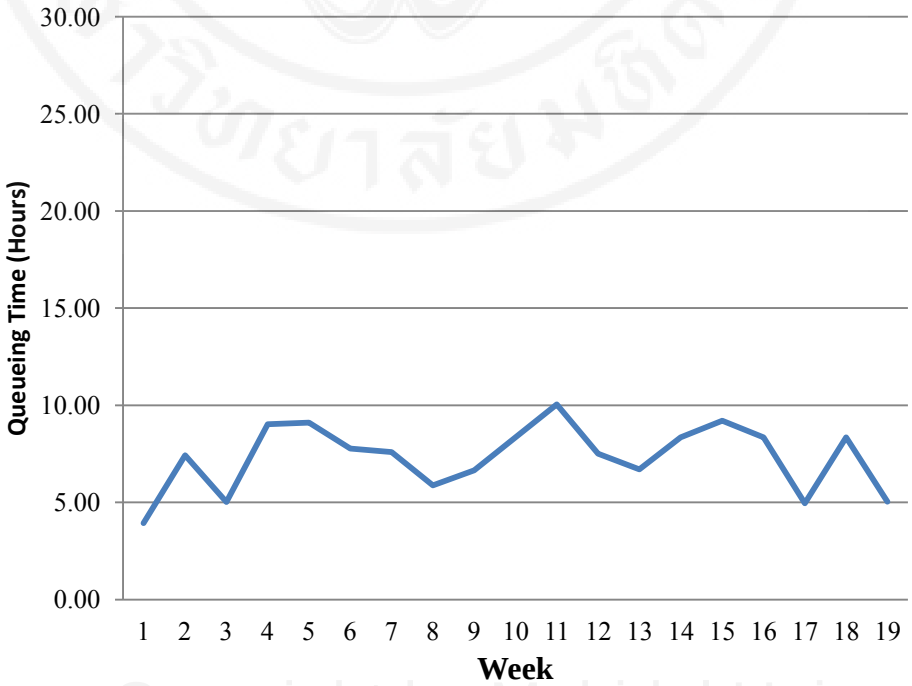

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Figure 4.11 Average waiting time of sugar cane truck/week: New Transportation Model 2

CHAPTER V
CONCLUSION AND DISCUSSION

5.1 Conclusion and Discussion.

This research is mainly a guideline for applying Geographic Information System (GIS) with mathematical modeling technique; k-mean clustering and vehicle routing technique. Though this study is scope on sugarcane transportation from farm to factory within the central region of Thailand, it can be applied to other region of the country as well as to other different kinds of crop.

The result comparison among three sugarcane transportation models (Traditional Transportation Model, New Transportation Model 1 and New Transportation Model 2) are summarized and presented in the following section. Table 5.1 presents the comparisons in terms of transportation distance and total transportation cost. While the comparisons in terms of average number of truck (trip) per day in the factory and the maximum queuing time are presented in table 5.2.

Table 5.1 Result comparison in terms of a transportation distance and a transportation cost between different transportation models

Transportation Method	Number of Service Stations	Transportation Distance (km.)	Transportation Cost (Baths)
Traditional Transportation Method	-	105,844,644.54	731,344,152.92
New Transportation Model 1	91 Stations	77,266,590.51	571,420,049.77
Total Reduction: Traditional VS New Model 1		28,578,054.03	159,924,103.15
% Different		27%	22%
New Transportation Model 2	9 Stations	84,744,951.27	597,714,658.89
Total Reduction: Traditional VS New Model 2		21,099,693.27	133,629,494.03
% Different		20%	18%

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Table 5.2 Result comparison in terms of an average number of trucks and queuing time between different transportation models

Transportation Method	Number of Service Stations	Average Number of Trucks at Factory (Trip/day)	Maximum Queuing Time (Hour)
Traditional Transportation Method	-	1,200 (fluctuated)	28
New Transportation Model 1	91 Stations	279 (evenly distributed)	6.5
Total Reduction: Traditional VS New Model 1		921	21.50
% Different		76.75%	76.79%
New Transportation Model 2	9 Stations	800 (evenly distributed)	10.5
Total Reduction: Traditional VS New Model 2		400	17.5
% Different		33.33%	62.50%

The new transportation models with suitable service stations or hub locations derived using k-mean clustering and vehicle routing model technique give better result than the traditional transport method that transport sugar cane directly to the factory. By using new transportation models, we can reduce the number of trucks at sugar factory from 1,200 trips to 279 trips (76.75% reduced) and 800 trips (33.33% reduced) for new transportation model 1 and new transportation model 2 respectively. The queuing time is also satisfactory decrease from 28 hour to 6.5 hours (76.79% reduced) and 10.5 hours (62.50% reduced) as presented in Table 5.2. The transportation distance and transportation cost is also decrease as indicated in Table 5.1. The transportation distance of 105.8 million kilometers by the traditional transportation method decreased to 28.6 million kilometers (27% reduced) and 21.1 million kilometers (20% reduced) by the new transportation model 1 and 2 respectively. In addition, the transportation cost reduced from 731.3 million baht in the traditional transportation method to 571.4 million baht (22% reduced) and 597.7 million baht (18% reduced) by the new transportation model 1 and 2, respectively.

From the results, we can conclude that setting up appropriate purchasing points and transportation routes can significantly reduce overall cost due to shorter transportation distance, shorter waiting time at factories, and more effective sugar production process. Because the period of time between sugar cane harvesting and milling has major effect on sugar production, the shorter the queuing time the better.

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Local farmers shall benefit from opening up Loading Service Stations as they can directly transport their sugar cane to Loading Service Stations.

The results from this study indicate that both new transportation models are recommended because of their costs which are less than of the traditional method. The next issue is which model is the most appropriate for this case. The "New Transportation Model 1" which has the minimum cost seems to be the best choice for this case. However, in the real world where the operating cost is 21.84 million-baht and 2.16 million-baht, respectively for model 1 and 2, we founded that the total cost that would be saved by implementing new transportation model 1 and 2 are 138.1 million-baht and 131.5 million-baht, respectively. The difference is only 0.90%.

The operating cost of 21.84 million-baht and 2.16 million-baht, respectively for model 1 and 2, must be included in to the consideration. The total cost that would be saved by implementing new transportation model 1 and 2 are 138.1 million-baht (18.88% reduction rate) and 131.5 million-baht (17.98% reduction rate), respectively. The new transportation model 1 is not much better than model 2. Because the transportation cost saved by “model 1” is only 0.90% more than “model 2” while the investment is very much greater. Moreover, the 91 service stations are not easy to manage compare to only 9 stations. For this reason, the new transportation model 2 might turns to be more suitable solution than the new transportation model 1.

5.2 Recommendation

The research results from the prediction of location by considering amount of sugar cane trading in each location. The working capacity is assumed to be 300 tons/day/service location by the current situation and the type of equations used to calculate appropriate node by combining value of investment in each product service station. This case has not been analyzed in terms of replication of situation or simulation that will help confirm the effectiveness of each form of transportation. This research solution will affect the cost of investment. The key to productivity and profitability of each area should be studied further. Contract farming and multimodal study should be done to improve cost function for the transportation from Loading Service Center to factory.

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APPENDICES

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APPENDIX A

LOCATION OF EACH COLLECTION AND PURCHASE CENTER

Table A Location of each collection center and purchase center in each area, total of 91 locations

Joint	UTM-X	UTM-Y	Joint	UTM-X	UTM-Y	Joint	UTM-X	UTM-Y
1	742,860	1,682,072	33	743340	1655946	65	727928	1645345
2	735721	1678116	34	758398	1657415	66	731687	1645301
3	728483	1676911	35	760371	1655243	67	729939	1644537
4	736540	1673967	36	726390	1657067	68	741249	1644727
5	741123	1674160	37	724403	1655927	69	735522	1643166
6	743825	1674690	38	727875	1655728	70	732554	1642719
7	750434	1674256	39	729860	1655350	71	738237	1642142
8	728340	1673157	40	731484	1655014	72	754974	1640377
9	733550	1671255	41	734179	1655826	73	729679	1641325
10	737939	1668990	42	736469	1655927	74	732931	1639497
11	744018	1669964	43	735180	1654249	75	739682	1638711
12	753521	1670011	44	725723	1653776	76	726124	1640142
13	748263	1667310	45	729577	1652686	77	728008	1638103
14	744982	1667937	46	733332	1653342	78	739334	1631025
15	727712	1669568	47	738965	1652914	79	725812	1634326
16	731329	1667541	48	742338	1651612	80	718192	1636946
17	729715	1664358	49	727801	1652789	81	717890	1633647
18	734514	1664598	50	735581	1651271	82	708673	1634550
19	739146	1664511	51	726355	1650270	83	708950	1639763
20	745176	1663933	52	730281	1650066	84	719400	1643989
21	726435	1662286	53	732249	1649817	85	716733	1647664
22	729041	1662138	54	738862	1650570	86	703403	1642410
23	734756	1661222	55	728344	1648967	87	699779	1645582
24	737794	1660171	56	726443	1647461	88	694120	1648068
25	741441	1660456	57	730782	1647867	89	705390	1659183
26	759409	1661567	58	733770	1648387	90	709669	1661888
27	731633	1660693	59	737649	1647752	91	707515	1665996
28	724217	1659620	60	740883	1648571	88	694120	1648068
29	727841	1659339	61	745176	1648979	89	705390	1659183
30	733193	1658756	62	753316	1647961	90	709669	1661888
31	729762	1658341	63	759779	1648405	91	707515	1665996
32	739848	1656870	64	734476	1646317			

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APPENDIX B

INFORMATION OF SUGARCANE IN THE CRUSHING SEASON

Table B Information of sugarcane each day in the crushing season of 2009/2010

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
26/11/2552	2,121.52	299.57	14.12	5.33	13.04	0	8.1	8.403	72.09	10.04	13.93	105	20.2
27/11/2552	4,954.51	1,351.08	27.27	5.78	13.04	0	8.68	9.84	74.72	10.451	13.99	246	20.14
28/11/2552	4,440.51	1,976.42	44.51	3.02	13.51	0	8.83	9.371	75.66	10.467	13.84	219	20.28
29/11/2552	4,096.18	1,993.90	48.68	3.73	13.04	0	8.93	9.124	76.06	10.606	13.94	196	20.9
30/11/2552	6,653.59	3,787.33	56.92	5.64	13.11	0	9.11	8.776	76.22	10.786	14.15	321	20.73
1/12/2552	5,798.55	3,201.83	55.22	4.93	13.18	0	9.14	9.142	76.22	10.778	14.14	283	20.49
2/12/2552	6,082.49	3,553.92	58.43	5.92	13.29	0	9.46	9.49	77.29	11.083	14.34	296	20.55
3/12/2552	5,244.86	3,279.52	62.53	5.32	13.37	0	9.44	10.119	77.32	11.065	14.31	243	21.58
4/12/2552	8,148.43	5,069.40	62.21	5.63	13.42	0	9.44	9.941	77.32	11.058	14.3	384	21.22
5/12/2552	8,216.25	5,066.03	61.66	4.29	13.35	0	9.62	9.947	77.6	11.231	14.47	384	21.4
6/12/2552	7,944.51	5,089.99	64.07	7.76	13.23	0	10.07	9.523	78.88	11.623	14.74	359	22.13
7/12/2552	8,906.82	5,211.27	58.51	7.65	13.3	0	9.89	9.156	78.46	11.47	14.61	406	21.94
8/12/2552	11,647.95	7,181.85	61.66	11.71	13.34	0	9.85	9.09	78.2	11.436	14.62	526	22.14
9/12/2552	11,935.19	7,095.37	59.45	6.89	13.4	0	9.99	9.959	78.47	11.567	14.74	541	22.06
10/12/2552	13,259.02	7,849.73	59.2	5	13.33	0	10.24	10.022	78.91	11.806	14.96	596	22.25
11/12/2552	15,207.52	9,370.49	61.62	5.05	13.27	0	10.37	10.227	79.27	11.928	15.05	683	22.27

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
12/12/2552	16,653.80	10,428.23	62.62	6.91	13.27	0	10.292	9.758	78.92	11.881	15.05	736	22.63
13/12/2552	19,957.93	12,153.57	60.9	5.48	13.24	0	10.355	10.231	78.99	11.932	15.1	877	22.76
14/12/2552	17,354.19	10,668.23	61.47	6.47	13.3	0	10.38	10.302	79.11	11.952	15.11	772	22.48
15/12/2552	26,547.48	16,633.48	62.66	5.33	13.28	0	10.492	10.625	79.19	12.071	15.24	1,172	22.65
16/12/2552	18,867.05	11,513.59	61.02	6.33	13.29	0	10.535	10.5	79.19	12.112	15.29	835	22.6
17/12/2552	18,977.18	12,065.00	63.58	5.74	13.26	0	10.553	10.28	79.26	12.141	15.32	843	22.51
18/12/2552	23,946.39	15,073.52	62.95	5.02	13.3	0	10.557	10.847	78.97	12.176	15.42	1,059	22.61
19/12/2552	22,623.87	14,674.06	64.86	5.47	13.28	0	10.646	10.572	79.04	12.268	15.52	1,012	22.36
20/12/2552	25,007.02	16,110.55	64.42	6.91	13.31	0	10.718	9.864	79.5	12.299	15.47	1,099	22.75
21/12/2552	22,812.94	14,414.32	63.18	7.57	13.28	0	10.778	10.724	79.51	12.36	15.55	1,005	22.7
22/12/2552	22,916.32	14,007.38	61.12	5.76	13.33	0	10.808	10.482	79.59	12.39	15.57	1,000	22.92
23/12/2552	25,137.69	15,674.72	62.36	5.47	13.35	0	10.941	10.586	79.76	12.524	15.7	1,093	23
24/12/2552	26,272.42	16,008.02	60.93	7.05	13.37	0	10.909	10.826	79.52	12.513	15.74	1,135	23.15
25/12/2552	26,672.74	16,415.67	61.54	5.17	13.31	0	11.001	10.997	79.48	12.623	15.88	1,159	23.01
26/12/2552	24,896.95	16,146.95	64.86	5.81	13.32	0	11.042	10.165	79.45	12.66	15.93	1,082	23.01
27/12/2552	23,799.92	15,298.51	64.28	5.8	13.35	0	10.972	10.214	79.22	12.629	15.94	1,029	23.13
28/12/2552	26,120.92	17,254.18	66.06	6.62	13.34	0	11.072	10.848	79.37	12.721	16.03	1,128	23.16
29/12/2552	28,127.84	17,977.37	63.91	5.87	13.32	0	10.995	10.86	79.02	12.673	16.04	1,215	23.15
30/12/2552	27,083.88	16,604.12	61.31	5.47	13.34	0	11.078	10.538	79.53	12.71	15.98	1,163	23.29
31/12/2552	25,403.54	15,124.96	59.54	6.05	13.38	0	11.136	10.735	79.66	12.755	16.01	1,114	22.8
1/1/2553	19,476.95	12,259.10	62.94	4.99	13.39	0	11.102	10.311	79.59	12.728	15.99	851	22.89
2/1/2553	3,816.97	2,565.91	67.22	4.86	13.32	0	10.98	9.105	79.31	12.625	15.92	164	23.27

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
3/1/2553	23,216.41	14,372.49	61.91	6.14	13.32	0	11.441	11.125	80.72	12.985	16.09	991	23.43
4/1/2553	25,257.66	16,071.85	63.63	4.91	13.3	0	11.447	10.921	80.76	12.994	16.09	1,088	23.21
5/1/2553	27,050.76	17,661.83	65.29	5.65	13.36	0	11.451	11.37	80.8	12.987	16.07	1,161	23.3
6/1/2553	26,425.20	17,149.09	64.9	5.69	13.49	0	11.428	11.305	80.68	12.986	16.1	1,149	23
7/1/2553	20,380.93	14,139.85	69.38	5.28	13.51	0	11.071	11.368	80.65	12.567	15.58	882	23.11
8/1/2553	7,840.52	4,577.15	58.38	6.64	13.53	0	11.17	10.394	81.57	12.578	15.42	360	21.78
9/1/2553	2,007.37	958.9	47.77	6.56	13.46	0	10.52	10.873	80.47	11.967	14.87	89	22.55
10/1/2553	11,457.27	6,405.83	55.91	5.43	13.44	0	10.898	10.147	80.8	12.359	15.3	539	21.26
11/1/2553	20,163.50	10,268.42	50.93	7.55	13.48	0	11.126	11.112	81.07	12.59	15.53	943	21.38
12/1/2553	16,919.97	9,528.02	56.31	5.8	13.5	0	11.092	11.117	80.44	12.624	15.69	787	21.5
13/01/2553	11,426.23	6,639.87	58.11	7.62	13.53	0	11.026	10.938	80	12.584	15.73	531	21.52
14/01/2553	24,074.56	14,358.35	59.64	4.69	13.69	0	11.256	11.085	80.42	12.806	15.92	1,105	21.79
15/01/2553	22,436.08	13,292.25	59.24	4.99	13.78	0	11.465	10.828	81.18	12.958	15.96	984	22.8
16/01/2553	19,329.18	11,521.91	59.61	5.45	13.83	0	11.336	11.47	80.68	12.867	15.95	848	22.79
17/01/2553	24,043.14	14,276.90	59.38	5.32	13.68	0	11.539	11.132	81.42	13.027	16	1,052	22.85
18/01/2553	24,174.30	14,210.83	58.78	5.37	13.71	0	11.621	11.001	81.57	13.093	16.05	1,051	23
19/01/2553	26,736.42	15,924.69	59.56	6.24	13.79	0	11.915	11.848	82.09	13.37	16.29	1,155	23.15
20/01/2553	26,051.63	15,337.97	58.88	6.91	13.85	0	11.776	11.55	81.88	13.248	16.18	1,119	23.28
21/01/2553	25,644.63	15,195.75	59.26	6.06	13.82	0	11.807	11.376	81.92	13.256	16.18	1,102	23.27
22/01/2553	23,478.49	14,624.69	62.29	6.25	13.75	0	11.784	11.691	82.37	13.196	16.02	993	23.64
23/01/2553	24,954.79	15,596.76	62.5	6.56	13.78	0	11.342	11.278	82.59	12.681	15.36	1,059	23.56
24/01/2553	21,809.71	13,149.13	60.29	6.54	13.8	0	11.328	11.325	82.8	12.653	15.28	939	23.23

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
25/01/2553	21,216.00	13,205.64	62.24	6.31	13.81	0	11.501	11.489	83.11	12.812	15.41	919	23.09
26/01/2553	23,562.89	14,820.35	62.9	7.06	13.8	0	11.476	11.23	82.7	12.815	15.49	1,014	23.24
27/01/2553	26,461.63	16,358.90	61.82	4.36	13.77	0	11.683	11.415	82.86	13.025	15.72	1,140	23.21
28/01/2553	28,085.76	18,198.95	64.8	7.09	13.81	0	11.817	11.215	82.61	13.201	15.98	1,188	23.64
29/01/2553	29,017.15	18,673.76	64.35	5.03	13.81	0	11.873	11.085	82.64	13.262	16.05	1,243	23.34
30/01/2553	22,790.09	14,264.21	62.59	7.26	13.86	0	11.87	11.648	82.52	13.264	16.07	987	23.09
31/01/2553	29,035.34	18,687.53	64.36	6.75	13.88	0	11.852	11.483	82.72	13.225	15.99	1,247	23.28
1/2/2553	15,543.78	9,851.67	63.38	6.32	13.86	0	11.823	11.435	82.75	13.195	15.95	665	23.37
2/2/2553	12,257.01	8,393.24	68.48	5.24	13.85	0	11.63	11.885	82.06	13.043	15.9	536	22.87
3/2/2553	26,940.37	17,764.44	65.94	5.7	13.83	0	11.738	11.836	82.26	13.16	16	1,178	22.87
4/2/2553	27,963.08	18,950.60	67.77	5.92	13.89	0	11.839	11.802	82.43	13.252	16.08	1,217	22.98
5/2/2553	25,768.34	17,655.87	68.52	5.16	13.87	0	11.791	11.786	82.46	13.171	15.97	1,117	23.07
6/2/2553	27,362.36	18,138.99	66.29	7.57	13.88	0	11.809	12.043	82.71	13.194	15.95	1,190	22.99
7/2/2553	26,895.75	18,555.50	68.99	7.72	13.98	0	11.915	11.783	82.79	13.284	16.05	1,153	23.33
8/2/2553	24,458.27	17,212.55	70.38	6.32	13.92	0	12.008	11.325	82.95	13.375	16.12	1,052	23.25
9/2/2553	23,957.87	16,814.00	70.18	5.5	13.92	0	11.97	11.187	82.79	13.349	16.12	1,037	23.1
10/2/2553	22,251.25	15,642.26	70.3	5.28	13.86	0	12.054	11.603	82.79	13.449	16.24	949	23.45
11/2/2553	17,718.43	12,611.98	71.18	5.61	13.89	0	12.049	11.842	82.63	13.457	16.29	763	23.22
12/2/2553	28,271.03	20,243.72	71.61	7.75	13.92	0	11.99	12.393	82.32	13.419	16.3	1,214	23.29
13/02/2553	29,205.15	20,926.93	71.65	4.5	13.9	0	12.028	11.709	82.4	13.457	16.33	1,243	23.5
14/02/2553	26,567.56	19,602.11	73.78	4.95	13.93	0	12.062	11.788	82.39	13.496	16.38	1,128	23.55
15/02/2553	26,779.70	20,097.28	75.05	3.47	13.95	0	12.029	11.712	82.46	13.449	16.31	1,152	23.25

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
16/02/2553	21,937.91	15,519.34	70.74	5.63	13.94	0	11.983	12.15	82.42	13.416	16.28	940	23.34
17/02/2553	27,912.57	20,675.37	74.07	7.06	13.92	0	12.183	12.118	82.58	13.62	16.49	1,207	23.13
18/02/2553	27,565.66	19,919.39	72.26	5.31	13.94	0	12.118	11.914	82.57	13.556	16.42	1,187	23.22
19/02/2553	26,394.70	19,232.88	72.87	3.94	13.96	0	12.162	12.124	82.79	13.57	16.39	1,107	23.84
20/02/2553	27,352.65	19,878.17	72.67	6.86	13.97	0	12.077	11.923	82.7	13.48	16.3	1,160	23.58
21/02/2553	26,533.89	19,282.78	72.67	6.69	13.96	0	12.13	12.039	82.78	13.539	16.35	1,124	23.61
22/02/2553	27,344.85	20,054.62	73.34	7.62	13.95	0	12.122	12.427	82.84	13.519	16.32	1,174	23.29
23/02/2553	24,980.67	18,884.21	75.6	6.02	13.99	0	12.162	12.156	82.67	13.577	16.42	1,083	23.07
24/02/2553	26,924.43	20,340.67	75.55	5.15	13.98	0	12.242	12.163	82.57	13.691	16.58	1,150	23.41
25/02/2553	23,964.60	17,992.40	75.08	7.29	14.01	0	12.262	12.334	82.62	13.694	16.57	1,030	23.27
26/02/2553	26,482.04	19,548.10	73.82	6.71	14.04	0	12.402	12.352	82.95	13.82	16.66	1,127	23.5
27/02/2553	22,496.87	17,063.10	75.85	5.1	14.11	0	12.354	12.057	82.84	13.777	16.63	941	23.91
28/02/2553	27,487.23	21,061.16	76.62	5.6	14.12	0	12.445	12.146	82.75	13.895	16.79	1,156	23.78
1/3/2553	23,996.28	17,896.88	74.58	4.12	14.02	0	12.374	11.871	81.96	13.895	16.95	1,017	23.6
2/3/2553	25,602.44	19,543.17	76.33	3.75	14.05	0	12.444	11.978	82.57	13.918	16.86	1,086	23.57
3/3/2553	19,429.68	14,263.15	73.41	7.42	14.09	0	12.379	12.301	82.36	13.863	16.83	828	23.47
4/3/2553	12,416.17	9,116.71	73.43	6.18	14.1	0	12.257	12.028	81.65	13.805	16.91	536	23.16
5/3/2553	24,946.19	18,585.07	74.5	4.5	14.05	0	12.431	12.367	82.15	13.941	16.97	1,058	23.58
6/3/2553	18,121.67	13,579.29	74.93	5.44	14.07	0	12.495	12.23	82.16	14.038	17.09	776	23.35
7/3/2553	24,864.57	18,709.06	75.24	5.76	14.09	0	12.466	12.056	82.21	13.984	17.01	1,040	23.91
8/3/2553	23,708.05	17,678.04	74.57	5.25	14.07	0	12.395	11.893	81.96	13.916	16.98	1,001	23.68
9/3/2553	24,529.22	18,501.56	75.43	4.95	14.09	0	12.477	12.665	82.26	13.985	17	1,032	23.77

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
10/3/2553	22,040.23	16,567.43	75.17	5.72	14.12	0	12.519	12.322	82.31	14.022	17.04	927	23.78
11/3/2553	26,716.81	19,343.93	72.4	5.51	14.15	0	12.486	12.243	82.25	13.993	17.01	1,132	23.6
12/3/2553	27,166.67	19,297.23	71.03	5.51	14.13	0	12.465	11.525	82.85	13.89	16.76	1,135	23.94
13/03/2553	26,900.51	19,560.96	72.72	6.36	14.16	0	12.595	12.432	82.91	14.049	16.94	1,122	23.98
14/03/2553	23,997.44	18,032.20	75.14	5.75	14.01	0	12.689	12.174	82.8	14.156	17.1	1,004	23.9
15/03/2553	23,306.12	17,792.33	76.34	7.03	13.91	0	12.623	12.578	82.77	14.103	17.04	997	23.38
16/03/2553	19,653.38	15,069.40	76.68	5.21	13.85	0	12.672	12.22	82.89	14.125	17.04	840	23.4
17/03/2553	19,412.59	15,816.24	81.47	5.69	13.92	0	12.654	12.36	83.08	14.102	16.97	851	22.81
18/03/2553	20,910.16	16,225.45	77.6	6.14	13.99	0	12.536	12.495	82.95	13.972	16.84	908	23.03
19/03/2553	21,133.67	16,853.92	79.75	6.01	14.03	0	12.656	12.172	83.07	14.088	16.96	904	23.38
20/03/2553	23,237.57	18,151.08	78.11	5.7	14.1	0	12.712	12.3	82.91	14.161	17.08	994	23.38
21/03/2553	18,153.30	14,984.38	82.54	5.78	14.13	0	12.795	13.28	82.98	14.252	17.18	774	23.45
22/03/2553	19,640.98	15,766.50	80.27	5.48	14.16	0	12.655	12.254	82.66	14.137	17.1	857	22.92
23/03/2553	17,295.80	13,894.57	80.33	5.06	14.13	0	12.706	11.969	82.91	14.163	17.08	752	23
24/03/2553	8,531.75	6,456.15	75.67	6.08	14.07	0	12.515	12.785	82.16	14.037	17.09	371	23
25/03/2553	11,153.93	8,394.83	75.26	6.97	14.14	0	12.499	12.289	81.72	14.071	17.22	489	22.81
26/03/2553	21,734.67	17,341.27	79.79	5.82	14.17	0	12.883	12.783	82.19	14.438	17.57	939	23.15
27/03/2553	15,028.29	12,465.50	82.95	5.93	14.08	0	12.741	12.65	82.91	14.194	17.12	662	22.7
28/03/2553	16,028.01	12,873.79	80.32	4.45	14	0	12.7	13.246	82.89	14.164	17.09	690	23.23
29/03/2553	15,081.43	11,960.94	79.31	6.35	13.9	0	12.83	12.087	83.21	14.27	17.15	652	23.13
30/03/2553	11,061.43	8,701.21	78.66	5.89	13.94	0	12.93	12.811	83.18	14.377	17.28	496	22.3
31/03/2553	11,225.66	8,998.75	80.16	7.63	13.95	0	12.97	11.959	83.19	14.432	17.35	504	22.27

Table B Information of sugarcane each day in the crushing season of 2009/2010 (cont.)

date	Cane Crushed (tons)	Burn Cane (tons)	Burn Cane (%)	Trash %	Fiber % (O.C.S.)	Fiber % (Q.C. Lab.)	C.C.S. % (O.C.S.)	C.C.S. % (Q.C. Lab.)	Purity	Pol %	Brix %	Cane Trucks	Tons per Trucks
1/4/2553	8,854.82	7,339.09	82.88	5.1	14.01	0	12.85	12.859	82.92	14.333	17.29	395	22.42
2/4/2553	7,456.96	5,827.02	78.14	5.53	14.14	0	12.83	12.23	82.92	14.311	17.26	337	22.13
3/4/2553	7,144.95	5,743.34	80.38	5	14.04	0	12.53	12.315	82.19	14.052	17.1	324	22.05
4/4/2553	4,541.73	3,583.02	78.89	5.14	14.08	0	12.49	13.302	81.65	14.062	17.22	212	21.42
5/4/2553	4,173.05	3,545.89	84.97	5.89	14.1	0	12.78	13.369	82.54	14.294	17.32	192	21.73
6/4/2553	3,828.53	3,288.31	85.89	5.95	14.14	0	12.59	12.133	81.8	14.165	17.32	187	20.47
7/4/2553	2,402.00	2,097.09	87.31	6.31	14.11	0	12.68	12.991	82.09	14.235	17.34	111	21.64
8/4/2553	2,298.51	2,050.77	89.22	5.82	14.04	0	12.56	12.611	81.81	14.117	17.26	109	21.09
9/4/2553	2,720.66	2,474.67	90.96	5.82	13.99	0	12.35	12.73	54.14	13.931	25.73	138	19.71

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APPENDIX C
DISTANCE BETWEEN LOCATIONS

Table C Distance between sugar collection and purchase center in 91 locations.

Object ID	Shape	Name	Total_minutes
1	Polyline M	Location 1 - Factory	92.480793
2	Polyline M	Location 2 - Factory	95.011179
3	Polyline M	Location 3 - Factory	95.230572
4	Polyline M	Location 4 - Factory	86.425881
5	Polyline M	Location 5 - Factory	85.08236
6	Polyline M	Location 6 - Factory	85.830377
7	Polyline M	Location 7 - Factory	87.269521
8	Polyline M	Location 8 - Factory	86.354983
9	Polyline M	Location 9 - Factory	79.444657
10	Polyline M	Location 10 - Factory	78.119777
11	Polyline M	Location 11 - Factory	79.176212
12	Polyline M	Location 12 - Factory	84.282398
13	Polyline M	Location 13 - Factory	78.065948
14	Polyline M	Location 14 - Factory	76.898524
15	Polyline M	Location 15 - Factory	82.883085
16	Polyline M	Location 16 - Factory	78.521212
17	Polyline M	Location 17 - Factory	73.251507
18	Polyline M	Location 18 - Factory	68.432473
19	Polyline M	Location 19 - Factory	67.262419
20	Polyline M	Location 20 - Factory	72.057531
21	Polyline M	Location 21 - Factory	78.23748
22	Polyline M	Location 22 - Factory	67.52961
23	Polyline M	Location 23 - Factory	66.019215
24	Polyline M	Location 24 - Factory	59.953868
25	Polyline M	Location 25 - Factory	61.624048
26	Polyline M	Location 26 - Factory	91.262926
27	Polyline M	Location 27 - Factory	67.047871
28	Polyline M	Location 28 - Factory	64.352755
29	Polyline M	Location 29 - Factory	62.120902
30	Polyline M	Location 30 - Factory	59.912271
31	Polyline M	Location 31 - Factory	60.45829
32	Polyline M	Location 32 - Factory	55.814857

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Table C Distance between sugar collection and purchase center in 91 locations (cont.).

Object ID	Shape	Name	Total_minutes
33	Polyline M	Location 33 - Factory	58.493326
34	Polyline M	Location 34 - Factory	82.096176
35	Polyline M	Location 35 - Factory	84.236161
36	Polyline M	Location 36 - Factory	59.58701
37	Polyline M	Location 37 - Factory	58.395465
38	Polyline M	Location 38 - Factory	55.251616
39	Polyline M	Location 39 - Factory	55.598675
40	Polyline M	Location 40 - Factory	54.67439
41	Polyline M	Location 41 - Factory	55.494462
42	Polyline M	Location 42 - Factory	55.623278
43	Polyline M	Location 43 - Factory	53.784877
44	Polyline M	Location 44 - Factory	53.226278
45	Polyline M	Location 45 - Factory	49.613923
46	Polyline M	Location 46 - Factory	50.099316
47	Polyline M	Location 47 - Factory	53.134753
48	Polyline M	Location 48 - Factory	54.785206
49	Polyline M	Location 49 - Factory	51.746731
50	Polyline M	Location 50 - Factory	44.912081
51	Polyline M	Location 51 - Factory	46.159806
52	Polyline M	Location 52 - Factory	51.388237
53	Polyline M	Location 53 - Factory	40.991411
54	Polyline M	Location 54 - Factory	47.160923
55	Polyline M	Location 55 - Factory	38.915915
56	Polyline M	Location 56 - Factory	37.645656
57	Polyline M	Location 57 - Factory	36.70529
58	Polyline M	Location 58 - Factory	38.933743
59	Polyline M	Location 59 - Factory	46.301559
60	Polyline M	Location 60 - Factory	50.808253
61	Polyline M	Location 61 - Factory	58.803909
62	Polyline M	Location 62 - Factory	70.932578
63	Polyline M	Location 63 - Factory	78.27704
64	Polyline M	Location 64 - Factory	38.815948
65	Polyline M	Location 65 - Factory	31.621958
66	Polyline M	Location 66 - Factory	33.583637
67	Polyline M	Location 67 - Factory	31.345917
68	Polyline M	Location 68 - Factory	50.192344
69	Polyline M	Location 69 - Factory	40.830079
70	Polyline M	Location 70 - Factory	35.473014
71	Polyline M	Location 71 - Factory	42.835578

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Table C Distance between sugar collection and purchase center in 91 locations (cont.).

Object ID	Shape	Name	Total_minutes
72	Polyline M	Location 72 - Factory	66.201445
73	Polyline M	Location 73 - Factory	28.434667
74	Polyline M	Location 74 - Factory	29.961027
75	Polyline M	Location 75 - Factory	44.051655
76	Polyline M	Location 76 - Factory	21.459286
77	Polyline M	Location 77 - Factory	27.456967
78	Polyline M	Location 78 - Factory	51.194708
79	Polyline M	Location 79 - Factory	33.869844
80	Polyline M	Location 80 - Factory	29.409067
81	Polyline M	Location 81 - Factory	35.628809
82	Polyline M	Location 82 - Factory	49.996896
83	Polyline M	Location 83 - Factory	49.545458
84	Polyline M	Location 84 - Factory	28.460416
85	Polyline M	Location 85 - Factory	36.839039
86	Polyline M	Location 86 - Factory	61.196461
87	Polyline M	Location 87 - Factory	72.894749
88	Polyline M	Location 88 - Factory	86.981322
89	Polyline M	Location 89 - Factory	68.187221
90	Polyline M	Location 90 - Factory	68.987036
91	Polyline M	Location 91 - Factory	79.492521

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APPENDIX D
RELATED PICTURES

Picture D1 "Purchasing-system problem solving" meeting at sugar factory in Saraburi.

Picture D2 "Producing-system problem solving" meeting at sugar factory in Saraburi.

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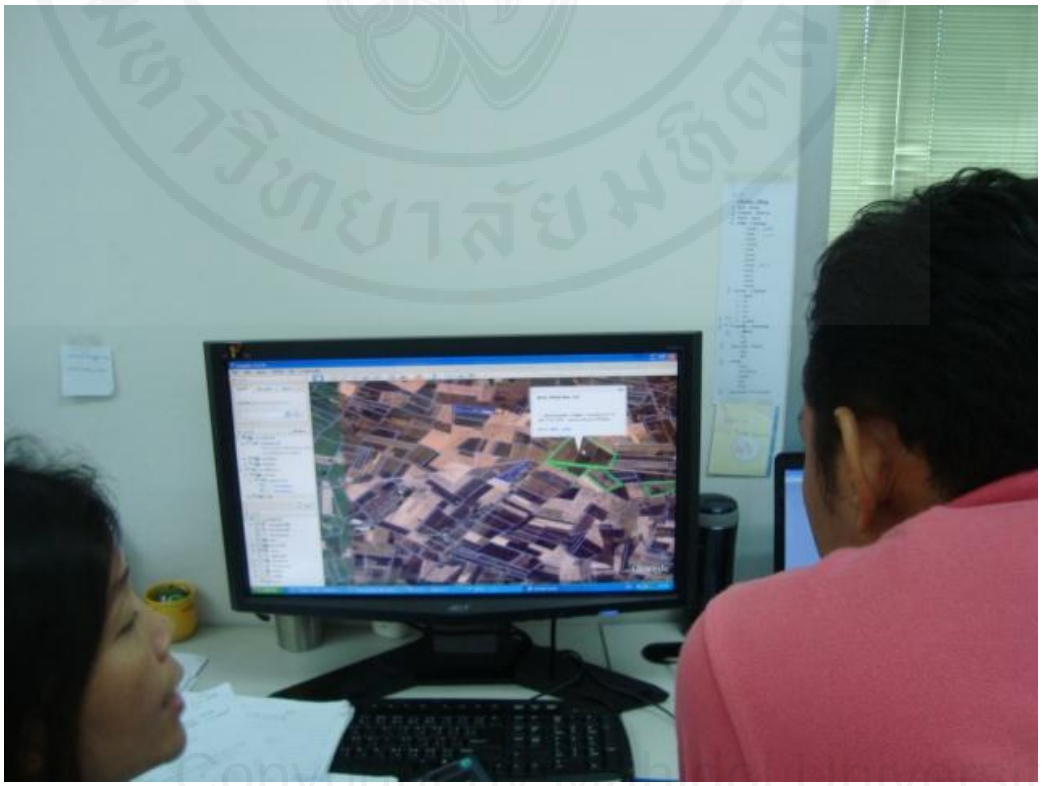
Picture D3 "Sugarcane-farmers' plantation-area" observation at sugar factory in Saraburi

Picture D4 Image from a meeting to solve producing system at sugar factory in Saraburi

Picture D5 Image from a meeting to solve producing system at sugar factory in Saraburi



Picture D6 Image from the analysis of sugar cane farmers' plantation with GoogleMap

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