IMPACT OF SUGAR MILL LIBERALIZATION ON INBOUND LOGISTICS OF SUGARCANE AND SUGAR PRODUCTION

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Thesis
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ABSTRACT

This research studied the impact of sugar mill liberalization on the inbound logistics of sugarcane and sugar production. The transportation mathematical model and Geographic Information System (GIS) were proposed as the analytical tools. Three main cases were analyzed based on the data from the production year 2008/2009 in Thailand. In case 1 with the optimal current situation of 46 mills, the results showed 95.24%, 43.08 kilometers, and 12,615,129,290 Baht for the overall capacity utilization, average transportation distance, and total transportation cost, respectively. In case 2, the liberalization could be achieved by adding a mill to the Eastern Region. This negatively affects the capacity utilization in the region and slightly decreases the average transportation distance and total transportation cost. In case 3, the recent cabinet resolutions regarding the relocation and/or capacity expansion of several mills were tested. The results showed a worsening overall capacity utilization to only 84.34%. Several mills might be severely affected by an insufficient amount of sugarcane. This emphasizes the utmost importance of the balance between sugarcane production and sugar mill capacity. In addition, sensitivity analyses were also carried out to investigate the impact of sugar mill liberalization due to the uncertainty of the sugarcane yield.

KEY WORDS: SUGAR MILL LIBERALIZATION / INBOUND LOGISTICS / TRANSPORTATION MODEL / GEOGRAPHIC INFORMATION SYSTEM / CABINET RESOLUTION

241 pages

ผลกระทบของการเปิดเสรีโรงงานน้ำตาลที่มีต่อระบบโลจิสติกส์ขาเข้าของอ้อยและการผลิตน้ำตาล
IMPACT OF SUGAR MILL LIBERALIZATION ON INBOUND LOGISTICS OF SUGARCANE AND SUGAR PRODUCTION

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลกระทบของการเปิดเสรีโรงงานน้ำตาลที่มีต่อระบบโลจิสติกส์ขาเข้าของอ้อยและการผลิตน้ำตาล โดยประยุกต์ใช้ตัวแบบจำลองคณิตศาสตร์การขนส่งและระบบภูมิศาสตร์สารสนเทศเป็นเครื่องมือสำหรับการวิเคราะห์ ซึ่งแบ่งการศึกษาออกเป็น 3 กรณี ได้แก่ กรณีที่ 1 ภายใต้สถานการณ์เหมาะสมที่สุดของปัจจุบัน (ปีการผลิต 2551/52) พบว่า อัตราการใช้กำลังการผลิตโดยรวมสูงถึง 95.24% ระยะทางขนส่งเฉลี่ยโดยรวมของระบบอยู่ที่ 43.08 กิโลเมตร ต้นทุนการขนส่งอ้อยไปยังโรงงานน้ำตาลอยู่ที่ 12,615,129,290 บาท กรณีที่ 2 การเพิ่มโรงงานน้ำตาลในภาคตะวันออกเสมือนให้มีการเปิดเสรีโรงงาน 1 โรง พบว่า อัตราการใช้กำลังการผลิตในภาคตะวันออกลดลงอย่างมาก ระยะทางขนส่งเฉลี่ยโดยรวมและต้นทุนค่าขนส่งรวมลดลงเล็กน้อย และกรณีที่ 3 การปฏิบัติตามมติคณะรัฐมนตรีที่เกี่ยวข้องกับการย้าย และ/หรือขยายกำลังการผลิตของโรงงานน้ำตาล ในขณะที่ปริมาณอ้อยเท่ากับปีการผลิต 2551/2552 พบว่า อัตราการใช้กำลังการผลิตโดยรวมลดลงมากเหลือเพียง 84.34% โรงงานน้ำตาลหลายแห่งได้รับอ้อยไม่เพียงพอ ซึ่งเป็นการเน้นย้ำความสำคัญของสมดุลย์ระหว่างปริมาณอ้อยกับกำลังการผลิตในการพิจารณาการเปิดเสรีโรงงานน้ำตาล นอกจากนี้ยังวิเคราะห์ความอ่อนไหวเพื่อให้ทราบถึงผลกระทบของการเปิดเสรีโรงงานน้ำตาล เมื่อปริมาณผลผลิตอ้อยมีความไม่แน่นอนอีกด้วย

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CHAPTER I
INTRODUCTION

1.1 Background of the problem

Sugarcane and sugar industry is important for Thailand in various aspects such as providing employment in both agricultural and industrial sectors and serving sugar consumption. As a major exporter of agricultural products in the world market, Thailand can produce a great quantity of sugar cane for supporting the country's sugar mills that produce sugar to be exported to global markets. In 2008, exportation of approximately 5,000,000 tons of sugar could bring foreign money into the country for over 47,600 million Baht (Office of Agricultural Economics, 2008), as shown in Table 1.1, which presents detailed comparison of Thailand's sugar exportations during 2007 – 2009.

As seen in Table 1.1, the growth trend of sugarcane and sugar industry in Thailand seems to be continuously increasing. In addition, this industry is important to the country since it involves people from various sectors including sugarcane farmers, sugar farm workers, sugar mill owners, sugar mill labors, as well as sugar consumer throughout the country. It can be said that sugarcane and sugar industry plays important roles in both agricultural sector and industrial sector. Since sugar is essential for daily living of human beings, sugar production can undoubtedly expand much further. Expansion of sugar production and sugar exportation to overseas will add income to the country continuously.

Table 1.1 Comparison of monthly sugar exportations of Thailand during 2007 – 2009.

Quantity: tons, Value: million Baht

Month	2007		2008		2009	
	Quantity	Value	Quantity	Value	Quantity	Value
January	295,041	3,155	355,915	3,238	264,067	2,654
February	389,106	4,186	344,202	3,089	395,507	4,222
March	512,809	5,230	378,600	3,541	455,753	5,218
April	587,763	5,763	387,326	3,368	528,753	5,990
May	441,317	4,556	447,391	4,050	476,343	5,772
June	570,211	5,449	583,964	5,441	461,357	5,664
July	439,649	4,132	663,045	6,241	461,207	5,641
August	342,425	3,266	597,341	5,510	401,093	5,058
September	219,699	2,107	374,462	3,810	448,512	5,723
October	233,353	2,230	323,499	3,469	438,458	5,829
November	230,173	2,176	317,298	3,353	407,380	5,453
December	164,533	1,558	238,780	2,530	314,139	4,362
Total	4,426,077	43,807	5,011,823	47,638	5,052,570	61,586

Historically, sugarcane and sugar industry in Thailand has been improving greatly, making the country change status from a sugar importer to become a major sugar exporter at present. The industry recently can bring money from overseas into the country for several tens billion Baht yearly. According to this importance, the government has taken action to play its role in this industry by setting up regulations for administering sugarcane and sugar industry as well as permitting a new sugar entrepreneur under the Sugarcane and Sugar Act, B.E. 2527 (1984). The act, which has been enforced for over 20 years, now seems to be somehow obsolete or inappropriate to be used with current situation. Analyses on condition of sugarcane and sugar industry in Thailand suggested that there should be reformation of structure and system of sugarcane and sugar industry. Two options have been suggested; namely,

1) No actions shall be taken, and leave sugarcane and sugar industry continue its processes like the previous situation.

2) Protection and control from the government should be reduced by means of, for example, establishing new sugar mills and/or allowing sugar mills to expand their production capacity freely (Office of the Cane and Sugar Board, 2009a).

1.2 Importance of the problem

The trend of world economic at present is going toward free trading system more and more for all merchandised items, including sugar products. This raises a question in Thailand whether the government should have a new policy to allow establishment of new sugar mills, relocation of existing mills, and capacity expansion of existing mills. The industry has long been controlled by the Sugarcane and Sugar Act, B.E. 2527 (1984), which controls the whole system of sugarcane and sugar industry starting from administration in sugarcane farm, sugar production in sugar mills, and exportation of sugar products, as well as new establishment of sugar mills. The act that has brought some stability to the growth of sugarcane and sugar industry is now seemed to be unsuitable due to globalization that has changed the world economy. With government's intervention by protecting the industry, entrepreneurs would lack of motivation to enhance their performance, be unable to rely on them, and be unable to compete with competitors in free trading markets. Therefore, sugarcane and sugar industry of Thailand is still in unreliable situation, and is not truly going toward sustainable development (Sanglor, 2004). Discussions and arguments among experts and stakeholders have been made on whether the government should allow the establishment of new sugar mills, relocation of existing mills, and expansion of production capacity of existing mills. Their opinions are different mainly in the aspect of benefits as to be listed below (Siamwala et al., 1993)

1) In the view of entrepreneurs of small sugar mills, which are old mills situated in areas with high competition on sugarcane, they agree with the strategies to allow existing mills to move to new areas where there is more sugarcane and allow expansion of production capacity. However, they disagree with the idea to allow

establishment of new sugar mills. They argue that new establishment of sugar mill will cause more severe competition on sugarcane purchasing.

2) In the view of entrepreneurs of large sugar mills that have recently been established and situated in areas without problems of sugarcane supply, particularly in the Northeastern region, they opined that the government should not allow the establishment of new sugar mills, relocation of existing mills, and expansion of production capacity. They reasoned that sugar mills are currently unable to process with their full production capacity due to insufficient quantity of sugarcane. Allowing new establishments of sugar mills in these areas would affect existing mills and cause more intense competition.

3) In the view of entrepreneurs who do not own a sugar mill at present, they absolutely agree to the permission of new establishment of sugar mills. They gave an opinion that, by having more sugar entrepreneurs, policies of the government can be implemented easier. Sugar industry at present does not allow free competition, and that makes sugar entrepreneurs gain unreasonable profits. However, it is expected that, after these new entrepreneurs have owned sugar mills, they would also request the government to disallow new establishment, relocation, and capacity expansion of sugar mills.

According to the afore-mentioned suggestions, conclusion on free establishment and expansion of sugar mills cannot be made. However, the cabinet has allowed relocation of existing sugar mills from areas with inadequate quantity of sugarcane to areas with more sugarcane supply. The government also allows capacity expansion of newly established mills to match supply of sugarcane in the new area. Existing mills are also allowed to expand their production capacity if quantity of sugarcane supply exceeds their existing capacity. It can be concluded that, in the views of either the government or the entrepreneurs, free system to be used with establishment or relocation of sugar mills should particularly considers quantity of sugarcane supply, since sugar cane is a main material for sugar production.

There are three major processes involving sugarcane and sugar industry; namely, inbound logistics which refers to the process of receiving sugarcane as a raw material for sugar production in sugar mills, sugar production which refers to the process of producing sugar in sugar mills, and outbound logistics which refers to the process of delivering sugar products to customers (Taechasook, 2008). The process of inbound logistics is highly important for sugar production of sugar mills, since sugarcane is the main material for production process. Therefore, to consider about allowing establishment of new sugar mills, relocation of existing mills, and capacity expansion of existing mills, the first aspect to study is their impact on inbound logistics. This research proposes a quantitative methodology for analyzing the impacts that might happen to inbound logistics of sugarcane to sugar mills. This research divides its impact analysis into four parts; namely, the optimal capacity utilization, the optimal transportation distance, the optimal transportation pattern, and the optimal transportation cost. The analyses also consider the sensitivity of impacts due to changes of sugarcane production. The research will provide fruitful guidelines on liberalization policies by the government in the future.

1.3 Research objectives

This research sets up two main objectives; namely,

1) To study the impacts from the liberalization policy on the sugar mill establishment regarding the inbound logistics of sugarcane and the utilization of sugar mill capacity.

2) To provide some suggestions and guidelines for liberalization policies regarding the new establishment of sugar mills.

1.4 Scope of the research

This research studies about impacts of liberalization policies on sugar mills with the following scope.

1) Data regarding quantity of sugar production to be used for analyses are data of the year 2008/2009, which was obtained from Office of the Cane and Sugar Board.

2) The research analyzes effects of liberalization policies on the utilization of sugar mills capacity.

3) The research analyzes changes the transportation distance due to the implementation of liberalization policies.

4) The research analyzes changes in patterns of sugarcane transportation due to the implementation of liberalization policies.

5) The research analyzes effects of liberalization policies on inbound logistics cost.

This chapter has discussed about background and importance of conducting this research. It provides clear understanding that sugarcane and sugar industry is highly important for both agricultural and industrial sectors in Thailand. Therefore, before implementing liberalization policies on sugar mills, comprehensive study should be carried out on impacts in all aspects, especially the impacts on inbound logistics process, which is highly important for sugar production of sugar mills. By analyzing the impacts, it is expected to know advantages and disadvantages of free trading implementation that will be useful for planning future liberalization policies. The next chapter will review relevant theories and researches that will provide fundamental knowledge required for understanding topics and issues of interest in this study.

CHAPTER II
LITERATURE REVIEW

This is a research to study the impacts from the liberalization policy of sugar mill on the processes of inbound logistics of sugarcane transportation into sugar mills. Therefore, this literature review chapter has been made by collecting relevant data from researches regarding sugarcane and sugar industry in order to review issues of interest in past researches and to learn the general characteristics of this industry. It is expected that the literature review will provide fundamental understandings required for achieving the research's goals.

2.1 Background of sugarcane and sugar industry

Sugarcane and sugar industry of Thailand is believed to start since Sukhothai Kingdom. At that time, sugar manufacturing did not involve so many machines or equipment. In the Sukhothai Era, sugar was produced by using hands to squeeze sugarcane to obtain fresh sugar juice. The juice was simmered until it turned to Mascovado (brown sugar), which were exported to overseas. Sugar industry has continuously been developed and expanded since then. A remarkably prosperous era of sugar industry came during the period of King Rama II of Rattanakosin Kingdom, when sugarcane fields were very huge. Later sugar industry became silent due to the diminished demand caused by too much sugar production. Price of sugar was very low, and that forced sugar industry to shut down in 1899.

In 1921, sugar industry recovered. However, sugar production could not meet demand of domestic consumption. Thus the government allowed vendors to import sugar from neighboring countries to serve domestic demand.

In 1937, the government realized importance of this industry. Therefore, the first white sugar mill has been established in Lampang province.

In 1942, the second white sugar mill was established in Uttaradit province. It was the same year that the government has founded the “Thai Industry Promotion Company Limited”, of which the major share was hold by the Ministry of Industry and the Ministry of Finance. The two white sugar mills were handed over to Thai Industry Promotion Co., Ltd. Later the company established 11 more sugar mills, situated in Udonthani, Lampang, Ubonratchathani, Nakhonratchasima, and Chonburi provinces.

In 1947, Thai Industry Promotion Co., Ltd. handed over all sugar mills to be administered by “Thai Sugar Organization”, an organization under the authority of the Ministry of Industry.

In 1948, many more sugar mills have been established. Among these new sugar mills, 6 of them belonged to the government and 16 of them belonged to the private companies. Later, there were excessive fields of sugar cane, which caused prices of sugarcane and sugar became declined.

In 1952, the declined price of sugar caused much trouble to sugarcane farmers and sugar mills. Hence the government decided to set up “Sugar Industry of Thailand Company Limited” in 1953 in order to be the sole sugar importer/exporter in Thailand. Meanwhile, the Thai Sugar Organization was responsible for taking care of production processes together with private entrepreneurs.

In 1959, the government formed the Board of Investment for Industrial Business. The Board encouraged and supported private entrepreneurs to set up more sugar mills. Number of sugar mills increased to 48 mills altogether. However, according to the situation of the world sugar market at that time, this increment of sugar mills was inappropriate. Sugar industry arrived at its saturation point because of sugar over supply in the market. Domestic sugar price in Thailand decreased greatly, and the government did not have pricing policy to assure sugar price. Therefore, the cabinet decided to prohibit sugar import, with the exception for only sugar used in the soft drink industry.

During 1960 – 1971, sugar production was more than sugar demand. The government had to forbid establishment of new sugar mills and disallow capacity expansion of existing sugar mills. Price of sugar which was sold below production cost resulted in the discontinuation of many sugar mills. Only 27 mills remained. The government attempted to find strategies to assist sugar entrepreneurs by supporting them to move their mills to more appropriate sites and to replace their old sugar manufacturing machines with the new ones.

During 1974 – 1977, price of sugar in the world market went down again due to the excessive sugar production. This was mainly because of the new establishment and expansion of sugar mills in foreign countries. Thus quantity of sugar was much more than market's demand. The Thai government therefore had policy to prohibit establishment of new sugar mills and expansion of existing sugar mills for 5 years (from 1977 to 1981), which was the implementation period of the 4th National Economic and Social Development Plans. However, sugar mills were allowed to change their machines as long as those new machines do not contribute to the expansion in capacity of sugar production.

In 1984, the government declared the Sugar Industry Act on August 8, 1984. Important contents of the act stated about benefit sharing system to be employed in the sugarcane and sugar industry.

During 1985 – 2008, the number of sugar mills has increased to 47 mills in total.

According to the background of sugarcane and sugar industry, it is observable that the government has been playing roles to protect and solve problems in this industry. For example, when sugar price in the world market went down because of excessive sugar production, the cabinet had a policy to prohibit establishment of new sugar mills and capacity expansions of existing mills. That was because the government realized that if new mills were established, there would have been more production and would have caused damage to the industry. This would eventually cause detrimental impacts on sugarcane farmers. On the contrary, when there was shortage of sugar supply, the government ceased the command of such prohibition. Additionally, the government supported sugar mills to expand their production capacities. In the case of sugarcane quantity becoming too high comparing to existing production capacity of sugar mills, the government would soften its policy regarding production capacity expansion. In that case, sugar mills were allowed to expand their production capacity in certain troubled areas. Sugar mills that had problems of sugarcane shortage were also allowed to move to the new sites and expand their capacity to meet sugarcane supply in those new regions.

The government has been playing active roles to protect this industry. The current effective law for this industry is the Cane and Sugar Act, BE 2527 (1984). However, the law has never been amended to keep up with changes in economical situations due to globalization. Analyses on the condition of sugarcane and sugar industry in Thailand suggest that the act still emphasizes on protecting this industry, leading to the lack of motivation to improve the industry's capability to be able to compete in the global free-trade markets. Therefore, sugar and sugarcane industry of Thailand is still in unreliable situation, and is not going toward true development (Sanglow, 2004). After analyzing the situation, stakeholders of sugarcane and sugar industry have realized importance of the problem and agreed that structure of this industry shall be reformed. On December 1st, 2005, Ministry of Industry has set up a working committee, called The Cane and Sugar Board, to solve problems of sugarcane and sugar industry by reforming the whole system. The Board consists of the minister of the Industry Ministry, as the chairman, and representatives from relevant organizations from governmental and private sectors, Sugarcane Farmers Institute, sugar mills, and experts from academic institutions. The Board proposed two options as solutions to the problems, namely (Office of the Cane and Sugar Board, 2009a).

Option 1

No action is needed to be taken. This option suggests that sugarcane and sugar industry shall be allowed to follow its previous path. Strict mechanisms to control all procedures shall still be enforced. Negotiations for agreements shall still be bargained to protect benefit of each side. Any encountered problems will be solved case by case.

Option 2

Adjustment of the whole system of sugarcane and sugar industry shall be performed in order to fully comply with free trading system. The system shall be allowed to be controlled by market mechanisms. This will enable problems of the system to be solved truly and efficiently. For this adjustment, these principles below shall be followed.

1) Let quantity and price of sugar to be controlled by market mechanisms.

2) Reduce protection and enforcement from the government

3) Change the role of government sector from being a controller to being a regulator, with functions to:

- Determine standards of sugar quality and efficiency of sugar production, and
- Improve proportions of benefit sharing to be more appropriate.

From the above two options to improve the structure of sugarcane and sugar industry system, the research chose to study the impact of the second option with the emphasis on the inbound logistics. Currently, it is widely recognized that the globalization and the free-trading commerce are inevitable. Even though some stakeholders in the sugar industry in many countries have tried to postpone and prolong the liberalization to protect their benefits, it does not mean that their governments would be able to support and protect their sugarcane and sugar industries endlessly. Eventually the trading system will change. After the trading system of global market is fully liberalized, sugar industries in countries with low competitiveness would eventually suffer. Only countries prepared for the change will be able to survive and gain benefits from such liberalization policy.

2.2 Implementation of the liberalization policy on sugar mill

Before discussing on the topic of improving structure of sugarcane and sugar industry system to be in agreement with free-trading system, definition of the liberalization should be clarified. Liberalization is an idea or policy to allow production and trading of merchandises to continue smoothly without the domination or monopoly of any vendor. Liberalization can be separated into two areas as follows.

- International liberalization, it can be enabled by promoting free trading, reducing or eliminating trade barriers, either in the form of taxing or non-taxing barriers. This would allow businesses to exchange their trades without barriers of country boundaries, except only for some necessary cases such as for life protection, for health of human and animals, for cultural protection, and for security of the country.

- Domestic liberalization, it refers to the discontinuation of monopoly system and the encouragement of the full competition of businesses. The government should have as little intervention as possible on the competition.

From the two afore-mentioned definitions, the options to adjust the system of sugarcane and sugar industry are considered to be a part of the domestic liberalization. Sugar mill liberalization will discontinue the lengthy roles of the government in controlling the establishment and capacity expansion of sugar mills. Regarding sugar industry controls, each country has different regulations. This research collected policies concerning allowances of sugar mill establishment and production capacity expansion of 15 countries from a report of the Advisor of Ministry of Industry at Commercial Offices in Overseas (Sugar Journal, 1998a). Details of these regulations and policies are summarized in Table 2.1.

Table 2.1 Policies regarding permission requests for establishing new sugar mills and expanding sugar production capacity in various countries

Country	Policies on the establishment/capacity expansion of sugar mills
Mexico	The National Chamber of Industry for Sugar and Alcohol is responsible for setting up policies regarding establishment or expansion of sugar mills. The Chamber also works on compromising negotiation between sugarcane farmers and sugar mills. Entrepreneurs who are interested in establishing new mills or expanding their mills must submit documents for permission to the National Chamber of Industry for Sugar and Alcohol.
Greece	Policies rely on EU regulation. Sugar production for exportation is very difficult in Greece. Therefore, despite liberalization on investment of the government, no investors are interested in establishing sugar mills or expanding sugar mills in Greece.

Table 2.1 Policies regarding permission requests for establishing new sugar mills and expanding sugar production capacity in various countries (Continued)

Country	Policies on the establishment/capacity expansion of sugar mills
United Kingdom	Establishment and capacity expansion of sugar mills much be under control of laws. Establishment of new sugar mills in any region requires permission from the Planning Authority of the Council in that region. Criteria to be considered before granting permission include: - Impacts of the establishment on traffic, security and environment. - Sugar mills are not allowed to be established in residential areas. - The Council must have accepted prior to the establishment.
United States of America	Establishment and expansion of sugar mills are freely allowed. The government takes no action to intervene market mechanism. Sugar price is allowed to fluctuate according to the global market's price. However, the activities of sugar mills must comply with the country's constitution and state laws, which are different in details among states.
Taiwan	Private entrepreneurs are still not allowed to establish new mills. However, some entrepreneurs have started planning. Establishment of new sugar mills should be allowed in the near future in order to comply with WTO's regulations that require member countries to liberalize sugar import.
Indonesia	The government has policy to persuade private sector to establish sugar mill outside the Java Island by allocating higher quotas for direct sugar sale. The government has announced the gradual relocation policy of the old and low-capacity sugar mills in Java Island to other areas.
The Philippines	Expansion of production capacity is prohibited. The country has no areas to promote sugarcane field.

Table 2.1 Policies regarding permission requests for establishing new sugar mills and expanding sugar production capacity in various countries (Continued)

Country	Policies on the establishment/capacity expansion of sugar mills
Belgium	Since policies regarding sugar production in Belgium are under the Framework Agreements on EU Settlement, the establishment or capacity expansion of sugar mills in Belgium must follow regulations of the EU regarding co-marketing, which include the following items. - Quotas for producing sugar of member countries are determined. Member countries will distribute these quotas to sugar mills in their countries. - If sugar production exceeds the allocated quota, the excessive quantity will not receive price assurance and will have to be exported outside EU countries. - Ministry of Agriculture is responsible for controlling production quantity. Therefore, sugar mills and their productions have been unchanged.
Vietnam	The government had a policy to prohibit expansion and establishment of sugar mills since the number of sugar mills is already high. Currently, 30 mills have been approved and other 14 mills are already in operation.
Egypt	The government fully liberalizes sugar production system. This is due to relentlessly growing demand of domestic sugar consumption. Private entrepreneurs are also allowed to import sugar from overseas to serve domestic demand.
India	There are laws to regulate the establishment of new mills and the expansion of existing mills. Request for permission must be submitted to the Secretariats for Industrial Assistant (SIA) of the Ministry of Industry.

Table 2.1 Policies regarding permission requests for establishing new sugar mills and expanding sugar production capacity in various countries (Continued)

Country	Policies on the establishment/capacity expansion of sugar mills
Japan	Establishment of sugar mills must follow regulations of the Ministry of Agriculture. Permission from the Cabinet is also required if the establishment request has passed consideration from the Ministry.
Republic of China	There are still no national laws to control the establishment of sugar mills. Each establishment only relies upon consideration of the local government. For expanding production capacity, sugar mills are also required to ask for permission from the local government in that area.
African Union (AU)	AU has tried to liberalize processes of production and trading in sugarcane and sugar industry. It has denounced the policy to control quotas allocated to farmers, sugar mills, and vendors. There are also policies to liberalize the expansion of sugar mills.
Australia	Establishment and expansion of sugar mills used to be regulated. However, the Sugar Industry Act 1991 is currently amended to allow the establishment of new sugar mills.

In the case of Thailand, the sugarcane and sugar industry is under control by the Sugarcane and Sugar Act, B.E. 2527 (1984). Policies and regulations regarding sugarcane and sugar industry are determined by The Cane and Sugar Board. The Board has an administration team with the authority to permit the establishment of new sugar mills if necessary.

Due to the monopoly-like characteristic of current sugarcane and sugar industry in Thailand, sugar mills have tried to cooperate to bargain with the government regarding sugar price. The government's policies to disallow the establishment of new sugar mills and to set the upper limit of sugar price effectively discourage the sugar mills to compete with each other. Because of this monopoly system, sugar mills are not required to improve efficiencies and technologies in their mills (Detpon, 1997). Discussions and arguments among experts and stakeholders have been made on whether the government should allow the establishment of new sugar mills, relocation of existing mills, and expansion of production capacity of existing mills. Series of resolutions from the ministerial cabinet meeting regarding the establishment, relocation, and capacity increment of sugar mills can be concluded as follows.

1) The cabinet resolution on August 15, 1989 had a policy to move sugar mills from areas with insufficient amount of sugarcane to areas with excessive sugarcane field. These mills shall not increase their production capacity.

2) The cabinet resolution on October 10, 1989 added these four following items to the policy derived from consensus on August 15, 1989.

- The establishment of new sugar mills is prohibited.
- Sugar mills are allowed to move from areas with inadequate sugarcane to areas with excessive sugarcane, and allowed to increase their production capacity according to the quantity of sugarcane in the new area.
- Sugar mills are allowed to increase their production capacity according to increased amount of sugarcane in that area.
- Relocation or changes in the production capacity shall be performed without causing expansion of sugarcane field areas.

3) The cabinet resolution on September 10, 1991 prohibited the establishment of new sugar mills as well as relocation and capacity increase of existing sugar mills.

4) The cabinet resolution at the meeting on April 13, 1993 derived a consensus as proposed by the Ministerial Committee on the Economy to revise the earlier cabinet resolution on September 10, 1991 regarding relocation and capacity increase of existing sugar mills. The cabinet had consensus to have Ministry of Industry take opinion from the Ministerial Committee on the Economy and proceed together on these following specifications.

- For limiting sugarcane production to be less than 55 million tons per year, the Ministry of Industry and the Ministry of Agriculture and Cooperatives shall cooperate to control the sugarcane production capacity by zoning sugarcane field.

Relocation of sugar mill and expansion of sugar production capacity shall be in agreement with the quantity of sugarcane in that respective area.

- Relocation of sugar mills must not lead to the expansion of field as specified in the zone. Consideration should be particularly taken to prevent field expanding into areas of National Reserved Forests.

5) The cabinet resolution on July 22, 2003 prohibited capacity expansion of sugar mills.

6) The cabinet resolution on October 16, 2007 regarding site relocation and production capacity expansion of sugar mills allowed for the relocation and expansion according to the principles proposed by the Ministry of Industry. Sugar mills facing problems of insufficient sugarcane for their existing production capacity are allowed to move their sites and increase their production capacity according to sugarcane production of the new area. According to the proposal, mills suggest that supports shall be given to sugarcane farmers in the new area to maintain sugarcane production according to sugar production capacity of the mills. In addition, they also suggest that sugar mills should be moved to areas without existing mills to prevent problems about sugarcane buying competition (Office of the Cane and Sugar Board, 2010).

According to the conclusion by the cabinet, the sugarcane and sugar is an important agricultural industry and links to sugarcane field. Sites of sugar mills and locations or sugarcane fields depend on each other (Intasen, 2001). Therefore, the area for the sugarcane plantation must be within the permitted area of the Ministry of Agriculture and Cooperatives. In principle, it should not be far away from mills since this would cause high transportation cost. In addition, after being cultivated, sugarcane should arrive mills as soon as possible to prevent losses in both weight and sweetness quality from lengthy storage, which is a major cause of low sugar production (Tumcharoen, 2008). Currently, quantity of sugarcane transported to mills depends on production capacity of the mills. The quantity is transported in the level that maintains continuous sugar production processes according to the mills' full production capacity (Taechasook, 2008). With the free trading of sugar in the global market, it is expected that prices of sugar products as well as sugar consumption will increase in the near future. Thailand, which is a major producer and exporter of sugar in the global market, will gain more income from the increasing prices. Despite more intense competition, sugar industry in Thailand is expected to be able to export more due to increasing production capacity (Tuampan, 2002). Moreover, Thailand is an agricultural country with a lot of raw material for sugar production in the country. Areas of plantation field have been expanding continuously over years, resulted in increasing number and size of sugar production mills. Sugar is essential for human lives, thus this industry can even be expanded further. Good management of sugar businesses would bring endless income to the country.

If sugar mills are liberalized, without any intervention or support from the government, competition in this industry will begin. The first important thing to consider after liberalization of sugar mill establishment and expansion is sugarcane quantity. Sugarcane is the main raw material for sugar production. Therefore, the establishment or expansion of sugar mills must consider the balance between the quantity of sugarcane grown in that area and the increasing production capacity of the mill at present and in the future. Thus this research chose to study the impacts of sugar mill liberalization on the processes of inbound logistics, particularly the transportation of sugarcane to sugar mills. Issues of interest include, but not limit to, changes in the utilization capacity, changes in the transportation distance, changes in the transportation pattern, and changes in the transportation cost.

2.3 Studies related to the impacts from liberalization policy in the sugarcane and sugar industry

Sugarcane and sugar is considered an important industry of the world. Changes in situation of this industry have impacts on stability of the world economy since the industry involves various groups of people such as sugarcane farmers, workers in sugar mills, sugar manufacturers, etc. Therefore, this industry in one of the most protected industries in the world. Consequently, many researches were conducted to study this industry in several aspects.

According to a study in Kenya, the liberalization of sugar mills was the objectives of the government to increase the participation of private sector and to reduce roles of governmental organizations who were owners of sugar production businesses. The study found that the liberalization policy had both positive and negative impacts on the efficiency of sugar mills. The positive impact was that sugar mills in Kenya could adapt to international standards regarding production and marketing, which may have taken longer to achieve if it was not open to competition. The negative impact was that the mean efficiency became reduced. Therefore, the study recommended that future policies on liberalization should be gradually implemented, and relevant factors should be well studied. Rushed policy implementations may harm industries (Mulwa et al, 2008). In the case of Thailand, there was a research in 1993 that studied on future of sugarcane and sugar industry in Thailand. The research stated that prohibition policies of the government regarding the establishment and expansion of sugar mills were appropriate. With such those policies, sugar canes were purchased according to their quality. If the new establishment or expansion of sugar mills were allowed, quality of sugarcane would be reduced due to the insufficient supply of sugarcane for sugar mills. With that situation, sugarcane farmers would cut their canes before they are fully mature, and that will cause direct detrimental impacts on efficiency development of sugar production (Siamwala et al, 1993). However, their study conducted in 2000 reflected their changed opinion to support sugar mill liberalization. They recognized the importance of sugar mill liberalization and suggested following guidelines (options) for the liberalization.

1) Liberalization should be implemented as fast as possible. The government should stop intervening sugar markets and start liberalizing the market soon. Even though this approach may result in negative impacts on sugarcane and sugar industry of Thailand in the short run. In the long run, the country will gain advantages over countries that start liberalization later.

2) Postpone or delay the liberalization as long as possible in order to protect Thai sugarcane and sugar industry. Support from the government to sugarcane and sugar industry should be reduced only when being forced by contracts or agreements that the country has made in the international trade negotiation floors.

3) In the long run, the government should plan for liberalization of sugar industry according to the trend of the market or agreements made in international

trade negotiations. The plan should have a clear direction and elaborated steps for implementation so that the liberalization will not cause serious impacts on all stakeholders in sugarcane and sugar industry of Thailand (Siamwala et al, 2000).

When sugar mill liberalization has been planed, researches were conducted to study impacts of free trading that may affect sugarcane and sugar industry in Thailand. Conclusion of results from the researches regarding impacts of sugar mill liberalization could be separated into two parts; namely, short-term strategies and long-term strategies. For short-term strategies, the government should support sugarcane and sugar producers in the country to improve their efficiency and prepare for free trading. For long-term strategies, the government should encourage farmers to grow more sugarcane and encourage mills to produce more sugar continuously. Sugar exportation should be targeted on markets situated in Asian region (Sakulkhemruethai, 2002). After sugar mill liberalization, sugarcane shortage might happen due to increasing production capacity. Researches were therefore conducted to assess the appropriate number of sugar mills and production capacities. A research found that 28 mills had the appropriate size. 12 mills could be expanded. The capacities of six mills should be limited. Currently, sugar mills has dispersed to Northern and Northeastern Regions, and made those regions as important as the Central Region in the aspect of sugar production. Meanwhile, the importance of the Eastern Region was found to be reduced (Suwansoon, 2002).

Another apparent phenomenon is the relationship of factors in free trading economics. Factors that have impacts on the changes of market mechanism have been the sugarcane demand of sugar mills and the sugarcane supply by the farmers. When sugar mills are established or their capacities are expanded, their demands for sugarcane would increase. This always resulted in price fluctuation as well as the shortage and waste of sugarcane. In the past, sugar canes were grown just for feeding household consumption, not for manufacturing. However, with the advancement of industry, sugar canes were grown to be raw material for sugar mills. Farmers started to grow more sugarcane to meet industrial demand. However, when sugar is produced in too much quantity, sugar price in the world market drops down, and resulted in losses of sugar mills and farmers. Due to the lowered sugar price, some sugarcane farmers started to grow other crops. Sugarcane and sugar production became insufficient again, resulted in high sugar price.

From previous discussion, it can be concluded that whenever there are new establishment, relocation, or expansion of sugar mills, areas of sugarcane field must be considered to ensure that there will always be sufficient sugarcane supply. Therefore, before entering the era of sugar mill liberalization, sugarcane quantity should be studied thoroughly in the cases of mill expansion, establishment or relocation either within a region or cross regions. Another noticeable point is that production capacity always increases whenever there is new establishment or relocation of a sugar mill (Sugar Journal, 1998b). Based on the literature review, it was found that all the reviewed research relating to sugarcane and sugar industry in Thailand studied about the trend of liberalization in this industry by using qualitative approaches. Most of them discussed about pros and cons of sugar mill liberalization, recommended stakeholders to prepare for the changes, and suggested about possibility of sugarcane insufficiency. However, none of the research discussed about impacts of sugar mill liberalization in a quantitative term. Therefore, this research proposed a methodology for quantitative analyses on the impacts of sugar mill liberalization.

2.4 Method for analyzing sugar mill liberalization

As explained earlier, approaches for analyzing impacts of sugar mill liberalization toward inbound logistics of sugarcane transportation to sugar mills in this research were divided into four parts; namely, the impacts on utilization of sugar production capacity, the impacts on transportation distance, the impacts on transportation patterns, and the impacts on the transportation cost. From literature review, it was found that problems in managing inbound logistics of sugarcane and sugar industry are concerned in many countries that cultivate sugarcane. Many researches tried to find a good solution to those problems. Here, two points of interests are drawn for the benefits of this research, i.e., the applicable mathematical model and the Geographic Information System (GIS).

1) Mathematical model

Mathematical model could be used efficiently to solve the logistic problems of sugarcane transportation. Most of the developed mathematical models used Linear Programming for solving problems. However, characteristics, limitations, and conditions of problems in those studies were different. Started in 1995, a research was conducted by developing a mathematical model with Linear Programming and the application of Genetic Algorithm to allocate trucks for transporting sugarcane to mills. An objective of the study was to obtain the minimum total transportation cost with the consideration on the limitation in number of trucks (Semenzato, 1995). Later, in 1998, implementation of the most appropriate model for sugarcane transportation was proposed. The objectives were to produce sugar at the highest quantity and to obtain the highest incomes with relevance to ages of sugarcane. The research presented methodology of using Linear Programming model for planning process (Higgins et al., 1998). In the same year, circumstances of sugarcane transportation from fields to sugar mills in South Africa were simulated. The study aimed to reduce delay of sugarcane transportation and to reduce time for each cycle of transportation starting from harvesting until sending sugarcane for sugar production process (Hansen et al., 1998).

In 2003, another study was conducted to increase efficiency of sugar production. The study proposed a methodology of using the Mixed Integer Linear Programming for managing harvest schedules in each field area before transporting sugarcane to the mills (Higgins and Muchow, 2003). In 2004, the paper describes the methods developed to identify opportunities for increased harvesting and transport efficiencies as well as the process intended to facilitate implementation by using a Tabu search mathematical method (Higgins et al., 2004). A Linear Programming model and the application of Genetic Algorithm was used to allocate trucks carrying sugarcane to mills with objective to reduce transportation cost as much as possible according to limitation in number of trucks (Chamnanhlaw, 2004). In 2006, a mathematical model was developed for scheduling road transport vehicles to pick up full trailers of cane form the loading pads located on the farm. Two meta-heuristic, i.e., tabu search, and variable neighborhood search, were applied to find solutions to the model in order to improve scheduling of road transport vehicles. The results provide the opportunity to cost saving, as it would reduce vehicle queue and mill idle times and hence the number of vehicles needs (Higgins, 2006).

From reviewing literature relating to the logistics of sugarcane and sugar industry, it was found that most logistic activities of sugarcane and sugar industry involve with transportation. The literature review also implies that the problems of transportation in logistics management of sugarcane and sugar industry interested many researchers. By considering the characteristics of the problems, the mathematical model on Transportation Problem was found to be applicable for studying the impacts of the liberalization policy on sugar mill. The results yield the quantity of sugar that each mill should receive from each farm in order to minimize the total transportation cost with the new mill in the certain area. The figures of the total received sugarcane quantity could then be used for analyzing the utilization rate by comparing with the production capacity of each mill in order to speculate the impacts from sugar mill liberalization. In addition, the changes in the optimal transportation distance and the optimal transportation pattern can also be analyzed.

2) Geographic Information System

Since the part of this research aims to study about the impacts of sugar mill liberalization on changes in distance and patterns of sugarcane transportation, the Geographic Information System (GIS) can be used as the analytical tool for this objective. GIS was selected because of its ability to display geographical features, such as road, river, mountain, building, agricultural area, etc., on digital map. In addition, GIS is capable to analyze network of roads to reveal patterns of transportation. This research will utilize these abilities of GIS to display geographical characteristics of sugarcane fields, roads, and positions of sugar mills and to calculate distance of sugarcane transportation. The GIS presents data in the form of maps which references their features to the real positions on the earth surface.

From the literature review, it is obvious that sugarcane and sugar industry is important for Thai economy. However, this industry has been protected by the government for many decades. Therefore, the sugar mills lack of motivation to enhance their efficiency. As a result, there are suggestions for the government to reform the system by liberalizing sugarcane and sugar industry. Roles of the government in intervening sugar market are suggested to be reduced. Thus this research chooses to study the impacts that may be resulted from such liberalization policies to discontinue prohibitions on the establishment, relocation, and capacity expansion of sugar mills. However, there is still no tool or approach to be used for analyzing quantitatively about sugar mill liberalization. This research has developed an approach by applying the Transportation model as an analytical tool for assessing impacts quantitatively. The next chapter will explain in details about data and analytical tools used for the analyses as well as procedures for conducting the research.

CHAPTER III
RESEARCH METHODOLOGY

This chapter discusses about research data, data processing, the mathematical model, analytical tool as well as the research stages. Results from them are to be analyzed in the aspect of logistics to reveal that whether sugar mill liberalization would cause changes in the utilization of sugar mill capacity, the distance of sugarcane transportation, the patterns of sugarcane transportation, and the inbound logistics cost. This chapter provides fundamental understanding on data and method used in this research.

3.1 Data

To conduct a research, data collection is an important part that affects accuracy of study results, which is important for obtaining facts. Good data should be accurate, clear, reliable, and corresponding with research problems. Data used in this research mostly were the secondary data obtained from several organizations including Office of Agricultural Economics, Office of the Cane and Sugar Board, Office of the Cane and Sugar Fund, Department of Industrial Works, Office of the Permanent Secretary Ministry of Transportation. Some of these sources are the regulator. Therefore, these data are considered to be reliable and accurate. In particular, Office of the Cane and Sugar Board and Office of the Permanent Secretary Ministry of Transportation are the sources provide very useful data. This research identifies the necessary data which is divided into two types, i.e., documentary data and spatial data.

3.1.1 Documentary data

This type of data covers all studies related to sugarcane and sugar industry. It was collected and synthesized in order to understand the background and the general characteristics of the industry. Also, the production capacity and number of operating days are used for calculating the parameters in the mathematical models. Details and sources of data document are explained below.

1) Sugar journal

The Sugar journal offers analysis, reviews and discourse to keep its readers known about the sugarcane and sugar industry. They are available in the library of the Office of the Cane and Sugar Board. The sugar journal also provides fundamental understandings regarding the liberalization policy in this industrial.

2) Production capacity and number of production days

This research has chosen to use mathematical model of transportation problem as the tool for analyzing impacts from sugar mill liberalization. Therefore, data on the production capacity of the mills and day of operation are needed for calculating sugarcane demand. It will be used as a parameter in mathematical model. Both data were obtained from Office of the Cane and Sugar Board. In this study, the data is for the production period of 2008/2009.

3.1.2 Spatial data

The Geographic Information System (GIS) was selected because of its ability to display geographical features, such as road, river, mountain, building, and agricultural area on digital maps. This research will utilize these abilities of GIS to display geographical characteristics of sugarcane fields, roads, and positions of sugar mills and to study the travel distance and patterns of sugarcane transportation. This study chose to use a GIS software package called ArcGIS Desktop 9.3. The application software requires three geographical spatial data; namely, 1) locations of sugar mills, 2) sugarcane fields and 3) transportation network data from the Fundamental Geographic Data Set (Transport FGDS). These three dataset will be used for calculating distances from all sugarcane fields to all sugar mills. Details and sources of the data are described as follows.

1) Location of sugar mills

Office of the Cane and Sugar Board has collected the locations of sugar mills in Thailand. The location data are for the production year 2008/2009. Currently, there are 46 mills in operation, located dispersedly in four regions of the country. The Eastern region (E) has four mills. The Northern region (N) has nine mills. The Central region (C) has 17 mills. Meanwhile, the Northeastern Region (NE) has 16 mills (Office of the Cane and Sugar Board, 2008). Details of data are explained in Table 3.1.

Table 3.1 List of existing sugar mills in Thailand

No.	Name of Sugar Mill	Region*	Location
1	Eastern Sugar and Cane	E	279, Moo 1, Tambol Huayjod, Wattananakorn District, Srakaew, 27160
2	New Kwang Soon Lee	E	24, Moo 1, Ban Nongbua Road, Tambol Mohnnang, Panasnikom District, Chonburi, 20140
3	Rayong	E	388, Moo 6, Kaokrathin-Nongborn Road, Tambol Thatthong, Bor-thong District, Chonburi, 20270
4	Chonburi Sugar and Trading	E	612, Moo 5, Tambol Nongphai-kaew, Banbueng District, Chonburi, 20220
5	Mae Wang Sugar Industry	N	325, Moo 7, Phaholyothin Road, Tambol Sala, Ko Ka District, Lampang, 52130
6	Uttaradit Sugar Industry	N	206, Moo 3, Srichao-wang Road, Tambol Wangkapee, Muang District, Uttaradit, 53170
7	Thai Identity	N	42/1, Moo 8, Tambol Koongtapao, Muang District, Uttaradit 53000
8	Kampangpetch	N	152, Moo 2, Tambol Trai-trueng, Muang District, Kamphaengphet, 62160
9	Nakornpetch	N	333, Moo 9, Tambol Thepnakorn, Muang District, Kamphaengphet, 62000
10	Ruamphol Nakhonsawan	N	1, Moo 7, Tambol Ban Maklua, Muang District, Nakhonsawan, 60000
11	Kaset Thai	N	1/1 Tambol Nongpho, Ta-klee District, Nakhonsawan, 60140
12	Thai Roong Ruang Industry	N	99, Moo 9, Tambol Sri-thep, Sri-thep District, Phetchabun, 67170
13	Phitsanulok	N	8/8, Moo 8, Tambol Phai Lorm, Bang Krathum District, Phitsanulok, 65110
14	Pranburi	C	16/7, Moo 4, Plai-nam Road, Tambol Khao Noi, Pranburi District, Prachuapkhirikhan, 77120
15	Ratchaburi	C	9, Moo 6, Berkprai-Khao Ngoo Road, Tambol Berkprai, Ban Pong District, Ratchaburi, 70110

Table 3.1 List of existing sugar mills in Thailand (Continued)

No.	Name of Sugar Mill	Region*	Location
16	Banpong	C	3/11, Moo 18, Saengchooto Road, Tambol Tha Pha, Ban Pong District, Ratchaburi, 70110
17	Mitrkasetr	C	93/1, Moo 9, Saengchooto Road, Tambol Don Kha-min, Tha Maka District, Kanchanaburi
18	Thai Sugar Mill	C	1, Moo 8, Saengchooto Road, Tambol Tha Mai, Tha Maka District, Kanchanaburi, 71120
19	New Krungthai	C	75 , Moo 9, Saengchooto Road, Tambol Tha Mai, Tha Maka District, Kanchanaburi, 71120
20	Thai Multi-Sugar Industry	C	84 , Moo 3, Saengchooto Road, Tambol Wangsala, Tha Muang District, Kanchanaburi, 71130
21	Tamaka	C	14/1 , Moo 10, Saengchooto Road, Tambol Tha Maka, Tha Maka District, Kanchanaburi, 71120
22	Prajuap Industry	C	14/2 , Moo 10, Saengchooto Road, Tambol Tha Maka, Tha Maka District, Kanchanaburi, 71120
23	Thai Sugar Industry	C	99 , Moo 9, Sai Pra-thaen Road, Tambol Takram-en, Tha Maka District, Kanchanaburi, 71130
24	T N Sugar	C	11, Moo 2, Tambol Kaengphakkood, Tha Luang District, Lopburi, 15230
25	Saraburi	C	188, Moo 1, Tambol Kampran, Wangmuang District, Saraburi, 18220
26	Suphanburi Sugar Industry	C	151 , Moo 6, Tambol Yanyao, Samchuk District, Suphanburi, 72130
27	Mitr-Phol	C	109, Moo 10, Tambol Nong Maka-mong, Dan Chang District, Suphanburi, 72180
28	U-thong	C	99, Moo 3, U-thong – Uthai-thani Road, Tambol Nong-ong, U-thong District, Suphanburi, 72160
29	Singburi	C	24/2, Moo 2, Tambol Mai-dud, Bang Rachan District, Singburi, 16130
30	Kanchanaburi Industry	C	88 , Moo 12, Dan Chang – Ban Rai Road, Tambol Thap Luang, Ban Rai District, Uthaithani, 61140
31	Wang Ka-nai	NE	222, Moo 9, Kosumphisai - Sarakam Road, Tambol Kaengkae, Kosumphisai District, Mahasarakham, 44140
32	Surin	NE	246, Moo 13, Tambol Prue, Prasat District, Surin, 32140

Table 3.1 List of existing sugar mills in Thailand (Continued)

No.	Name of Sugar Mill	Region*	Location
33	Burirum	NE	237, Moo 2, Tambol Hin Lek Fire, Koo-muang District, Burirum, 31190
34	Saha Ruang	NE	76, Moo 8, Tambol Bangsaiyai, Muang District, Mukdaharn, 49000
35	Rerm Udom	NE	11 , Moo 6, Udon – Sakonnakhon Road, Tambol Nong Sra-pla, Nong Harn District, Udonthani, 41320
36	Kasetr Phol	NE	9, Moo 9, Mittraparp (Friendship) Road, Tambol Pako, Kumpawapee District, Udonthani, 41370
37	Kumphawapi	NE	73, Moo 11, Pone Thong Road, Tambol Kumpawapee, Kumpawapee District, Udonthani, 41110
38	Khon Kaen	NE	43, Moo 10, Nam-phong – Kra-nuan Road, Tambol Nam-phong, Nam-phong District, Khonkaen, 40140
39	Mitr Poo-Viang	NE	365, Moo 1, Maliwan Road, Tambol Nong-rua, Nong-rua District, Khonkaen, 40210
40	United Farmers and Industry	NE	99, Moo 10, Tambol Kok Sa-ad, Phu Khiew District, Chaiyaphum, 36110
41	Korach Industry	NE	111, Moo 18, Tambol Nong Ra-wiang, Phimai District, Nakhonratchasima, 30110
42	Andvian (Ratchasima)	NE	223, Moo 1, Niwet-rat Road, Tambol Kaeng Sa-nam-nang, Kaeng Sa-nam-nang District, Nakhonratchasima, 30120
43	Konburi	NE	289, Moo 2, Tambol Jorake-hin (Rocky Crocodile), Kornburi District, Nakhonratchasima, 30250
44	E-Saan Sugar Industry	NE	99, Moo 9, Tambol Samran, Samchai District, Kalasin, 46180
45	Mitr Kalasin	NE	99, Moo 1, Tambol Som Sa-ad, Kuchi-narai District, Kalasin, 46110
46	Erawan	NE	111, Moo 12, Tambol Na-klang, Na-klang District, Nongbualampoo, 39170

Remark: Region* E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

The locations of sugar mills were mapped using ArcMap of ArcGIS Desktop 9.3 as shown in Figure 3.1. Detailed address of each numbered mill can be found in Table 3.1.

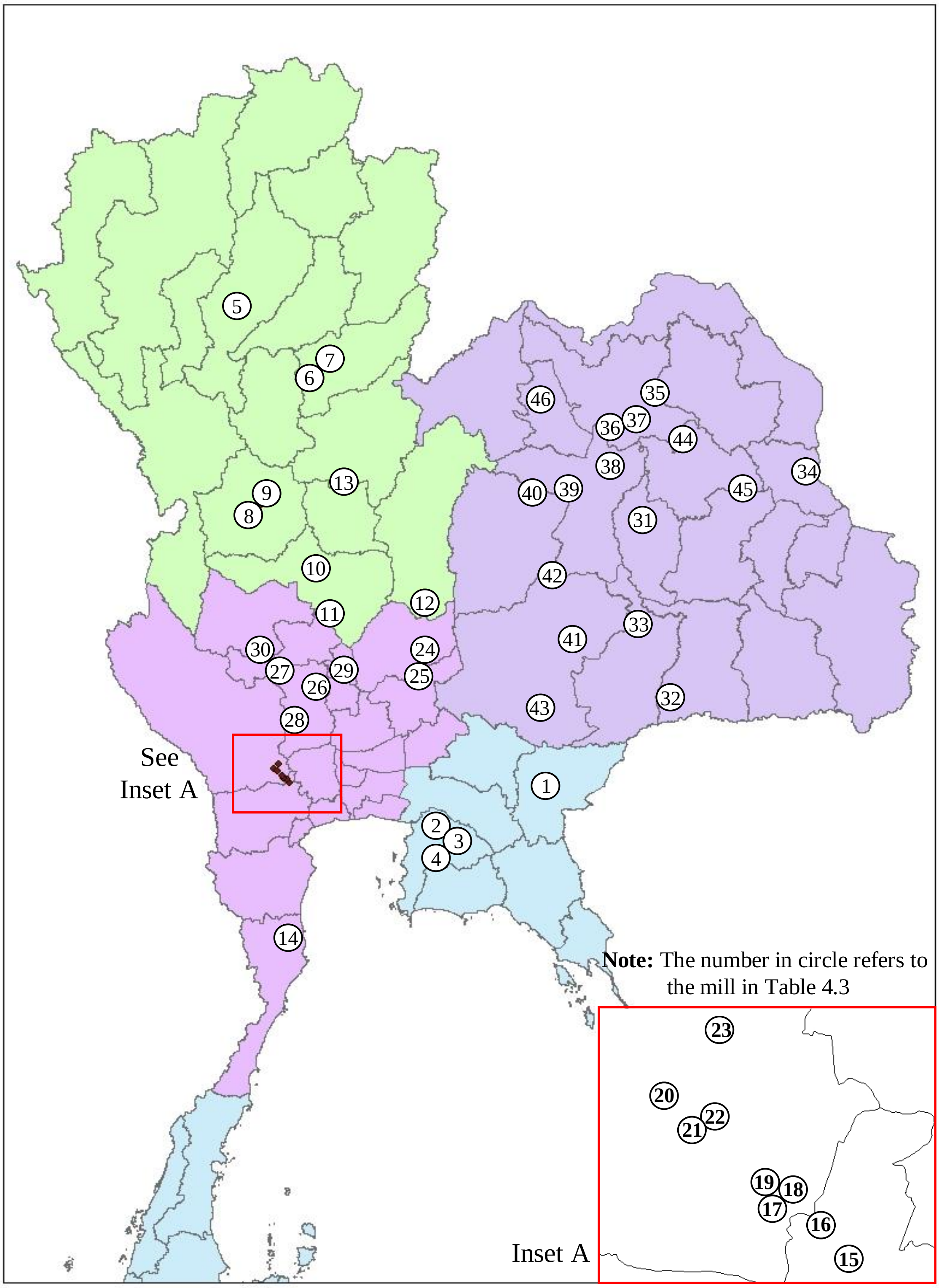


Figure 3.1 Locations of 46 sugar mills in Thailand

2) Sugarcane fields

This dataset has been collected by the Office of the Cane and Sugar Board. In the research, the data is for the production year during 2008/2009. The total area of sugarcane fields throughout Thailand is 6,831,892 rais. These fields are dispersedly located in all regions of the country; namely, Northern, Central, Eastern, and Northeastern regions. This dataset was last updated in June 2008. Locations of these field areas were mapped using ArcMap 9.3 as shown in Figure 3.2.

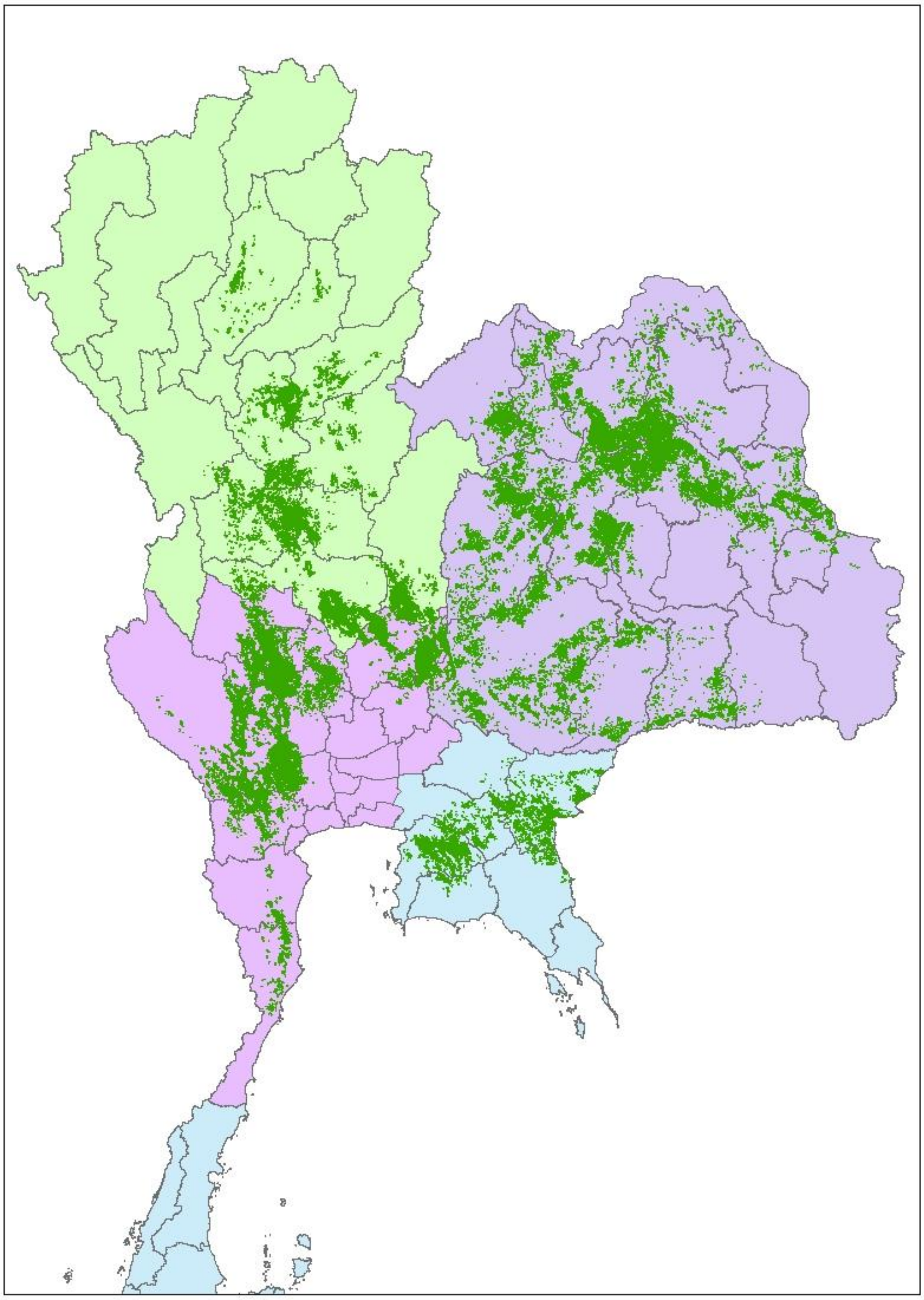


Figure 3.2 Sugarcane field areas

3) Transport fundamental geographic data set (Transport FGDS)

This dataset has been maintained by the Permanent Secretariat Office of Ministry of Transport. It was last updated in March 2007 (Ministry of Transport, 2007). Figure 3.3 displays a map of transportation network in Thailand, prepared by using ArcMap.

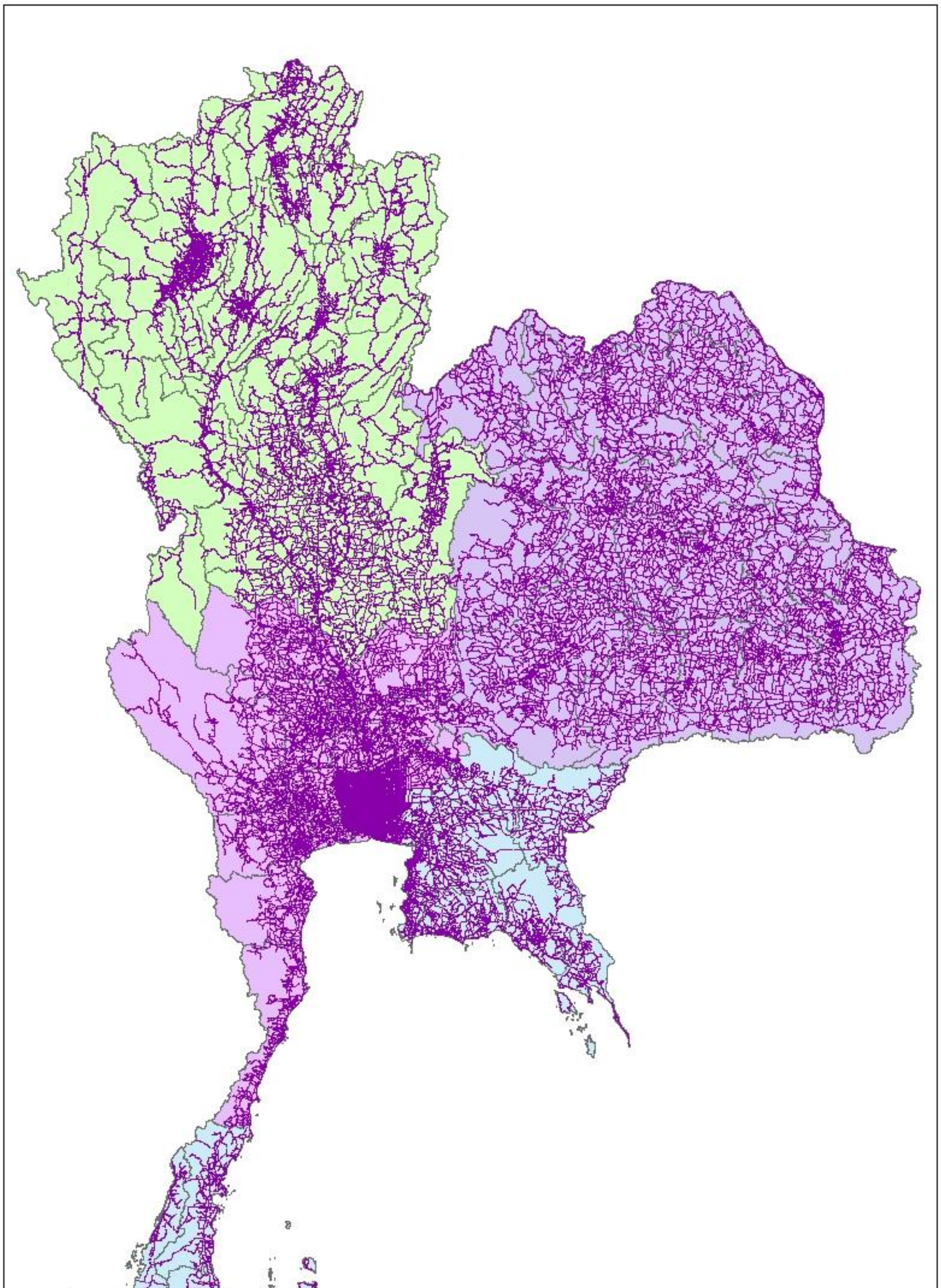


Figure 3.3 Transport Fundamental Geographic Data Set

3.2 Data processing

The analyses on data described in Section 3.1.2 are carried out in this stage to determine the distance from all sugarcane fields to all sugar mills. Before that, the collected data are configured for format conversion. The Network Dataset is also created to facilitate subsequent analyses.

1) The compression of sugarcane field data

The data of sugarcane field obtained from the Office of the Cane and Sugar contain 388,104 records of polygon shapefiles covering the total area of 6,831,892 rais during the growing period of 2008/2009. However, the data is too large to handle by the application software. Therefore, the researcher has grouped these many sugarcane fields by district into 404 records.

2) Creating Network Dataset

The creation of Network Dataset in ArcCatalog (Figure 3.4) is to connect all roads in the digital map. Configured travel time in Item Configuration of travel time in each road across the digital map is put into the Network Dataset. All roads, u-turns and turnings are connected in the way that most resembles physical roads.

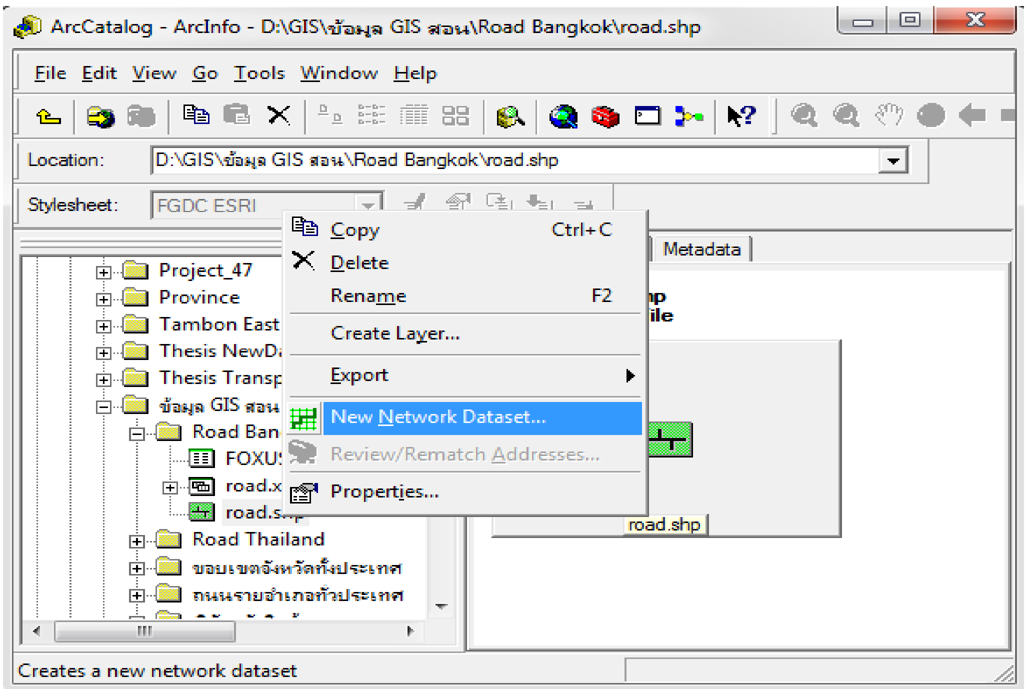


Figure 3.4 Creating Network Dataset

3) Creating a Closet facility

Network Analyst Extension of ArcMap Version 9.3 is used in the analysis of Closest Facility (Figure 3.5). The analysis of closet facility is to determine the distance from a field to a mill. The resulting distance is the input for the parameter in the mathematical modeling stage. In addition, it is useful for visualizing patterns of transportation.

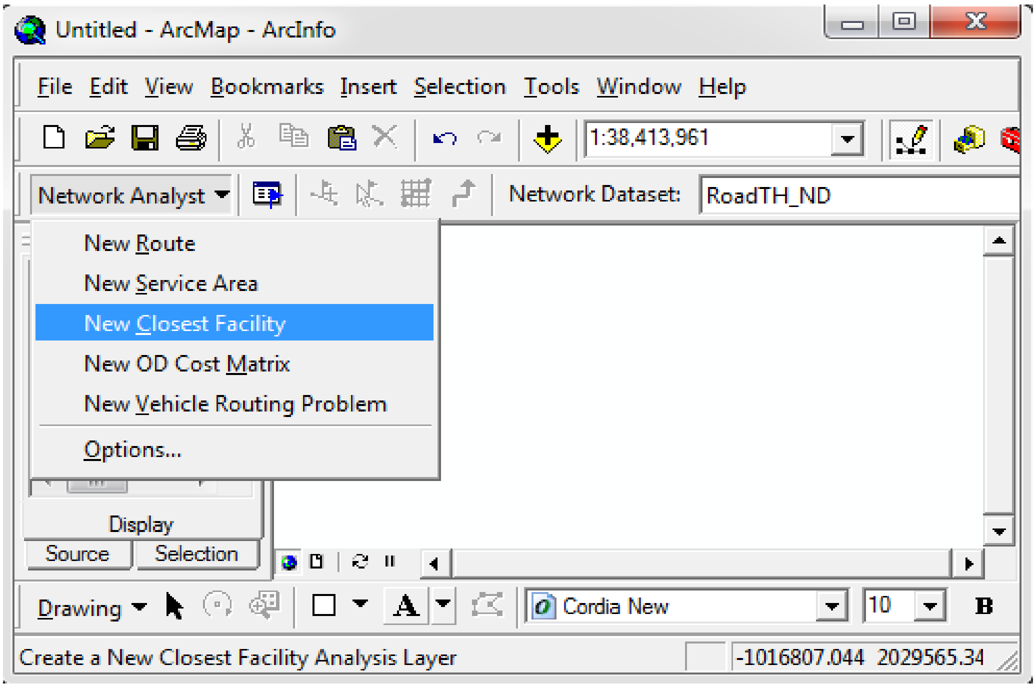


Figure 3.5 Finding the Closet Facility in ArcMap

3.3 Transportation model

This study emphasizes on the analyses from the aspect of logistics management to see whether and how liberalization impact the process of inbound logistics of sugarcane transportation from fields to sugar mills. Therefore, the analysis on transportation is a part of logistics analyses. Considering characteristics of problems to be analyzed, it was found that the transportation problem is an appropriate analytical tool to be used for analyzing sugarcane quantity that each mill should receive in order to keep system transportation cost as low as possible.

Transportation model is a special type of network problems that explains the shipping of a commodity from sources (e.g., sugarcane field) to destinations (e.g., sugar mill). Transportation model deals with getting the minimum-cost plan to transport a commodity from a number of sources (*m*) to number of destination (*n*). It can be solved by using the linear programming method in order to determine the value of the objective function which aims to minimize the total transportation cost. Also, the problem determines the number of units that should be transported from source *i* to destination *j*. Variables and notations in the mathematical models are defined as follows:

When

i = the source (i.e., sugarcane field)

j = the destination (i.e., sugar mill)

m = the number of sources

n = the number of destinations

Decision Variable

X_{ij} = the number of units shipped from source *i* to destination *j*

Parameter

C_{ij} = the unit transportation cost for transporting a unit from source *i* to destination *j*

D_j = the number of demand units required at destination *j* (j=1, 2, 3,…,n)

S_i = the number of supply units available at source *i* (i=1, 2, 3,…,m)

The linear programming model is expressed by;

Objective Function: Minimize the total transportation cost

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

Subject to

$$\sum_{j=1}^{n} X_{ij} \le S_i \qquad ;\forall_i \qquad (2)$$

$$\sum_{i=1}^{m} X_{ij} \ge D_j \qquad ;\forall_j \qquad (3)$$

$$X_{ij} \ge 0 \qquad (4)$$

Each constraint of the mathematical model can be explained as follows:

Objective function in (1)

The objective function is aimed to minimize the total transportation cost for transporting sugarcane from all fields to all mills. It is subject to the following constraints.

Constraint in (2)

The constraint *(2)* is the compulsory condition limiting the total units shipped from a source (sugarcane field) to all destinations (mills). The total quantity to be transported from any source must not exceed its total available supply units.

Constraint in (3)

The constraint *(3)* is the compulsory condition fulfilling the demand quantity such that the total demand units at any destination j must be satisfied.

Constraint in (4)

The constraint *(4)* specifies that the amount of supply transported from any source to any destination must not be negative.

A transportation problem is said to be balanced if the total supply from all sources equals the total demand in all destinations. In other words,

$$\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j \qquad (5)$$

Otherwise it is called unbalanced.

3.4 Analytical tools

The main analytical tools used for this research consists of ArcGIS Desktop 9.3, LINDO 6.1, Microsoft Excel and computer which can be described as follows:

3.4.1 ArcGIS Desktop 9.3

With its capability to display interested data on digital maps, Geographic Information System (GIS) is chosen to be used as a tool for analyzing the transportation distances from fields to sugar mills as well as visualizing the patterns of sugarcane transportation. This study chose to use a GIS software package called ArcGIS Desktop 9.3. To complete the calculation, the software requires three geographic datasets; namely, 1) locations of sugar mills, 2) sugarcane fields and 3) transportation network data from the Fundamental Geographic Data Set (Transport FGDS).

1) Transportation distances

ArcGIS Desktop 9.3 with network analyst feature provides the capability to perform the network-based spatial analysis, such as routing, travel directions, closest facility, service area, and location-allocation. The Closest facility of Network Analyst Extension in ArcGIS Desktop 9.3 software is used for road network analysis to determine distances from the fields to the sugar mills. The distance matrix is replaced the C_{ij} parameters in the transportation model.

2) Visual patterns of transportation

After the Transportation Problem was solved by using a solver program, the outputs were sugarcane quantities from all fields to all sugar mills. This represents the optimal patterns of sugarcane transportation. ArcGIS Desktop 9.3 can be used to visualize the patterns of transportation.

3.4.2 Visual Basic 2005

This software was also used in this research for writing mathematical formulation. Due to the fact that the formulation contains so many constraints, it results in long typing. Visual basic 2005 is then applied accordingly in order to write out the formulation that agrees with mathematical modeling. This research used Microsoft Access mainly for preparing and storing database of preliminary data that will be accessed and processed by Visual basic 2005. Then the mathematical model will be solved. One way to solve these models is to use the package called LINDO 6.1.

3.4.3 LINDO 6.1

The main purpose of LINDO (Linear Interactive Discrete Optmizer) is to allow a user to quickly input a linear programming (LP formulation); solve it; assess the correctness or appropriateness of the formulation based on the solution and then quickly make minor modifications to the formulation and repeat the process. This research uses LINDO 6.1 which can accommodate the number of variables up to 200,000 and up to 64,000 constraints. The pattern of transportation and sugarcane quantity to be transported from the fields to the sugar mills with minimum cost can then be calculated by using LINDO 6.1 after the preparation process of all required parameters for the mathematical model has been completed.

3.4.4 Microsoft Excel

Microsoft Excel was used for preliminary data preparation and analysis. This software stores data of distances obtained from the calculation by ArcGIS 9.3. The analysis results from solving the transportation problem shows the optimal pattern of transportation and the sugarcane quantity transported to sugar mills from each sugarcane field. The capacity utilization of a sugar mill then can be calculated based on the comparison between the total sugarcane quantity transported from all sugarcane fields and its production capacity.

3.4.5 Computer

A desktop personal computer and a laptop PC are used. These computers use Intel Core I5 M520 @2.40 GHz CPU, with 4.00 GB of RAM. They are run under 64-bit system of Windows 7 Ultimate Operating System.

3.5 Research stages

In brief, this research has been divided into six major stages. These include problem identification, determination of study scope, data collection and analysis, analysis of impacts, and the cases for analyzing impacts from sugar mill liberalization.

3.5.1 Problem identification

Sugar is a controlled product in Thailand. Sugarcane, the main raw material for produce sugar, is also controlled by regulations and laws. However, it is widely recognized that the globalization and free-trading commerce are inevitable. It is now in public attention that whether the structure of sugarcane and sugar industry in Thailand should be reformed by ending the monopoly system or minimizing intervention from Thai government. This research chooses to study about the reduced protection and enforcement from the government by means of liberalizing the establishment of sugar mills.

3.5.2 Determination of study scope

Because of extensive scope of free-trading system that aims to reduce the protection and intervention from the government, this research chooses to study only about the impacts of liberalization that the government plans to apply on the establishment, relocation, and capacity expansion of the sugar mills. This research is aimed to study the impacts of sugar mill liberalization on certain aspects of the inbound logistics of cane. The optimization-based mathematical model and Geographic Information System (GIS) are used as the tool for the analysis.

3.5.3 Data collection and analysis

This research has chosen to use mathematical model of transportation problem as the tool for analyzing impacts from sugar mill liberalization. Therefore, data collection is to prepare parameters to be used in the model. Data to be prepared for this mathematical problem were divided into the following three datasets.

1) Supply or sugarcane quantity from each sugarcane field

To determine sugarcane supply, the research needs to use two sets of data, which were data of sugarcane fields and data of average sugarcane production per field. The sugarcane production quantity can then be calculated by multiplying the two sets of data.

2) Distance matrix

In order to calculate for a distance matrix of transporting sugarcane from all fields to all sugar mills, this research chooses to use Network Analyst module of

ArcGIS Desktop 9.3. To complete the calculation, the software requires three geographic datasets; namely, 1) locations of sugar mills, 2) sugarcane fields and 3) transportation network data from the Fundamental Geographic Data Set (Transport FGDS).

3) Demand or sugarcane quantity required by each sugar mill

This set of data is obtained by calculating two fundamental datasets; namely, data of production capacities that mills are permitted by the government and number of working days of individual mills during 2008/2009. These data are used to calculate the sugarcane demand by sugar mills. The calculation is carried out by multiplying permitted capacities with the number of working days of each mill.

In order to analyze the impacts from the sugar mill liberalization on the capacity utilization of sugar mill, the transportation distance, the transportation pattern, and the inbound logistics cost, efficient tools are needed. This research applied the transportation model for analyzing sugarcane quantity that each mill should receive in order to minimize the total transportation cost. The Geographic Information Systems (GIS) is used for calculating distances from fields to sugar mills, and visualizing the patterns of the optimal sugarcane transportation obtained from solving the transportation problem.

After the preparation process of all required parameters has been completed, Visual Basic 2008 is used to write the mathematical formulation of transportation model. LINDO 6.1 (Linear Interactive Discrete Optimizer) software can be applied to solve the mathematical model to obtain the solution.

3.5.4 Analysis of impacts

After the transportation problem has been solved by LINDO 6.1, the results can then be used for analyzing impacts from sugar mill liberalization in the aspect of inbound logistics of sugarcane transported to sugar mills. There are four points to be considered when analyzing for such impacts.

1) Capacity utilization

The capacity utilization of mill *j* is the ratio between total amount of sugarcane received ($\sum_{i=1}^{m} X_{ij}$) and its permitted capacity (D_j). The total amount of sugarcane can be computed from the summation of total transported sugarcane from all fields to the mill. The impact from the sugar mill liberalization is quantified by the difference between before and after the implementation of such policy.

2) Transportation distance

Not only the results from solving the transportation problem provide the sugarcane quantity transported from all fields to all mills (X_{ij}), but also imply about the transportation distance from all fields to all mills. Given that X_{ij} is not zero, the distance between any field *i* to any mill *j* can be looked up from the distance matrix. The transportation distances are described into three parts. The shortage (min) distance refers to the shortest distance required for transporting sugarcane from that a field to the nearest mill. The weighted average (mean) distance refers to the mean distance calculated from integrating the multiplication of sugarcane quantity supplied to the mill and the distance from the corresponding field, and divided the total of supplied quantity. Finally, the longest (max) distance refers to the farthest distance required for transporting sugarcane from a field to the mill.

3) Transportation pattern

From solving the mathematical transportation problem, the optimal distribution pattern from any field to any sugar mill can be known. Then ArcGIS Desktop 9.3 will be used to display patterns of sugarcane transportation. To analyze the impacts from sugar mill liberalization on sugarcane transportation system, results from before and after such implementation are compared. The difference may be implied as the impacts.

4) The inbound logistics cost

The inbound logistics cost mainly consists of transportation cost from solving the transportation problem, the opportunity cost of sugar mills, and the opportunity cost of sugarcane farmers. The opportunity cost of a sugar mill is incurred when the overall quantity of sugarcane supply is less than its production capacity. This cost can be calculated by multiplying the shortage quantity with the average sugar yield per ton of sugarcane and then multiplied with sugar price. The opportunity cost of sugarcane farmers happens when the overall sugarcane supply exceeds the overall sugarcane demand. This cost can be calculated by multiplying the excessive quantity of sugarcane with the average cost of sugarcane.

3.5.5 The cases for analyzing impacts from sugar mill liberalization

In order to know impacts from sugar mill liberalization on inbound logistics of sugarcane and sugar production, the research studies several cases. The various situations represent different aspects and factors of the sugar mill liberalization policy. The study is conducted based on these following three situations.

Case 1 is the case of analyzing the optimal patterns of sugarcane transportation under current situation. The results on optimal capacity utilization, distance, pattern, and transportation cost are compared with the results obtained in the subsequent cases. The difference implies the impact of such policy.

Case 2 is the case of analyzing the situation when a sugar mill is added into the system. This case assumes that the establishment of a new sugar mill is allowed freely. Coincidently, Chonburi Sugar Industry mill was ceased and waiting for relocation to other province. The added sugar mill in this case is therefore Chonburi Sugar Industry mill in the Eastern region. The difference of results as compared to case 1 represents impacts of sugar mill liberalization

Case 3 is the case of analyzing situations when assuming that the cabinet resolution regarding the relocation and/or capacity expansion of sugar mills on October 16, 2007 are fully enforced. This resolution is rather comprehensive involving relocation and capacity of several mills simultaneously.

In addition to analyzing the impacts from sugar mill liberalization according to the three afore-mentioned situations, this research analyzes further by using the sensitivity analysis to assess impacts from sugar mill liberalization due to uncertainty of sugarcane supply. This is because, currently, sugarcane production is found to be highly variable. The unpredictable amount of sugarcane supply has direct impact on sugar production as well as the policies or approvals regarding new sugar mill establishment, relocation, and capacity expansion of sugar mills.

This chapter discussed about data, analytical tools and procedures used in the research. Results from implementing these tools and data will be analyzed to show the impact of sugar mill liberalization on the capacity utilization of sugar mill, distance of sugarcane transportation, patterns of sugarcane transportation and inbound logistics cost. Steps of the study from beginning till the end are also explained comprehensively herein. In Chapter 4, the results of Cases 1, 2 and 3 demonstrates all the procedures. The discussions are also provided.

CHAPTER IV
RESULTS AND DISCUSSION

Entire research methodology is explained in previous chapter to reflect steps taken by the researcher and which tools or data are applied during the course of this research. Therefore, this chapter utilizes the methodology discussed in Chapter III for calculations and analyses of the impacts resulting from the sugar mill liberalization. In this case study, a hypothesized sugar mill was experimentally added into the current system for the case of liberalization. Furthermore, the cabinet resolution regarding the relocation and capacity expansion of sugar mills were used for case study. It is assumed that the difference from the current situation implies impacts from sugar mill liberalization.

4.1 Case study

This research is aimed to study the impacts of sugar mill liberalization on certain aspects of the inbound logistics of sugarcane. In particular, it was focused the impacts on the optimal capacity utilization, the optimal transportation distance, the optimal transportation pattern, and the optimal transportation cost resulting from the addition of new mills in various regions of the country. The optimization-based mathematical model and Geographic Information System (GIS) were used as the tool for the analysis. Especially, it was focused on the balance between demand for sugarcane in the area (or total mill capacity) and the supply of sugarcane. The study started by analyzing the current situation of all existing sugar mills in the country, experimentally added a sugar mill in the Eastern region, and then used the cabinet resolution regarding the relocation and capacity expansion of sugar mills as the case study in order to analyze impacts from sugar mill liberalization. Results of the analyses before and after adding the sugar mill were compared. The obtained differences represent impacts from the sugar mill liberalization. The data of production year 2008/2009 was analyzed in this study.

In the production year 2008/2009, the total number of sugar mills in Thailand is 46 mills. They are located dispersedly in four regions of the country; namely, 4, 9, 17, and 16 mills in the Eastern, Northern, Central and Northeastern regions, respectively. Details of data were explained in Chapter III. The total area of sugarcane field area throughout Thailand is 6,831,892 fields (Office of the Cane and Sugar Board, 2009b). These fields are dispersedly located in the Northern, Central, Eastern, and Northeastern regions.

This study uses the sugarcane field data for calculating distances from the fields to the sugar mills. In order to analyze for the distances with Network Analyst in ArcGIS, the Geographic Information System (GIS) data is required. The field data obtained from the Office of the Cane and Sugar contains record of polygons, covering total area of 6,831,892 fields. This seems to be too large and too difficult for calculation by the solver software. Thus these so many fields were grouped by the district in Thailand, resulting in a total of 404 groups of sugarcane fields to be used for distance calculation. The Network Analyst calculates distances between point features. Therefore, the polygon dataset of sugarcane field areas had to be converted to a point dataset. The procedure for converting polygons of these groups to point features was explained in details in Appendix A. The groups of sugarcane field areas were displayed in Figure 4.1.

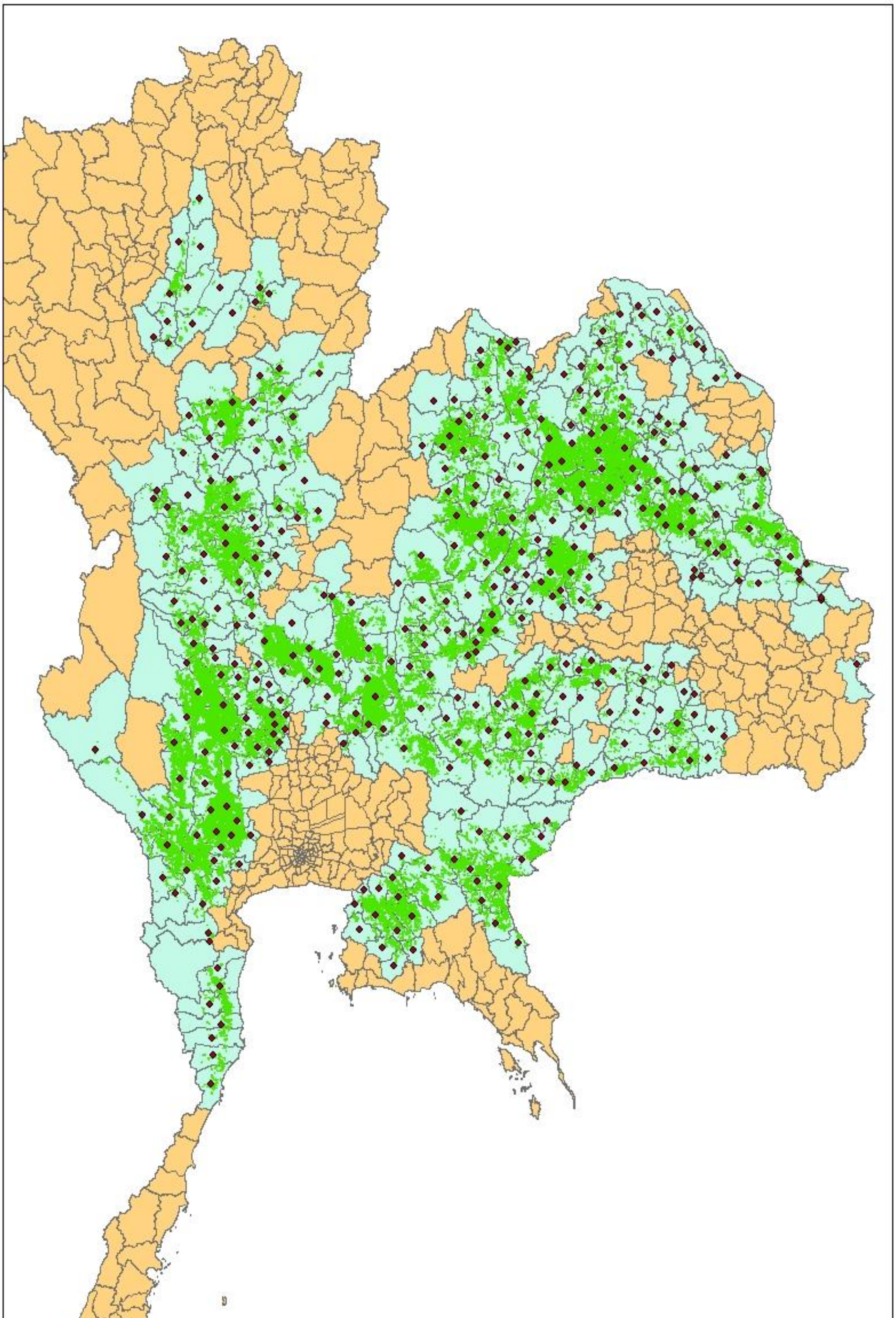


Figure 4.1 The groups of sugarcane fields

4.2 Developing the transportation model

When considering characteristics of problems to be analyzed, the mathematical model of transportation problem was found to be an appropriate tool. The model provides the optimal sugarcane quantity that each sugar mill should be supplied in order to minimize the total transportation cost. In order to reduce the complexity of the mathematical model in the processes of calculation and result analysis, the assumption has been specified that the distance represents the transportation cost between the field and the mill. The transportation model can be expressed mathematically below;

When

i = Sugarcane fields; $i = 1, 2, \ldots, m$

j = Sugar mills; $j = 1, 2, \ldots, n$

m = Number of the sugarcane fields

n = Number of the sugar mills

Decision variable

X_{ij} = Sugarcane quantity transported from field area i to the mill j (tons)

Parameter

C_{ij} = Transportation distance from field area i to the mill j (kilometers)

D_j = Sugarcane demand that the mill j requires for its production process (tons)

S_i = Sugarcane supply at the field area i (tons)

Mathematical Formulation

Objective Function: Minimize the total transportation cost

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \quad (1)$$

Subject to

$$\sum_{j=1}^{n} X_{ij} \le S_i \quad ; \forall_i \quad (2)$$

$$\sum_{i=1}^{m} X_{ij} \ge D_j \quad ; \forall_j \quad (3)$$

$$X_{ij} \ge 0 \quad (4)$$

The objective function in (1) is aimed to minimize the total transportation cost between all fields to all mills. Constraint (2) is the limitation of sugarcane supply from each field area. The total quantity to be transported from any field area must not exceed sugarcane quantity in that area. Constraint (3) guarantees that each mill receives sugarcane at least as much as is required. The demand for sugarcane must be satisfied. Constraint (4) specifies the non-negative value for the quantity of transported sugarcane.

It is assumed that the unit transportation cost per ton of sugarcane is identical for all field-mill pairs. The cost only varies by the transportation distance. The model has a feasible solution if and only if the total sugarcane quantity from field areas equal to the total demand by the sugar mills. In other words, $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j$. It is therefore necessary to check the balance between the total supply and demand and treat the model correctly. There are two cases to be considered, as follows:

1) When the total demand for sugarcane exceeds the total supply of sugarcane, a dummy field area must be added. The production capacity of the dummy field equals to the excessive demand.

2) When the total demand for sugarcane is lower than the total supply of sugarcane, a dummy mill must be added to the system in order to balance the demand and supply. Its capacity is equal to the excessive production of the fields.

Details of the data preparation for the mathematical model are going to be explained in details next.

4.3 Data preparation for the mathematical model

Data to be prepared for this mathematical problem were divided into three sets; namely, 1) sugarcane supply (sugarcane quantity from each field), 2) distance matrix (distances for transporting sugarcane from all fields to all sugar mills) and 3) sugarcane demand (sugarcane quantity required by each sugar mill). Details of data preparation process for the mathematical model are explained below.

4.3.1 Sugarcane supply, S_i

To determine the sugarcane supply, the research needs two sets of data, which were the sugarcane fields area and the average sugarcane production per unit area in Thailand during the growing period of 2008/2009. These data have been collected and summarized in a report on sugarcane field survey by the Office of the Cane and Sugar Board.

1) Sugarcane field area categorized by district has been collected by the Office of the Cane and Sugar Board who surveyed sugarcane fields during the growing period of 2008/2009 by using satellite images together with field surveys. According to the data, it can be summarized that sugarcane fields are distributed in 46 provinces or 404 districts of the country.

2) Sugarcane production rate per unit area was also obtained from the report of the Office of the Cane and Sugar Board (Office of the Cane and Sugar Board, 2009c) who surveyed sugarcane fields during the growing period of 2008/2009. According to the data, Phichit province had the highest sugarcane production rate of 12.50 tons/ rai. Meanwhile Chachoengsao province had the lowest rate at only 8.15 tons/ rai.

Sugarcane production quantity is the product of sugarcane field area categorized by district and the average sugarcane production per rai. However, since there was great amount of data, the details are then presented in Appendix B.

4.3.2 Distance matrix, C_{ij}

In order to calculate for distances from the fields to the sugar mills, this research chose to use Network Analyst module of ArcGIS Desktop 9.3. The software requires three geographic datasets; namely, 1) locations of sugar mills, 2) sugarcane fields and 3) transportation network data from the Fundamental Geographic Data Set (Transport FGDS). For the whole country, there are 46 sugar mills, and 6,831,892 rais. These so many fields are grouped into 404 districts (Amphor). After the preparation of required data has been completed; distance calculation can be conducted using the Closet Facility of Network Analyst. Appendix C shows the details of the calculation procedure by using New Kwang Soon Lee mill as an example. For all other mills, the procedure is the same.

Table 4.1 showed the example of results on the distance matrix for the Eastern region. In this region, there are four sugar mills; namely, Eastern Sugar and Cane, New Kwang Soon Lee, Rayong Sugar, and Chonburi Sugar and Trading mills. Sugarcane areas were distributed in 28 districts or 28 groups of fields.

Table 4.1 Distances from all fields to all mills in the Eastern region

No	District	Distance (Kilometers)			
		Eastern Sugar and Cane	New Kwang Soon Lee	Rayong Sugar	Chonburi Sugar & Trading
1	Mueang Chon Buri	177.88	31.07	41.41	35.27
2	Ban Bueng	157.75	29.35	23.86	11.35
3	Nong Yai	176.01	49.89	31.19	20.44
4	Phan Thong	145.70	18.04	42.38	39.41
5	Phanat Nikhom	129.46	8.77	33.10	36.69
6	Si Racha	181.56	55.44	47.67	35.10
7	Bo Thong	148.78	41.77	25.93	44.62
8	King Amphoe Ko Chan	127.54	23.70	30.12	35.28
9	Wang Chan	191.10	73.81	53.59	44.36
10	Ban Khai	206.41	80.29	72.53	49.97
11	Pluak Daeng	183.66	57.55	49.78	27.22
12	Pong Nam Ron	122.88	190.31	187.10	177.87
13	Soi Dao	83.12	159.57	159.68	171.15
14	Phanom Sarakham	90.17	69.85	76.26	81.42
15	Sanam Chai Khet	86.13	83.35	89.77	94.93
16	Plaeng Yao	113.40	41.76	48.18	53.34
17	Tha Takiap	91.49	70.91	71.02	82.49
18	Kabin Buri	55.81	114.62	121.04	126.20
19	Mueang Sa Kaeo	72.62	136.79	143.21	148.37
20	Khlong Hat	29.56	147.02	153.44	158.60
21	Ta Phraya	44.58	138.84	138.95	150.42
22	Wang Nam Yen	82.33	226.07	232.49	237.64
23	Watthana Nakhon	46.34	121.67	121.78	133.25
24	Aranyaprathet	32.10	175.84	182.25	187.41

Table 4.1 Distances from all fields to all mills in the Eastern region (Continued)

No	District	Distance (Kilometers)			
		Eastern Sugar and Cane	New Kwang Soon Lee	Rayong Sugar	Chonburi Sugar & Trading
25	Khao Chakan	34.85	178.59	185.01	190.16
26	King Amphoe Khok Sung	34.32	142.66	149.08	154.23
27	King Amphoe Wang Sombun	58.50	202.23	208.65	213.81
28	Mueang Sa Kaeo	65.85	121.23	121.33	132.81

4.3.3 Sugarcane demand, D_j

This parameter is obtained from the product of two fundamental datasets; namely, the permitted production capacity of the mills by the government and the number of operating days during 2008/2009. Details for obtaining sugarcane demand are explained below.

1) Production capacity of sugar mills as permitted by the Thai government were obtained from the Office of the Cane and Sugar Board. The highest permitted production capacity was 40,000 tons/day, which belongs to Kaset Thai mill. Meanwhile the lowest production capacity was 2,683 tons/day by Uttaradit Sugar Industry mill (Office of the Cane and Sugar Board, 2009d). Both mills are located in the Northern region.

2) Number of days that each mill worked to produce sugar during the production period of 2008/2009 was obtained from the Office of the Cane and Sugar Board (Office of the Cane and Sugar Board, 2009e). Kaset Thai mill had the highest number of working days, which was 152 days. Meanwhile Wang Ka-nai mill had the lowest number, which was 67 days.

The sugar demand is simply the product between the permitted production capacity and the number of working days. The estimated sugarcane demands of all mills are shown in Table 4.2.

Table 4.2 The estimated sugarcane demands in the production year 2008/2009

No	Sugar Mill	Region	Capacity (tons/days)	Day of Production (days)	Demand (tons)
1	Eastern Sugar and Cane	E	17,978	126	2,265,228
2	New Kwang Soon Lee	E	6,479	94	609,026
3	Rayong Sugar	E	5,560	106	589,360
4	Chonburi Sugar and Trading	E	5,800	91	527,800
5	Mae Wang Sugar Industry	N	2,950	111	327,450
6	Uttaradit Sugar Industry	N	2,683	145	389,035
7	Thai Identity	N	18,000	152	2,736,000
8	Kampangpetch	N	8,000	108	864,000
9	Nakornpetch	N	24,000	116	2,784,000
10	Ruamphol Nakhonsawan	N	8,800	142	1,249,600
11	Kaset Thai	N	40,000	159	6,360,000
12	Thai Roong Ruang Industry	N	24,000	126	3,024,000
13	Phitsanulok	N	11,994	115	1,379,310
14	Pranburi	C	7,000	90	630,000
15	Ratchaburi	C	12,000	104	1,248,000
16	Banpong	C	9,131	89	812,659
17	Mitrkasetr	C	11,890	103	1,224,670
18	Thai Sugar Mill	C	11,764	100	1,176,400
19	New Krungthai	C	8,385	95	796,575
20	Thai Multi-Sugar Industry	C	9,635	99	953,865
21	Tamaka	C	18,038	105	1,893,990
22	Prajuap Industry	C	9,131	97	885,707
23	Thai Sugar Industry	C	14,447	101	1,459,147
24	T N Sugar	C	18,000	107	1,926,000

Table 4.2 The estimated demand of sugarcane in the production year 2008/2009 (Continued)

No	Sugar Mill	Region	Capacity (tons/days)	Day of Production (days)	Demand (tons)
25	Saraburi	C	22,970	121	2,779,370
26	Suphanburi Sugar Industry	C	4,228	111	469,308
27	Mitr-Phol	C	21,511	140	3,011,540
28	U-thong	C	17,731	86	1,524,866
29	Singburi	C	11,000	136	1,496,000
30	Banrai Industry	C	11,990	127	1,522,730
31	Wang Ka-nai	NE	15,453	67	1,035,351
32	Surin	NE	16,000	88	1,408,000
33	Burirum	NE	12,000	108	1,296,000
34	Saha Ruang	NE	14,000	105	1,470,000
35	Rerm Udom	NE	20,582	98	2,017,036
36	Kasetr Phol	NE	10,211	99	1,010,889
37	Kumphawapi	NE	12,000	106	1,272,000
38	Khon Kaen	NE	20,400	105	2,142,000
39	Mitr Poo-Viang	NE	15,162	114	1,728,468
40	United Farmers and Industry	NE	18,000	125	2,250,000
41	Korach Industry	NE	24,000	113	2,712,000
42	Andvian (Ratchasima)	NE	36,000	88	3,168,000
43	Konburi	NE	13,690	121	1,656,490
44	E-Saan Sugar Industry	NE	15,000	93	1,395,000
45	Mitr Kalasin	NE	20,000	114	2,280,000
46	Erawan	NE	8,117	108	876,636

After the preparation process of all required parameters for the mathematical model has been completed, Microsoft Access was used to store these parameters in the database (See Figure 4.2). This research used Visual basic 2005 for writing the mathematical formulation of transportation model by taking in the parameters from the Access database. Figure 4.3 shows an example of VB coding captured screen.

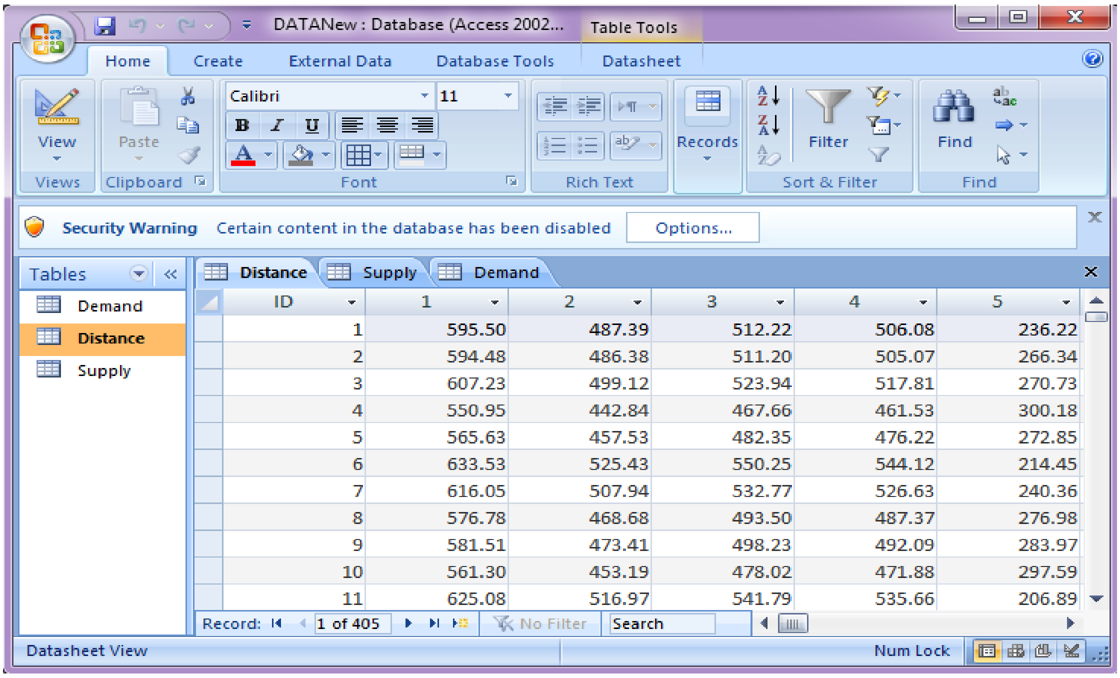


Figure 4.2 The database in Microsoft Access

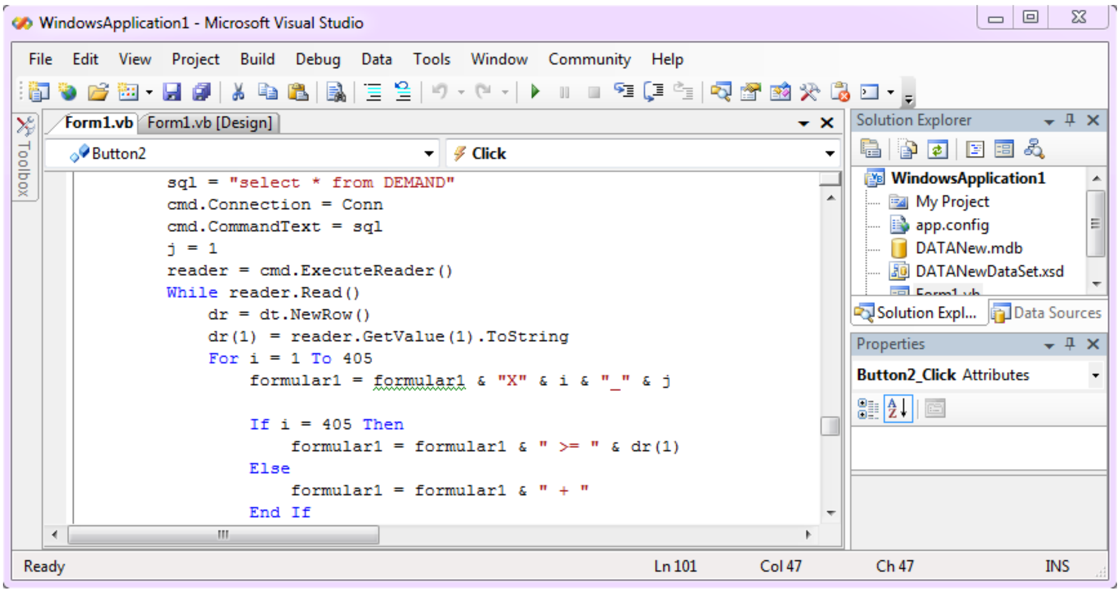


Figure 4.3 An example of VB coding

LINDO 6.1 is used in this research for finding the optimal solution. This software is capable to accommodate 200,000 variables and the maximum number of 64,000 constraints (See Figure 4.4). The mathematical formulation written by Visual basic 2005 is then copied onto LINDO 6.1 window (See Figure 4.5). On the menu bar, click Solve to find the optimal solution.

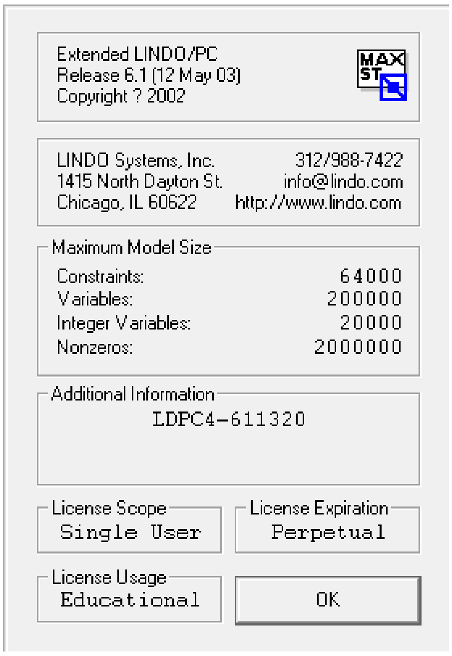


Figure 4.4 LINDO software version 6.1

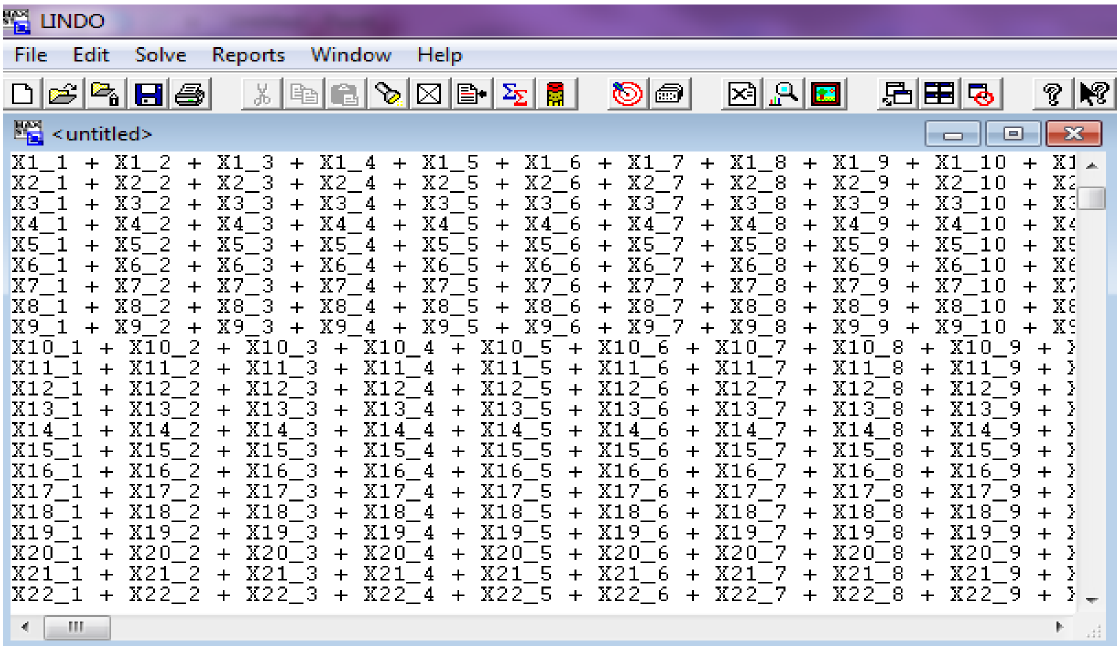


Figure 4.5 Mathematical formulation in LINDO window

4.4 Impacts of sugar mill liberalization

The impacts of sugar mill liberalization on the inbound logistics were analyzed in four regards; namely, 1) the capacity utilization of sugar mill, 2) the optimal transportation distance, 3) the optimal transportation patterns, and 4) the optimal transportation cost. The developed Transportation model was solved by using LINDO 6.1 (Linear Interactive Discrete Optimizer) software. The outputs were the optimal distribution pattern and sugarcane quantity from all fields to all sugar mills. These numbers are used to analyze the utilization of each sugar mill capacity. The calculation can be done by summing the sugarcane supplies from all areas and divided by the production capacity of the mill, then multiplied by 100 to obtain the percentage of utilization. With ArcMap 9.3, GIS data of sugar mill locations can also be used to display the pattern of the optimal sugarcane transportation from fields to sugar mills. In order to analyze impacts from sugar mill liberalization on inbound logistics of sugarcane and sugar production, the research studied by dividing the situations of impacts into three cases.

Case 1 is the optimal current situation of the production year 2008/2009. The data of production year 2008/2009 was analyzed in this study. The data consists of sugarcane fields, locations of sugar mills, permitted production capacities of the mills, and number of production days. The results were analyzed for optimal (ideal) distribution of the sugar mills (The results would reveal patterns of sugarcane distribution and the amount of sugarcane that each mill should receive in order to achieve the minimum transportation cost). Transportation model was the tool applied for the analysis. The results were used as the base case for comparing with other cases to investigate impacts of liberalization regarding new establishment, relocation, and capacity expansion of the sugar mills.

Case 2 is the situation when a new sugar mill has been added in the Eastern region. This case assumes that the establishment of new sugar mills is allowed freely. The added sugar mill in this case is Chonburi Sugar Industry mill, of which operation has been ceased in order to wait for relocation. The reason for choosing that mill was because of the availability of its location data.

Case 3 represents the assumption of the situation when the cabinet's resolution has agreed with the proposal of the Ministry of Industry regarding the liberalization of relocation and/or capacity expansion of sugar mills. Difference of results between cases 2 and 3 in comparison with case 1 represents impacts from liberalization resulting from the implementation of cases 2 and 3, respectively. Details of data for each case can be summarized in Table 4.3.

Table 4.3 Comparison of the three case studies

Data	Case 1	Case 2	Case 3
Number of sugar mill (mills)			
- East region	4	5 (New=1)	4 (Relocate=1)
- Northern region	9	9	11 (New=2)
- Central region	17	17	16 (Relocate=1)
- Northeastern region	16	16	16
Total	46	47	47
Permitted production capacity (tons)			
- East region	3,989,414	4,606,834	5,299,988
- Northern region	19,113,395	19,113,395	25,106,085
- Central region	23,810,827	23,810,827	25,410,863
- Northeastern region	27,717,870	27,717,870	28,461,234
Total	74,633,506	75,248,926	84,278,170
Sugarcane supply (tons)			
- East region	3,989,236		
- Northern region	15,020,413		
- Central region	24,441,278		
- Northeastern region	27,632,146		
Total	71,083,073		

4.4.1 Case 1: The optimal current situation

In the production year 2008/2009, there were 46 sugar mills operating throughout Thailand. The total sugarcane demand from 46 mills in that year was 74,633,506 tons. Meanwhile the total sugarcane production all over the country during that year was only 71,083,073 tons from a total growing area of 6,831,892 rais. In order to study impacts of sugar mill liberalization on inbound logistics of sugarcane transportation and sugar production, the current optimal patterns of sugarcane transportation and utilization of sugar mill capacity first need to be studied. However, it is very difficult and time-consuming to collect sugarcane transportation data from all plantation areas to each mill and the supplied quantity. Therefore, the researcher decided to use the optimal results. The results from this method will inform about pattern of sugarcane transportation and sugarcane quantity that each mill should be supplied in order to minimize the total transportation cost. The study was conducted by developing a mathematical model of transportation problem, and then used LINDO 6.1 software to solve for the optimal solution. While studying, it was found that the data on sugarcane plantation fields from the Office of Cane and Sugar Board has been recorded as polygons in GIS, and there are as many as 388,987 polygons. These polygons are of different size, and altogether they cover about 6,831,892 rais of sugarcane plantation area in the whole country. However, due to the limitation of LINDO 6.1 software that was used for calculation, the growing fields had to be combined into districts to enable the analysis by this software. Therefore, the results of this case are patterns of sugarcane distribution and supplied quantity of sugarcane from 404 area groups to the destinations of 46 sugar mills.

The results from the analysis in this case will be used as the benchmark for comparing with other cases. Table 4.4 summarized all the results. Note that the mean of transportation distance was calculated by using the weighted average method. The analysis results by region are discussed next.

Table 4.4 The results from solving the transportation problem: the optimal current situation

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	16	2,263,050	2,265,228	99.90	29.56	52.13	112.15	25.51
2	New Kwang Soon Lee	E	7	609,026	609,026	100.00	8.77	35.14	70.91	20.09
3	Rayong Sugar	E	3	589,360	589,360	100.00	25.93	28.38	53.59	14.69
4	Chonburi Sugar and Trading	E	5	527,800	527,800	100.00	11.35	18.32	49.97	14.70
	Eastern Region		**31**	**3,989,236**	**3,991,414**	**99.95**	**8.77**	**41.55**	**112.15**	**26.02**
5	Mae Wang Sugar Industry	N	11	274,595	327,450	83.86	9.51	43.04	128.65	37.24
6	Uttaradit Sugar Industry	N	4	389,035	389,035	100.00	27.54	38.54	83.97	25.68
7	Thai Identity Sugar	N	14	2,155,625	2,736,000	78.79	13.69	65.19	109.5	31.21
8	Kampangpetch	N	4	864,000	864,000	100.00	15.46	34.54	52.20	17.05
9	Nakornpetch	N	13	2,784,000	2,784,000	100.00	17.34	42.11	99.22	21.77
10	Ruamphol Nakhonsawan	N	13	1,249,600	1,249,600	100.00	12.30	54.77	94.82	27.80
11	Kaset Thai Industry Sugar	N	22	6,360,000	6,360,000	100.00	18.04	49.02	120.62	29.02
12	Thai Roong Ruang Industry	N	7	3,024,000	3,024,000	100.00	4.64	29.69	101.49	35.01
13	Phitsanulok	N	14	1,379,310	1,379,310	100.00	1.72	53.11	80.26	20.56
	Northern Region		**102**	**18,480,165**	**19,113,395**	**96.69**	**1.72**	**46.41**	**128.65**	**28.23**
14	Pranburi Sugar Industry	C	7	630,000	630,000	100.00	13.54	42.77	70.84	19.65
15	Ratchaburi	C	8	649,943	1,248,000	52.08	6.55	41.38	131.58	43.34
16	Banpong	C	1	190,771	812,659	23.47	16.05	16.05	16.05	0.00
17	Mitrkasetr Industry	C	2	1,005,534	1,224,670	82.11	26.16	29.89	31.93	4.08

Table 4.4 The results from solving the transportation problem: the optimal current situation (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	2	790,297	1,176,400	67.18	53.44	54.61	60.50	4.99
19	New Krungthai	C	2	605,389	796,575	76.00	8.43	10.48	81.74	51.84
20	Thai Multi-Sugar Industry	C	2	953,865	953,865	100.00	19.65	24.07	47.78	19.89
21	Tamaka	C	8	1,893,990	1,893,990	100.00	52.90	67.30	158.46	34.83
22	Prajuap Industry	C	1	885,707	885,707	100.00	75.31	75.31	75.31	0.00
23	Thai Sugar Industry	C	3	1,459,147	1,459,147	100.00	18.56	25.73	48.78	15.61
24	T N Sugar	C	4	1,926,000	1,926,000	100.00	14.35	22.18	81.58	30.95
25	Saraburi	C	8	2,779,370	2,779,370	100.00	8.98	33.82	99.99	29.67
26	Suphanburi Sugar Industry	C	3	469,308	469,308	100.00	7.40	20.85	32.23	12.99
27	Mitr-Phol	C	5	3,011,540	3,011,540	100.00	24.09	34.69	51.43	10.15
28	U-thong Industry	C	5	1,524,866	1,524,866	100.00	2.09	24.33	72.91	25.75
29	Singburi	C	13	1,496,000	1,496,000	100.00	11.51	37.69	72.65	20.40
30	Banrai Industry	C	1	1,522,730	1,522,730	100.00	13.73	13.73	13.73	0.00
	Central Region		**75**	**21,794,457**	**23,810,827**	**91.53**	**2.09**	**34.71**	**158.46**	**30.83**
31	Wang Ka-nai	NE	8	1,035,351	1,035,351	100.00	6.70	33.69	58.53	18.10
32	Surin Sugar	NE	23	1,033,964	1,408,000	73.43	10.74	63.00	109.68	28.82
33	Burirum	NE	17	1,182,511	1,296,000	91.24	7.97	78.77	137.49	38.23
34	Saha Ruang	NE	24	1,470,000	1,470,000	100.00	16.01	48.77	210.28	55.00
35	Rerm Udom	NE	32	2,017,036	2,017,036	100.00	17.04	62.44	146.74	40.00

Table 4.4 The results from solving the transportation problem: the optimal current situation (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
36	Kasetr Phol	NE	3	1,010,889	1,010,889	100.00	16.99	26.06	46.36	16.07
37	Kumphawapi	NE	4	1,272,000	1,272,000	100.00	3.66	24.73	42.95	17.57
38	Khon Kaen	NE	9	2,142,000	2,142,000	100.00	6.64	31.20	89.73	24.12
39	Mitr Poo-Viang	NE	10	1,728,468	1,728,468	100.00	3.07	45.22	98.60	27.26
40	United Farmers and Industry	NE	7	2,250,000	2,250,000	100.00	16.52	31.80	86.49	24.93
41	Korach Industry	NE	21	2,300,870	2,712,000	84.84	15.10	64.86	140.93	35.69
42	Andvian (Ratchasima)	NE	18	3,168,000	3,168,000	100.00	9.22	62.67	105.73	27.38
43	Konburi	NE	11	1,656,490	1,656,490	100.00	0.56	43.74	102.01	24.84
44	E-Saan Sugar Industry	NE	4	1,395,000	1,395,000	100.00	11.70	30.11	50.09	18.25
45	Mitr Kalasin	NE	29	2,280,000	2,280,000	100.00	7.17	48.29	139.09	34.02
46	Erawan Sugar	NE	11	876,636	876,636	100.00	1.61	50.74	85.20	25.94
	Northeastern Region		**231**	**26,819,215**	**27,717,870**	**96.76**	**0.56**	**47.80**	**210.28**	**38.34**
	Total		**439**	**71,083,073**	**74,633,506**	**95.24**	**0.56**	**43.08**	**210.28**	**35.02**

Note 1) E = Eastern, N = Northern, C = Central, NE = Northeastern

2) Objective function (including dummy fields) = 38,566,254,585 tons-kilometers

Objective function (excluding dummy fields) = 3,061,924,585 tons-kilometers

- The optimal current situation in the Eastern region

In the production year 2008/2009, there were four sugar mills operating in the Eastern region. The analysis results using the transportation model are summarized in Table 4.4. The sugar mills in the Eastern region were supplied from sugarcane plantation areas of 31 fields. Eastern Sugar and Cane mill, which received the most of supply, was supplied from 16 fields with the total sugarcane of 2,263,050 tons. The quantity of sugarcane supplied in this region is 3,989,236 tons. Meanwhile, the overall sugarcane demand as indicated by the permitted production capacity of all four mills is 3,991,414 tons. The capacity utilization of all sugar mills is almost 100%, except for the Eastern Sugar and Cane mill that utilized about 99.90% of its capacity. The utilization of nearly 100% of sugar mills in the Eastern region is because the fifth mill, Chonburi Sugar Industry mill had ceased its operation. It will be relocated to Nakhonsawan province. Therefore, sugarcane that had been supplied to the mill was then supplied to the remaining four mills instead.

Based on the resulting transportation distance in column (8) of Table 4.4, the Eastern region is the one with the shortest (min) distance from sugarcane fields to the nearest mill, New Kwang Soon Lee mill which is 8.77 kilometers. The average transportation distance (mean) of the Chonburi Sugar and Trading mill is the shortest at 18.32 kilometers. Meanwhile, the average distance for Eastern Sugar and Cane mill is the longest at 52.13 kilometers. The reason might be because the demand of Eastern Sugar and Cane mill was higher than other mills in the same region for about 3-5 folds. Therefore, it had to transport sugarcane from several areas in order to have sufficient sugarcane for its production, and that resulted in its status of being the mill with the maximum transportation distance, which is 112.15 kilometers, as shown in column (10).

- The optimal current situation in the Northern region

In the production year 2008/2009, there were nine sugar mills operating in the Northern region. From the results of optimal solution as shown in Table 4.4, there were 102 fields, supplying a total of 18,480,165 tons of sugarcane to sugar mills in this region. Meanwhile, the overall sugarcane demand determined by the permitted production capacity is 19,113,395 tons. The overall capacity utilization in the Northern region is 96.69%. These seem to be the chance to establish a new mill or expand the production capacity of the existing mills because there was some unused capacity left. From column (7), it was found that only two out of nine mills; namely, Mae Wang Sugar Industry and Thai Identity Sugar mill underutilized their capacity about 83.86% and 78.79%, respectively.

The resulting transportation distance in column (8) of Table 4.4, indicate that among all sugar mills in the Northern region, Phitsanulok mill is the one with the shortest distance (min) between the nearest field and the mill, which is 1.72 kilometers. Meanwhile, Mae Wang Sugar Industry mill has the longest transportation distance (max) of 128.65 kilometers, as shown in column (10). The average transportation distance (mean) from the fields to the mills in the Northern region is 53.11 kilometers. Thai Roong Ruang Industry mill has the shortest average transportation distance of 29.69 kilometers. Meanwhile, Thai Identity Sugar mill has the longest average transportation distance of 65.19 kilometers. The reason for Thai Identity Sugar mill has the longest average transportation distance because Thai Identity Sugar mill (7) required sugarcane for its capacity as much as almost three million tons, while supply from nearby sugarcane fields was insufficient. Consequently, the mill had to compete for sugarcane with Uttaradit Sugar Industry mill (6). Nevertheless, the mill had to transport sugarcane from areas further away in order to obtain the sufficient quantity for its capacity. This reflects the fact that sugarcane farmers who had contracts to supply their sugarcane to Thai Identity mill have made a meeting and submitted a request to the government to relocate the mill from Uttaradit province to Sukhothai province in order to shorten the transportation distance from 78-80 kilometers to merely 20 kilometers. The shorten distance is expected to save the transportation cost for as much as 100 million Baht a year (Prachachat Online, 2011)

- The optimal current situation in the Central region

Most of sugar mills were in the Central region. In the production year 2008/2009, there were 17 sugar mills operating in the Central region. According to the optimal results in the Table 4.4, the sugarcane quantity supplied from 75 fields of sugarcane area groups is 21,794,457 tons. Meanwhile, the overall sugarcane demand by the permitted production capacity in this region is 23,810,827 tons. The overall capacity utilization in the Central region is 91.53%. The optimal results in the Table 4.4 showed that five out of 17 mills underutilized their capacity. The rates are at 52.08%, 23.47%, 82.11%, 67.18% and 76.00% for Ratchaburi mill, Banpong mill, Mitrkasetr Industry mill, Thai Sugar mill, and New Krungthai mills, respectively. Comparing to sugarcane supply for the five sugar mills as appeared in column (5), the amount of sugarcane that the New Krungthai mill had received 605,389 tons, was much below its capacity. Meanwhile, Banpong mill was found to have very little amount of sugarcane supply at 190,771 tons. From the total sugarcane demand of 812,659 tons, the capacity utilization was only 23.47%. Considering locations of the five underutilized mills in the Figure 4.6, they were situated in the same area, which are Thamaka and Banpong district. Insufficient sugarcane supply might have resulted in high competition and low utilization. Therefore, it is reasonable that some mills may be relocated out of the area so that sugarcane supply in the region will be sufficient for the remaining mills. This corresponds to the fact that Banpong mill was in a process of relocating to the Northern region according to the Cabinet Resolution of 16 October 2007 due to insufficient sugarcane supply in the old area.

When using the transportation model to analyze for patterns of sugarcane transportation from the field to sugar mills in the Central region, U-thong Industry mill has the shortest transportation distance (min) of 2.09 kilometers, while Tamaka mill has the longest (maximum) distance of 158.46 kilometers. In column (10), the longest average transportation distance is at Prajuap Industry mill with 75.31 kilometers whereas the shortest average distance is at New Krungthai mill with 10.48 kilometers. Comparing the overall average distances among all regions, the Central region has the lowest average distance at 34.71 kilometers. This might be due to most sugar mills from overall 17 mills are properly located near sugarcane fields.

- The optimal current situation in the Northeastern region

In the production year 2008/2009, there were 16 sugar mills operating in the Northeastern region. From Table 4.4, the sugarcane quantity supplied 26,819,215 tons from 231 fields of sugarcane area. Meanwhile, the sugarcane demand determined by the permitted production capacity in this region is 27,717,870 tons. The overall capacity utilization is very high of 96.76%. Three sugar mills out of 16 in the Northeastern region underutilized their capacity. They include Surin Sugar mill (73.43%), Burirum mill (91.24%), and Korach Industry mill (84.84%). This implied that the sugarcane quantity in this region may be also high. With more promotion and support for sugarcane farming, it is believed that all the mills in this region will certainly be able to expand their production capacity with no issue of sugarcane supply shortage.

Regarding transportation distances as obtained from the analysis with transportation model, the shortest (min) distance of 0.56 kilometers in column (8) occurred at Konburi mill. Meanwhile, the longest (max) distance of 210.28 kilometers in column (10) occurred at Saha Ruang mill. The overall average (mean) distance in this region, shown in column (9) is 47.80 kilometers. The longest average transportation distance is at Burirum mill with 78.77 kilometers. Meanwhile, Kumphawapi mill has the shortest average distance of 24.73 kilometers.

The objective function assuming that the transportation cost is proportional to the travel distance yields the minimum total transportation cost for the whole country in the production year 2008/2009 at 3,061,924,585 tons-kilometers. The monetary cost of transportation can be calculated by multiplying the figure with the estimated mean transportation cost between plantation areas to sugar mills. The mean cost was found from the research entitled "*Analyzing cost and lead time of harvesting and transporting the sugarcane to a factory for increase competitiveness*" (Tumcharoen, 2008), to be 4.12 Baht/ton/kilometer. Then the resulting overall transportation cost for the whole country in the production year 2008/2009 was 3,061,924,585 tons-kilometers x 4.12 Baht/ton/kilometer = 12,615,129,290 Baht, or over twelve billion Baht.

By using the Closest Facility function of Network Analyst Extension in ArcMap9.3, the optimal patterns of sugarcane transportation can be displayed as shown in Figure 4.6. The number in the circle refers to the sugar mill in the Table 4.4. According to the figure, sugarcanes were supplied to sugar mills nearby first in order to yield the optimal solution (minimum total transportation cost). Due to unequal sugarcane demands of sugar mills, quantities of sugarcane supplied to mills from field areas are different.

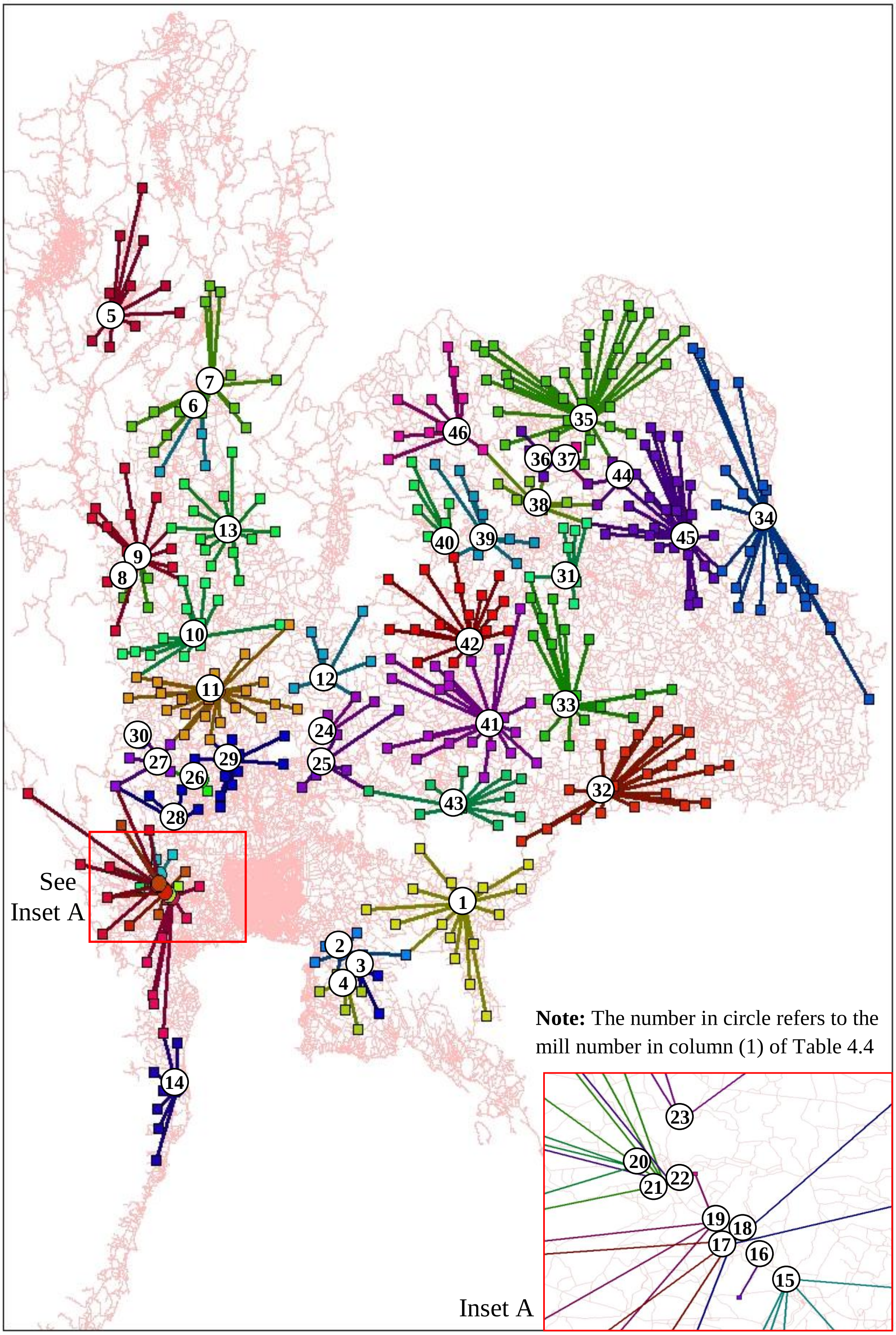


Figure 4.6 The optimal transportation pattern for case 1

In general, the optimal current utilization of most sugar mills capacity is quite high. 35 mills out of 46 fully utilized their maximum capacity. The overall capacity utilization is very high at 95.24%. The capacity utilization is lowest in the Central region at 91.53%, which might be caused by its highest number of sugar mills, 17 mills, most of which are clustered in the area of Kanchanaburi, Ratchaburi, and Nakhonpathom provinces. Insufficient sugarcane supply might have resulted in high competition and low utilization. Meanwhile, the capacity utilization is highest in the Eastern region at 99.95%. The reason for this might be because the Chonburi Sugar Industry mill had just ceased its operation for relocation. As a result, the number of mills in the Eastern region is fewer, but the supply remains the same.

Observe that the overall average transportation distance is 43.08 kilometers. This is considered appropriate because the Ministry of Agriculture and Cooperatives used to specify that the distance for sugarcane transportation should not exceed 50 kilometers (Nilpan, 2008). The reason is that, if the distance is longer the transportation cost will be too high. When the transportation pattern was taken into consideration, sugarcane fields were supplied to sugar mills nearby first. This pattern is considered appropriate. Since sugarcane fields were not transported across regions, the pattern would not lead to waste of unnecessary transportation cost. Together with the very high overall capacity utilization at 95.24%, the results in case 1 may be implied that the current number and location of mills seem to be appropriate.

Therefore, in case 2, which aims to clarify this impact, the researcher has tested by adding the Chonburi Sugar Industry mill back into the system. This addition is conducted in order to simulate the impact of sugar mill liberalization that allows new establishment of a sugar mill in the Eastern region. It is expected that the results after having all five mills in the system will reveal the motive behind the relocation of Chonburi Sugar Industry mill.

4.4.2 Case 2: The case of adding a new sugar mill in the Eastern region

The results from the optimal current situation in the production year 2008/2009 are needed as the benchmark for comparison. In order to study impacts of sugar mill liberalization on inbound logistics of sugarcane transportation and sugar production, a new sugar mill was experimentally added in the Eastern region to simulate the effect of sugar mill liberalization. The objective for this procedure is to analyze impacts of sugar mill liberalization on transportation patterns and capacity utilization due to the increasing sugarcane demand. The study tested by adding the Chonburi Sugar Industry mill, which ceased its operation since 2007/2008, back into the system. Details regarding the mill's sugarcane demand are as follows.

1) The allowable production capacity was 6,838 tons/day.

2) Chonburi Sugar Industry mill was assumed to operate for 90 days during the period of 2008/2009.

The above two numbers were then multiplied to obtain a result of 615,420 tons, which represents sugarcane demand of Chonburi Sugar Industry mill (D_{47}).

Therefore, in this case there are 47 sugar mills altogether, and their estimated overall sugarcane demand is 75,248,926 tons. However, the quantity of sugarcane production is still the same as the data of the year 2008/2009, which is 71,083,073 tons.

Table 4.5 presents results from solving the transportation problem with an additional new sugar mill in the Eastern region. The results in this table were also compared to results in Table 4.4. The differences between the two tables are interpreted as the impacts from the addition of a new sugar mill on the optimal inbound logistics. The following symbols were used in Table 4.5.

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 4.5 The results from solving the transportation problem: with the addition of a new sugar mill in the Eastern region

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	13 (-)	2,002,182 (-)	2,265,228 (0)	88.39 (-)	29.56 (0)	47.38 (-)	112.15 (0)	23.92 (-)
2	New Kwang Soon Lee	E	7 (0)	609,026 (0)	609,026 (0)	100.00 (0)	8.77 (0)	48.19 (+)	83.35 (+)	29.62 (+)
3	Rayong Sugar	E	2 (-)	589,215 (-)	589,360 (0)	99.98 (-)	25.93 (0)	34.42 (+)	71.02 (+)	31.88 (+)
4	Chonburi Sugar and Trading	E	5 (0)	379,433 (-)	527,800 (0)	71.89 (-)	20.44 (-)	26.12 (+)	49.97 (0)	12.08 (-)
47	Addition Mill in the East	E	2	409,380	615,420	66.52	5.24	5.69	24.09	13.33
	Eastern Region		**29 (-)**	**3,989,236 (0)**	**4,606,834 (+)**	**86.59 (-)**	**5.24 (-)**	**39.29 (-)**	**112.15 (0)**	**24.98 (-)**
5	Mae Wang Sugar Industry	N	11 (0)	274,595 (0)	327,450 (0)	83.86 (0)	9.51 (0)	43.04 (0)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	5 (+)	389,035 (0)	389,035 (0)	100.00 (0)	37.08 (+)	58.76 (+)	83.97 (0)	20.38 (-)
7	Thai Identity Sugar	N	13 (-)	2,155,625 (0)	2,736,000 (0)	78.79 (0)	13.69 (0)	61.55 (-)	109.5 (0)	30.85 (0)
8	Kampangpetch	N	4 (0)	864,000 (0)	864,000 (0)	100.00 (0)	15.46 (0)	34.54 (0)	52.20 (0)	17.05 (0)
9	Nakornpetch	N	13 (0)	2,784,000 (0)	2,784,000 (0)	100.00 (0)	17.34 (0)	42.11 (0)	99.22 (0)	21.77 (0)
10	Ruamphol Nakhonsawan	N	13 (0)	1,249,600 (0)	1,249,600 (0)	100.00 (0)	12.30 (0)	54.77 (0)	94.82 (0)	27.80 (0)
11	Kaset Thai Industry Sugar	N	22 (0)	6,360,000 (0)	6,360,000 (0)	100.00 (0)	18.04 (0)	49.02 (0)	120.62 (0)	29.02 (0)
12	Thai Roong Ruang Industry	N	7 (0)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	29.06 (-)	101.49 (0)	35.01 (0)
13	Phitsanulok	N	14 (0)	1,379,310 (0)	1,379,310 (0)	100.00 (0)	1.72 (0)	53.11 (0)	80.26 (0)	20.56(0)
	Northern Region		**102 (0)**	**18,480,165 (0)**	**19,113,395 (0)**	**96.69 (0)**	**1.72 (0)**	**46.41 (0)**	**128.65 (0)**	**27.85 (-)**
14	Pranburi Sugar Industry	C	7 (0)	630,000 (0)	630,000 (0)	100.00 (0)	13.54 (0)	42.77 (0)	70.84 (0)	19.65 (0)
15	Ratchaburi	C	8 (0)	649,943 (0)	1,248,000 (0)	52.08 (0)	6.55 (0)	41.38 (0)	131.58 (0)	43.34 (0)
16	Banpong	C	1 (0)	190,771 (0)	812,659 (0)	23.47 (0)	16.05 (0)	16.05 (0)	16.05 (0)	0.00 (0)
17	Mitrkasetr Industry	C	2 (0)	1,005,534 (0)	1,224,670 (0)	82.11 (0)	26.16 (0)	29.89 (0)	31.93 (0)	4.08 (0)

Table 4.5 The results from solving the transportation problem: with the addition of a new sugar mill in the Eastern region (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	2 (0)	1,137,701 (+)	1,176,400 (0)	96.71 (+)	53.44 (0)	56.41 (+)	60.50 (0)	4.99 (0)
19	New Krungthai	C	2 (0)	257,985 (-)	796,575 (0)	32.39 (-)	8.43 (0)	13.24 (+)	81.74 (0)	51.84 (0)
20	Thai Multi-Sugar Industry	C	2 (0)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	24.07 (0)	47.78 (0)	19.89 (0)
21	Tamaka	C	7 (-)	1,893,990 (0)	1,893,990 (0)	100.00 (0)	52.90 (0)	77.32 (+)	158.46 (0)	35.85 (+)
22	Prajuap Industry	C	2 (+)	885,707 (0)	885,707 (0)	100.00 (0)	4.78 (-)	33.45 (-)	51.96 (-)	33.36 (+)
23	Thai Sugar Industry	C	3 (0)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	25.73 (0)	48.78 (0)	15.61 (0)
24	T N Sugar	C	4 (0)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	22.18 (0)	81.58 (0)	30.95 (0)
25	Saraburi	C	8 (0)	2,779,370 (0)	2,779,370 (0)	100.00 (0)	8.98 (0)	33.82 (0)	99.99 (0)	29.67 (0)
26	Suphanburi Sugar Industry	C	3 (0)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	20.85 (0)	32.23 (0)	12.99 (0)
27	Mitr-Phol	C	5 (0)	3,011,540 (0)	3,011,540 (0)	100.00 (0)	24.09 (0)	34.69 (0)	51.43 (0)	10.15 (0)
28	U-thong Industry	C	5 (0)	1,524,866 (0)	1,524,866 (0)	100.00 (0)	2.09 (0)	24.33 (0)	72.91 (0)	25.75 (0)
29	Singburi	C	13 (0)	1,496,000 (0)	1,496,000 (0)	100.00 (0)	11.51 (0)	37.69 (0)	72.65 (0)	20.40 (0)
30	Banrai Industry	C	1 (0)	1,522,730 (0)	1,522,730 (0)	100.00 (0)	13.73 (0)	13.73 (0)	13.73 (0)	0.00 (0)
	Central Region		**75 (0)**	**21,794,457 (0)**	**23,810,827 (0)**	**91.53 (0)**	**2.09 (0)**	**34.71 (0)**	**158.46 (0)**	**30.96 (+)**
31	Wang Ka-nai	NE	8 (0)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	33.69 (0)	58.53 (0)	18.10 (0)
32	Surin Sugar	NE	23 (0)	1,033,964 (0)	1,408,000 (0)	73.43 (0)	10.74 (0)	63.00 (0)	109.68 (0)	28.82 (0)
33	Burirum	NE	17 (0)	1,182,511 (0)	1,296,000 (0)	91.24 (0)	7.97 (0)	78.77 (0)	137.49 (0)	38.23 (0)
34	Saha Ruang	NE	24 (0)	1,470,000 (0)	1,470,000 (0)	100.00 (0)	16.01 (0)	48.77 (0)	210.28 (0)	55.00 (0)
35	Rerm Udom	NE	32 (0)	2,017,036 (0)	2,017,036 (0)	100.00 (0)	17.04 (0)	62.44 (0)	146.74 (0)	40.00 (0)
36	Kasetr Phol	NE	3 (0)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	26.06 (0)	46.36 (0)	16.07 (0)

Table 4.5 The results from solving the transportation problem: with the addition of a new sugar mill in the Eastern region (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	4 (0)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	24.73 (0)	42.95 (0)	17.57 (0)
38	Khon Kaen	NE	9 (0)	2,142,000 (0)	2,142,000 (0)	100.00 (0)	6.64 (0)	31.20 (0)	89.73 (0)	24.12 (0)
39	Mitr Poo-Viang	NE	10 (0)	1,728,468 (0)	1,728,468 (0)	100.00 (0)	3.07 (0)	45.22 (0)	98.60 (0)	27.26 (0)
40	United Farmers and Industry	NE	7 (0)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	31.80 (0)	86.49 (0)	24.93 (0)
41	Korach Industry	NE	21 (0)	2,300,870 (0)	2,712,000 (0)	84.84 (0)	15.10 (0)	64.86 (0)	140.93 (0)	35.69 (0)
42	Andvian (Ratchasima)	NE	18 (0)	3,168,000 (0)	3,168,000 (0)	100.00 (0)	9.22 (0)	62.67 (0)	105.73 (0)	27.38 (0)
43	Konburi	NE	11(0)	1,656,490 (0)	1,656,490 (0)	100.00 (0)	0.56 (0)	43.74 (0)	102.01 (0)	24.84 (0)
44	E-Saan Sugar Industry	NE	4 (0)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	30.11 (0)	50.09 (0)	18.25 (0)
45	Mitr Kalasin	NE	29 (0)	2,280,000 (0)	2,280,000 (0)	100.00 (0)	7.17 (0)	48.29 (0)	139.09 (0)	34.02 (0)
46	Erawan Sugar	NE	11 (0)	876,636 (0)	876,636 (0)	100.00 (0)	1.61 (0)	50.74 (0)	85.20 (0)	25.94 (0)
	Northeastern Region		**231 (0)**	**26,819,215 (0)**	**27,717,870 (0)**	**96.76 (0)**	**0.56 (0)**	**47.80 (0)**	**210.28 (0)**	**38.34 (0)**
	Total		**437 (-)**	**71,083,073 (0)**	**75,248,926 (+)**	**94.46 (-)**	**0.56 (0)**	**42.95 (-)**	**210.28 (0)**	**35.04 (-)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy fields) = 44,711,427,211 tons-kilometers

Objective function (excluding dummy fields) = 3,052,897,212 tons-kilometers

Having compared the results of the new situation (Table 4.5) with the optimal current situation (Table 4.4), the impacts on the system of the sugar mills can be divided into four cases; namely, 1) the impact on the optimal capacity utilization 2) the impact on the optimal transportation distance 3) the impact on the optimal transportation pattern and 4) the impact on the optimal transportation cost.

1) The impact on the optimal capacity utilization

According to the optimal results in Table 4.5, the added Chonburi Industry Sugar mill achieved only 66.52% of its production capacity. This should be the reason that Chonburi Industry Sugar mill had requested to move out to another area. Obviously in column (7), the utilization of all sugar mills in the Eastern region have decreased, from 99.90% to 88.39%, 100% to 99.98%, 100% to 71.89% and 76.00% to 32.29%, for Eastern Sugar and Cane, Rayong Sugar Chonburi Sugar and Trading and New Krungthai mills, respectively. Note that only sugar mills in the Eastern region had lower utilization. The three sugar mills near the added one had lower capacity utilization because of more intense competition. However, in other regions, there was only New Krungthai mill that had reduced capacity utilization. In the same area Thai Sugar mill increased its utilization from 67.18% to 96.71%. The capacity utilization of all other sugar mills that was not mentioned remained unchanged. That means the addition of a sugar mill impacts the system by causing reduction in capacity utilization of nearby sugar mills, but had no influence at all for other sugar mills located far away.

The researcher has studied further about the situation of Chonburi Sugar Industry mill and found that the mill is a small one, and is not able to expand its area. Despite introducing high-technology machine, its operation is still uneconomical. In addition, since the areas around Chonburi province are promoted for industrial development, the land price is very high, and the government could not promote sugarcane plantation program to obtain sufficient supply for sugar mills there (Ministry of Industry, 2009). Since there was not enough sugarcane for its capacity, the mill realized that the more they operate, the more they would suffer a loss. Thus the mill has ceased its operation since the production year 2007/2008, and is now waiting for relocation.

2) The impact on the optimal transportation distance

According to the optimal results in columns (8) of Table 4.5, it is found that the shortest (min) transportation distance of Chonburi Sugar and Trading mill in the Eastern region increases from 11.35 to 20.44 kilometers. The reason might be because the newly added Chonburi Sugar Industry mill is located near the existing Chonburi Sugar and Trading mill. Thus sugarcane field in that area, which is 11.35 kilometers away from Chonburi Sugar and Trading mill and only 5.24 kilometers away from Chonburi Sugar Industry mill, turns to supply sugarcane to this mill instead. This change also affects the overall transportation distance. According to the results of the weighted average distance in Table 4.5 column (9), it was found that the overall average transportation distance from all sugarcane field areas to all sugar mills in the country decreased from 43.08 to 42.95 kilometers. Among those mills with increasing average distances, New Kwang Soon Lee mill increased from 35.14 to 48.19 kilometers. Rayong Sugar mill increased from 28.38 to 34.42 kilometers. Chonburi Sugar and Trading mill increased from 18.32 to 26.12 kilometers. According to those figures, it is evident that, by adding one more sugar mill in the Eastern region, the average transportation distances could increase as much as 6 – 13 kilometers. The reason is probably because the sugar mill addition caused changes in transportation patterns of some sugar mills, especially the sugar mills situating near the added one. By adding a sugar mill into the system, sugarcane competition could become more intense, leading to an increase in the average transportation distances of other sugar mills near the added one. For example, Uttaradit Sugar Industry mill increased the average distance from 38.54 to 58.76 kilometers. Thai Sugar Mill was up from 54.61 to 56.41 kilometers. New Krungthai mill was up from 10.48 to 13.24 kilometers. Meanwhile Tamaka mill increased from 67.30 to 77.32 kilometers.

On the contrary, the average transportation distances of Eastern Sugar and Cane mill decreased from 52.13 to 47.38 kilometers. It probably occurred because sugar cane from some fields changed the transportation route to the mill which is the nearest. There are slight changes at the mills in other regions. For example, the average transportation distance of Thai Identity mill decreased from 65.19 to 61.55 kilometers. Thai Roong Ruang mill decreased from 29.69 to 29.06 kilometers. Prajuap Industry mill decreased from 75.31 to 33.45 kilometers. Meanwhile, the average transportation distances of all other 35 sugar mills remained the same. These sugar mills were located very far from the added one. Thus they were not affected by the addition of the new sugar mill. Finally, the addition of Chonburi Sugar Industry mill has a negative effect on the longest (max) transportation distances in column (10) of New Kwang Soon Lee mill and Rayong mill. The longest distances for transporting sugarcane to these mills, which are located near the newly added Chonburi Sugar Industry mill, will increase due to the increasing competition for sugarcane. Consequently, these mills will have to transport sugarcane from fields further away in order to gain enough supply for their capacity.

3) The impact on the optimal transportation pattern

By using the Closest Facility function of Network Analyst Extension in ArcMap 9.3, the pattern of the optimal sugarcane transportation with the addition of a new sugar mill into the system can be displayed in Figure 4.7. According to the figure, it was found that the transportation routes of some sugarcane field areas have changed due to the impact of sugar mill addition. For example, some plantation areas that used to transport their sugarcane to the Eastern Sugar and Cane mill (1) have changed their destination. They started to transport sugarcane to the newly added sugar mill, which is closer. Therefore, the routes for transporting their sugarcane have changed. In addition, quantity of sugarcane supply to each sugar mill also changed. Some of the existing sugarcane supply would be provided to the new sugar mill. Therefore, the routes for transporting sugarcane to each mill could also be impacted.

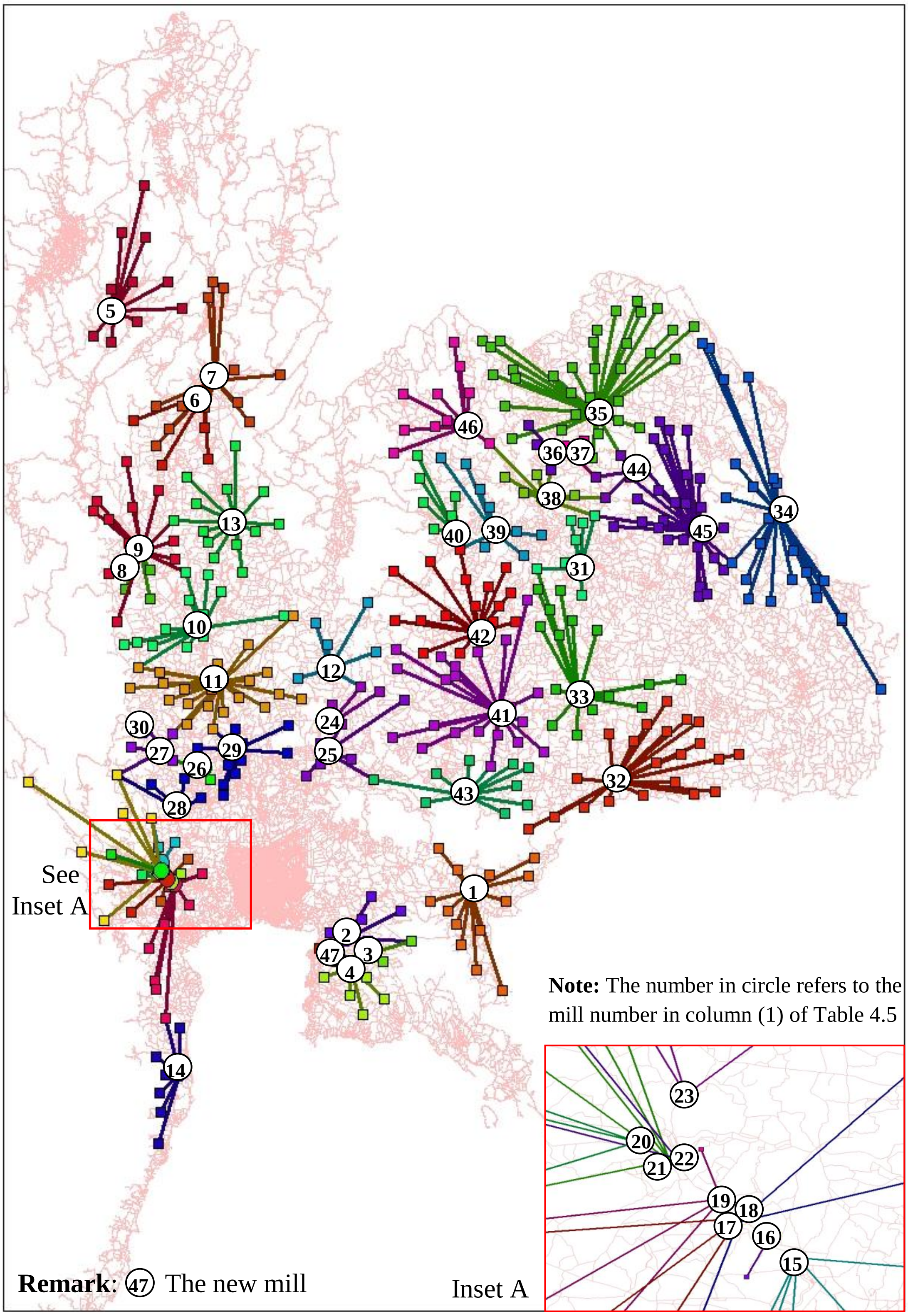


Figure 4.7 The optimal transportation pattern with the addition of a new mill in the Eastern region

4) The impact on the optimal transportation cost

This case intended to simulate the situation when there is liberalization such that the new establishment of one sugar mill is allowed. The objective function shows that the minimum total transportation cost for the whole country in the production year 2008/2009 would decrease from 3,061,924,585 to 3,052,897,212 tons-kilometers. The monetary transportation cost can then be calculated by using the mean sugarcane transportation cost of 4.12 Baht/ton/kilometer (Tumcharoen, 2008). The resulting total transportation cost would be 3,052,897,212 tons-kilometers x 4.12 Baht/ton/kilometer = 12,577,936,513 Baht. By adding one sugar mill in the Eastern region, the overall cost for sugarcane transportation in Thailand would decrease from 12,615,129,290 Baht to 12,577,936,513 Baht which means a reduction of about 37 million Baht. It is implied that under certain circumstances the liberalization of sugar mill could lead to lower optimal system transportation cost. A benefit has not been explicitly mentioned during the past consideration.

4.4.3 Case 3: The Cabinet Resolution

Previously, there has been several Cabinet resolution regarding the relocation and capacity expansion of sugar mills. Policies on relocation and capacity expansion are a part of sugar mill liberalization. This research aims to study impacts from sugar mill liberalization that may happen when the new mill establishment, relocation, and capacity expansion are freely allowed. Therefore, the Cabinet Resolution dated on 16 October 2007 regarding the relocation and capacity expansion of some sugar mills in the future, is used as the case study. The cabinet resolution on 16 October 2007 has approved the relocation and/or capacity expansion of five sugar mills altogether; namely, the relocation and capacity expansion of New Kwang Soon Lee mill, Banpong mill, and New Krungthai mill; and the capacity expansion of Phitsanulok mill and Banrai mill. In the production year 2010/2011, these five mills have not completed their relocation/expansion processes. They were allowed to complete the processes within five years after receiving the permission from the Ministry of Industry. Thus it is expected that their processes will be completed in the production year 2013/2014. However, if the deadline is due and they could not complete the processes, they have an option to request for extending the period from the Ministry of Industry.

In this case, besides using primarily the cabinet resolution dated on 16 October 2007 regarding relocation and/or capacity expansion of the five sugar mills as discussed previously, the case will also include the capacity expansion of Erawan mill from 8,117 tons to 15,000 tons which has already finished the expansion process in the production year 2009/2010. Chonburi Sugar Industry mill has ceased its operation since the production year 2007/2008 for relocating and expanding its capacity. The request of the mill has just been approved by the cabinet on 1 March 2011, and its relocation/expansion processes is expected to be completed during the production year 2016/2017. Therefore, there are 47 sugar mills altogether in this assumed case. The analysis should reveal impacts of the situations when changes regarding capacity expansion and relocation of sugar mills truly happen. It is the good opportunity to apply the methodology for analyzing the real case of the liberalization policy.

The cabinet has accepted in principle regarding the relocation and the expansion of production capacity of seven sugar mills according to the proposal by the Ministry of Industry. Details of the ministerial resolution are as follows;

1) New Kwang Soon Lee mill had requested to move its location from Panusnikom district, Chonburi province, to a new location in Tapraya district, Srakaew province. The mill also requested to expand its production capacity from 6,479 to 20,400 tons/day.

2) Banpong mill had requested to move its location from Ban Pong district, Ratchaburi province to a new location in Bandan-larnhoi district, Sukhothai province. The mill also requested to expand its production capacity from 9,131 to 18,000 tons/day.

3) New Krungthai mill had requested to move its location from Thamaka district, Kanchanaburi province, to a new location in Borploy district also in Kanchanaburi province. The mill also requested to expand its production capacity from 8,385 to 20,400 tons/day.

4) Chonburi Industry Sugar mill had requested to move its location from Banbueng district, Chonburi province to a new location in Nongbua district, Nakhonsawan province. The mill also requested to expand its production capacity from 6,868 to 36,000 tons/day.

5) Phitsanulok mill had requested to expand its production capacity from 11,994 to 22,000 tons/day.

6) Banrai Industry mill had requested to expand its production capacity from 11,990 to 22,000 tons/day.

7) Erawan Sugar mill had requested to expand its production capacity from 8,117 to 15,000 tons/day.

Since the relocation and/or capacity expansion of these mills have not truly happened, their numbers of operation days to be used for the analysis have been assumed to be as same as the corresponding figures in the production year 2008/2009. However, there is an exception for Chonburi Sugar Industry mill, which has ceased its operation since the year 2007/2008. For this mill, its number of operation days in the year 2007/2008 is used instead for the analysis with the transportation model. The model parameters for this case can be concluded as follows;

1) New Kwang Soon Lee mill had been allowed to expand its production capacity from 6,479 to 20,400 tons/day. The number of production days is 94 days. Therefore, the sugarcane demand of this sugar mill (D_2) is 20,400 × 94 = 1,917,600 tons.

2) Banpong mill had been allowed to expand its production capacity from 9,131 to 18,000 tons/day. The number of production days is 89 days. Therefore, the sugarcane demand of this sugar mill (D_{16}) is 18,000 × 89 = 1,602,000 tons.

3) New Krung Thai mill had been allowed to expand its production capacity from 8,385 to 20,400 tons/day. The number of production days is 95 days. Therefore, the sugarcane demand of this sugar mill (D_{19}) is 20,400 × 95 = 1,938,000 tons.

4) Chonburi Industry Sugar mill had been allowed to expand its production capacity from 6,868 to 36,000 tons/day. The number of production days is 89 days. Therefore, the sugarcane demand of this sugar mill (D_{47}) is 36,000 × 90 = 3,240,000 tons.

Regarding the relocation of approved sugar mills, the cabinet resolution gives details about the new locations only at the district. For example, the resolution specifies that the cabinet has approved Chonburi Industry Sugar mill to relocate to Nongbua district, Nakhonsawan province. The resolution does not state clearly about the exact location probably because the relocation needs to be investigated with the criteria of the Ministry of Industry, which prohibits relocation if the new location is less than 80 kilometers away, along the shortest route, from the sugar mill in the old location. Therefore, the exact positions of the new locations of these mills are not known. To assume a new position for each mill, this research has to analyze for the centroid of the district to where each mill is allowed to relocate. The centroid analysis was conducted using ET GeoWizards extension in ArcMap in order to find the new positions of the approved mills. The distances from sugarcane plantation areas to the new location of the four sugar mills can then be calculated by using ArcMap software.

5) Phitsanulok mill had been allowed to expand its production capacity from 11,994 to 22,000 tons/day. The number of production days is 115 days. Therefore, the sugarcane demand of this sugar mill (D_{13}) is 22,000 × 115 = 2,530,000 tons.

6) Banrai Industry mill had been allowed to expand its production capacity from 11,990 to 22,000 tons/day. The number of production days is 127 days. Therefore, the sugarcane demand of this sugar mill (D_{30}) is 22,000 × 127 = 2,794,000 tons.

7) Erawan Sugar mill had been allowed to expand its production capacity from 8,117 to 15,000 tons/day. The number of production days is 108 days. Therefore, the sugarcane demand of this sugar mill (D_{46}) is 15,000 × 108 = 1,620,000 tons.

According to the cabinet resolution regarding the approval for relocation and/or capacity expansion of those sugar mills, it is expected that their processes will be completed in the production year 2013/2014. However, there is no forecasted figure of sugarcane growing area for that year. This study therefore assumes that the processes of relocation and/or expansion of these mills are completed in the production year 2008/2009. The data of sugarcane area in 2008/2009 is then used instead in the analysis. The cabinet's approval resulted in an increase in sugarcane demand of all sugar mills in the country from 74,633,506 tons to 84,278,170 tons, while the quantity of sugarcane production remains the same at 71,083,073 tons. Table 4.6 presents results from solving the transportation problem supposed that the cabinet resolution would be implemented. The results in this table were also compared to results in Table 4.4. The differences between the two tables are interpreted as the impacts of this resolution on the optimal inbound logistics. The following symbols were used in Table 4.6.

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 4.6 The results from solving the transportation problem: the Cabinet Resolution

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	18 (-)	2,265,228 (+)	2,265,228 (0)	100.00 (+)	29.56 (0)	73.68 (+)	148.78 (+)	40.09 (+)
2	New Kwang Soon Lee	E	7 (0)	775,659 (+)	1,917,600 (+)	40.45 (-)	11.56 (+)	52.13 (+)	63.36 (-)	18.63 (-)
3	Rayong Sugar	E	4 (+)	589,360 (0)	589,360 (0)	100.00 (0)	23.86 (-)	29.52 (+)	53.59 (0)	13.65 (-)
4	Chonburi Sugar and Trading	E	4 (-)	527,800 (0)	527,800 (0)	100.00 (0)	11.35 (0)	16.05 (-)	49.97 (0)	16.09 (+)
	Sum of the Eastern		**33 (+)**	**4,158,047 (+)**	**5,299,988 (+)**	**78.45 (-)**	**11.35 (+)**	**56.06 (+)**	**148.78 (+)**	**38.56 (+)**
5	Mae Wang Sugar Industry	N	11 (0)	274,595 (0)	327,450 (0)	83.86 (0)	9.51 (0)	43.04 (0)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	2 (-)	389,035 (0)	389,035 (0)	100.00 (0)	27.54 (0)	30.44 (-)	37.08 (-)	6.75 (+)
7	Thai Identity Sugar	N	11 (-)	1,052,261 (-)	2,736,000 (0)	38.46 (-)	13.69 (0)	56.97 (-)	109.5 (0)	32.63 (+)
8	Kampangpetch	N	4 (0)	864,000 (0)	864,000 (0)	100.00 (0)	15.46 (0)	34.54 (0)	52.20 (0)	17.05 (0)
9	Nakornpetch	N	10 (-)	2,784,000 (0)	2,784,000 (0)	100.00 (0)	17.34 (0)	40.50 (-)	86.75 (-)	18.47 (-)
10	Ruamphol Nakhonsawan	N	12 (-)	980,085 (-)	1,249,600 (0)	78.43 (-)	12.30 (0)	48.36 (-)	90.87 (-)	24.80 (-)
11	Kaset Thai Industry Sugar	N	13 (-)	4,999,725 (-)	6,360,000 (0)	78.61 (-)	18.04 (0)	40.36 (-)	89.46 (-)	23.56 (-)
12	Thai Roong Ruang Industry	N	7 (0)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	30.60 (+)	101.49 (0)	35.26 (+)
13	Phitsanulok	N	13 (-)	1,040,812 (-)	2,530,000 (+)	41.14 (-)	1.72 (0)	50.51 (-)	80.26 (0)	20.96(+)
16	Banpong	N	9 (+)	1,602,000 (+)	1,602,000 (+)	100.00 (+)	1.93 (-)	62.00 (+)	72.46 (+)	21.87 (+)
47	Chonburi Sugar Industry	N	6	441,847	3,240,000	13.64	18.92	45.51	121.43	35.77
	Sum of the Northern		**98 (0)**	**17,452,360 (-)**	**25,106,085 (+)**	**69.51 (-)**	**1.72 (0)**	**42.40 (-)**	**128.65 (0)**	**26.70 (-)**
14	Pranburi Sugar Industry	C	7 (0)	630,000 (0)	630,000 (0)	100.00 (0)	13.54 (0)	42.77 (0)	70.84 (0)	19.65 (0)
15	Ratchaburi	C	10 (+)	850,404 (+)	1,248,000 (0)	68.14 (+)	6.55 (0)	37.32 (-)	181.68 (+)	56.13 (+)
17	Mitrkasetr Industry	C	2 (0)	955,928 (-)	1,224,670 (0)	78.06 (-)	26.16 (0)	29.79 (-)	31.93 (0)	4.08 (0)

Table 4.6 The results from solving the transportation problem: the Cabinet Resolution (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	1 (-)	658,815 (-)	1,176,400 (0)	56.00 (-)	53.44 (0)	53.44 (-)	53.44 (-)	0.00 (-)
19	New Krungthai	C	3 (+)	1,938,000 (+)	1,938,000 (+)	100.00 (+)	18.39 (+)	28.28 (+)	46.82 (-)	14.66 (-)
20	Thai Multi-Sugar Industry	C	2 (0)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	24.07 (0)	47.78 (0)	19.89 (0)
21	Tamaka	C	5 (-)	984,617 (-)	1,893,990 (0)	51.99 (-)	52.90 (0)	62.46 (-)	158.46 (0)	42.35 (+)
22	Prajuap Industry	C	3 (+)	885,707 (0)	885,707 (0)	100.00 (0)	4.78 (-)	21.16 (-)	80.56 (+)	38.27 (+)
23	Thai Sugar Industry	C	3 (0)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	25.00 (-)	27.22 (-)	4.91 (-)
24	T N Sugar	C	2 (-)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	18.68 (-)	21.36 (-)	4.96 (-)
25	Saraburi	C	7 (-)	2,779,370 (0)	2,779,370 (0)	100.00 (0)	8.98 (0)	35.63 (+)	99.99 (0)	31.93 (+)
26	Suphanburi Sugar Industry	C	5 (+)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	17.86 (-)	26.73 (-)	8.85 (-)
27	Mitr-Phol	C	5 (0)	3,011,540 (0)	3,011,540 (0)	100.00 (0)	24.09 (0)	31.81 (-)	45.20 (-)	7.77 (-)
28	U-thong Industry	C	5 (0)	1,524,866 (0)	1,524,866 (0)	100.00 (0)	2.09 (0)	21.56 (-)	41.77 (-)	15.03 (-)
29	Singburi	C	13 (0)	1,211,679 (-)	1,496,000 (0)	80.99 (-)	11.51 (0)	35.60 (-)	75.13 (+)	23.16 (+)
30	Banrai Industry	C	5 (+)	2,794,000 (+)	2,794,000 (+)	100.00 (0)	13.73 (0)	26.38 (+)	74.68 (+)	23.72 (+)
	Central Region		**78 (+)**	**23,033,246 (+)**	**25,410,863 (+)**	**90.64 (-)**	**2.09 (0)**	**30.64 (-)**	**181.68 (+)**	**33.40 (+)**
31	Wang Ka-nai	NE	8 (0)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	33.00 (-)	55.80 (-)	15.98 (-)
32	Surin Sugar	NE	21 (-)	873,277 (-)	1,408,000 (0)	62.02 (-)	10.74 (0)	57.90 (-)	109.68 (0)	29.71 (+)
33	Burirum	NE	16 (-)	1,048,619 (-)	1,296,000 (0)	80.91 (-)	7.97 (0)	72.44 (-)	118.37 (-)	34.87 (-)
34	Saha Ruang	NE	23 (-)	1,334,958 (-)	1,470,000 (0)	90.81 (-)	16.01 (0)	45.22 (-)	210.28 (0)	56.18 (+)
35	Rerm Udom	NE	30 (-)	2,017,036 (0)	2,017,036 (0)	100.00 (0)	17.04 (0)	54.46 (-)	142.88 (-)	37.46 (-)
36	Kasetr Phol	NE	3 (0)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	24.61 (-)	46.36 (0)	16.07 (0)

Table 4.6 The results from solving the transportation problem: the Cabinet Resolution (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	4 (0)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	25.55 (+)	42.95 (0)	17.57 (0)
38	Khon Kaen	NE	9 (0)	2,142,000 (0)	2,142,000 (0)	100.00 (0)	6.64 (0)	30.64 (-)	61.12 (-)	16.83 (-)
39	Mitr Poo-Viang	NE	10 (0)	1,728,468 (0)	1,728,468 (0)	100.00 (0)	3.07 (0)	37.07 (-)	71.01 (-)	19.37 (-)
40	United Farmers and Industry	NE	6 (-)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	26.66 (-)	66.95 (-)	19.17 (-)
41	Korach Industry	NE	16 (-)	1,719,468 (-)	2,712,000 (0)	63.40 (-)	15.10 (0)	56.67 (-)	132.71 (-)	35.14 (-)
42	Andvian (Ratchasima)	NE	21 (+)	3,168,000 (0)	3,168,000 (0)	100.00 (0)	9.22 (0)	57.22 (-)	105.73 (0)	26.01 (-)
43	Konburi	NE	9 (-)	1,544,354 (-)	1,656,490 (0)	93.23 (-)	0.56 (0)	36.55 (-)	70.74 (-)	19.64 (-)
44	E-Saan Sugar Industry	NE	3 (-)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	26.84 (-)	50.09 (0)	19.47 (+)
45	Mitr Kalasin	NE	29 (0)	2,280,000 (0)	2,280,000 (0)	100.00 (0)	7.17 (0)	47.06 (-)	139.09 (0)	34.02 (0)
46	Erawan Sugar	NE	17 (+)	1,620,000 (+)	1,620,000 (+)	100.00 (0)	1.61 (0)	55.40 (+)	97.92 (+)	26.16 (+)
	Northeastern Region		**225 (-)**	**26,439,420 (-)**	**28,461,234 (+)**	**92.90 (-)**	**0.56 (0)**	**43.41 (-)**	**210.28 (0)**	**37.04 (-)**
	Total		**434 (-)**	**71,083,073(0)**	**84,278,170 (+)**	**84.34 (-)**	**0.56 (0)**	**39.76 (-)**	**210.28 (0)**	**35.16 (-)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy fields) = 134,777,441,493 tons-kilometers

Objective function (excluding dummy fields) = 2,826,471,493 tons-kilometers

- Impacts of the Cabinet resolution in the Eastern region

Having assuming that the relocation and capacity expansion of New Kwang Soon Lee mill according to the cabinet resolution was implemented in the production year 2008/2009, the overall sugarcane demand in this region also increases from 3,991,414 tons to 5,299,988 tons. The relocation of New Kwang Soon Lee mill to be located near the Northeastern region leads to more sugarcane in the Northeastern area being supplied to the Eastern region. Therefore, the overall sugarcane supply to this region has increased from 3,989,239 tons to 4,158,047 tons. Considering only New Kwang Soon Lee mill, it will receive more sugarcane supply from 609,026 tons to 775,659 tons. However, since it has requested to expand its capacity for almost three times of the current capacity in the production year 2008/2009, the relocation and expansion will lead to decreased capacity utilization of this mill to only 40.45%. This is different from the situation of Eastern Sugar and Cane mill, whose capacity utilization would increase from 99.90% to 100%.

Consideration should be made regarding the impact that may happen to New Kwang Soon Lee mill after it has relocated from Panusnikom district, Chonburi province, to Tapraya district, Srakaew province, and has expanded its capacity. If quantity of sugarcane supply remains the same as the production year 2008/2009, the mill will have very low capacity utilization at 40.45%, and this can lead to capital loss or bankruptcy of the mill. The mill might have to end its business eventually. However, the truth is that, the company has not finished its relocation and expansion processes, which is expected to complete in the year 2013/2014. There is still time for preparation. After seeing these figures and realizing this impact, the mill should prepare in advance by promoting sugarcane plantation in the new location, as stated in the plan proposed to the Ministry of Industry. With effective preparation, the mill will be able to obtain sufficient sugarcane supply that matches its requested capacity.

The analysis was conducted using the transportation model with the case when the cabinet resolution has been implemented. The results in Table 4.6 reveal that the shortest (min) distance of the Eastern region increase from 8.77 to 11.56 kilometers. The reason is because of the relocation of New Kwang Soon Lee mill from Chonburi province to Srakaew province. The average (mean) distances in column (9), three-fourths of the mills in this region increased average distances. These mills with increased average distances are Eastern Sugar and Cane mill, New Kwang Soon Lee mill, and Rayong mill, from 52.13 to 73.68 kilometers, from 35.14 to 52.13 kilometers, and from 28.38 to 29.52 kilometers, respectively. Chonburi Sugar and Trading mill is the only mill with decreased average distance from 18.32 to 16.05 kilometers. Regarding the longest (max) distance, the relocation of New Kwang Soon Lee mill will make the longest (max) distance decrease from 70.91 to 63.36 kilometers. On the other hand, this relocation will make the longest (max) distance of Eastern Sugar and Cane mill increase from 112.15 km to 148.78 km. The reason could be explained by examining the Figure 4.6, and compare with Figure 4.8. From comparing these figures, it can be seen that the fields that used to supply sugarcane for Eastern Sugar and Cane mill will change to New Kwang Soon Lee mill after the relocation, because of the shorter transportation distance. As a result, Eastern Sugar and Cane mill will have insufficient sugarcane supply for its operation, thus it will have to transport sugarcane from the fields in Chonburi province, which are further away.

- Impacts of the Cabinet resolution in the Northern region

In the production year 2008/2009, there were nine mills operating in the Northern region. After the relocation and capacity expansion of some mills according to the cabinet resolution, number of the mills in this region will increase to 11 mills. The newcomers are Banpong mill (from the Central region) and Chonburi Sugar Industry mill (from the Eastern region). Besides, with the capacity expansion of Phitsanulok mill, the overall capacity of all mills in this region will increase from 140,427 to 204,433 tons/day. As a consequence, overall sugarcane demand in this region will increase from 19,113,395 tons to 25,106,085 tons. The analysis was conducted by assuming that the relocation and capacity expansion of the afore-mentioned mills has been completed within the production year 2008/2009. Based on the results in column (7) of Table 4.6, the utilization of these mills have decreased, from 78.79% to 38.46%, 100% to 78.43%, 100% to 78.61%, and 100% to 41.14%, for Thai Identity, Ruamphol Nakhonsawam, Kaset Thai, and Phitsanulok mill, respectively. On the other hand, Banpong mill, after relocating to this region, would gain more sugarcane supply, and its capacity utilization would increase from 24.47%

to 100%. Meanwhile, the capacity utilization of Chonburi Sugar Industry mill would be at 13.64%.

The very low capacity utilization of Chonburi Sugar Industry mill might make the results look skeptical. It is believed that the main cause is the usage of old data in the production year 2008/2009 for the analysis. In fact, the sugarcane yield in the present year (the production year 2011/12) should be higher than that of 2008/2009, and that means the mill should be able to utilize more of its capacity. However, there are some other reasons to explain about this low utilization. The terrain in Nongbua district of Nakhonsawan province where Chonburi Sugar Industry mill requested to relocate is mostly mountainous. The soil in some plains that exist in the area is sandy and dry, with insufficiency of water supply, making it unsuitable for sugarcane cultivation. Additionally, another cause is that Nakhonsawan province already has two sugar mills; namely, Ruamphol Naknonsawan mill and Kaset Thai mill. Sugarcane quantity in the area is already insufficient for production capacity of these two existing mills, and this makes Nakhonsawan authority strongly disagreed with the new establishment of Chonburi Sugar Industry mill in the area (Ministry of Industry, 2011). According to the analysis in this case, Chonburi Sugar Industry mill has relocated to Nakhonsawan province while sugarcane quantity in the area is equal to that of the production year 2008/2009. Ruamphol Naknonsawan mill and Kaset Thai mill would have lower capacity utilization. Chonburi Sugar Industry mill is also affected. Its capacity utilization will be only 13.64% due to the insufficiency of sugarcane supply in the area.

The overall capacity utilization of the Northern region, if the relocation and capacity expansion has been in effect since the production year 2008/2009, the overall capacity utilization of sugar mills in this region would apparently decrease from 96.69% to 69.51%. The mill that deserves the greatest concern is Chonburi Sugar Industry mill, whose capacity utilization will at 13.64%.

Regarding the transportation distances in Table 4.6, the relocation of Banpong mill from the Central region and Chonburi Sugar Industry mill from the Eastern region to the Northern region would make the shortest (min) distance of Banpong mill decrease from 16.05 to 1.93 kilometers. Six mills would have decreased average (mean) transportation distances as shown in column (9). Thai Roong Ruang

Industry mill is the only one that would increase the average distance, from 29.69 up to 30.60 kilometers. Examining locations of the mills, Thai Roong Ruang Industry mill is located near the newly relocated mill, Chonburi Sugar Industry mill. These two mills would have to compete for sugarcane supply in that area. Many mills were found to have decreased the longest (max) transportation distances, as shown in column (10). The reason should be due to the new coming of the two sugar mills. Under the current situation in the production year 2008/2009, sugarcane had to be transported from the fields being far away from the existing mills. With the relocation of the two mills, sugarcane fields would have options to transport with shorter distances.

- Impacts of the Cabinet resolution in the Central region

In the production year 2008/2009, there were 17 sugar mills operating in the Central region. After the relocation of Banpong mill to the Northern region according to the cabinet resolution, the number of the mills in the Central region will decrease to 16 mills. However, the overall sugarcane demand will increase from 23,810,827 tons to 25,410,863 tons, because of the capacity expansion of New Krungthai mill and Banrai mill in the Central region. Supposed that the relocation and capacity expansion of the mills were in effect within the production year 2008/2009, the analysis results in Table 4.6 show that the relocation of Banpong mill to the Northern region would have a positive impact on capacity utilization of Ratchaburi mill, up from 52.08% to 68.14%. These two mills are currently located near each other. After Banpong mill was moved out, Ratchaburi mill would receive more sugarcane supply from the fields that used to supply sugarcane to Banpong mill. In case of New Krungthai mill, although its relocation and capacity expansion would make its capacity utilization remain to be 100%, but the increasing demand from 605,389 tons to 1,938,000 tons would have a negative impact on sugar mills locating near its new location. These mills, whose capacity utilizations would be impacted and become decreased, are Mitrkasetr mill (from 82.11% to 78.06%), Thai Sugar mill (from 67.18% to 56%) and Tamaka mill (from 100% to 51.99%). Considering the overall capacity utilization in this region with the assumption that the relocation and capacity expansion had completed in the production year 2008/2009, the impact might lead to decreased overall capacity utilization of sugar mills in this region from 91.53%

to 90.64%. Sugar mills that would be impacted most with decreased production capacities are those located near Kanchanaburi province or nearby provinces.

Based on the optimal solution from the transportation model in the Table 4.6, it is found that the shortest (min) distance for sugarcane transportation in the Central region occurs at U-thong mill of 2.09 kilometers. Regarding the average (mean) distance as shown in column (9), it is found that only three mills; namely, New Krungthai mill, Saraburi mill, and Banrai mill that have increased average distance. When considering the longest (maximum) distance in column (10) and comparing the optimal current situation in Table 4.4 to the situation with implementation of the cabinet resolution in Table 4.6, the longest (maximum) distance increased from 158.46 to 181.68 kilometers. These changes might be caused from the capacity expansion of sugar mills in this region, which makes overall sugarcane demand become higher. However, since there is insufficient sugarcane supply in this region, some of the supply then has to be imported from another region. As seen in Figure 4.8, some sugarcane is transported from the Eastern region to the Central region. The sugar mill that receives sugarcane supply from the Eastern region is Ratchaburi mill.

- Impacts of the Cabinet resolution in the Northeastern region

In the production year 2008/2009, numbers of sugar mills in Northeastern region were 16 mills. The sugarcane demand in this region was estimated to be 27,717,870 tons, as shown in Table 4.4. However, due to the capacity expansion of Erawan mill, the overall sugarcane demand in this region will increase to 28,461,234 tons, as shown in Table 4.6. In addition, the relocation of New Kwang Soon Lee mill to be closer to this region, together with its expanded capacity according to the cabinet resolution, will make Surin, Burirum, Korach Industry, and Konburi mills have decreased capacity utilizations, as shown in column (7), from 73.43% to 62.02%, 91.24% to 80.91%, 84.84% to 63.40%, and 100% to 93.23%, respectively. This is because these mills are located near the new location of New Kwang Soon Lee mill. The reduction in capacity utilization of these mills resulted in an overall reduction of the region’s capacity utilization from 96.76% to 92.90%. The reason should be because of the decreased quantity of sugarcane supply from 26,819,215 tons to 26,439,420 tons.

Considering transportation distances from sugarcane fields to the sugar mills in the Northeastern region, the shortest (min) distance in column (8) of Table 4.6 occurred at Konburi mill at 0.56 kilometers. Meanwhile, the longest (max) distance in column (10) is the transportation to Saha Ruang mill at 210.28 kilometers. The most sugar mills in Northeastern region in column (9) have decreased average (mean) distances, with the exception of only two mills; namely, Kumphawapi mill and Erawan mill, whose average distances increase from 24.73 to 25.55 kilometers, and 50.74 to 55.40 kilometers, respectively. This might be resulted from the capacity expansion of Erawan mill, which forces both mills to transport sugarcane from the fields being further away in order to gain sufficient supply for its capacity. The nearby sugar mill, like Kumphawapi mill, is also affected in a similar way from that expansion.

Figure 4.8 represents the optimal pattern of sugarcane transportation from sugarcane fields to each sugar mill after assuming that the cabinet resolution has been in effect in the production year 2008/2009. Comparing Figure 4.8 with the optimal current situation in Figure 4.6, it is found that the relocation of New Kwang Soon Lee mill would make the fields that used to supply sugarcane to this mill having to supply to other mills that are located further away. Some sugarcane from these fields would be transported to Eastern Sugar and Cane mill (1), and some would go to the mills in the Central region. This is because Rayong mill (3) and Chonburi Sugar and Trading mill (4), which are located near these fields, have already fully utilized their capacity. Thus they could not receive any more sugarcane. Regarding the relocation of Banpong mill (16) and Chonburi Sugar Industry mill (47) to the Northern region, the pattern of transportation in that region would be changed due to this relocation. This is particularly true for areas around the new locations of the two mills, because some sugarcane fields will certainly switch to supply to these new mills due to the closer distances.

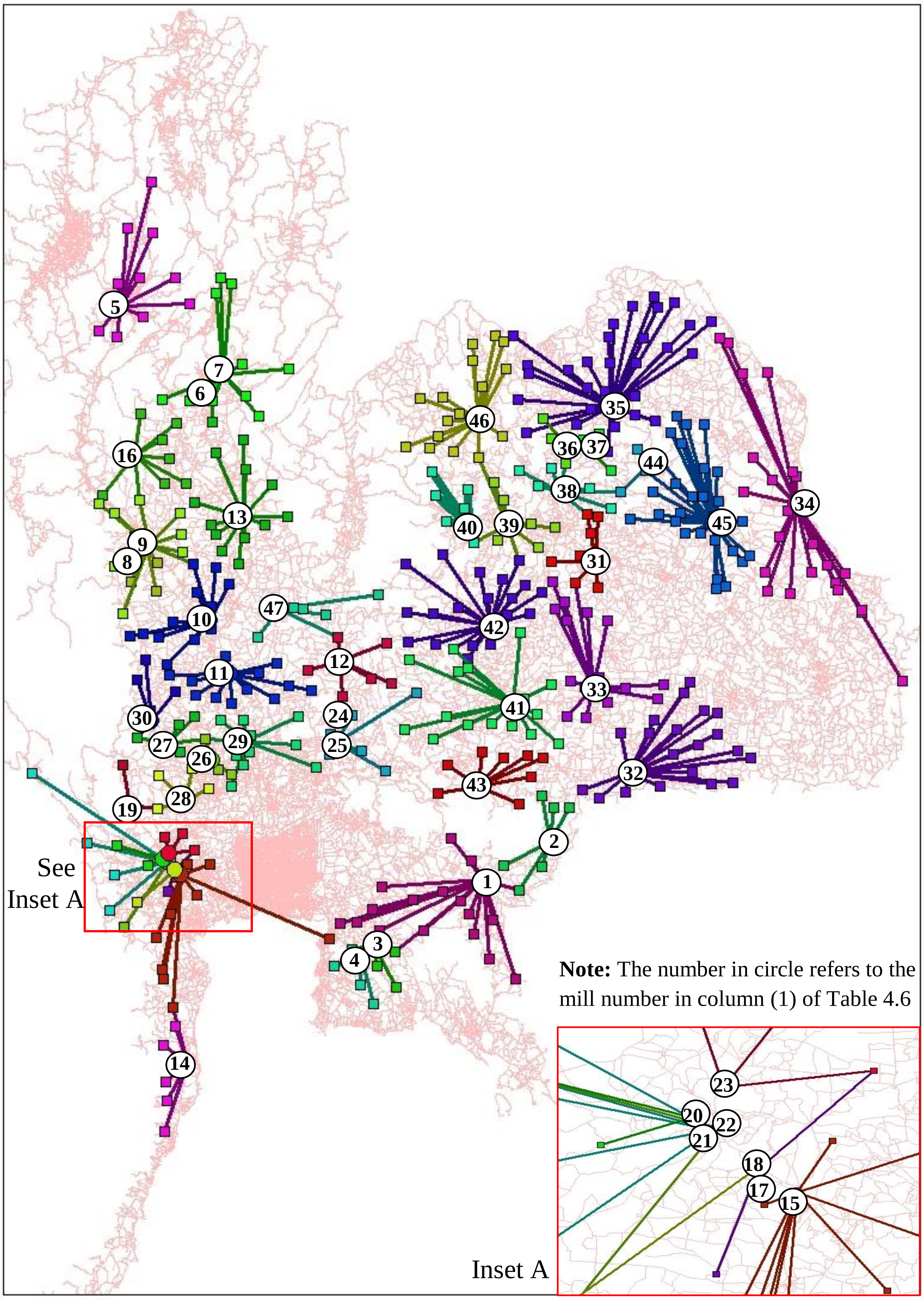


Figure 4.8 The optimal transportation pattern for the case of the Cabinet Resolutions

The objective function unit derived from the transportation model, leaving out the value of dummy fields, reduces from 3,061,924,585 tons-kilometers to 2,826,471,493 tons-kilometers. When these figures are multiplied with the mean sugarcane transportation cost of 4.12 Baht/ton/kilometer, the resulting overall sugarcane transportation cost is found to reduce from 12,615,129,290 Baht to 11,645,062,551 Baht. The cause might be because the sugarcane quantity used in the analysis was the data of the production year 2008/2009, making the sugarcane quantity become insufficient for the increased demand from the capacity expansion. With insufficiency of sugarcane supply, transportation becomes less, and the overall transportation cost is reduced. In addition, since some sugar mills will relocate from areas with inadequate sugarcane supply to areas with more supply, they will not have to transport sugarcane from areas further away in order to meet their capacity. Moreover, some sugar mills situated in areas with high amount of sugarcane supply are allowed to expand their capacity, so the excessive sugarcane will not have to be transported to sugar mills in other areas. With all these reasons, the overall transportation distance and transportation cost in the country become reduced.

In summary, the impacts of the ministerial resolution on the inbould logistics by region are as follows;

The Eastern region: Based on the sugarcane yield data of the production year 2008/2009, after New Kwang Soon Lee mill have relocated from Chonburi province to Srakaew province and expanded its capacity, the capacity utilization of the mill would significantly decrease, by being down to only 40.45%. If this prediction is true, it could be considered that the mill has made a wrong decision. The investment for relocation and capacity expansion requires a huge budget of almost 4,000 million Baht (Ministry of Industry, 2008). With this very low capacity utilization, the mill might face a crisis and may suffer a loss in its operation. This will also lead to negative impacts to the farmers, as noticed in the pattern of transportation illustrated in Figure 4.8. From the figure, some groups of the growing areas that used to supply sugarcane to New Kwang Soon Lee mill require longer distance for transporting sugarcane to another mill. Since the mills nearby already have enough sugarcane, some farmers many have to take a burden of extra transportation cost because they have to transport their sugarcane to a mill in the Central region.

The Northern region: after the relocation of Banpong mill and Chonburi Sugar Industry mill to this region, together with the capacity expansion of Phitsanulok mill, the farmers seem to be impacted positively, mainly because of shorter transportation distances. The farmers can save their transportation cost quite much. The results from the analysis with the transportation model reveal that Banpong mill might have made a right decision for moving to the Northern region. After the relocation, its capacity utilization will increase greatly from a very low figure of 23.47% at the old location to be as high as 100% at the new location in the Northern region. Its situation is much different from Chonburi Sugar Industry mill, which also relocates to the same region and also expands its capacity. As predicted by using the sugarcane data of the production year 2008/2009, the new capacity utilization of Chonburi Sugar Industry mill might turn to be as low as 13.64%. This capacity utilization is considered very low, and can result in a great loss of the business. Thus, if this prediction is true, it may be said that Chonburi Sugar Industry mill has made a wrong decision for this relocation and expansion. Finally, regarding the capacity expansion of Phitsanulok mill, if there is no increment of sugarcane yield from the yield produced during 2008/2009, the expansion would result in a decrease of its capacity utilization from 100% to 41.14%. Being unable to fully utilize the capacity can lead to financial loss of the mill. Therefore, it can also conclude that the mill has made a mistake for requesting to expand its capacity, which requires an investment of almost 1,000 million Baht (Ministry of Industry, 2008).

The Central region: from the decisions about the relocation and capacity expansion of New Krungthai mill and the capacity expansion of Banrai mill, the two mills probably have made a right decision. The changes should enable these two mills to gain more sugarcane supply, and be able to achieve 100% capacity utilization. However, in the overview, the relocation and capacity expansion of these two mills might cause negative impacts on nearby sugar mills, such as Mitrkasetr mill, Thai Sugar mill, Tamaka mill, etc., which would have decreased capacity utilization. This might be resulted from insufficient sugarcane supply in the region, which forces the sugar mills to compete with the others for sugarcane.

The Northeastern region: according to the result from the analysis using the transportation model under the simulated situation after the capacity expansion of Erawan mill, it can be concluded that the mill might have made a right decision. By expanding its capacity, the mill would not only gain more sugarcane supply, but also be able to utilize its capacity fully at 100%.

Caution should be taken when interpreting or implementing the findings explained above. The relocation and capacity expansion of seven sugar mills following the approval by the cabinet resolution have not been completed. The processes are expected to be completed within the production year 2013/2014, except Chonburi Sugar Industry mill that expects to complete its relocation and expansion in 2016/2017. Results from the analysis are derived based on the assumption that their processes were completed in the production year 2008/2009. The sugarcane supply used in the analysis (71,083,073 tons in 2008/2009) is much lower than the current production year (almost 100 million tons in 2010/2011). Therefore, according to the analysis, sugarcane production seems to be insufficient for capacity expansion of many mills, and that leads to considerably too low capacity utilizations of some mills. Therefore, the conclusions regarding whether these mills have made correct or incorrect decisions might have some errors. In order to analyze the impacts of increasing or decreasing sugarcane field, the next chapter will discuss about the sensitivity analysis subject to the changes in sugarcane supply.

4.5 Summary

This chapter explained about details of data used in the research. In addition, the transportation model developed as a tool for analyzing impact of sugar mill liberalization was also explained. However, since the attempt for collecting data regarding sugarcane transportation and quantity of sugarcane supplied to each sugar mill from each field is difficult and time-consuming, this research decided to analyze the optimal (ideal) situation instead. The results from solving the transportation model were used as a benchmark for comparison. The results showed the optimum pattern of sugarcane transportation that incurs minimum transportation cost. Additionally, quantities of sugarcane that each mill should receive were investigated. The received quantity of sugarcane can then be used to calculate for capacity utilization of each sugar mill by comparing with the production capacities of the sugar mill. The parameters were prepared for the transportation model including S_i (sugarcane supply), D_j (sugarcane demand), and C_{ij} (distance matrix). Sugarcane supply and demand were estimated from the report of the office of the Cane and Sugar Board. The distance matrix between all fields and all mills was computed by ArcMap 9.3 software. The model has been prepared in Visual basic 2005 and solved for the optimal solution by using LINDO 6.1. In order to analyze the impact of sugar mill liberalization, the study was conducted based on three cases.

In Case 1; the optimal current situation was studied by using the real production data in the year 2008/2009. The result was used as the baseline data for analyzing effects of the changing situation in the future. The difference will reflect effects of sugar mill liberalization. In general, the current utilization of most sugar mills capacity is quite high. 35 mills out of 46 fully utilized their maximum capacity. The overall capacity utilization is very high at 95.24%. Among regions, the Eastern highly utilized its production capacity. The reason for this might be because the Chonburi Sugar Industry mill had just ceased its operation for relocation.

In Case 2; the study tested by adding the Chonburi Sugar Industry mill, which ceased its operation in 2007/2008, back into the system. The optimal solution indicates that the added Chonburi Industry Sugar mill achieved only 65% of its production capacity. This implies that the quantity of sugarcane supply in this region was not sufficient for all five mills in the region. This may be the reason that Chonburi Industry Sugar mill had requested to move out to another area.

In Case 3; the Cabinet Resolution on the relocation and capacity expansion of sugar mills is analyzed. The study assumed that the implementation of such resolution was in effect during the production year 2008/2009. Followed the resolution, the sugarcane demand increased greatly from 71,083,073 tons to 74,633,506 tons, while the figure of sugarcane supply remained the same in order to reveal the impacts from sugar mill liberalization on capacity utilization and transportation pattern. The overall capacity utilization decreased from 95.24% to

84.34%. It was found that the expansion of production capacity of sugar mills resulted in higher demand for sugarcane supply. If the quantity of sugarcane remains the same, many sugar mills in the system would obviously be affected negatively. Therefore, the sugar mill needs to prepare some plans and strategies to promote or support sugarcane growing in the new area where it moved to.

Additionally, sugarcane production is found to be fluctuate and inconsistent. The unpredictable amount of sugarcane supply has direct impact on sugar production as well as the policies or approvals regarding new sugar mill establishment, relocation, and capacity expansion of sugar mills. Therefore, the sensitivity analysis for the cases of changes in sugarcane quantity is important and absolutely deserves to be studied. The next chapter will discuss about the sensitivity analysis.

CHAPTER V
SENSITIVITY ANALYSIS

Chapter 4 has discussed about the methodology for analyzing impacts of sugar mill liberalization on patterns of transportation and capacity utilization. The analysis was conducted by using a transportation model, and was divided into three case studies. Case 1 was the case of the optimal current situation in the production year 2008/2009. The result of this case was used as a benchmark, which represents the situation before the beginning of sugar mill liberalization (when the sugar mill are allowed to open, close, relocate, and expand capacity freely). Case 2 was the case when Chonburi Sugar Industry mill was added into the system. This case intended to simulate the situation when there is liberalization such that the new establishment of one sugar mill is allowed. The added mill was supposed to be in the Eastern region. The result revealed that the analysis methodology was reliable. The findings were in agreement with the actual reasons that the mill has given to the Ministry of Industry in order to cease its operation and wait for relocation. Finally, Case 3 was the case that simulated the situations according to the Cabinet Resolutions dated on 16 October 2007 and on 1 March 2011, which agreed to the proposal of the Ministry of Industry and allowed relocation and/or capacity expansion of seven sugar mills. The analysis on this case was intended to analyze the situation that is about to happen in the near future. Those cabinet resolutions effectively increase the overall capacity of sugar mills in the country, thus higher sugarcane demand should be expected. Therefore, if the quantity of sugarcane, which is the main raw material for sugar production, remains the same, the resolutions may lead to negative impacts on many mills in the system.

However, sugarcane plantation in Thailand relies mainly on natural rain, and sugarcane production of the country in each year depends on the climate. As a result, the total production of sugarcane always fluctuates, and is difficult to forecast. The actual yearly production is usually either more or less than the forecasted amount.

Therefore, the reliability of the analysis result also depends on the accuracy of the sugarcane quantity data that is used as the input for the analysis. With this regard, this research also conducted a sensitivity analysis to reflect the fluctuation of sugarcane quantity. This chapter explains about the sensitivity analysis, which is based on Case 3 in order to examine results of the liberalization policy when sugarcane quantities are more or less than the prediction.

5.1 Sensitivity analysis due to uncertain sugarcane production

Sugar industry is an industry that transforms an agricultural raw material, which is sugarcane; through several processes until derive the final product, which is sugar. Thus sugarcane and sugar have strong correlation. Changes in the quantity of sugarcane production will directly impact sugar production. There are two main factors that affect changes of the sugarcane quantity; namely, 1) area of the sugarcane plantation (rais), which might change because farmers may turn to grow another crop; and 2) productivity of sugarcane (tons/ rai), which might change because of the natural climate. Therefore, it is difficult to obtain an accurate forecast about the quantity of sugarcane production.

From the statistics of the sugarcane growing in the past, it can be found that there have been always differences between the forecasted quantity and the real quantity of sugarcane production in each year. Uncertainty always involves with the estimation, which is done based on the weather forecast, data of sugarcane plantation in the previous growing season, as well as the results of the field survey to check conditions of areas that planted sugarcane in the previous year. Those data are analyzed together to obtain possible quantity of the sugarcane production in the next growing season. For this purpose, Office of The Cane and Sugar Board has applied GIS (Geographic Information Systems) for collecting data of sugarcane plantation areas. From conducting spatial analyses with the GIS data, the results inform about areas of the sugarcane plantation, appropriateness of the soil for growing sugarcane, as well as the status of whether the area of sugarcane plantation is inside or outside a zone of irrigation service (Office of the Cane and Sugar Board, 2008). If the area is outside the irrigation zone, it would be even more difficult to forecast sugarcane production correctly because such area has to rely mainly on rain. Since sugarcane areas outside irrigation system are abundant in Thailand, the yearly forecasts of the sugarcane production always have some errors.

Table 5.1 Comparison of the forecasted and the actual quantity of annual sugarcane production

The production year	Sugarcane Production (million tons)		Difference	
	Forecast	Actual	(million tons)	(%)
(1)	(2)	(3)	(4)	(5)
2004/2005	60.56	49.59	-10.97	-22.12
2005/2006	42.50	47.66	5.16	10.83
2006/2007	57.83	64.37	6.54	10.16
2007/2008	66.84	73.50	6.66	9.06
2008/2009	78.00	71.08	-6.92	-9.74
2009/2010	71.60	72.85	1.25	1.72
2010/2011	68.89	95.95	27.06	28.20
2011/2012	101.37	-	-	-

From comparing the forecasted quantity with the actual quantity of sugarcane production in Table 5.1, it is found that the difference is always more than five percents, except in 2009/2010. For example, in the production year 2004/2005, the forecasted quantity of sugarcane was as high as 60.56 million tons, while the actual sugarcane quantity was just 49.59 million tons. The cause of this error is believed to be due to dry climate and the absence of seasonal rain. That means the actual quantity was lower than prediction by 10.97 million tons, or 22.12%. For the production year 2008/2009, of which data is used as baseline data in this research, the forecasted quantity was 78 million tons. Meanwhile, the actual sugarcane quantity was 71.08 million tons, resulting in a high error of 6.92 million tons or 9.74%. The main reason should be due to highly dry climate during the harvest season, making sugarcane loses its weight and some immature canes become damaged. In addition, due to a low price of the previous year, some sugarcane farmers turned to grow other crops that produced better yield, such as cassava. The production year with the largest difference between the forecasted quantity and the actual quantity was apparently in 2010/2011. Due to the severe drought in the middle of the year 2010, sugarcane plantation seemed to be greatly affected, thus it was forecasted that sugarcane quantity would be only 68.89 million tons. However, late in the year 2010, the rain was abundant and continued until early of the year 2011, which made the actual sugarcane quantity for the production year 2010/2011 become as high as 95.95 million tons. After using the figures in Table 5.1 to plot a graph of actual sugarcane quantities versus forecasted quantities in order to gain a clearer image for comparison, it can be seen that the forecasted figures are often erroneous, and the differences can be in the range of -10.97 million tons (-22.12%) to +27.06 million tons (+28.20%). In the production year 2009/2010, the actual sugarcane quantity and the forecasted quantity are almost the same, while, contrarily, the difference in the production year 2011/2012 is almost 30%.

Therefore, sensitivity analysis was used for investigating the effects of changes in the quantity of sugarcane production. This analysis is conducted on Case 3 assuming that the Cabinet Resolution dated on 16 October 2007 and on 1 March 2011 has been implemented. Thus the situation of this case study is such that some sugar mills have relocated and/or expanded their capacity according to the approval of the cabinet. The situation is expected to truly happen in the near future (details of the cabinet resolution are explained in Section 4.4.3). The analysis aims to reveal how the impact of sugar mill liberalization on pattern of transportation and capacity utilization will be affected from the fluctuation of sugarcane production. Regarding the fluctuation or the changes in sugarcane production, the analysis will consider the situations when the production is different from the forecasted quantity by ± 10% and ± 20%. The range is based on the observation regarding the percentages of differences between the forecasted and the actual production quantity shown in Table 5.1. It is assumed that the relocation and capacity expansion according to the cabinet resolution were completed by the production year 2008/2009. The actual sugarcane quantity in the year 2008/2009 is used as the baseline data for studying about effects of fluctuation of sugarcane quantities.

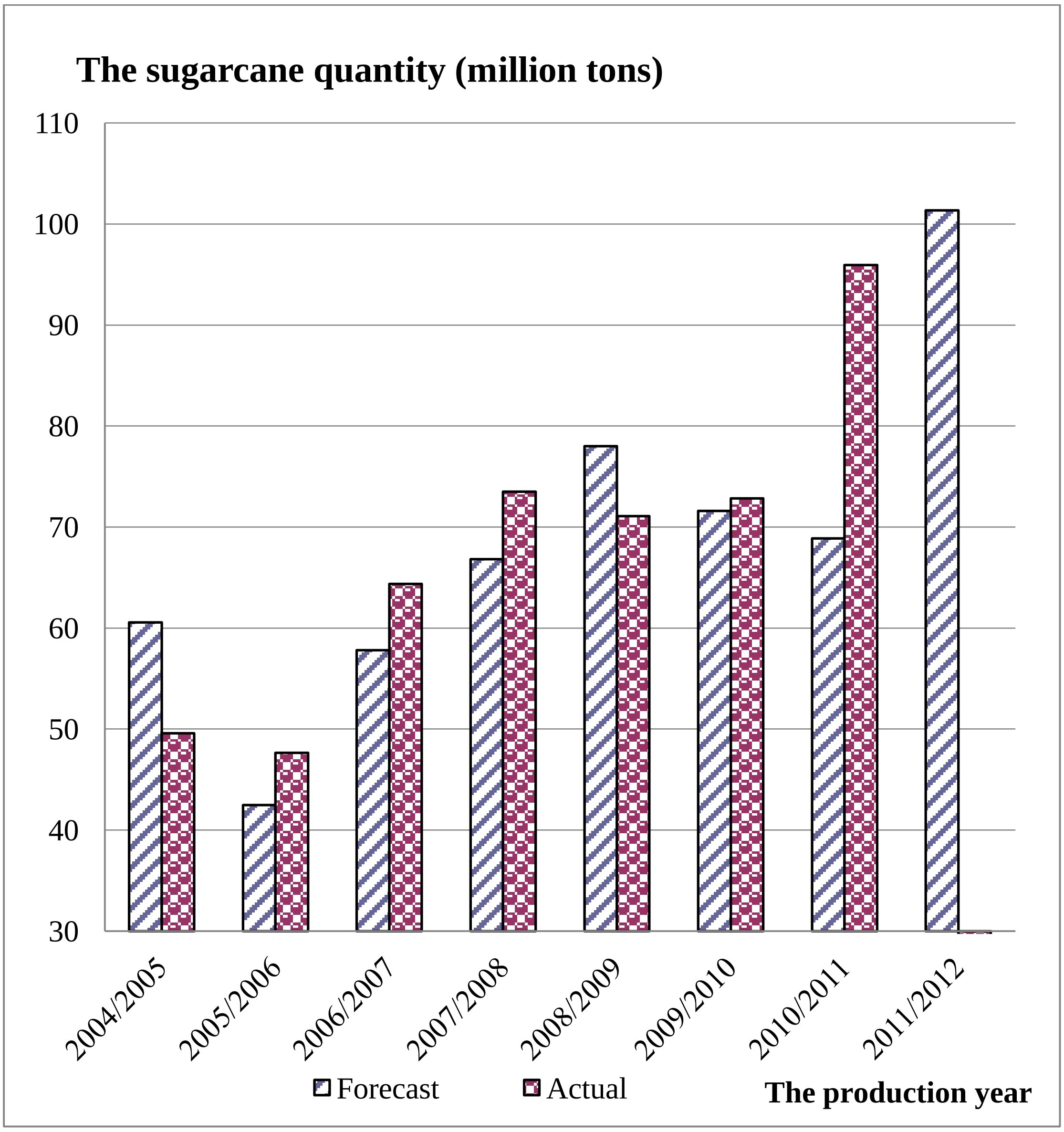


Figure 5.1 The forecasted and actual quantity of annual sugarcane production

5.1.1 The case when the actual sugarcane yield is lower than prediction

Sugarcane is an agricultural product that can be harvested for about 4-5 months per year. Sugarcane plantation in Thailand relies primarily on rain, and that make the sugarcane quantity depends on the weather and climate. The sugarcane quantity in some years was less than prediction due to drought weather. For example, in the production year 2004/2005, the quantity of sugarcane production was less than prediction. The quantity of sugarcane was only 49.59 tons or 22.12% lower than that predicted 60.56 million tons. The main reason was because of the continuously long absence of rain throughout the year 2004, and that reduced the sugarcane production per area (sugarcane tons/rai) very low. Such reduction made some sugar mills unable to utilize their capacity fully (Office of the Cane and Sugar Board, 2005).

Therefore, when there is liberalization of sugar mills in the future, such an over-prediction will be very critical to the decision maker. The operation of each sugar mill requires a great financial investment, and the operation can continue only for some periods in a year (normally during the period of sugarcane production, which is from November to April). Beyond this period, the mills are almost useless. Hence, the sugar mill entrepreneurs have to make sure that they can find sufficient and continuous sugarcane supply for their mills. The permission for establishment of a sugar mill in a new area should be based on thorough and careful study on the trend of sugarcane production in that area. It is essential to make sure that the production will be sufficient for the increased capacity of the new mill. In the research, the sensitivity analysis is carried out for two under prediction; i.e., 10% and 20% lower.

1) The sugarcane quantity decreased by 10%

Permission for relocation and capacity expansion of sugar mills have been based on the consideration about sugarcane quantity in the area. For example, having faced the problem of sugarcane shortage in the Central region, Banpong mill was permitted to relocate to the Northern region and expand its capacity to match the quantity of sugarcane supply in the new area. Another example is Banrai mill also in the Central region. This mill also received permission from the cabinet to expand its capacity because it is situated in an area where the sugarcane supply exceeds the capacity of the mill. The cabinet gave such permissions by considering the trend of sugarcane productions in both current and new areas. However, in reality, the sugarcane production can be lower than the predicted figure due to uncertain climate, which might cause drought, flood, etc. Area of sugarcane plantation can also change because the farmers turn to grow other crops. For example, in the production year 2008/2009, the forecasted quantity of the sugarcane production was lower than the actual figure for almost 10%.

The approved relocation and capacity expansion of some sugar mills according to the Cabinet Resolutions dated on 16 October 2007 and 1 March 2011, which will become true in the future, were used as the case study. The relocation and expansion were assumed to be completed in the production year 2008/2009. Sensitivity analysis was conducted on this case by assuming that the sugarcane quantities decrease by 10%. Sugarcane quantity can be calculated from the real data of the production year 2008/2009. By assuming that sugarcane quantity in all 404 sugarcane fields (S_i) is decreased by 10%, the quantity of sugarcane production will decrease from 71,083,073 tons to 63,974,785 tons. Meanwhile, the overall sugarcane demand of all sugar mills in the country in that production year will increase to 84,278,170 tons due to the permission of the cabinet for capacity expansion of some sugar mills.

Table 5.2 summarizes the results from solving the transportation model in this case. The sensitivity analysis assumes that the sugarcane quantities decreased by 10%. This Table used symbols (-), (+), and (0), in order to represent the impacts, where:

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 5.2 The results from solving the transportation problem: sugarcane quantities decreased by 10%

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	19 (+)	2,265,228 (+)	2,265,228 (0)	100.00 (+)	29.56 (0)	64.00 (+)	148.78 (+)	40.63(+)
2	New Kwang Soon Lee	E	6 (-)	775,659 (+)	1,917,600 (+)	18.77 (-)	11.56 (+)	42.93 (+)	60.07 (-)	18.08 (-)
3	Rayong Sugar	E	3 (0)	589,360 (0)	589,360 (0)	100.00 (0)	25.93 (0)	28.79 (+)	53.59 (0)	14.69 (0)
4	Chonburi Sugar and Trading	E	5 (0)	527,800 (0)	527,800 (0)	100.00 (0)	11.35 (0)	16.36 (-)	49.97 (0)	14.70(0)
	Eastern Region		**33 (+)**	**3,742,244 (-)**	**5,299,988 (+)**	**70.61 (-)**	**11.35 (+)**	**49.71 (+)**	**148.78 (+)**	**39.02 (+)**
5	Mae Wang Sugar Industry	N	11 (0)	274,595 (0)	327,450 (0)	75.47(-)	9.51 (0)	43.04 (0)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	3 (-)	389,035 (0)	389,035 (0)	100.00 (0)	27.54 (0)	30.63 (-)	50.89 (-)	11.74 (-)
7	Thai Identity Sugar	N	10 (-)	1,052,261 (-)	2,736,000 (0)	38.48 (-)	13.69 (0)	57.33 (-)	109.50 (-)	33.92 (+)
8	Kampangpetch	N	4 (0)	864,000 (0)	864,000 (0)	100.00 (0)	15.46 (0)	32.63(-)	52.20 (0)	17.05 (0)
9	Nakornpetch	N	11 (-)	2,784,000 (0)	2,784,000 (0)	97.43 (-)	17.34 (0)	42.48 (+)	86.75 (-)	18.09 (-)
10	Ruamphol Nakhonsawan	N	10 (-)	980,085 (-)	1,249,600 (0)	68.71 (-)	12.30 (0)	47.83 (-)	90.87 (-)	25.84 (-)
11	Kaset Thai Industry Sugar	N	11 (-)	4,999,725 (-)	6,360,000 (0)	59.91 (-)	18.04 (0)	33.85 (-)	73.20 (-)	20.12 (-)
12	Thai Roong Ruang Industry	N	6 (-)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	31.04 (+)	92.83(-)	30.65 (-)
13	Phitsanulok	N	13 (-)	1,040,812 (-)	2,530,000 (+)	37.02 (-)	1.72 (0)	50.51 (-)	80.26 (0)	20.96 (+)
16	Banpong	N	7 (+)	1,602,000 (+)	1,160,690 (+)	72.45 (+)	1.93 (-)	61.76 (+)	68.35 (+)	22.95 (+)
47	Chonburi Sugar Industry	N	4	351,469	3,240,000	10.85	18.92	40.82	47.27	13.18
	Northern Region		**90 (-)**	**15,270,677 (-)**	**25,106,085 (+)**	**60.82 (-)**	**1.72 (0)**	**40.32 (-)**	**128.65 (0)**	**25.43 (-)**
14	Pranburi Sugar Industry	C	8 (+)	630,000 (0)	630,000 (0)	96.23 (-)	13.54 (0)	44.33 (+)	94.44(+)	25.49 (+)
15	Ratchaburi	C	8 (0)	850,404 (+)	1,248,000 (0)	58.18 (+)	6.55 (0)	32.33 (-)	181.68 (+)	57.14 (+)
17	Mitrkasetr Industry	C	2 (0)	955,928 (-)	1,224,670 (0)	58.34 (-)	26.16 (0)	29.35 (-)	31.93 (0)	4.08 (0)

Table 5.2 The results from solving the transportation problem: sugarcane quantities decreased by 10% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	1 (-)	658,815 (-)	1,176,400 (0)	50.40 (-)	53.44 (0)	53.44 (-)	53.44 (-)	0.00 (-)
19	New Krungthai	C	5 (+)	1,938,000 (+)	1,938,000 (+)	100.00 (+)	18.39 (+)	33.39 (+)	150.17 (+)	50.74 (-)
20	Thai Multi-Sugar Industry	C	2 (0)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	26.44 (+)	47.78 (0)	19.89 (0)
21	Tamaka	C	2 (-)	483,013 (-)	1,893,990 (0)	25.50 (-)	57.79 (+)	60.18 (-)	79.95 (-)	15.67 (-)
22	Prajuap Industry	C	2 (+)	544,850 (-)	885,707 (0)	61.52 (-)	4.78 (-)	6.90 (-)	80.56 (+)	53.58 (+)
23	Thai Sugar Industry	C	3 (0)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	25.22 (-)	27.22 (-)	4.91 (-)
24	T N Sugar	C	6 (-)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	26.64 (+)	81.58 (0)	24.21 (-)
25	Saraburi	C	9 (-)	2,779,370 (0)	2,779,370 (0)	100.00 (0)	8.98 (0)	33.51 (-)	101.80 (+)	28.25 (-)
26	Suphanburi Sugar Industry	C	6 (+)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	18.97 (-)	37.01 (+)	10.61 (-)
27	Mitr-Phol	C	6 (0)	2,877,821 (-)	3,011,540 (0)	95.56 (-)	24.09 (0)	33.27 (-)	51.43 (0)	9.60 (-)
28	U-thong Industry	C	4 (0)	1,492,179 (-)	1,524,866 (0)	97.86 (-)	2.09 (0)	22.16 (-)	41.77 (-)	16.58 (-)
29	Singburi	C	8 (0)	639,355 (-)	1,496,000 (0)	42.74 (-)	11.51 (0)	18.69 (-)	39.68 (-)	10.65 (-)
30	Banrai Industry	C	7 (+)	2,794,000 (+)	2,794,000 (+)	100.00 (0)	13.73 (0)	27.10 (+)	74.68 (+)	21.75 (+)
	Central Region		**79 (+)**	**20,996,626 (-)**	**25,410,863 (+)**	**82.63 (-)**	**2.09 (0)**	**30.12 (-)**	**181.68 (+)**	**30.77 (-)**
31	Wang Ka-nai	NE	10 (0)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	33.87 (+)	61.32 (+)	17.68 (-)
32	Surin Sugar	NE	21 (-)	785,951 (-)	1,408,000 (0)	55.82 (-)	10.74 (0)	57.90 (-)	109.68 (0)	29.71 (+)
33	Burirum	NE	10 (-)	406,078 (-)	1,296,000 (0)	31.33 (-)	7.97 (0)	26.83 (-)	73.20 (-)	23.90 (-)
34	Saha Ruang	NE	19 (-)	1,114,679 (-)	1,470,000 (0)	75.83 (-)	16.01 (0)	41.48 (-)	210.28 (0)	47.38 (-)
35	Rerm Udom	NE	37 (-)	1,973,242 (-)	2,017,036 (0)	97.83 (-)	17.04 (0)	57.39 (-)	149.96 (+)	38.78 (-)
36	Kasetr Phol	NE	2 (0)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	17.92 (-)	20.36 (-)	2.38 (-)

Table 5.2 The results from solving the transportation problem: sugarcane quantities decreased by 10% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	5 (+)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	26.73 (+)	42.95 (0)	15.50 (-)
38	Khon Kaen	NE	12 (+)	2,142,000 (0)	2,142,000 (0)	100.00 (0)	6.64 (0)	36.91 (+)	68.41 (-)	18.27 (-)
39	Mitr Poo-Viang	NE	10 (0)	1,728,468 (0)	1,728,468 (0)	100.00 (0)	3.07 (0)	36.56 (-)	71.01 (-)	19.37 (-)
40	United Farmers and Industry	NE	7 (0)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	29.54 (-)	66.95 (-)	17.50 (-)
41	Korach Industry	NE	10 (-)	1,095,285 (-)	2,712,000 (0)	40.39 (-)	15.10 (0)	35.97 (-)	91.12 (-)	25.23 (-)
42	Andvian (Ratchasima)	NE	27 (+)	2,995,413 (-)	3,168,000 (0)	94.55 (-)	9.22 (0)	57.38 (-)	112.56 (0)	27.19 (-)
43	Konburi	NE	9 (-)	1,389,918 (-)	1,656,490 (0)	83.91 (-)	0.56 (0)	36.55 (-)	70.74 (-)	19.64 (-)
44	E-Saan Sugar Industry	NE	7 (+)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	23.63 (+)	51.51 (0)	16.00 (-)
45	Mitr Kalasin	NE	21 (-)	1,750,964 (-)	2,280,000 (0)	76.80 (-)	7.17 (0)	38.59 (+)	76.81 (0)	19.50 (-)
46	Erawan Sugar	NE	17 (+)	1,620,000 (+)	1,620,000 (+)	100.00 (0)	1.61 (0)	53.61 (-)	97.92 (+)	26.16 (-)
	Northeastern Region		**223 (-)**	**23,965,238 (-)**	**28,461,234 (+)**	**84.20 (-)**	**0.56 (0)**	**40.11 (-)**	**210.28 (0)**	**33.30 (-)**
	Total		**425 (-)**	**63,974,785 (-)**	**84,278,170 (+)**	**75.91 (-)**	**0.56 (0)**	**37.44 (-)**	**210.28 (0)**	**32.41 (+)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy fields) = 205,429,247,813 tons-kilometers

Objective function (excluding dummy fields) = 2,395,397,813 tons-kilometers

- The impacts on the sugar mills in the Eastern region

In the production year 2008/2009, there were four sugar mills in the Eastern region. The total capacity of these four mills, as permitted by the cabinet was 35,817 tons/day. That means they need to be supplied with approximately 3,991,414 tons of sugarcane per production year. The figure of 3,991,414 tons was calculated by multiplying the permitted capacity with number of operation days in each year of each mill. Due to the cabinet approval for the relocation and capacity expansion of New Kwang Soon Lee mill from Chonburi province to Srakaew province, the overall sugarcane demand in this region will increase to 5,299,988 tons. Suppose the sugarcane quantities decreased by 10%, the result from analyzing with the Transportation model reveals that sugarcane quantity were supplied to the mills in this region would decrease from 3,989,236 tons (Table 4.4) to 3,742,244 tons (Table 5.2). When comparing with the optimal current situation in the production year 2008/2009 (Table 4.4), the approval may cause the total capacity utilization of the sugar mills in this region down from 99.95% (Table 4.4) to 70.61% (Table 5.2). Regarding capacity utilization of individual mills in column (7), Eastern Sugar and Cane mill, Rayong mill, and Chonburi Sugar and Trading mill may be able to fully utilize their capacity. If the situation really happens as analyzed by the model, New Kwang Soon Lee mill, whose capacity utilization possibly at only 18.77% (Table 5.2), may be the only mill that cannot fully utilize its capacity. The reason behind this is because the mill has requested to expand its capacity to almost three times, which will make its sugarcane demand increase from 609,026 to 1,917,600 tons. Thus when there is 10% reduction in the sugarcane production, the mill would not have sufficient supply for its increased capacity.

Resulting transportation distances obtained from the optimal solution are shown in columns (8)-(11) of Table 5.2. Chonburi Sugar and Trading mill has the shortest (min) distance of 11.35 kilometers from the nearest sugarcane field. The overall average (mean) transportation distance in this region, as shown in column (9), is found to increase from 41.55 (Table 4.4) to 49.71 kilometers (Table 5.2), which might be caused by the relocation and capacity expansion of New Kwang Soon Lee mill. In column (10), the Eastern Sugar and Cane mill has the longest transportation distance of 148.78 kilometers. The overall standard deviation (S.D.), as shown in column (11), is found to be 39.02 kilometers.

- The impacts on the sugar mills in the Northern region

In the production year 2008/2009, the number of sugar mills in the Northern region was nine mills. The number will increase to 11 mills after the relocations of Banpong mill from the Central region and Chonburi Sugar Industry mill from the Eastern region. According to the cabinet resolution, Phitsanulok has also been approved to expand its capacity. These changes regarding relocation and capacity expansion will make the overall sugarcane demand in this region increase from 19,113,395 tons (Table 4.4) to 25,106,085 tons (Table 5.2). When assuming that the sugarcane quantities decreased by 10%, the analysis using Transportation model reveals that the overall sugarcane were supplied to sugar mills in the Northern region for sugar production decrease from 18,480,165 tons (Table 4.4) to 15,270,677 tons (Table 5.2). The overall capacity utilization may decrease, down to only 60.82%. According to column (7) of Table 5.2, there are five mills that will have significant reduction in their capacity utilization. These five mills are Mae Wang Sugar Industry mill, Thai Identity mill, Nakornpetch mill, Ruamphol Nakhonsawan mill, and Kaset Thai mill.

The capacity expansion of Phitsanulok mill will make the sugarcane demand in this mill increase from 1,379,310 tons (Table 4.4) to 2,530,000 tons (Table 5.2). When assuming that the sugarcane quantities decreased by 10%, the mill would not have sufficient supply for its increases capacity. The capacity utilization may decrease, down to only 37.02%. The relocation of Chonburi Sugar Industry mill from the Eastern region to the Northern region may cause severely low capacity utilization of only 10.85%. This should be because the new location of the mill is far from sugarcane plantation areas. It has been reported that the district to where Chonburi Sugar Industry mill requested to move to has many mountainous terrains, while the remaining flat areas have sandy and dry soil without sufficient water supply. Thus the district is considered inappropriate for sugarcane cultivation (Ministry of Industry, 2011). If there is a decline in the trend of sugarcane quantity as in the assumption, sugarcane supply in the new area may be insufficient for the expanded capacity.

Regarding the transportation distances as shown in column (8) of Table 5.2, Phitsanulok mill has the shortest (min) distance of 1.72 kilometers from the nearest sugarcane field. Mae Wang Sugar Industry mill has the longest (max) distance of 128.65 kilometers, as shown in column (10). When considering the average (mean) distance in column (9) and the longest (max) distance in column (10), it is found that most sugar mills may experience decreasing average transportation distance. Only Nakornpetch mill and Thai Roong Ruang Industry mill would face increasing average transportation distances. The reason might be because these two mills are located near Phitsanulok mill, which will increase its capacity, thus sugarcane quantity in the area will become insufficient. As a result, the two mills would have to transport from fields further away.

- The impacts on the sugar mills in the Central region

This impact is analyzed with the assumption that New Krungthai mill and Banrai mill completed expanding their capacity according to the cabinet resolution in the production year 2008/2009. The overall sugarcane demand in this region will increase from 23,810,827 to 25,410,863 tons. The result of the analysis using the transportation model based on the assumption that the sugarcane quantities decrease by 10% is shown in Table 5.2. According to column (5), the quantity of sugarcane that the mills in this region would receive decreases from 21,794,457 tons (Table 4.4) to 20,996,626 tons (Table 5.2). This will result in the reduction of capacity utilization of sugar mills in the Central region from 91.53% (Table 4.4) to 82.63% (Table 5.2). The relocation of New Krungthai mill from Tamaka district to Bo Ploy district in Kanchanaburi province and its capacity expansion will increase its sugarcane demand from 605,389 tons to 1,938,000 tons. Even though the mill's demand increases for almost three times, the relocation to the new area may enable the mill to fully utilize its capacity at 100%. The changes might cause negative impacts on the capacity utilization of Mitrkasetr mill, Thai Sugar mill, Tamaka mill, and Prajuab Industry mill. All these mills are also in Kanchanaburi province.

Regarding transportation distances, when comparing the results in Table 5.2 with the results of the optimal current situation (Table 4.4), it is seen that the shortest (min) distance from the nearest field to the mill is 2.09 kilometers for U-thong

Industry mill, as shown in column (8). The overall average (mean) transportation distance, as shown in column (9), reduces from 34.71 to 30.12 kilometers. However, considering only New Krungthai mill and Banrai Industry mill, the two mills would possibly have longer average transportation distance. This might be because their capacity expansion, which make them have to transport more sugar in order to sufficiently supply their capacity. Considering also the pattern of transportation shown in Figure 5.2, it can be seen that some sugarcane will be transported from the Eastern region to Ratchaburi mill. This will result in an increase of the longest (max) distance, as shown in column (10), to be as high as 181.68 kilometers. Regarding the S.D. values shown in column (11), it would decrease slightly from 30.83 to 30.77 kilometers.

- The impacts on the sugar mills in the Northeastern region

In the Northeastern region, when Erawan mill has expanded its capacity according to the cabinet resolution, the overall sugarcane demand in this region will increase from 27,717,870 tons to 28,461,234 tons. When assuming that the sugarcane quantities decreased by 10%, the result from the optimal situation analysis in column (5) of Table 5.2 reveals that sugarcane supplied to the mills in this region might decrease from 26,819,215 to 23,965,238 tons when comparing with the result of Case 1 (Table 4.4). The overall capacity utilization may decrease from 96.76% (Table 4.4) to 84.20% (Table 5.2). The cause might be from the reduction of sugarcane production as well as from the relocation and capacity expansion of New Kwang Soon Lee mill to be nearer to this region. Hence, the sugarcane quantity in the area may become insufficient for the sugar production. As a result, there may be eight sugar mills in the Northeastern region that have decreased capacity utilization. The reduction is particularly apparent for the cases of Surin mill and Burirum mill, which are very near the new location of New Kwang Soon Lee mill. These two mills' capacity utilization reduced from 73.43% (Table 4.4) to 31.33% (Table 5.2) and from 91.24% (Table 4.4) to 55.82% (Table 5.2), respectively.

Regarding transportation distances, as shown in column (8) of Table 5.2, the shortest (min) transportation distance of all sugar mill in the Northeastern region may not change. This is because there is no relocation of any mill in this region.

However, due to the capacity expansion of Erawan mill and the reduction in the overall sugarcane quantities by 10%, the overall average (mean) transportation distance in this region would be decreased.

The objective function shows that if the sugarcane forecast is right, the minimum total transportation cost for the whole country in the production year 2008/2009 would be 3,061,924,585 tons-kilometers. The cost of transportation can be calculated by multiplying the figure with the average unit transportation cost from plantation areas to sugar mills. The mean cost was found, from the research entitled “Analyzing cost and lead time of harvesting and transporting the sugarcane to a factory for increase competitiveness” (Tumcharoen, 2008), to be 4.12 Baht/ton/kilometer. After multiplying the mean cost with the objective function unit, the resulting overall transportation cost for the whole country in the production year 2008/2009 was found to be 3,061,924,585 tons-kilometers x 4.12 Baht/ton/kilometer = 12,615,129,290 Baht, or about 12.6 billion Baht.

When the amount of sugarcane is decreased by 10%, the minimum total transportation cost for the whole country in this case would reduce from 3,061,924,585 to 2,395,397,813 tons-kilometers. The overall transportation cost can then be calculated by using the average unit transportation cost of 4.12 Baht/ton/kilometer, resulting about 2,395,397,813 tons-kilometers x 4.12 Baht/ton/kilometer = 9,869,038,990 Baht.

Figure 5.2 shows the optimal transportation pattern, after the implementation of the cabinet resolution and the sugarcane quantities decreased by 10%. When comparing with the optimal current situation in Figure 4.6, it is observed that the relocation of New Kwang Soon Lee mill (2) lead to an increase in the transportation distances from the fields that used to supply sugarcane to this mill. Some fields in the Eastern region then had to transport sugarcane to the Central region because sugar mills around that area have fully utilized their capacity at 100%. In case of the Northern region, when Banpong mill (16) and Chonburi Sugar Industry mill (47) have relocated into this region, the transportation pattern in the region will change apparently. Some sugarcane fields would turn to transport sugarcane to these two mills instead, because the distance to these mills is shorter than to the existing mills.

Regarding the relocation and capacity expansion of New Krungthai mill (19) in the Central region, some sugarcane fields near the new location will have shorter maximum transportation distance. The most evident one is the group of sugarcane fields in Thong-Pha-Poom district, which is at the leftmost of the figure. This area group used to supply sugarcane to Tamaka mill (21), where the maximum transportation distance is as far as 158.46 kilometers. When New Krungthai mill has moved to this area, the maximum transportation distance of that area group will be down to only 150.17 kilometers.

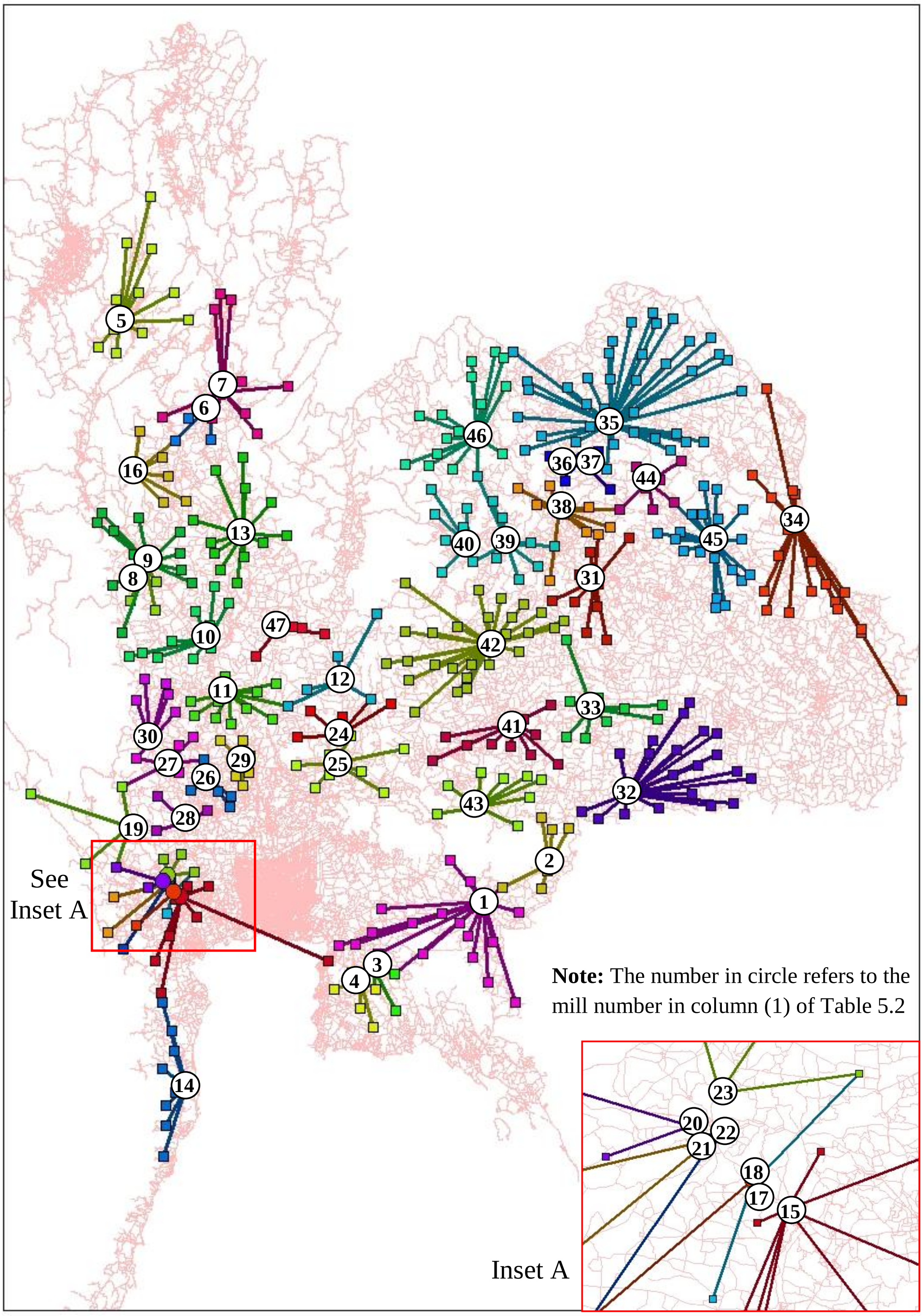


Figure 5.2 Optimal transportation patterns: sugarcane quantities decreased by 10%

2) The sugarcane quantities decreased by 20%

As previously stated, the sugarcane production can be either high or low, depending mainly on the climate. Thus it is very difficult to predict quantity of the sugar production with high precision. There can always be cases when the sugarcane production becomes lower than the predicted quantity. For example, due to the great flood in 2011 that lasted from August until almost the end of the year, sugarcane growing areas in the Northern, Northeastern, and Central regions were flooded for approximately 160,000 rais. Among these flooded fields, an area of approximately 20,000 rais was completely damaged and cannot provide any production at all. Being flooded for a long time can halt the growth of sugarcane, which should be recovered with a correct method as soon as possible. Too long flooding can result in the dead of sugarcane, which seriously affect the farmers who need sugarcane stumps for the next growing season 2012/2013 (Sattayanikom, 2011). Therefore, it is important to study the situation for clear understanding about the effects on sugar mills from such this an event that caused great reduction in sugarcane production.

The sensitivity analysis for this situation assumes that the sugarcane quantities decreased by 20%, the relocation and capacity expansion according to the cabinet resolution have been finished in the production year 2008/2009. Sugarcane in all 404 fields (S_i) is assumed to reduce for 20%, resulting in a reduction of the total sugarcane production in the whole country from 71,083,073 tons to only 56,866,454 tons. Meanwhile, the overall sugarcane demand of sugar mills throughout the country remains to be 84,278,170 tons.

Table 5.3 summarizes the results from solving the transportation model for this case to examine the impacts of relocation and capacity expansion according to the cabinet resolution as well as the impacts from the sugarcane quantities decrease by 20%. This Table uses symbols (-), (+), and (0) in order to represent the impacts, while:

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 5.3 The results from solving the transportation problem: sugarcane quantities decreased by 20%

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	16 (0)	1,944,514 (-)	2,265,228 (0)	85.84 (-)	29.56 (0)	59.18 (+)	129.46 (+)	32.86 (+)
2	New Kwang Soon Lee	E	5 (-)	272,516 (-)	1,917,600 (+)	14.21 (-)	11.56 (+)	39.95 (+)	54.37 (-)	17.14 (-)
3	Rayong Sugar	E	7 (+)	589,360 (0)	589,360 (0)	100.00 (0)	25.93 (0)	29.12 (+)	53.59 (0)	9.51 (-)
4	Chonburi Sugar and Trading	E	5 (0)	527,800 (0)	527,800 (0)	100.00 (0)	11.35 (0)	16.81 (-)	49.97 (0)	14.70 (0)
	Eastern Region		**33 (+)**	**3,334,190 (-)**	**5,299,988 (+)**	**62.91 (-)**	**11.35 (+)**	**45.59 (+)**	**129.46 (+)**	**29.81 (+)**
5	Mae Wang Sugar Industry	N	11 (0)	219,677 (-)	327,450 (0)	67.09 (-)	9.51 (0)	43.04 (0)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	3 (-)	389,035 (0)	389,035 (0)	100.00 (0)	27.54 (0)	32.88 (-)	50.89 (-)	11.74 (-)
7	Thai Identity Sugar	N	10 (-)	814,331 (-)	2,736,000 (0)	29.76 (-)	13.69 (0)	57.33 (-)	109.50 (0)	33.92 (+)
8	Kampangpetch	N	4 (0)	864,000 (0)	864,000 (0)	100.00 (0)	15.46 (0)	30.72 (-)	52.20 (0)	17.05 (0)
9	Nakornpetch	N	11 (-)	2,315,187 (-)	2,784,000 (0)	83.16 (-)	17.34 (0)	43.52 (+)	86.75 (-)	18.09 (-)
10	Ruamphol Nakhonsawan	N	10 (-)	763,243 (-)	1,249,600 (0)	61.08 (-)	12.30 (0)	47.83 (-)	90.87 (-)	25.84 (-)
11	Kaset Thai Industry Sugar	N	10 (-)	3,024,339 (-)	6,360,000 (0)	47.55 (-)	18.04 (0)	29.13 (-)	64.57 (-)	18.22 (-)
12	Thai Roong Ruang Industry	N	6 (-)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	33.43 (+)	92.83 (-)	30.65 (-)
13	Phitsanulok	N	13 (-)	832,648 (-)	2,530,000 (+)	32.91 (-)	1.72 (0)	50.51 (-)	80.26 (0)	20.96 (+)
16	Banpong	N	7 (+)	988,499 (+)	1,602,000 (+)	61.70 (+)	1.93 (-)	61.47 (+)	68.35 (+)	22.95 (+)
47	Chonburi Sugar Industry	N	4	312,417	3,240,000	9.64	18.92	40.82	47.27	13.18
	Northern Region		**89 (-)**	**13,547,376 (-)**	**25,106,085 (+)**	**50.96 (-)**	**1.72 (0)**	**39.68 (-)**	**128.65 (0)**	**25.44 (-)**
14	Pranburi Sugar Industry	C	8 (+)	538, 890 (-)	630,000 (0)	85.54 (-)	13.54 (0)	44.33 (+)	94.44 (+)	25.49 (+)
15	Ratchaburi	C	7 (-)	637,681 (-)	1,248,000 (0)	51.10 (-)	6.55 (0)	30.52 (-)	102.73 (-)	33.49 (-)
17	Mitrkasetr Industry	C	2 (0)	472,913 (-)	1,224,670 (0)	38.62 (-)	26.16 (0)	28.46 (-)	31.93 (0)	4.08 0)

Table 5.3 The results from solving the transportation problem: sugarcane quantities decreased by 20% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	1 (-)	527,052 (-)	1,176,400 (0)	44.80 (-)	53.44 (0)	53.44 (-)	53.44 (-)	0.00 (-)
19	New Krungthai	C	5 (+)	1,938,000 (+)	1,938,000 (+)	100.00 (+)	18.39 (+)	34.88 (+)	150.17 (+)	50.74 (-)
20	Thai Multi-Sugar Industry	C	3 (+)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	29.92 (+)	57.59 (0)	19.69 (-)
21	Tamaka	C	2 (-)	321,382 (-)	1,893,990 (0)	16.97 (-)	57.79 (+)	79.95 (+)	79.95 (-)	15.67 (-)
22	Prajuap Industry	C	2 (+)	484,311 (-)	885,707 (0)	54.68 (-)	4.78 (-)	6.90 (-)	80.56 (+)	53.58 (+)
23	Thai Sugar Industry	C	3 (0)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	25.44 (-)	27.22 (-)	4.91 (-)
24	T N Sugar	C	6 (+)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	25.80 (+)	81.58 (0)	24.21 (-)
25	Saraburi	C	10 (+)	2,527,846 (-)	2,779,370 (0)	90.95 (-)	8.98 (0)	39.76 (+)	101.80 (+)	35.71 (+)
26	Suphanburi Sugar Industry	C	6 (+)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	19.83 (-)	37.01 (+)	10.61 (-)
27	Mitr-Phol	C	5 (0)	1,982,115 (-)	3,011,540 (0)	65.82 (-)	24.09 (0)	31.08 (-)	45.20 (0)	7.77 (-)
28	U-thong Industry	C	4 (-)	1,326,381 (-)	1,524,866 (0)	86.98 (-)	2.09 (0)	22.16 (-)	41.77 (-)	16.58 (-)
29	Singburi	C	8 (-)	568,317 (-)	1,496,000 (0)	37.99 (-)	11.51 (0)	18.69 (-)	39.68 (-)	10.65 (-)
30	Banrai Industry	C	7 (+)	2,794,000 (+)	2,794,000 (+)	100.00 (0)	13.73 (0)	27.23 (+)	74.68 (+)	21.75 (+)
	Central Region		**79 (+)**	**18,927,208 (-)**	**25,410,863 (+)**	**74.48 (-)**	**2.09 (0)**	**30.56 (-)**	**150.17 (-)**	**27.21 (-)**
31	Wang Ka-nai	NE	12 (+)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	36.09 (+)	65.15 (+)	18.01 (0)
32	Surin Sugar	NE	21 (-)	698,622 (-)	1,408,000 (0)	49.62 (-)	10.74 (0)	57.90 (-)	109.68 (0)	29.71 (+)
33	Burirum	NE	10 (-)	360,957 (-)	1,296,000 (0)	27.85 (-)	7.97 (0)	26.83 (-)	73.20 (-)	23.90 (-)
34	Saha Ruang	NE	19 (-)	990,826 (-)	1,470,000 (0)	67.40 (-)	16.01 (0)	41.48 (-)	210.28 (0)	47.38 (-)
35	Rerm Udom	NE	32 (0)	1,229,575 (-)	2,017,036 (0)	60.96 (-)	17.04 (0)	52.06 (-)	149.96 (+)	39.52 (-)
36	Kasetr Phol	NE	3 (0)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	24.25 (-)	46.36 (-)	16.070)

Table 5.3 The results from solving the transportation problem: sugarcane quantities decreased by 20% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	4 (0)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	27.97 (+)	42.95 (0)	17.57 (0)
38	Khon Kaen	NE	10 (+)	1,797,876 (-)	2,142,000 (0)	83.93 (-)	6.64 (0)	34.27 (+)	68.41 (-)	18.52 (-)
39	Mitr Poo-Viang	NE	10 (0)	1,556,885 (-)	1,728,468 (0)	90.07 (-)	3.07 (0)	38.61 (-)	58.80 (-)	17.25 (-)
40	United Farmers and Industry	NE	7 (0)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	28.09 (-)	66.95 (-)	17.50 (-)
41	Korach Industry	NE	10 (-)	973,586 (-)	2,712,000 (0)	35.90 (-)	15.10 (0)	35.97 (-)	91.12 (-)	25.23 (-)
42	Andvian (Ratchasima)	NE	24 (+)	2,131,098 (-)	3,168,000 (0)	67.27 (-)	9.22 (0)	51.13 (-)	112.56 (+)	26.83 (-)
43	Konburi	NE	9 (-)	1,235,484 (-)	1,656,490 (0)	74.58 (-)	0.56 (0)	36.55 (-)	70.74 (-)	19.64 (-)
44	E-Saan Sugar Industry	NE	7 (+)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	26.08 (-)	51.51 (+)	16.00 (-)
45	Mitr Kalasin	NE	20 (-)	1,499,531 (-)	2,280,000 (0)	65.77 (-)	7.17 (0)	37.84 (-)	76.81 (-)	19.85 (-)
46	Erawan Sugar	NE	22 (+)	1,620,000 (+)	1,620,000 (+)	100.00 (0)	1.61 (0)	54.45 (+)	111.55 (+)	26.43 (+)
	Northeastern Region		**220 (-)**	**21,057,680 (-)**	**28,461,234 (+)**	**73.99 (-)**	**0.56 (0)**	**38.38 (-)**	**210.28 (0)**	**32.65 (-)**
	Total		**421 (-)**	**56,866,454 (-)**	**84,278,170(+)**	**67.47 (-)**	**0.56 (0)**	**36.51 (-)**	**210.28 (0)**	**30.60 (-)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy fields) = 276,193,190,321 tons-kilometers

Objective function (excluding dummy fields) = 2,076,030,321 tons-kilometers

- The impacts on the sugar mills in the Eastern region

According to the cabinet resolution, the overall sugarcane demand in this region will increase from 3,991,414 tons to be as high as 5,299,988 tons due mainly to the capacity expansion of New Kwang Soon Lee mill. Having assumed 20% reduction in sugarcane production and things happened as analyzed with the transportation model, sugarcane quantity supplied to this region may decrease from 3,989,236 tons (Table 4.4) to 3,334,190 tons (Table 5.3). The optimal solution showed that the overall capacity utilization in this area may decrease from 99.95% (Table 4.4) to 62.91% (Table 5.3). The capacity utilization of Eastern Sugar and Cane mill may decrease from 99.90% (Table 4.4) to 85.84% (Table 5.3). New Kwang Soon Lee mill, the soon-to-be-relocated mill from Chonburi province to Srakaew province would suffer a reduction in its capacity utilization from 100% (Table 4.4) to be only 14.21% (Table 5.3). The main reason should be from the low sugarcane production of 71,083,073 tons in the production year 2008/2009, while the total sugarcane demand in the whole country was higher at 74,633,506 tons. Obviously, the overwhelming demand of sugarcane will cause some sugar mills to underutilize their capacity. The cabinet's approval for capacity expansion of seven sugar mills even worsen the case by making the overall sugarcane demand in the country becoming as high as 84,278,170 tons. This problem may be severe in the future if the trend of sugarcane quantity is getting decreased as in the assumption. Without a campaign or measure to promote sugarcane plantation in Srakaew province, the area to where New Kwang Soon Lee mill will be relocated to, the mill will certainly suffer insufficiency of sugarcane supply and will encounter a loss to its investment in production processes. This situation might force the mill to request for another relocation or, even worse, to end its business.

Regarding transportation distances, the overall average (mean) transportation distance of the Eastern region, as shown in column (9) of Table 5.3 would be higher, increasing from 41.55 kilometers (Table 4.4) to 45.59 kilometers (Table 5.3). This is partly because the longest (maximum) transportation distance of Eastern Sugar and Cane mill increases from 112.15 kilometers (Table 4.4) to 129.46 kilometers (Table 5.3).

- The impacts on the sugar mills in the Northern region

This analysis was conducted with the assumption that the sugarcane quantities decrease by 20% and the quantity of sugarcane demand in this region increases from 19,113,395 to 25,106,085 tons, which is a result of the capacity expansion of Phitsanulok mill and the relocation of Banpong mill (from the Central region) and Chonburi Sugar Industry mill (from the Eastern region) into this region according to the cabinet resolution. The results from analyzing with the transportation model, as shown in Table 5.3, show that the overall sugarcane quantity supplied to the mills in this region would decrease from 18,480,165 tons (Table 4.4) to 13,547,376 tons (Table 5.3). Due to the decreased sugarcane supply to this region, the capacity utilization of six sugar mills in this region probably will also decrease, as shown in column (7). They are Mae Wang Sugar Industry mill, Uttaradit Sugar Industry mill, Nakornpetch mill, Ruamphol Nakhonsawan mill, Kaset Thai mill, and Phitsanulok mill. The most negatively affected might be Chonburi Sugar Industry mill that have just relocated into the region. If the optimal result of the analysis with the transportation model was true, this mill would have suffered a great reduction in its capacity utilization down to just 9.64%. In addition to insufficient sugarcane supply, another reason might be because the new area to where this mill relocates to is not suitable and far from sugar fields.

From Table 5.3, the overall average (mean) transportation distance in the Northern region would decrease from 46.41 kilometers (Table 4.4) to 39.68 kilometers (Table 5.3). The shortest (min) and the longest (max) transportation distance from the sugarcane fields to the sugar mills in this region would remain unchanged. The shortest distance would still be the distance to Phitsanulok mill. The longest would be to Mae Wang Sugar Industry mill.

- The impacts on the sugar mills in the Central region

After New Krungthai mill and Banrai mill in the Central region have expanded their capacity according to the cabinet resolution, the overall sugarcane demand in this region will increase from 23,810,827 to 25,410,863 tons. When analyzed with the transportation model, with the assumption that the sugarcane quantities decrease by 20%, it is found that the sugarcane quantity to be supplied to mills in this region will decrease from 21,794,457 tons (Table 4.4) to only 18,927,208 tons (Table 5.3). According to column (7) of Table 5.3, it can be seen that ten out of 16 mills in this region may have their capacity reduced. Four of them might utilize their capacity under 50%. These four mills are Tamaka mill (decreased from 100% to only 16.97%), Singburi mill (decreased from 100% to 37.99%), Mitrkasetr mill (decreased from 82.11% to 38.62%) and Thai Sugar mill (from 67.18% to 44.80%). Therefore, if the sugarcane production in the Central region tends to decrease in the future, these mills might request for relocation to a new area due to insufficiency of the supply. Otherwise they might have to end their businesses eventually.

Regarding transportation distances, according to column (8), the shortest (min) distance from the nearest sugarcane fields to the mills in the Central region will be the distance to New Krungthai mill (increased to 18.39 kilometers), Tamaka mill (increased to 57.79 kilometers), and Prajuap Industry mill (decreased to 4.78 kilometers). These changes in the transportation distance are affected from the relocation of New Krungthai mill from Tamaka district to Boploy district of Kanchanaburi province. The relocation also alters the optimal pattern of transportation in the nearby area. The overall shortest (min) transportation distance in this region would be the distance to U-thong Industry mill at 2.09 kilometers. The overall average (mean) transportation distance, shown in column (9), would decrease from 34.71 kilometers (Table 4.4) to 30.56 kilometers (Table 5.3). The longest (max) transportation distance, column (10), would be the distance to New Krungthai mill of 150.17 kilometers. This new longest distance reduces from the value obtained from the optimal current situation analysis, which used to be the distance to Tamaka mill of 158.46 kilometers. This change should be resulted from the relocation of New Krungthai mill to be closer to the sugarcane fields. The changes also make the overall S.D. in this region decrease from 30.83 kilometers (Table 4.4) to 27.21 kilometers (Table 5.3).

- The impacts on the sugar mills in the Northeastern region

From Table 5.3, when that the sugarcane quantities decrease by 20%, the sugarcane quantity supplied to this region decreased from 26,819,251 to only 21,057,680 tons. Since the total demand in this region is 28,461,234 tons, the overall capacity utilization of sugar mills in the region will be only 73.99%. Regarding capacity utilization of each mill, results from solving the transportation model indicate that ten of 16 mills would have their capacity utilization reduced. Among them, Burirum mill would be affected most severely. Its sugarcane supplied to this mill might decrease from 1,182,511 tons (Table 4.4) to 360,957 tons (Table 5.3), while its demand is at 1,296,000 tons of sugarcane. Thus its capacity utilization would be reduced from 91.24% (Table 4.4) to only 27.85% (Table 5.3). Ranking second for the most severely affected mills is Surin mill. This mill would receive the sugarcane only 698,622 tons, which is much less than the quantity before the reduction of the sugarcane production (1,033,964 tons). This low amount of supply may cause the mill to underutilize its capacity at only 49.62%, as compared to the demand of 1,408,000 tons. This might be caused by the relocation of New Kwang Soon Lee mill to an area closer to these two mills. The relocation, together with the 20% reduction of the yield below the predicted amount, would contribute to the fierce competition for sugarcane in this area.

Regarding the average transportation distance, as shown in column (8), Konburi mill has the shortest (min) distance of 0.56 kilometers from the nearest field. The overall average (mean) transportation distance in this region, as shown in column (9), would decrease from 47.80 kilometers (Table 4.4) to 38.38 kilometers (Table 5.3), which is also caused by the reduction of the sugarcane production that prohibits transportation. In case of the longest (max) distance, as shown in column (10), Saha Ruang mill has the longest transportation distance of 210.28 kilometers.

When considering the total cost for transporting sugarcane from all fields to all mills in the country, after the amount of sugarcane supply is reduced 20%, the objective function (leaving out the value of dummy fields) reduces from 3,061,924,585 to 2,076,030,321 tons-kilometers. Multiplied the figures with the mean sugarcane transportation cost of 4.12 Baht/ton/kilometer, the resulting overall sugarcane transportation cost in the whole country is found to reduce from 12,615,129,290 to 8,553,244,923 Baht. This is because the amount of sugarcane is very limited. The sugarcane quantity is insufficient for the sugarcane demand; thus, the transportation is discontinued, resulting in a decrease of overall transportation cost in the country.

Figure 5.3 shows the optimal pattern of sugarcane transportation from all sugarcane fields to all sugar mills. Comparing with the current optimal transportation pattern in Figure 4.6, the change in patterns can be observed. Some groups of the sugarcane fields, which used to supply sugarcane to more than one sugar mills due to their previously high sugarcane production, will supply to only one nearest mill, after sugarcane quantities decreased by 20%. For example, the current optimal transportation pattern in Figure 4.6 showed one area group transports sugarcane to both Saraburi mill and Konburi mill. When the yield is reduced by 20%, however, this field turns to transport sugarcane only to Saraburi mill, which is closer. This change also happens to other area groups around Andvian (Ratchasima) mill (42) which used to transport sugarcane for a long distance to Korach Industry mill (41) because Andvian (Ratchasima) mill (42) had fully utilized its capacity. When the sugarcane quantities decrease by 20%, these fields start to supply sugarcane to Andvian mill (42) instead, because it is closer than Korach Industry mill (41).

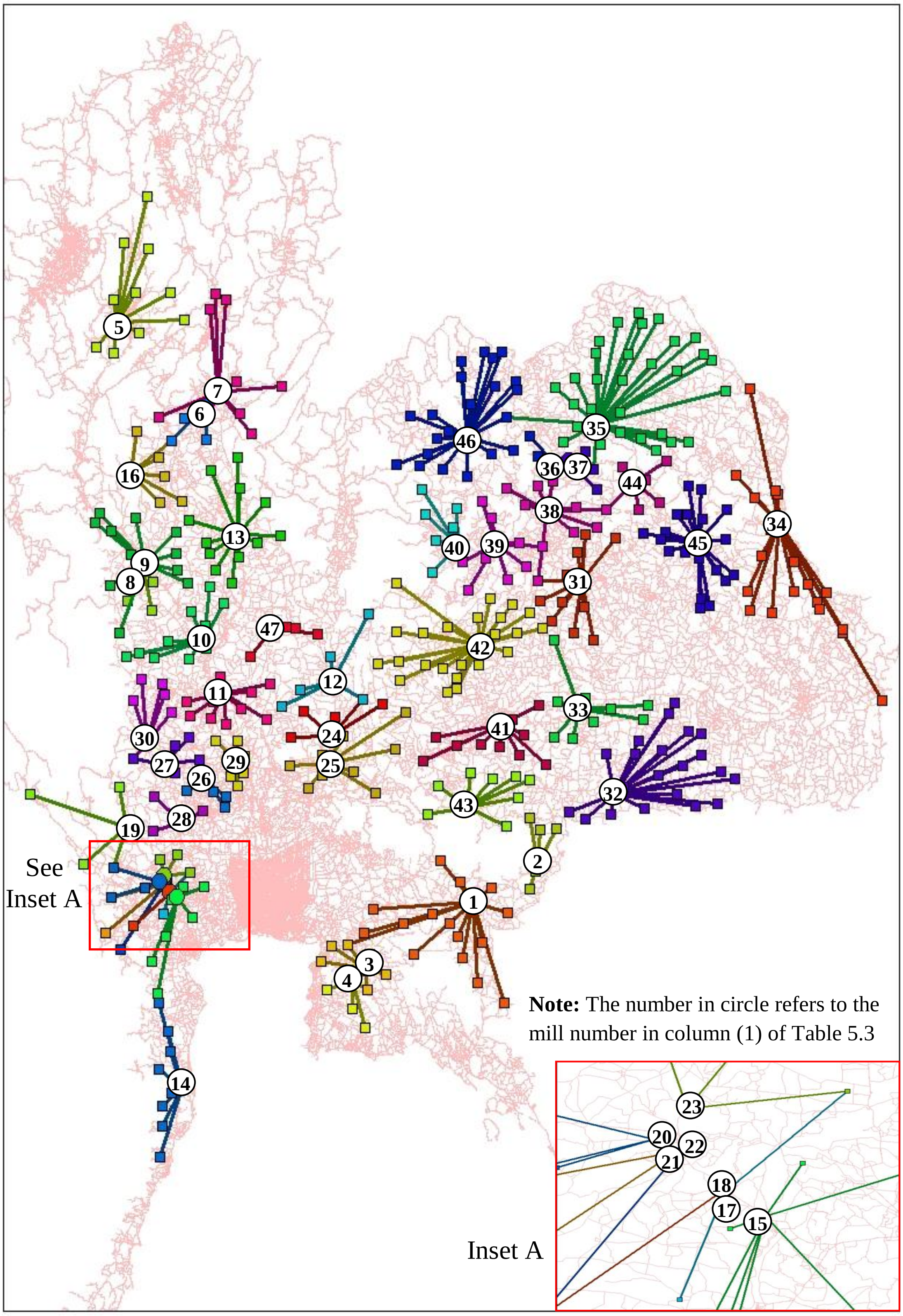


Figure 5.3 Optimal transportation patterns: sugarcane quantities decreased by 20%

5.1.2 The case when the actual sugarcane yield is higher than prediction

Sugarcane quantity is an important factor for making decision about new establishment, relocation, and/or capacity expansion of sugar mills. This is obvious when considering the cases that some sugar mills were allowed to relocate from an area with insufficient sugarcane to an area with excessive sugarcane quantity. In addition to relocation, these mills may be allowed to expand their capacity to match sugarcane quantity in the new area. Some mills that did not request for relocation but requested for capacity expansion were also allowed to do so if sugarcane quantity was more than the mill's capacity. According to previous statistics, the sugarcane production in Thailand keeps increasing almost every year, especially in the production year 2010/2011. In that production year, it had been expected that the sugarcane quantity would have been less than 65,661,709 million tons of the previous production year (2009/2010). The prediction was based on the drought that occurred during April to August 2010. However, after September until December 2010, there was an abundance of rain, and it kept on raining continuously until March 2011. Thus sugarcane yield in that production year became much higher than prediction, resulting in a total of 95,358,928 million tons of sugarcane fed to sugarcane crushers of all sugar mills (Office of The Cane and Sugar Board, 2011). That amount is the record breaking in the history of the industry. As a result, the operation time of sugar mills in that year lasted longer than any previous years. For the production year 2011/2012, it was predicted that sugarcane production will increase to as high as 100 million tons (Noiwan, 2011). Therefore, it is reasonable to conduct a sensitivity analysis for the cases of actual sugarcane production being higher than prediction, which can also impact the decision regarding the liberalization of sugar mills. In this regards, the sensitivity analysis will be conducted for two cases; i.e. 10% and 20% above the prediction.

1) The sugarcane quantity increased by 10%

Sugarcane production has a trend of keeping increasing almost every year, which is mainly because sugar mills that have expanded their capacity try to promote sugarcane plantation around the mill. By doing so, they can manage those fields more efficiently and have a better chance to have sufficient supply for the mill's capacity. The ever-growing price of sugarcane is also another factor that induces new farmers to replace their old crops with sugarcane. Therefore, if sugarcane production is higher than prediction, but not too high over the permitted capacity of the mills, it will certainly be beneficial to sugar mills since they will be able to produce sugar more efficiently. However, if the yield exceeds capacity of the mills, the persons who are negatively affected are sugarcane farmers. In this case, sugarcane price will be low. According to Figure 5.1, the actual amount of sugarcane during the production year 2006/2007 was higher than the predicted quantity by approximately 10%.

The sensitivity analysis was conducted based on the cabinet resolution regarding relocation and capacity expansion of sugar mills. It was assumed that the implementation is completed in the production year 2008/2009. Thus the overall sugarcane demand of sugar mills throughout the country will increase from 74,633,506 to 84,278,170 tons. Meanwhile, the sugarcane production was assumed that the actual quantity of the sugarcane in the production year 2008/2009 became 10% higher than the predicted figures in all 404 area groups (S_i). Therefore, sugarcane production (supply) in the whole country will increase from 71,083,073 to 78,191,401 tons.

Table 5.4 summarizes the results from solving the transportation model according to the relocation and capacity expansion as permitted by the cabinet resolution, together with the assumption that sugarcane quantities increase by 10%. The following symbols were used in Table 5.4.

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 5.4 The results from solving the transportation problem: sugarcane quantities increased by 10%

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	15 (-)	2,265,228 (0)	2,265,228 (0)	100.00 (+)	29.56 (0)	76.51 (+)	148.78 (+)	37.82 (+)
2	New Kwang Soon Lee	E	11 (+)	1,235,030 (+)	1,917,600 (+)	64.40 (-)	11.56 (+)	69.51 (+)	167.52 (+)	46.35 (+)
3	Rayong Sugar	E	4 (+)	589,360 (0)	589,360 (0)	100.00 (0)	23.86 (-)	29.81 (+)	53.59 (0)	13.65 (-)
4	Chonburi Sugar and Trading	E	3 (-)	527,800 (0)	527,800 (0)	100.00 (0)	11.35 (0)	15.10 (-)	49.97 (0)	19.41 (+)
	Eastern Region		**33 (+)**	**4,617,418 (+)**	**5,299,988 (+)**	**87.12 (-)**	**11.35 (+)**	**61.66 (+)**	**167.52 (+)**	**41.03 (+)**
5	Mae Wang Sugar Industry	N	11 (0)	302,055 (+)	327,450 (0)	92.24 (+)	9.51 (0)	43.04 (0)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	3 (-)	389,035 (0)	389,035 (0)	100.00 (0)	27.54 (0)	36.42 (-)	50.89 (-)	11.74 (-)
7	Thai Identity Sugar	N	11 (-)	1,291,120 (-)	2,736,000 (0)	47.19 (-)	13.69 (0)	55.85 (-)	109.50 (0)	32.63 (+)
8	Kampangpetch	N	4 (0)	864,000 (0)	864,000 (0)	100.00 (0)	15.46 (0)	36.44 (+)	52.20 (0)	17.05 (0)
9	Nakornpetch	N	9 (-)	2,784,000 (0)	2,784,000 (0)	100.00 (0)	17.34 (0)	36.68 (-)	86.75 (-)	19.59 (-)
10	Ruamphol Nakhonsawan	N	11 (-)	1,249,600 (0)	1,249,600 (0)	100.00 (0)	12.30 (0)	55.35 (+)	94.82 (0)	28.20 (+)
11	Kaset Thai Industry Sugar	N	17 (-)	6,360,000 (-)	6,360,000 (0)	95.21 (-)	18.04 (0)	43.92 (-)	98.76 (-)	25.23 (-)
12	Thai Roong Ruang Industry	N	8 (+)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	33.96 (+)	117.25 (+)	40.08 (+)
13	Phitsanulok	N	16 (+)	1,630,412 (+)	2,530,000 (+)	64.44 (-)	1.72 (0)	56.86 (+)	253.44 (+)	69.00 (+)
16	Banpong	N	9 (+)	1,602,000 (+)	1,602,000 (+)	100.00 (0)	1.93 (-)	61.61 (+)	72.46 (+)	21.87 (+)
47	Chonburi Sugar Industry	N	10	1,996,672	3,240,000	61.63	18.92	86.57	199.61	62.14
	Northern Region		**109 (+)**	**21,188,003(+)**	**25,106,085 (+)**	**84.39 (-)**	**1.72 (0)**	**49.11 (+)**	**253.44 (+)**	**42.25 (+)**
14	Pranburi Sugar Industry	C	7 (0)	630,000 (0)	630,000 (0)	100.00 (0)	13.54 (0)	40.62 (-)	70.84 (0)	19.65 (0)
15	Ratchaburi	C	12 (+)	1,043,376 (+)	1,248,000 (0)	83.60 (+)	6.55 (0)	50.13 (+)	211.68 (+)	69.85 (+)
17	Mitrkasetr Industry	C	2 (0)	1,106,087 (+)	1,224,670 (0)	90.32 (+)	26.16 (0)	29.89 (0)	31.93 (0)	4.08 (0)

Table 5.4 The results from solving the transportation problem: sugarcane quantities increased by 10% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	1 (-)	724,697 (-)	1,176,400 (0)	61.60 (-)	53.44 (0)	53.44 (-)	53.44 (-)	0.00 (-)
19	New Krungthai	C	3 (+)	1,938,000 (+)	1,938,000 (+)	100.00 (+)	18.39 (+)	25.53 (+)	46.82 (-)	14.66 (-)
20	Thai Multi-Sugar Industry	C	2 (0)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	21.69 (-)	47.78 (0)	19.85 (0)
21	Tamaka	C	7 (-)	1,417,314 (-)	1,893,990 (0)	74.83 (-)	25.73 (-)	58.58 (-)	158.46 (0)	42.17 (+)
22	Prajuap Industry	C	3 (+)	885,707 (0)	885,707 (0)	100.00 (0)	4.78 (-)	18.08 (-)	80.56 (+)	38.27 (+)
23	Thai Sugar Industry	C	2 (-)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	25.32 (-)	26.89 (-)	5.89 (-)
24	T N Sugar	C	4 (0)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	32.96 (+)	88.11 (+)	38.13 (+)
25	Saraburi	C	6 (-)	2,779,370 (0)	2,779,370 (0)	100.00 (0)	8.98 (0)	29.66 (-)	101.80 (+)	35.59 (+)
26	Suphanburi Sugar Industry	C	5 (+)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	16.96 (-)	26.73 (-)	8.85 (-)
27	Mitr-Phol	C	5 (0)	3,011,540 (0)	3,011,540 (0)	100.00 (0)	24.09 (0)	32.70 (-)	51.43 (0)	9.96 (-)
28	U-thong Industry	C	4 (-)	1,524,866 (0)	1,524,866 (0)	100.00 (0)	2.09 (0)	20.76 (-)	41.77 (-)	16.58 (-)
29	Singburi	C	13 (0)	1,496,000 (0)	1,496,000 (0)	100.00 (0)	11.51 (0)	36.80 (-)	75.13 (+)	23.16 (+)
30	Banrai Industry	C	3 (+)	2,794,000 (+)	2,794,000 (+)	100.00 (0)	13.73 (0)	18.50 (+)	54.36 (+)	20.59 (+)
	Central Region		**79 (+)**	**24,159,277(+)**	**25,410,863 (+)**	**95.07 (+)**	**2.09 (0)**	**30.90 (-)**	**211.68 (+)**	**41.43 (+)**
31	Wang Ka-nai	NE	8 (0)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	38.85 (+)	85.92 (+)	24.57 (+)
32	Surin Sugar	NE	31 (+)	1,173,469 (+)	1,408,000 (0)	83.34 (+)	10.74 (0)	67.54 (+)	276.19 (+)	56.77 (+)
33	Burirum	NE	15 (-)	1,296,000 (+)	1,296,000 (0)	100.00 (+)	7.97 (0)	84.68 (+)	137.49 (0)	44.98 (+)
34	Saha Ruang	NE	23 (-)	1,470,000 (0)	1,470,000 (0)	100.00 (0)	16.01 (0)	45.19 (-)	199.90 (-)	50.38 (-)
35	Rerm Udom	NE	27 (-)	2,017,036 (0)	2,017,036 (0)	100.00 (0)	17.04 (0)	47.60 (-)	132.71 (-)	35.71 (-)
36	Kasetr Phol	NE	3 (0)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	24.25 (-)	46.36 (0)	16.07 (0)

Table 5.4 The results from solving the transportation problem: sugarcane quantities increased by 10% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	4 (0)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	24.34 (-)	42.95 (0)	17.57 (0)
38	Khon Kaen	NE	5 (-)	2,142,000 (0)	2,142,000 (0)	100.00 (0)	6.64 (0)	31.66 (+)	61.12 (-)	19.29 (-)
39	Mitr Poo-Viang	NE	13 (+)	1,728,468 (0)	1,728,468 (0)	100.00 (0)	3.07 (0)	49.67 (+)	98.60 (0)	31.01 (+)
40	United Farmers and Industry	NE	7 (0)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	33.33 (+)	86.49 (0)	24.93 (0)
41	Korach Industry	NE	18 (-)	2,712,000 (+)	2,712,000 (0)	100.00 (+)	15.10 (0)	68.41 (+)	141.21 (+)	36.12 (+)
42	Andvian (Ratchasima)	NE	13 (-)	3,168,000 (0)	3,168,000 (0)	100.00 (0)	9.22 (0)	64.98 (+)	95.94 (-)	25.97 (-)
43	Konburi	NE	9 (-)	1,656,490 (0)	1,656,490 (0)	100.00 (0)	0.56 (0)	38.27 (-)	93.86 (-)	27.77 (+)
44	E-Saan Sugar Industry	NE	3 (-)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	21.47 (-)	25.23 (-)	7.09 (-)
45	Mitr Kalasin	NE	23 (-)	2,280,000 (0)	2,280,000 (0)	100.00 (0)	7.17 (0)	42.24 (-)	115.93 (-)	28.99 (-)
46	Erawan Sugar	NE	17 (+)	1,620,000 (+)	1,620,000 (+)	100.00 (0)	1.61 (0)	56.09 (+)	111.55 (+)	28.86 (+)
	Northeastern Region		**219 (-)**	**28,226,703(+)**	**28,461,234 (+)**	**99.18 (+)**	**0.56 (0)**	**47.75 (-)**	**276.19 (+)**	**42.01 (+)**
	Total		**440 (+)**	**78,191,401(+)**	**84,278,170(+)**	**92.78 (-)**	**0.56 (0)**	**43.73 (+)**	**276.19 (+)**	**42.33 (+)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy fields) = 64,286,258,513 tons-kilometers

Objective function (excluding dummy fields) = 3,419,568,513 tons-kilometers

- The impacts on the sugar mills in the Eastern region

From the optimal current situation analysis of the production year 2008/2009, as shown in Table 4.4, there were four sugar mills in the Eastern region, and their total sugarcane demand were 3,991,414 tons. When New Kwang Soon Lee mill expands its capacity according to the cabinet resolution, the total sugarcane demand in this region will increase to 5,299,988 tons. According to the result from transportation model analysis with the assumption that the sugarcane quantities increased by 10%, as shown in Table 5.4, the amount of sugarcane supplied to the mills in this region will increase from 3,989,236 tons (Table 4.4) to 4,617,418 tons (Table 5.4). As a result, three out of four sugar mills would be able to fully utilize their capacity. Especially, Eastern Sugar and Cane mill would be able to increase its capacity utilization from 99.90% (Table 4.4) to 100% (Table 5.4). Meanwhile, the capacity utilization of Rayong sugar mill and Chonburi Sugar and Trading mill would remain unchanged at 100%. Only New Kwang Soon Lee mill may not be able to fully utilize its capacity because its capacity has been increased for three times, which boosts the sugarcane demand from 609,026 to 1,917,600 tons. Meanwhile, the increased sugarcane quantity still does not meet its demand, thus its capacity utilization may reduce from 100% (Table 4.4) down to only 64.40% (Table 5.4).

Resulting transportation distances obtained from transportation model are shown in columns (8)-(11) of Table 5.4. The shortest (min) distance from the nearest field to the mill in this region may increase from 8.77 kilometers (Table 4.4) to 11.35 kilometers (Table 5.4). Meanwhile, the overall average (mean) transportation distance may increase from 41.55 kilometers (Table 4.4) to 61.66 kilometers (Table 5.4). These changes are caused mainly from the relocation and capacity expansion of New Kwang Soon Lee mill. Because of such relocation and expansion, sugarcane will have to be transported across region from the Northeastern region to the Eastern region, as shown in Figure 5.4. Consequently, the maximum transportation distance also becomes farther with an increase from 148.78 kilometers (Table 4.4) to 167.52 kilometers (Table 5.4).

- The impacts on the sugar mills in the Northern region

In the production year 2008/2009, there were actually nine sugar mills in the Northern region. Due to the cabinet resolution, it was assumed that two more mills were added in that year, making up totally 11 mills. The two added sugar mills were relocated into this region. They are Banpong mill and Chonburi Sugar Industry mill from the Central and the Eastern regions, respectively. The relocation of these two mills, together with the capacity expansion of Phitsanulok mill in the Northern region, makes the overall sugarcane demand in this region increase from 19,113,395 to 25,106,085 tons. Therefore, even though the sugarcane quantities increase by 10%, the result from transportation model analysis reveals that the sugarcane quantity supplied to this region will increase from 18,480,165 tons (Table 4.4) to 21,188,003 tons (Table 5.4), but sugarcane quantity supplied is still short of 3,918,082 tons. Consequently, five out of 11 mills might not be able to fully utilize their capacity, as shown in column (7). These five mills and their respective capacity utilization in parentheses are Mae Wang Sugar Industry mill (92.24%), Thai Identity mill (47.19%), Kaset Thai mill (95.21%), Phitsanulok mill (64.44%), and Chonburi Sugar Industry mill (61.63%).

The increasing number of sugar mills in the Northern region from nine to 11 mills, together with the capacity expansion of Phitsanulok mill according to the cabinet resolution, boosts the sugarcane demand in this region much higher. Therefore, if the sugarcane production in the region is below the total capacity of the mills, the mills have to transport more sugarcane from another region in order to sufficiently supply their capacity. For this reason, the average (mean) distance and the longest (max) distance from the sugarcane fields to this mill become higher (the longest distance increase from 128.65 kilometers (Table 4.4) to 253.44 kilometers (Table 5.4). As seen clearly in Figure 5.4, some sugarcane from the Northeastern region is transported to Phitsanulok mill (13) in this region.

- The impacts on the sugar mills in the Central region

The Central region is the region with the highest number of sugar mills, 17 mills. The optimal current situation analysis for the production year 2008/2009 reveals that the Central region requires a total sugarcane supply of 23,810,827 tons. According to the cabinet resolution, Banpong mill will be relocated to the Northern region. This will make the number of sugar mills in this region become 16 mills. Meanwhile, New Krungthai mill and Banrai mill will expand their capacity, and the total sugarcane demand in this region will increase to 25,410,863 tons. The transportation model analysis was conducted by assuming that the sugarcane quantities increase by 10%. The result reveals that the total amount of supplied sugarcane to this region should be 24,159,277 tons. This will cause the overall capacity utilization become 95.07%, as shown in column (5) of Table 5.4. Four mills; i.e., New Krungthai mill, Banrai mill, Ratchaburi mill, and Mitrkasetr mill have higher sugarcane supply.

Possibly its relocation from Tamaka district to Boploy district in Kanchanaburi province contributed to the longer shortest (minimum) transportation distance of 18.34 kilometers (up from 8.43 kilometers in case 1) for New Krungthai mill as show in column (8). Its average (mean) transportation distance changed from 10.48 to 21.69 kilometers as show in column (9). However, its longest (max) transportation distance might decrease from 81.74 kilometers (Table 4.4) to 46.82 kilometers (Table 5.4). This can be explained that, the surrounding sugar fields in the new area in general may sufficiently supply sugarcane to this mill. Thus the mill does not have to transport sugarcane from farter fields anymore. This makes its S.D. value becomes as low as 14.66 kilometers.

- The impacts on the sugar mills in the Northeastern region

The overall sugarcane demand in this region is 28,461,234 tons. Results in Table 5.4, reveals that sugarcane quantity was supplied to the mills in this region will increase from 26,819,215 tons (Table 4.4) to 28,226,703 tons (Table 5.4). When considering the results between sugarcane supplied and sugarcane demand, it is found that the overall capacity utilization of sugar mills in this region can be as high as 99.18%. Considering capacity utilization of each mill in column (7), it is found that most mills have 100% capacity utilization, with the exception of only Surin mill, whose capacity utilization is 83.34%. The cause of this might be the relocation of New Kwang Soon Lee mill, which has relocated from the Eastern region to an area close to Surin mill, and created higher competition. Comparing the patterns of transportation in Figure 4.4 with Figure 5.4, it can be seen clearly that some sugarcane fields that used to supply sugarcane to Surin mill (32) have changed to supply to New Kwang Soon

Lee mill (2) instead, leading to the inability of Surin mill to utilize its full capacity of 100%.

Regarding transportation distance, column (8) of the Table 5.4 shows that the shortest (min) transportation distance of each sugar mill in the Northeastern region remains unchanged. This might be because there is no relocation of any mill in this region. The only change is the capacity expansion of Erawan mill, which results in its higher average (mean) transportation distance from 50.74 kilometers (Table 4.4) to 56.09 kilometers (Table 5.4). Its longest (max) transportation distance also increases from 85.20 kilometers (Table 4.4) to 111.55 kilometers (Table 5.4). The increases in these distances were because the mill has to find sufficient sugarcane for its increased capacity. Considering the whole region, the overall average (mean) transportation distance decreases from 47.80 kilometers (Table 4.4) to 47.75 kilometers (Table 5.4). However, due to the increased longest (max) transportation distance of Surin mill from 109.68 kilometers (Table 4.4) to 276.19 kilometers (Table 5.4), the overall S.D. value of this region, as shown in column (11), also increases.

Considering the objective function, the minimum total transportation cost for this case would increase from 3,061,924,585 to 3,419,568,513 tons-kilometers. When these figures are multiplied with the average unit transportation cost of 4.12 Baht/ton/kilo-meter, the resulting overall sugarcane transportation cost in the whole country is found to increase from 12,615,129,290 to 14,088,622,270 Baht.

As compared to the optimal current transportation pattern in Figure 4.6, this case shows that some sugarcane fields would have to transport longer. For example in the Eastern region, after New Kwang Soon Lee mill (2) expanded its capacity and relocated from Chonburi province to Srakaew province, some sugarcane fields that used to send sugarcane to this mill had to transport sugarcane across the region from the Eastern region to the Central region. This is because all nearby sugar mills, such as Eastern Sugar and Cane mill (1), Rayong mill (3), and Chonburi Sugar and Trading mill (4), have already fully utilized their capacity at 100%, and are not able to receive any more sugarcane. For the Northeastern region, the mill that is found to have an apparent change in transportation pattern is Surin mill (32). This mill will have to take sugarcane from further fields in order to gain sufficient supply for its operation. Considering the whole region, there are many sugarcane fields in the Northeastern region that will have to transport sugarcane to either the Northern region or the Central region because the capacity of most sugar mills in its own region has been fully utilized at 100%.

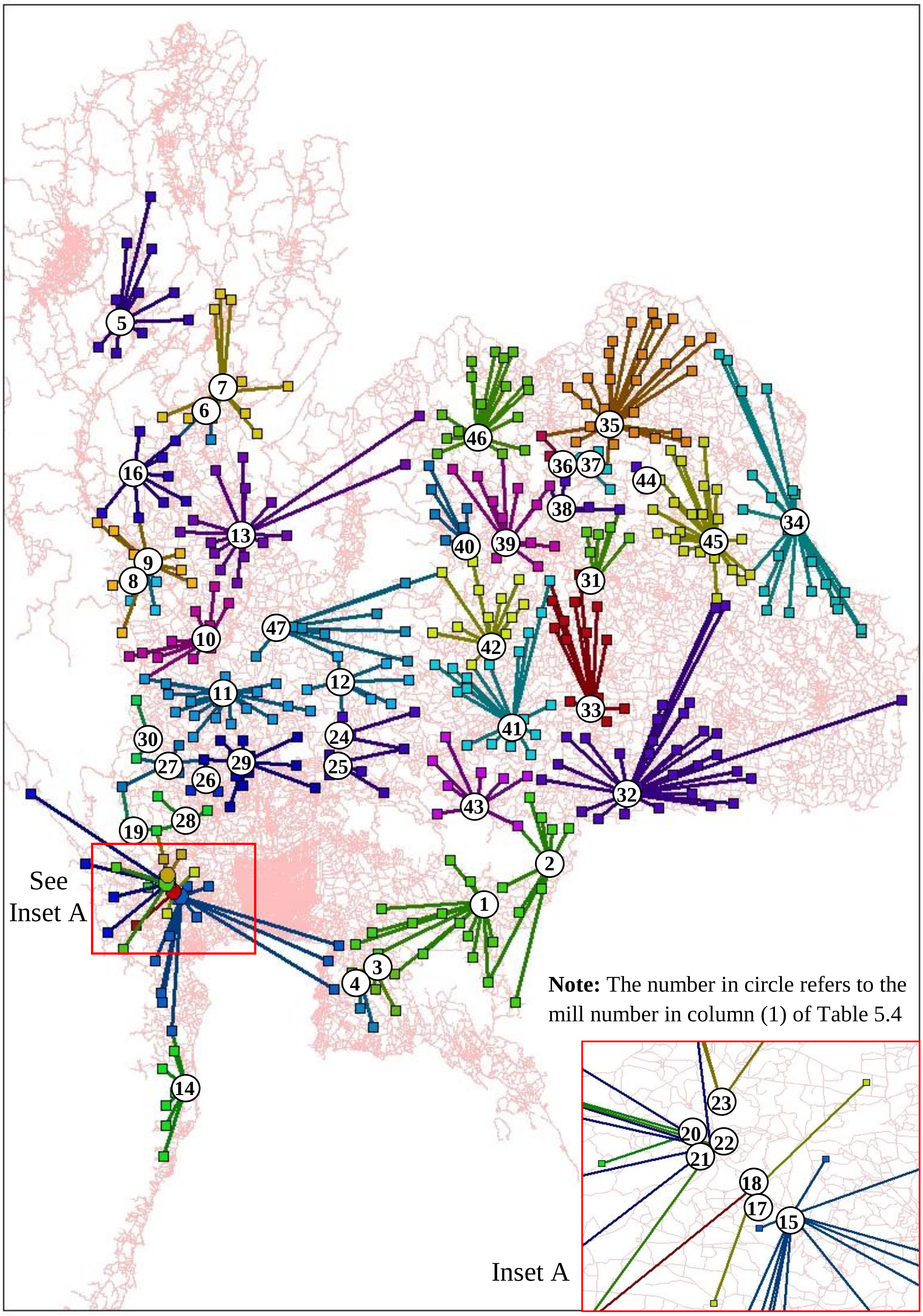


Figure 5.4 Optimal transportation patterns: sugarcane quantities increased by 10%

2) The sugarcane quantity increased by 20%

Number of days for pressing sugarcane depends on sugarcane quantity available for being pressed in each growing season. Therefore, if there is a situation when the actual sugarcane quantity becomes more than the forecasted quantity, it would certainly be beneficial for sugar production of sugar mills. Sugar mills will be able to fully utilize their capacity and to produce sugar more efficiently due to having more sugarcane pressing days. However, whenever sugarcane quantity becomes higher than the forecasted quantity, and also higher than the permitted capacity of sugar mills, such this situation would certainly cause negative impacts on several stakeholders. For clearer understanding, there is an example of the case in the production year 2010/2011, when the actual sugarcane quantity was higher than the forecasted quantity for almost 30 million tons. The situation led to a too-long period of operational days of many sugar mills, and, as a result, there were problems in harvesting and transporting sugarcane to sugar mills in many areas. The problems can be concluded as follows;

1) Normally sugar mills stop their operation before mid April, which is before the beginning of Songkran festival. That means sugarcane-harvesting workers will be able to go back to their hometown for a long vacation. When sugarcane is more than prediction, sugar mills will have to extend the period of sugarcane press. They will face a problem of worker shortage. Sugarcane farmers will also have a problem of high labor cost for harvesting their sugarcane, and may have difficulty in getting sufficient workers after the Songkran festival.

2) If the sugarcane pressing period is extended over Songkran festival, rain that commonly falls during that time can cause the harvested sugarcane become much contaminated with soil. Operating with excessive soil-contaminated sugarcane can damage the sugarcane pressing machine, which will consequently require frequent maintenance services. As a result, the efficiency and productivity would be low.

Nonetheless, the sensitivity analysis conducted with the case of higher sugarcane quantity than prediction can help to visualize a future trend about capacity utilization of each sugar mill. The analysis results can also be used to support decision making regarding new the establishment, relocation, and capacity expansion of sugar mills. With this analysis, authorities will be able to determine the capacity of sugar mills that matches sugarcane quantity in that area in order to prevent the situation of having excessive sugarcane quantity that exceeds the total permitted capacity of sugar mills in that area.

The cabinet resolution regarding relocation and capacity expansion of some sugar mills that will be truly in effect in the future was used as the case study. It is assumed that the operations according to the cabinet resolution will be completed in the production year 2008/2009. Thus the overall sugarcane demand throughout the country will be 84,278,170 tons. A sensitivity analysis was conducted based on that assumption together with another assumption that the sugarcane quantity in that year was more than the actual quantity by 20%. The increasing sugarcane quantity was assumed to spread evenly all over 404 area groups (S_i). As a result, the total sugarcane quantity for the whole country will increase from 71,083,073 to 85,299,692 tons.

Table 5.5 summarizes the results from solving the transportation model according to the relocation and capacity expansion as permitted by the cabinet resolution, together with the assumption that sugarcane quantities increase by 20%. This Table uses symbols (-), (+), and (0) in order to represent the impacts, while:

- The (-) symbol indicates the decrease when compared with the results of the optimal current situation in Table 4.4.
- The (+) symbol indicates the increase when compared with the results of the optimal current situation in Table 4.4.
- The (0) symbol indicates no change or zero effect when compared with the results of the optimal current situation in Table 4.4.

Table 5.5 The results from solving the transportation problem: sugarcane quantities increased by 20%

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Eastern Sugar and Cane	E	13 (-)	2,265,228 (0)	2,265,228 (0)	100.00 (+)	29.56 (0)	83.45 (+)	148.78 (+)	40.21 (+)
2	New Kwang Soon Lee	E	17 (+)	1,917,600 (+)	1,917,600 (+)	100.00 (0)	11.56 (+)	79.32 (+)	167.52 (+)	39.41 (+)
3	Rayong Sugar	E	4 (+)	589,360 (0)	589,360 (0)	100.00 (0)	23.86 (-)	29.99 (+)	53.59 (0)	13.65 (-)
4	Chonburi Sugar and Trading	E	3 (-)	527,800 (0)	527,800 (0)	100.00 (0)	11.35 (0)	15.44 (-)	49.97 (0)	19.41 (+)
	Eastern Region		**37 (+)**	**5,299,988 (+)**	**5,299,988 (+)**	**100 (+)**	**11.35 (+)**	**69.24 (+)**	**167.52 (+)**	**40.39 (+)**
5	Mae Wang Sugar Industry	N	11 (0)	327,450 (+)	327,450 (0)	100.00 (+)	9.51 (0)	42.78 (-)	128.65 (0)	37.24 (0)
6	Uttaradit Sugar Industry	N	3 (-)	389,035 (0)	389,035 (0)	100.00 (0)	37.08 (+)	48.14 (+)	63.88 (-)	13.40 (-)
7	Thai Identity Sugar	N	18 (+)	2,736,000 (+)	2,736,000 (0)	100.00 (+)	13.69 (0)	119.46 (+)	298.99 (+)	100.88 (+)
8	Kampangpetch	N	3 (-)	864,000 (0)	864,000 (0)	100.00 (0)	26.22 (+)	37.75 (+)	52.20 (0)	13.54 (-)
9	Nakornpetch	N	8 (-)	2,784,000 (0)	2,784,000 (0)	100.00 (0)	17.34 (0)	38.46 (-)	99.21 (0)	27.13 (+)
10	Ruamphol Nakhonsawan	N	13 (0)	1,249,600 (0)	1,249,600 (0)	100.00 (0)	12.30 (0)	67.11 (+)	111.02 (+)	31.55 (+)
11	Kaset Thai Industry Sugar	N	17 (-)	6,360,000 (0)	6,360,000 (0)	100.00 (0)	18.04 (0)	43.80 (-)	89.46 (-)	24.80 (+)
12	Thai Roong Ruang Industry	N	6 (-)	3,024,000 (0)	3,024,000 (0)	100.00 (0)	4.64 (0)	33.12 (+)	117.25 (+)	41.76 (+)
13	Phitsanulok	N	19 (+)	2,530,000 (+)	2,530,000 (+)	100.00 (0)	1.72 (0)	82.64 (+)	258.92 (+)	74.46 (+)
16	Banpong	N	11 (+)	1,602,000 (+)	1,602,000 (+)	100.00 (+)	1.93 (-)	61.17 (+)	86.92 (+)	23.23 (+)
47	Chonburi Sugar Industry	N	13	3,240,000	3,240,000	100.00	18.92	83.52	199.61	57.26
	Northern Region		**122 (+)**	**25,106,085(+)**	**25,106,085 (+)**	**100 (+)**	**1.72 (0)**	**61.32 (+)**	**298.99 (+)**	**60.71 (+)**
14	Pranburi Sugar Industry	C	6 (-)	630,000 (0)	630,000 (0)	100.00 (0)	13.54 (0)	40.11 (-)	70.84 (0)	19.19 (-)
15	Ratchaburi	C	14 (+)	1,248,000 (+)	1,248,000 (0)	100.00 (+)	6.55 (0)	53.76 (+)	211.68 (+)	68.93 (+)
17	Mitrkasetr Industry	C	4 (+)	1,224,670 (+)	1,224,670 (0)	100.00 (+)	11.83 (-)	30.23 (+)	85.14 (+)	32.05 (+)

Table 5.5 The results from solving the transportation problem: sugarcane quantities increased by 20% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
18	Thai Sugar Mill	C	2 (0)	1,176,400 (+)	1,176,400 (0)	100.00 (+)	53.44 (0)	55.76 (+)	60.50 (0)	4.99 (0)
19	New Krungthai	C	2 (0)	1,938,000 (+)	1,938,000 (+)	100.00 (+)	18.39 (+)	27.88 (+)	46.82 (-)	20.10 (-)
20	Thai Multi-Sugar Industry	C	1 (-)	953,865 (0)	953,865 (0)	100.00 (0)	19.65 (0)	19.65 (-)	19.65 (-)	0.00 (-)
21	Tamaka	C	8 (0)	1,893,990 (0)	1,893,990 (0)	100.00 (0)	25.73 (-)	53.77 (-)	158.46 (0)	42.44 (+)
22	Prajuap Industry	C	3 (+)	885,707 (0)	885,707 (0)	100.00 (0)	4.78 (-)	19.76 (-)	75.31 (0)	35.93 (+)
23	Thai Sugar Industry	C	3 (0)	1,459,147 (0)	1,459,147 (0)	100.00 (0)	18.56 (0)	29.59 (+)	81.38 (+)	34.12 (+)
24	T N Sugar	C	5 (+)	1,926,000 (0)	1,926,000 (0)	100.00 (0)	14.35 (0)	40.74 (+)	88.11 (+)	35.06 (+)
25	Saraburi	C	5 (-)	2,779,370 (0)	2,779,370 (0)	100.00 (0)	8.98 (0)	25.56 (-)	61.48 (-)	20.48 (-)
26	Suphanburi Sugar Industry	C	4 (+)	469,308 (0)	469,308 (0)	100.00 (0)	7.40 (0)	16.93 (-)	32.23 (0)	11.34 (-)
27	Mitr-Phol	C	4 (-)	3,011,540 (0)	3,011,540 (0)	100.00 (0)	24.09 (0)	31.72 (-)	24.09 (-)	11.30 (+)
28	U-thong Industry	C	3 (-)	1,524,866 (0)	1,524,866 (0)	100.00 (0)	2.09 (0)	19.29 (-)	41.77 (-)	19.96 (-)
29	Singburi	C	13 (0)	1,496,000 (0)	1,496,000 (0)	100.00 (0)	11.51 (0)	32.39 (-)	75.13 (+)	23.28 (+)
30	Banrai Industry	C	2 (+)	2,794,000 (+)	2,794,000 (+)	100.00 (0)	13.73 (0)	16.54 (+)	28.28 (+)	10.29 (+)
	Central Region		**79 (+)**	**25,410,863(+)**	**25,410,863 (+)**	**100 (+)**	**2.09 (0)**	**31.77 (-)**	**211.68 (+)**	**43.13 (+)**
31	Wang Ka-nai	NE	7 (-)	1,035,351 (0)	1,035,351 (0)	100.00 (0)	6.70 (0)	36.30 (+)	58.53 (0)	19.41 (+)
32	Surin Sugar	NE	33 (+)	1,408,000 (+)	1,408,000 (0)	100.00 (+)	10.74 (0)	78.57 (+)	241.01 (+)	65.49 (+)
33	Burirum	NE	14 (-)	1,296,000 (+)	1,296,000 (0)	100.00 (+)	7.97 (0)	88.76 (+)	136.97 (-)	43.51 (+)
34	Saha Ruang	NE	11 (-)	1,470,000 (0)	1,470,000 (0)	100.00 (0)	16.01 (0)	39.51 (-)	76.47 (-)	22.16 (-)
35	Rerm Udom	NE	15 (-)	2,017,036 (0)	2,017,036 (0)	100.00 (0)	17.04 (0)	37.86 (-)	67.32 (-)	17.42 (-)
36	Kasetr Phol	NE	2(-)	1,010,889 (0)	1,010,889 (0)	100.00 (0)	16.99 (0)	17.82 (-)	20.36 (-)	2.38 (-)

Table 5.5 The results from solving the transportation problem: sugarcane quantities increased by 20% (Continued)

No	Sugar Mill	Region	Number of Supply Fields	Supplied Quantity (tons)	Permitted Production Capacity (tons)	Utilization (%)	Transportation Distance (Kilometers)			
							Min	Mean	Max	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
37	Kumphawapi	NE	5 (+)	1,272,000 (0)	1,272,000 (0)	100.00 (0)	3.66 (0)	22.69 (-)	42.95 (0)	15.50 (-)
38	Khon Kaen	NE	5 (-)	2,142,000 (0)	2,142,000 (0)	100.00 (0)	6.64 (0)	30.74 (-)	61.12 (-)	19.29 (-)
39	Mitr Poo-Viang	NE	12 (+)	1,728,468 (0)	1,728,468 (0)	100.00 (0)	3.07 (0)	35.57 (-)	82.98 (-)	25.05 (-)
40	United Farmers and Industry	NE	5 (-)	2,250,000 (0)	2,250,000 (0)	100.00 (0)	16.52 (0)	26.91 (-)	66.95 (-)	20.25 (-)
41	Korach Industry	NE	17 (-)	2,712,000 (+)	2,712,000 (0)	100.00 (+)	15.10 (0)	67.20 (+)	141.21 (+)	37.14 (+)
42	Andvian (Ratchasima)	NE	14 (-)	3,168,000 (0)	3,168,000 (0)	100.00 (0)	9.22 (0)	58.94 (-)	95.94 (-)	25.11 (-)
43	Konburi	NE	8 (-)	1,656,490 (0)	1,656,490 (0)	100.00 (0)	0.56 (0)	37.47 (-)	102.01 (0)	34.49 (+)
44	E-Saan Sugar Industry	NE	3 (-)	1,395,000 (0)	1,395,000 (0)	100.00 (0)	11.70 (0)	20.22 (-)	25.23 (-)	7.09 (-)
45	Mitr Kalasin	NE	18 (-)	2,280,000 (0)	2,280,000 (0)	100.00 (0)	7.17 (0)	38.09 (-)	69.36 (-)	19.06 (-)
46	Erawan Sugar	NE	11 (0)	1,620,000 (+)	1,620,000 (+)	100.00 (0)	1.61 (0)	54.52 (+)	69.50 (-)	21.39 (-)
	Northeastern Region		**180 (+)**	**28,416,234(+)**	**28,461,234 (+)**	**100 (+)**	**0.56 (+)**	**44.51 (+)**	**241.01 (+)**	**43.97 (+)**
	Total		**418 (+)**	**84,278,170(+)**	**84,278,170 (+)**	**100.00 (+)**	**0.56 (0)**	**47.23 (+)**	**298.99 (+)**	**49.67 (+)**

Remark: 1) E = Eastern region, N = Northern region, C = Central region, NE = Northeastern region

2) (0) = No change, (-) = Decreasing, (+) = Increasing

3) Objective function (including dummy mill) = 14,195,843,008 tons-kilometers

Objective function (excluding dummy mill) = 3,980,623,008 tons-kilometers

- The impacts on the sugar mills in the Eastern region

This situation is assumed that New Kwang Soon Lee mill has expanded its production capacity and relocated from Chonburi province to Srakaew province according to the Cabinet resolution, while there is 20% increase in sugarcane yield. With this assumption, the overall sugar demand in this region will increase to 5,299,998 tons. The results obtaining from the analysis using the transportation model (Table 5.5) reveal that the sugarcane quantity supplied to this region will be sufficient for consumption demand in this region, which is 5,299,998 tons. As a result, capacity utilization of all mills in this region will reach their 100%. Regarding transportation distance, as shown in column (8), it was found that the shortest (min) transportation distance from the nearest sugarcane field to the sugar mill in the Eastern region will be the distance to Chonburi Sugar and Trading mill (increase to 11.35 from 8.77 kilometers). The cause is expected to be due to the relocation of a sugar mill in this region. The overall average (mean) transportation distance in column (9), would increase from 41.55 kilometers (Table 4.4) to 69.24 kilometers (Table 5.5). When comparing to the optimal current situation, the longest (max) transportation distance in this region will increase from 112.15 kilometers (Table 4.4) to 167.52 kilometers (Table 5.5), which might be due to the capacity expansion of New Kwang Soon Lee mill. Therefore, sugarcane yield in this region will become insufficient, and more sugarcane will need to be transported from the Northeastern region into this region. Thus the longest transportation distance will increase.

- The impacts on the sugar mills in the Northern region

After assuming that Banpong mill and Chonburi Sugar Industry mill have moved into the Northern region, and the capacity utilization of Pitsanulok mill has been increased, the quantity of sugarcane demand in this region will increase from 19,113,395 tons to 25,106,085 tons. When assuming that sugarcane yield has increased by 20%, the results as calculated by using the transportation model reveal that sugarcane quantity supplied to this region will be sufficient for the demand of all sugar mills in this region. Therefore, all mills in this region will be able to fully utilize their capacity at 100%. Regarding transportation distances, according to column (8) of Table 5.5, it is found that the shortest (min) distance from the nearest sugarcane plantation area to sugar mill will be 1.72 kilometers. This is the distance for transporting sugarcane to Phitsanulok mill. The overall average (mean) distance in column (9), would increase from 46.41 kilometers (Table 4.4) to 61.32 kilometers (Table 5.5). This might be because there will be more sugarcane imported from growing areas in other regions, such as from the Northeastern region or the Central region, to this region. Therefore, the overall average distance will become increased. Similarly, the maximum distance in this region will also increase from 128.65 kilometers (Table 4.4) to 289.99 kilometers (Table 5.5).

- The impacts on the sugar mills in the Central region

When New Krungthai mill and Banrai mill in the Central region expanded its production capacity, it is found that the sugarcane demand in this region will increase from 23,810,827 tons to 25,410,863 tons. However, by assuming that the sugarcane yield in the whole country has increased by 20%, the results obtained from the model reveal that more sugarcane quantity will be available for supplying to sugar mills in this region. The increase of sugarcane supply will be sufficient for the increased demand of the region’s sugar mills. As a result, capacity utilization of all mills in this region will be fully at 100%. In case of transportation distances, according to column (8) of Table 5.5, the shortest distance will be 2.09 kilometers, which is the distance for transporting to U-thong Industry mill. Regarding the overall average (mean) distance, according to column (9), the analysis reveals that it will decrease from 34.71 kilometers (Table 4.4) to 31.77 kilometers (Table 5.5), comparing to the case of the optimal current situation. However, the maximum transportation distance in the region will increase from 158.46 kilometers (Table 4.4) to 211.68 kilometers (Table 5.5).

- The impacts on the sugar mills in the Northeastern region

It is true that the increase in production capacity of Erawan mill according to the cabinet resolution will make the overall sugarcane demand in this region become increased from 27,717,870 tons to 28,461,234 tons. However, when assuming that the sugarcane yield has increased by 20%, it is found that sugarcane supplied to this region will be sufficient for production capacity of all mills, making them able to utilize their capacity fully at 100%. When considering transportation distances, as shown in column (8) of Table 5.5, the shortest (min) transportation distance from the nearest sugarcane growing area to the mill in the Northeastern region is 0.56 kilometers, which is the distance for transporting to Konburi mill. Regarding the overall average (mean) distance, as shown in column (9), it appears that the overall average distance will increase from 43.08 kilometers (Table 4.4) to 47.23 kilometers (Table 5.5). The longest (max) transportation distance will increase from 210.28 kilometers (Table 4.4) to 241.01 kilometers (Table 5.5).

Considering the objective function, when sugarcane yield increased by 20% the minimum total transportation cost would increase from 3,061,924,585 to 3,980,623,008 tons-kilometers. When these figures are multiplied with the average unit sugarcane transportation cost of 4.12 Baht/ton/kilometer, the resulting overall sugarcane transportation cost in the whole country is found to increase from 12,615,129,290 to 16,400,166,793 Baht. The increase in overall sugarcane transportation cost in the whole country is likely to be because sugarcane from some growing fields in the Northeastern region will have to be transported to the Northern region and the Central region. Therefore, the transportation distances become farther, and the overall cost becomes higher.

Considering the pattern of transportation as shown in Figure 5.5, it can be seen that some sugarcane is apparently transported from growing fields in the Northeastern region into the Central region and the Northern region. This might be because the Northeastern region has excessive sugarcane supply. In addition, since there is insufficient sugarcane yield in the Central region and the Northern region, some remaining sugarcane will then be transported to sugar mill in those regions. The result from the transportation model analysis reveals that the excessive sugarcane quantity is found in area groups in the Northeastern region, mainly around Sakonnakhon, Nongkhai, Nakhonphanom, Amnat-charoen, Ubonratchathani, and Udonthani. Therefore, in the future, some mills might be relocated to be near these areas with high sugarcane production in order to balance the production capacity of the area.

Studying further on the cabinet resolution regarding the new establishment, relocation, and capacity expansion of sugar mills, it is found that

Erawan mill (46) was allowed to expand its capacity from 15,000 to 20,117 tons/day according to the resolution dated on 2 December 2008, and was allowed to expand its capacity again from 20,117 to 27,000 tons/day according to the resolution dated on 26 April 2011. The approvals in the resolutions are in agreement with the findings in this research, which found that this mill is situated in an area with excessive sugarcane supply. At present (the production year 2010/2011), sugarcane production is as high as 95,358,928 tons, and there is a trend that the sugarcane production will keep on increasing. Therefore, in order to balance sugarcane production and capacity of sugar mills, capacity expansion within the region should be considered. A possible option is to relocate some sugar mills from other regions, particularly from the Central and the Eastern regions, into this area.

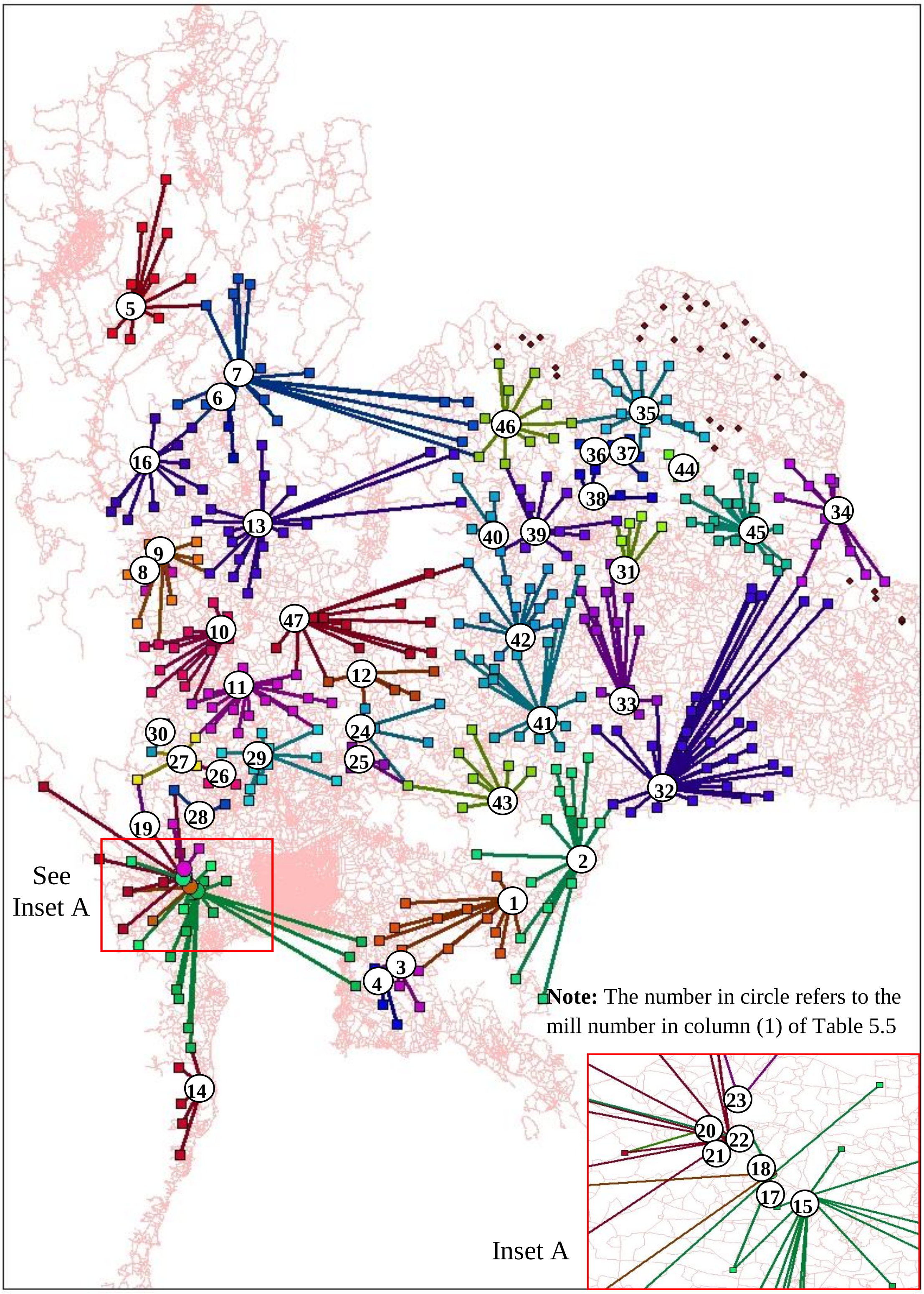


Figure 5.5 Optimal transportation patterns: sugarcane quantities increased by 20%

5.2 Summary of the sensitivity analysis

This chapter has studied the sensitivity analysis of the impacts with respect to the change in the amount of sugarcane production. The analysis is carried out for the case of the cabinet resolution regarding the relocation and capacity expansion of sugar mills. It was assumed that the cabinet resolution has been implemented in the production year 2008/2009. Several scenarios were tested when the sugarcane quantity have been lower than prediction by 10% and 20% and higher than prediction 10% and 20%. With these regards, the comparison is made in order to compare the impacts from uncertainty in the yield with the current optimal situation in the production year 2008/2009 (the Base case). This comparison is conducted in order to reveal changes to the impacts on inbound logistics from sugar mill liberalization. There are four aspects of the impacts to be analyzed and compared: 1) capacity utilization 2) transportation distance 3) transportation pattern and 4) the optimal inbound logistics cost.

1) Capacity utilization

The impacts on capacity utilization is categorized by regions; namely, Eastern, Northern, Central, and Northeastern regions. The results are also compared with the base case of the optimal current transportation. Note that the value of capacity utilization is calculated by the ratio between total sugarcane supply in the region and the summation of permitted capacity from all sugar mills in the respective region. The result is then multiplied by 100 to get percentage. In Figure 5.6, it plots the capacity utilization by region for difference cases.

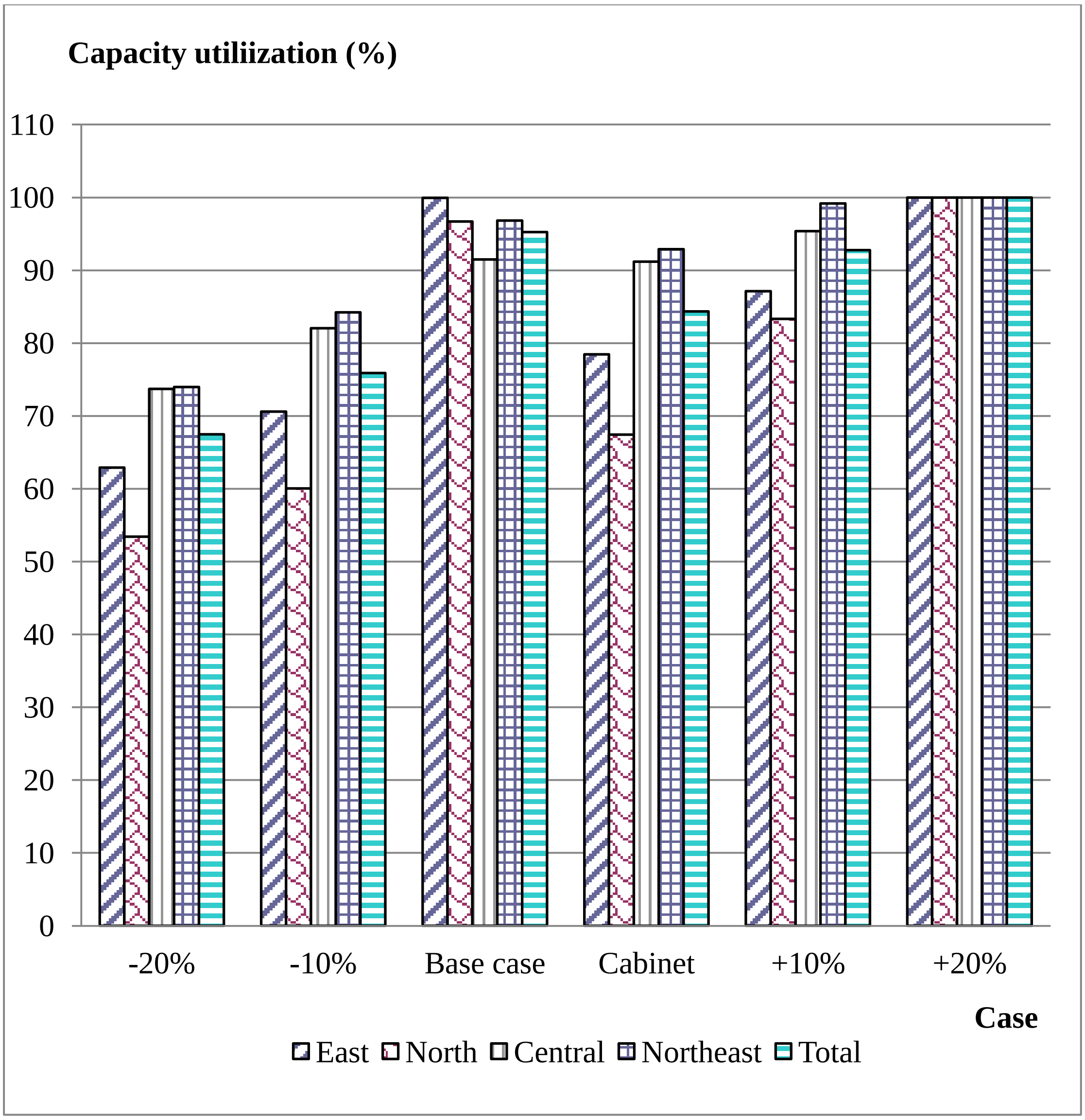


Figure 5.6 The impacts of sugarcane quantity on capacity utilization

Base Case: the capacity utilization is highest in the Eastern region. This might be because there used to be five sugar mills in this region. However, since Chonburi Sugar Industry mill has ceased its operation for relocation, the overall sugarcane demand in the region becomes decreased, and this results in full capacity utilization of the remaining four mills. Meanwhile, the capacity utilization is lowest in the Central region, which might be caused by its highest number of sugar mills, 17 mills. Insufficient sugarcane supply might have resulted in high competition and low utilization.

Cabinet resolution case: the Northern region will have particularly decreased capacity utilization by being down to only 67%. The cause might be from the capacity expansion of Phitsanulok mill and the relocation of two sugar mills (Banpong mill and Chonburi Sugar Industry mill) from other regions into this region. The quantity of sugarcane in this region then becomes insufficient.

The sugarcane quantities decreased by 10% and 20%: the capacity utilization of sugar mills in all regions will be lower in corresponding to the decreased sugarcane production. This is because sugarcane productions from an area group and sugarcane demand are two main factors that determine capacity utilization of a mill. When sugarcane production becomes insufficient for the demand, this will result in a reduction of capacity utilization. The Northern and the Eastern region are the most impact of capacity utilization.

The sugarcane quantities increased by 10% and 20%: in the first case, the average capacity utilization of sugar mills in the Central region and the Northeastern region will be higher than the Base case, but still not reaching the full capacity of 100%. This is different from the case when the sugarcane quantities increased by 20%, all sugar mills in all regions will be able to utilize their capacity fully at 100%. In addition, the quantity of sugarcane exceeds the overall demand in the whole country for 1,021,522 tons in the Northeastern region. Therefore, regarding the policy of sugar mill liberalization, it might be possible to allow sugar mills in the Northeastern region to expand their capacity in order to balance between sugarcane supply and sugarcane demand in the region.

2) Transportation distance

This research assumes that the distances transportation from sugarcane fields to sugar mills can be used as a representative of unit transportation cost. This is because the transportation cost is usually varied by the travel distance. The results obtained from solving the transportation model do not only give sugarcane quantity transported from all sugarcane fields to all sugar mills, but they also reveal the corresponding transported distances.

- Shortest (min) distance

This is the minimum distance from the nearest sugarcane field to a sugar mill in the region. The shortest distance for transporting sugarcane to the mill in that region is used. Figure 5.7 illustrates comparison of the shortest transportation distances across regions.

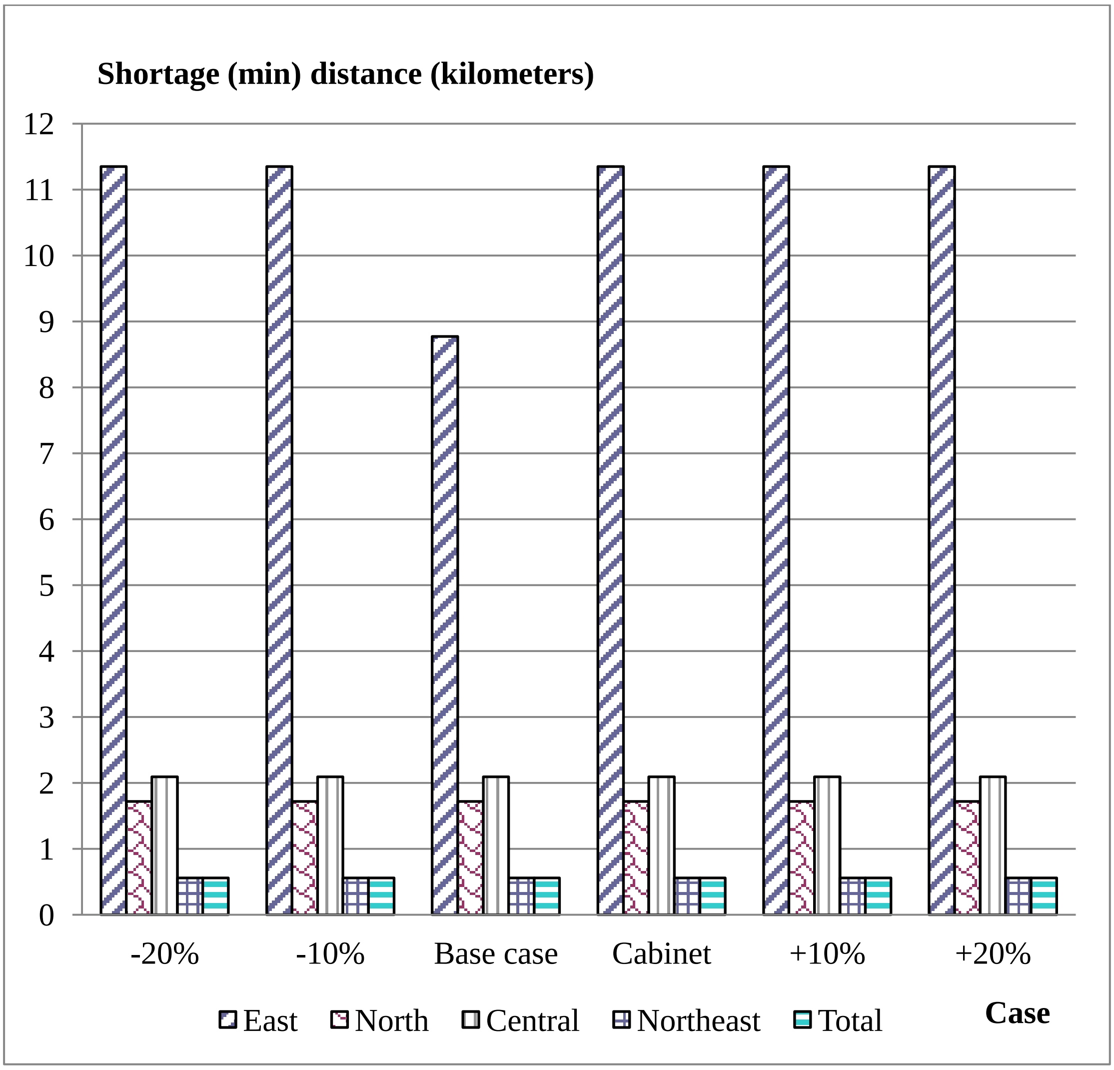


Figure 5.7 Impacts of sugarcane quantity on the shortest distances between sugarcane fields and the mills

According to the Base Case in Figure 5.7, it is found that the shortest distance in the Eastern region is farther than other regions for over six kilometers. The relocation of New Kwang Soon Lee mill from Chonburi province to Srakaew province according to the cabinet resolution will even worsen the situation. The shortest distance in the Eastern region will be increased even more than before. Impacts of sugarcane quantity on the shortest distances between sugarcane fields and the mills, while assuming that sugarcane yields were greater or lower than the predicted figures, were also studied. It is found that the shortest transportation distance in the Eastern region will still be equal to the corresponding distance of the Cabinet case, while the shortest distance in other regions (Northern, Central, and Northeastern regions) will also remain unchanged.

- Weighted Average (mean) distance

This is the average transportation distance in each region weighted by the sugarcane quantity. The formula can be written as follow.

$$\overline{C} = \frac{\sum_{i \in 1}^{m}\sum_{j \in 1}^{n} C_{ij} X_{ij}}{\sum_{i \in 1}^{m}\sum_{j \in 1}^{n} X_{ij}}$$

When

$\overline{C}$ = weighted average (mean) distance (kilometers)

C_{ij} = transportation distance from field *i* to mill *j*

X_{ij} = sugarcane quantity transported from field *i* to mill *j*

i = field; i = 1, 2,…, m

j = sugar mill; j= 1, 2,…, n

m = the number of fields

n = the number of sugar mills

Figure 5.8 compares the weighted average distances across the four regions by calculating only distances of non-dummy fields/mills.

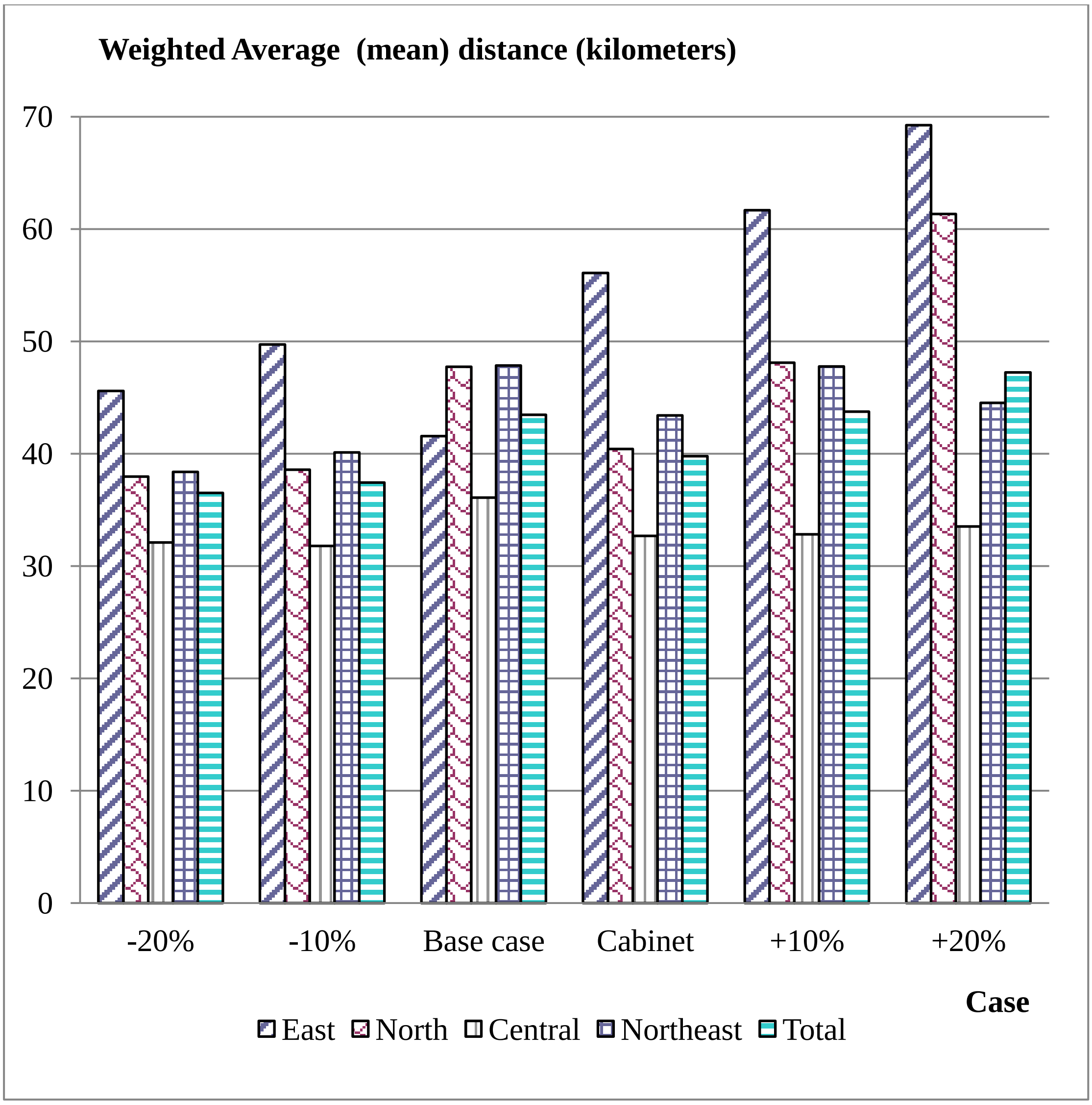


Figure 5.8 Impacts of sugarcane quantity on the average distances between sugarcane fields and the mills

From Figure 5.8 in the Base Case, the average (mean) transportation distances for transporting sugarcane from fields to sugar mills in all regions of the country ranged from 35 to 48 kilometers. These distances are considered appropriate, given the fact that the Ministry of Agriculture and Cooperatives has specified the appropriate transportation distance to be within 50 kilometers (Nilpan, 2008). As seen apparently in Figure 5.8, sugar mills in the Central region have the lowest average transportation distance. This might be because there are the highest numbers of sugar mills ready to take sugarcane around the region. Due to the cabinet approval the relocation and capacity expansion of seven sugar mills, the overall average (mean) transportation distance for the whole country will decrease, comparing to the figure of the Base case. However, the average transportation distance in the Eastern region will increase apparently, which is due mainly to the relocation and the three-fold capacity expansion of New Kwang Soon Lee mill. With insufficiency of the sugarcane supply with respect to demand, sugar mills in this region have to transport sugarcane from other regions to serve their capacity. When assumed that the sugarcane quantities decreased by 10% and 20%, the overall average transportation distance has a decreasing trend according to the rates of the reduced yields.

According to the analysis with the transportation model in order to attain the optimal solution (the lowest transportation cost), this can be explained that, when sugarcane production becomes insufficient for the capacity, the transportation is discontinued, resulting in a decrease of the average transportation distance. When assumed that the sugarcane quantities increased by 10% and 20%, the average (mean) transportation distance will increase in corresponding to the increase of the sugarcane production. This might be because the assumption was made by assuming that the yield has increased equally in all sugarcane area groups, which have different sizes and different numbers of the sugarcane fields. In addition, since numbers of sugar mills are different across regions, their sugarcane demands are different too. When the overall sugarcane production in the country increases, some sugar mills that used to have insufficient sugarcane supply will have to transport sugarcane from areas further away in order to serve its capacity. Consequently, the average transportation distance becomes increased.

- Longest (max) distance

Figure 5.7 compares the longest or maximum distances from sugarcane fields to sugar mills across regions. Calculations were made in order to reveal impacts of sugarcane yields on longest transportation distances between the fields and the mills. This comparison considers only transportation distances from non-dummy fields to the sugar mills and the sugarcane fields to non-dummy mills.

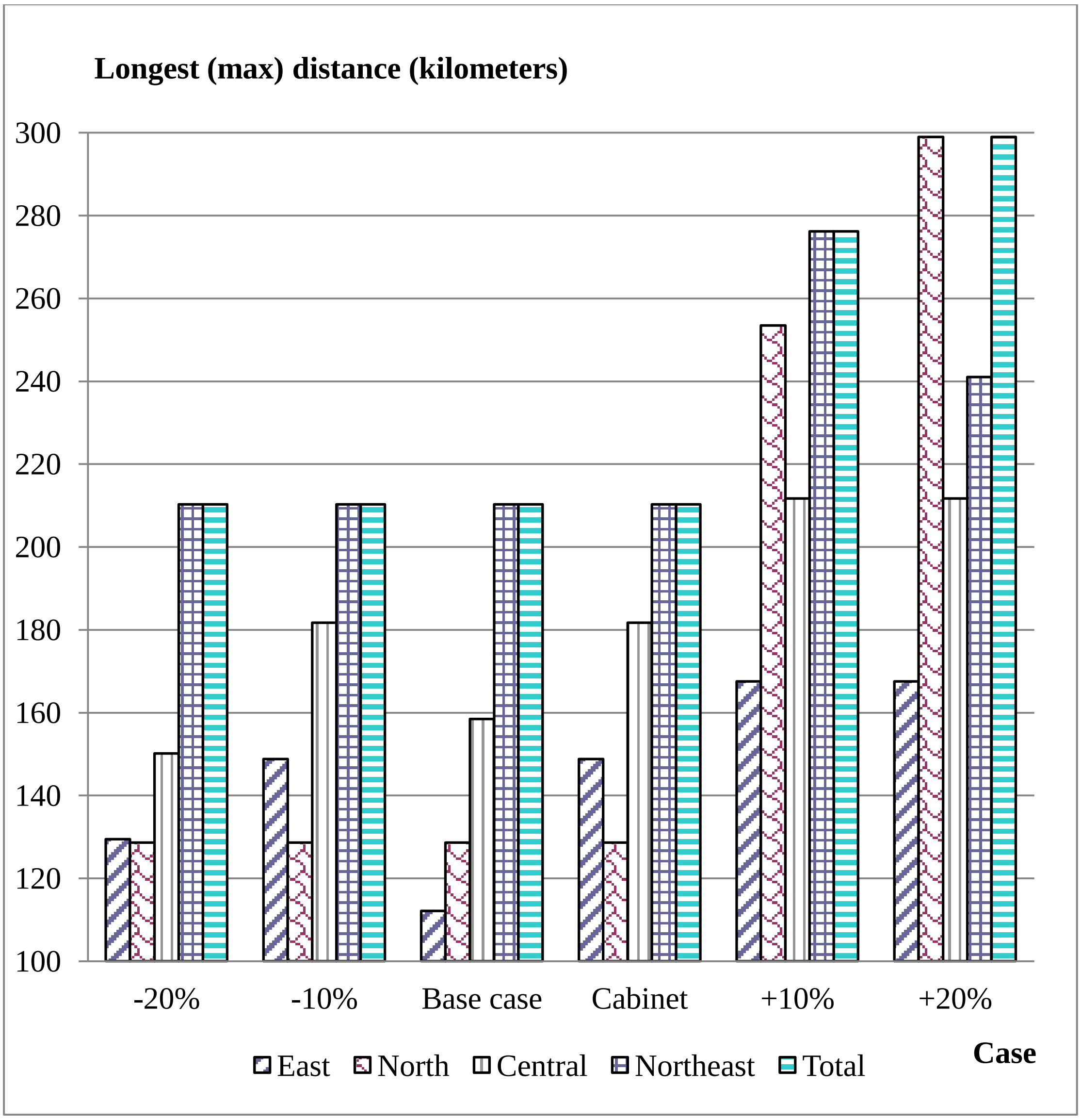


Figure 5.9 Impacts of sugarcane quantity on the longest distances between sugarcane fields and the mills

According to Base case in Figure 5.9, it can be seen that the longest sugarcane transportation distance in the Eastern region is apparently lower than in other regions. This is because three out of four sugar mills in the region (namely, Rayong mill, New Kwang Soon Lee mill, and Chanburi Sugar Trading mill) are located collectively in Chonburi province, which is the province that grows the highest quantity of sugarcane. With addition of sugarcane yield from nearby provinces, the overall quantity is sufficient for demands of these mills. Therefore, there was no need to transport sugarcane from areas farther away. However, when New Kwang Soon Lee mill has relocated and expanded its capacity according to the cabinet resolution, it is found that the longest distance in the Eastern region would be increased. This is likely to be because sugarcane quantity is insufficient for the increased demand, thus more sugarcane from other regions will have to be transported into this region. Some interesting results were found when analyzing for impacts of sugarcane yields on the longest distances from sugarcane fields to sugar mills. In the cases of 10% and 20% increase in sugarcane quantity, it is found that the longest distance in the Northern region will increase. This is the highest increase among all regions. This might be because of the relocation of two sugar mills (namely Ban Pong mill and Chonburi Sugar Industry mill) into this region. In addition, due to capacity expansion of Phitsanulok mill, quantity of sugarcane demand in this region will become increased greatly. However, since sugarcane quantity in the region is not sufficient for the increased demand, some sugarcane will need to be transported from nearby regions, particularly from the Northeastern region so that the quantity meets the increased capacity of the sugar mills. As a result, the longest distance becomes increased as well.

Therefore, before allowing the new establishment or capacity expansion of any sugar mill in the future, particularly in the Easter region and the Northern region, preparation should be made in advance. This preparation can be done by promoting sugarcane plantation in areas around the mill. This will allow sufficient sugarcane supply to serve the mill's capacity, and will not result in a long-distance transportation, which will lead to high transportation cost.

3) Transportation pattern

Sensitivity analysis simply changes some parameters in the model and re-solves it. Here sugarcane supply (S_i) is changed. Such a change did have direct impact on the patterns of sugarcane transportation. The analysis results can be discussed according to the assumed cases. In the cases of cabinet resolution, which represents relocation and capacity expansion of some sugar mills, will result in increased sugarcane demand. When sugarcane in the region becomes insufficient, some sugarcane will need to be transported from nearby areas for sugar mills to be able to produce sugar at their full capacity. That makes pattern of sugarcane transportation become changed. This is particularly obvious in the Eastern region and the Central region, as shown in Figure 4.8, when compared with the case of the optimal current situation (Figure 4.6). It is found that some sugarcane growing fields in the Eastern region will start transporting sugarcane to sugar mills in the Central region. Another noticeable case is the case when sugarcane yield is assumed to be increased by 20%. In this case, patterns of sugarcane transportation changed apparently when comparing to the optimal current situation case (Figure 4.6). Due to the yield change, pattern of transportation becomes farther, and more sugarcane from the Northeastern region will be transported to the Northern region and the Central region. This is probably because the Northeastern region is the region with the largest sugarcane growing area. Therefore, after assuming the 20% increase, sugarcane yield in this region became greater than demand of sugar mills in the region. Meanwhile, other regions still had insufficient sugarcane supply, thus sugarcanes from the Northeastern region were transported to other regions as well.

4) The optimal inbound logistics cost

Table 5.6 summarizes overall costs of inbound logistics for all cases. Table 5.6 contains nine columns; namely,

Column (1) presents each case study.

Column (2) presents the value of objective function with the inclusion of dummy fields/mills (tons-kilometers).

Column (3) presents the value of objective function without dummy fields/mills (tons-kilometers).

Column (4) presents the total transportation cost in Baht, which is calculated by multiplying the objective function in column (3) with 4.12 Baht/ton/kilometer. This constant value is the estimated unit cost for transporting sugarcane from farms to sugar mills. It is obtained from the research entitled “Analysis cost and lead time of havesting and transporting the sugarcane to a factory for increase competitiveness” (Tumcharoen, 2008).

Column (5) shows the excessive sugarcane quantity when the total sugarcane supply is greater than (>) the total sugarcane demand (tons).

Column (6) shows the shortage of sugarcane quantity when the total sugarcane supply is lower than (<) the total sugarcane demand (tons).

Column (7) presents opportunity cost of sugar mills when the total sugarcane supply is lower than the total sugarcane demand. This column is calculated by using figures in column (6) to multiply with 110 kilograms/ton (the average sugar yield per ton of sugarcane obtained from the Office of the Cane and Sugar Board), and then multiply with 25 Baht/ kilogram (the price of sugar per kilogram).

Column (8) presents opportunity cost of sugarcane farmers when the total sugarcane supply is greater than the total sugarcane demand. This is calculated by multiplying column (5) with 920 Baht/ton, which is the average price of sugarcane per ton obtained from Office of the Cane and Sugar Board.

Column (9) presents the overall cost of the whole system in each studied case. This column is calculated by summing up values in columns (4), (7), and (8) together.

Note that this research has specified that the transportation cost to a dummy mill or from a dummy field is equivalent to 10,000 kilometers. This expensive figure is used to resist the transportation which does not really exist.

Table 5.6 Comparison of the optimal inbound logistics cost

Case	Objective Function (tons-kilometers)		Transportation cost (Baht)	Imbalance (ton)		Opportunity cost (Baht)		The optimal inbound logistics cost (Baht)
	Including dummy fields/mills	Excluding dummy fields/mills		Excessive supply	Shortage of demand	Mill	Farmer	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
The optimal current situation	38,566,254,585	3,061,924,585	12,615,129,290	-	3,550,433	9,763,690,750	-	22,378,820,040
The cabinet resolution	134,777,441,493	2,826,471,493	11,645,062,551	-	9,644,644	26,522,771,000	-	38,167,833,551
The sugarcane quantities decreased by 10%	205,429,247,813	2,395,397,813	9,869,038,990	-	20,303,385	55,834,308,750	-	65,703,347,740
The sugarcane quantities decreased by 20%	276,193,190,321	2,076,030,321	8,553,244,923	-	27,411,716	75,382,219,000	-	83,935,463,923
The sugarcane quantities increased by 10%	64,286,258,513	3,419,568,513	14,088,622,274	-	6,086,769	16,738,614,750	-	30,827,237,024
The sugarcane quantities increased by 20%	14,195,843,008	3,980,623,008	16,400,166,793	1,021,522	-	-	939,800,240	17,339,967,033

The optimal current situation (in the production 2008/2009): the overall sugarcane demand of all sugar mills in the country is 74,633,506 tons. However, since the overall sugarcane supply is only 71,083,073 tons, a dummy field then has to be added. The optimal solution in Table 5.6 yields the objective function of 38,566,254,585 tons-kilometers as shown in column (2). When the dummy field is excluded, the function value is 3,061,924,585 tons-kilometers as shown in column (3). The minimum total transportation cost is 12,615,129,290 Baht. However, during that production year, sugarcane supply is short of the sugarcane demand by 3,550,433 tons. The sugar mills would have the opportunity cost due to insufficient sugarcane for their production capacity as high as 9,763,690,750 Baht. Thus the total cost of the whole system in this case is 22,378,820,040 Baht.

The cabinet resolution: there are relocations and capacity expansions of seven sugar mills according to the cabinet resolution. Due to the capacity expansions, sugarcane demand of all sugar mills in the country will increase from 71,083,073 tons to 84,278,170 tons. By solving the transportation model, the optimal objective function excluding the dummy field is 2,826,471,493 tons-kilometers. This is equivalent to the total transportation cost of 11,645,062,551 Baht, which is relatively low when comparing to the optimal current situation case. However, due to the increased capacity expansion, the sugarcane supply becomes insufficient for the sugarcane demand with the shortage as high as 9,644,644 sugarcane tons. This results in a very high opportunity cost to sugar mills at 26,522,771,000 Baht as shown in column (7). Therefore, the total inbound logistics cost of the system when implementing the cabinet resolution becomes as high as 38,167,833,551 Baht.

The sugarcane quantities decreased by 10%: the optimal objective function by excluding a dummy field was found to decrease from 3,061,924,585 to 2,395,397,813 tons-kilometers. The total transportation cost from all sugarcane fields to all sugar mills appears to be 9,869,038,990 Baht. Due to the capacity expansion of sugar mills, the overall sugarcane demand of sugar mills in the country becomes increased. When assuming that overall sugarcane quantity in the country decreases by 10%, as shown in column (6), it is found that the overall sugarcane quantity will be insufficient for the overall demand, with a deficit of 20,303,385 tons. This results in an overall opportunity cost of sugar mills for as high as 55,834,308,750 Baht. Thus the total cost of inbound logistics will be 65,703,347,740 Baht.

The sugarcane quantities decreased by 20%: according to column (4), it can be seen that the total sugarcane transportation cost of the country will decrease from 12,615,129,290 Baht to 8,553,244,923 Baht. This might be due to the application of transportation model for solving the research's problems. The result is obtained in a form of optimal solution. When sugarcane yield has become lower than prediction and does not meet sugarcane demand, there becomes no sugarcane transportation from sugarcane fields to sugar mills. Therefore, the total transportation cost in the country becomes reduced. On the other hand, the opportunity cost of sugar mills, as shown in column (7) becomes greatly increased. Due to the great insufficiency of sugarcane for their production capacity, sugar mills has a very high opportunity cost, by being increased from 9,763,690,750 Baht to 75,382,219,000 Baht. As a result, the total cost of inbound logistics for this case becomes to be as high as 83,935,463,923 Baht.

The sugarcane quantities increased by 10%: the overall transportation cost in the country will be 14,088,622,274 Baht, as shown in column (4). Even though the sugarcane quantity increases by 10%, there will still be insufficiency of sugarcane supply. The sugarcane supply will be lower than the demand for 6,086,769 tons, resulting in the overall opportunity cost of all sugar mills for as high as 55,834,308,750 Baht. Therefore, the total cost of the whole inbound logistics system is 30,827,237,024 Baht.

The sugarcane quantities increased by 20%: according to column (4), it can be seen that the overall transportation cost for transporting sugarcane from all fields to all mills in the country is 16,400,166,793 Baht. Due to the increase of sugarcane quantity by 20% according to the assumption, the overall sugarcane supply will be greater than the overall sugarcane demand. There will be an excessive quantity of sugarcane for 1,021,522 tons. This will result in an opportunity cost of farmers due to being unable to sell their excessive sugarcane to sugar mills for 939,800,240 Baht. Therefore, the total inbound logistics cost of the system will be 17,339,967,033 Baht.

This chapter performed the sensitivity analysis on the impact of sugar mill liberalization according to the cabinet resolution regarding relocation and capacity expansion of sugar mill with respect to the variation of sugarcane quantity. Section 5.1 discussed about analyses when there are changes in sugarcane quantity. The analyses were conducted for the two cases; namely, 1) when sugarcane quantity is lower than expectation and 2) when the quantity is greater than expectation. For the first case, the analysis revealed that the overall capacity utilization of sugar mills would also decrease. This is obvious for sugar mills in the Eastern region and the Northern region, whose utilization rates decrease apparently. This phenomenon is expected to be caused by the capacity expansion of sugar mills in these regions due to the cabinet resolution, which will make sugarcane demand for the regions become higher. In addition, since it was assumed that the sugarcane yield becomes decreased, sugarcane quantity is even more insufficient for the demand. This has direct impact on capacity utilization of sugar mills. For the latter case, when sugarcane quantity is higher than expectation, the analysis revealed that capacity utilization of sugar mills will also increase. In the case of assuming sugarcane quantity to be 20% greater than expectation, the analysis results show that capacity utilization of all sugar mills in the country will be 100%. The increase of sugarcane quantity will also result in an excessive quantity of sugarcane in the Northeastern region for 1,564,228 tons. If the excess is persistent, it may allow for the capacity expansion of some sugar mills in the future. Section 5.2 presents a summary of impacts from the changes in sugarcane quantity; namely, 1) capacity utilization 2) transportation distance 3) transportation pattern and 4) the optimal inbound logistics cost. The next chapter will conclude all findings and results obtained from this research.

CHAPTER VI
CONCLUSIONS

Sugarcane and sugar industry is important to the Thai economy in many aspects, including employment in both agricultural and industrial sectors. According to this importance, the government has been trying to play a role in solving problems in this industry. Thus, sugarcane and sugar industry in Thailand has long been controlled by the Sugarcane and Sugar Act, B.E. 2527 (1984). From economists' point of view, this policy seems to be somehow obsolete and inappropriate under the current trend of globalization that moves toward the free trading system. Possibly, the trend is soon coming to the sugar industry which may call for the reformation of the industry structure. It is now in the public attention that whether the structure of sugarcane and sugar industry in Thailand should be reformed by ending the monopoly system or minimizing the intervention from the Thai government. It has been recognized that if the government continues its protection on this industry, the management of sugar mills will lack motivation to enhance their capability and will be unable to compete in the free-trade markets. However, because this industry is so important, impacts from liberalizing sugar mills should be well studied to prevent damage to the economy and to prepare for the adaptation of the industry.

This research studied impacts from the liberalization of the sugar mills that may happen due to the government's policy to discontinue its control on the new establishment of the sugar mill, the relocation of the existing sugar mill, and capacity expansion of the existing sugar mill. The research is interested in studying the impact on inbound logistics process of sugarcane transportation and the capacity utilization sugar mills. The research proposed a methodology for analyzing such impact. Geographic locations of sugar mills and field areas were collected in order to be analyzed for transportation distances by using the GIS software called ArcMap 9.3. Then a mathematical model of transportation problem was developed and solved by using software package called LINDO 6.1 (Linear Interactive Discrete Optimizer).

The results yield the optimal sugarcane distribution to be supplied to individual sugar mills so that the total transportation cost will be minimized. Finally, the utilization of sugar mills capacity, the optimal transportation distance, the optimal transportation pattern, and the optimal inbound logistics cost were concluded. In this research, there are three cases subject to the analysis; namely, the optimal current situation in the production year 2008/2009, adding a new sugar mill in the Eastern region and the Cabinet Resolution. In addition, the sensitivity analysis was also carried out based on the case of cabinet resolution.

6.1 The policy regarding the sugar mill liberalization in Thailand

So far there is still no approval given in response to the request for sugar mill liberalization in Thailand, which seeks for liberty to conduct certain activities such as new establishment, relocation, and capacity expansion of sugar mills. Nevertheless, at present, sugar mills are given a chance to relocate and/or expand their capacity, which requires prior agreement from the cabinet. The cabinet resolution dated on 10 October 1989 has declared that no new establishment of sugar mills should be allowed. However, sugar mills were allowed to relocate from an area where there is insufficient sugarcane supply to another area where there is excessive sugarcane supply. In addition, the relocated mills may expand their production capacity to match the available quantity of sugarcane in the new area. Sugar mills located in areas with excessive sugarcane supply were also allowed to expand their capacity corresponding to availability of the sugarcane supply (The Secretariat of the Cabinet, 1989). The cabinet resolution dated on 22 July 2003 prohibits capacity expansion of sugar mills (Ministry of Industry, 2003a). Therefore, when there are requests from sugar mill entrepreneurs for relocation and/or capacity expansion, the Ministry of Industry, as the main responsible organization, has to submit their proposals to the cabinet for consideration whether an approval will be given or not. Sugar mills do not have freedom to relocate or expand their capacity at will. From studying the procedures for taking consideration on relocation and/or capacity expansion of sugar mills in Thailand, details can be summarized as follows:

1) Entrepreneurs of sugar mills may submit their requests for relocation and/or capacity expansion to the Ministry of Industry if they face problems regarding insufficient sugarcane supply in the old area and want to move their locations to another area, or if their sugar mills are located in an area with excessive sugarcane supply and they want to expand the mill's capacity to match the supplied quantity.

2) The Ministry of Industry will appoint the committee to consider the suitability of relocation, capacity expansion of sugar mills and capacity calculation. The committee then submits its opinion to the Ministry of Industry for reconsidering.

3) After the Ministry of Industry has finished the consideration process, it will propose the decision and opinion to the cabinet for final decision whether approval in principle will be given for the relocation and/or capacity expansion request.

4) The Secretariat of the Cabinet will inform about this matter to relevant authorities including Ministry of Agriculture and Cooperatives, Ministry of Natural Resources and Environment, Ministry of Commerce, Ministry of Interior, Ministry of Energy, Ministry of Finance, or National Economic and Social Development Board so that they can give some comments or concerns (according to their relevancies) which will be useful information for the consideration of the cabinet.

5) After the cabinet has approved in principle regarding the relocation and/or capacity expansion of the sugar mill, the entrepreneur can submit an application to the Ministry of Industry (Department of Industrial Works) to obtain a permit for factory operation. In case that there are comments or requirements from relevant ministries, the entrepreneur will need to contact those ministries and complete the requirements before obtaining the permit from the Department of Industrial Works.

6) After all relevant ministries have satisfied with the action of the entrepreneur in response to their requirements and have informed the Department of Industrial Works about their consideration, the Department of Industrial Works will then consider about granting a permit for factory operation. The entrepreneur of the sugar mill then can use it for starting the relocation and/or capacity expansion operation.

7) After being granted the permission for relocation and/or capacity expansion, the sugar mill entrepreneur must complete the operation within five years, which is counted from the date of obtaining the letter from the Ministry of Industry.

Notice that although the cabinet has approved in principle for the relocation and/or capacity expansion request, the sugar mill entrepreneur cannot immediately start the operation. The entrepreneur has to follow and fulfill all requirements of the relevant ministries first before the Department of Industrial Works will grant a permit for factory operation. On this regard, there is a variety in details of comments or requirements from relevant ministries, depending on the case. For example, the requirements relating to the cabinet resolution dated on 16 October 2007 are as follows:

1) Ministry of Industry: The ministry proposed a regulation that the shortest distance between the new mill and the current mill must be at least 80 kilometers. In addition, the relocating mill must prepare sugarcane to be supplied to the mill in the first year at least 50% of the production capacity allowed for that sugarcane crushing season. The average number of sugarcane crushing days for the calculation is set to be 120 days per year. For this preparation, the sugarcane must not be from farmers who are contractors of the current mills (Ministry of Industry, 2007).

2) Ministry of Natural Resources and Environment: The ministry added a comment that, in order to request for relocation and/or capacity expansion, the sugar mill must submit the report on the Environmental Impact Assessment (EIA) according to the declaration of the Ministry of Science and Technology entitled “Type and size of projects or operations of governmental organizations, state enterprise organizations, or private organizations that are required to report an EIA, the Third Edition (B.E. 2539)” and the declaration of the Ministry of Science and Technology entitled “Criteria, methods, regulations, and approaches for conducting the EIA, the Third Edition (B.E. 2539)”. In addition, the ministry suggested that the mill should arrange some public hearings in order to listen to opinions of local people regarding impacts that may result from utilizing the natural resources and effects on quality of the environment from the mill’s operation such as a spill of molasses (Ministry of Natural Resources and Environment, 2007).

3) Ministry of Interior: The ministry gave an additional opinion that the relocation and/or capacity expansion of the sugar mill should be conducted with concern on environmental impact problems. It should have measures for preventing smell and dust and for wastewater treatment. The mill should employ cleaner production technology to enhance its capability in handling with all kinds of pollution. The mill should also publicize in advance to local communities that may be affected from the relocation and/or capacity expansion and should confirm them that the operation will not cause any environmental problems. On this regard, the entrepreneur might set up an agreement with the provincial authority in order to provide confidence to people living nearby the sugar mill (Ministry of Interior, 2007).

6.2 Proposed analytical tools for analyzing impacts from liberalization policy

Permission regarding relocation or capacity expansion of sugar mills always incurs both support and disagreement from various stakeholders. Most differences in opinions of the stakeholders are resulted from the perspective of their benefits. Therefore, there should be a tool or an approach for analyzing the impacts that may happen to all stakeholders before granting any permission. The tool should also be able to provide results that are easy to understand for all stakeholders. However, at present, there is still no tool or approach to be used for analyzing quantitatively about the pros and cons of sugar mill relocation and/or capacity expansion that can assist decision making of authorities. Hence this research has developed an approach by applying the Transportation model as an analytical tool for assessing impacts quantitatively. The proposed approach has been applied to analyze the impacts of several past cases. One of them is the case of analyzing impacts from the relocation and capacity expansion of New Krungthai mill that were permitted by the cabinet resolution dated on 16 October 2007. By assuming that the operation had been implemented in the production year 2008/2009, the results showed that the relocation and capacity expansion might be advantageous for the mill but become disadvantageous for the existing mills in the new area. It was expected that New

Krungthai mill would gain higher quantity of sugarcane supply, which possibly increases from 605,389 to 1,938,000 tons. Consequently, its capacity utilization would increase from 76.45% to 100%. On the other hand, the existing mills that are located around the new area of New Krungthai mill may experience decreased capacity utilization. Comparing to the results from the analysis on Case 1 the optimal current situation in the production year 2008/2009, the capacity utilization of Mitrkasetr mill, Thai Sugar Mill, and Tamaka mill will reduce from 82.11%, 67.18% and 100%, to 78.06%, 56.00%, and 51.99%, respectively.

The above results should enable all stakeholders in the sugarcane and sugar industry to understand the trend of situations that may happen in the future. It allows sufficient time to prepare and adjust them in advance. This also helps preparing the stakeholders for the liberalization of sugar mills, which require a good preparation of sufficient sugarcane production for the changing production capacity. In addition, the entrepreneurs will have information for developing their sugar production. This is essential for their survival in case of high competition in the future. The proposed approach for quantitative analysis is also easy for implementation because the fundamental data needed by the tool has already been collected by relevant organizations. These fundamental data can be listed as follows:

1) Documentary data: It consists of permitted capacity of sugar mills and their annual production days. Such data have been collected by the Office of the Cane and Sugar Board. By multiplying these two datasets, the quantity of sugarcane demand of each mill can be calculated.

2) Spatial data: These data have been created and collected in shapefile format. These data include locations of sugar mills and sugarcane plantation areas (collected by the Office of the Cane and Sugar Board) and transportation-related data (collected by Office of Permanent Secretary, Ministry of Transport and Communications). By applying GIS software for analyzing these three datasets, distances from all sugarcane plantation area to all sugar mills can be calculated.

The tools used for these analyses are also popular among general users. These tools comprise ArcMap 9.3 (GIS application used in this research for calculating the distance matrix from plantation areas to sugar mills), Microsoft Access (a database application), Visual Basic 2005 (for developing a mathematical model), and LINDO (an optimization software for solving linear program problem to obtain the optimum solution). It was also found that the results from methodology used in this research are in good agreement with the real situations.

Case 1 *The optimal current situation (the production year 2008/2009)*: In the Central region, there are seven out of 17 mills located crowdedly in the area of Ratchaburi province and Kanchanaburi province. According to the calculation, five mills in that area; namely, Ratchaburi mill, Banpong mill, Mitrkasetr mill, Thai Sugar Mill, and New Krungthai mill had not received sufficient quantity of sugarcane to meet their demand. Particularly, Banpong mill received only 190,771 sugarcane tons, while its demand was 812,659 tons, resulting in its very low capacity utilization of 23.47%. New Krungthai mill also received sugarcane for only 605,389 tons from the total demand of 796,575 tons, resulting in capacity utilization of 76.00%. These figures are in agreement with the cabinet resolution dated on 16 October 2007, which have granted permission for both mills to relocate due to the insufficiency of sugarcane supply in the old areas.

Case 2 *Adding a new sugar mill in the Eastern region*: This case was analyzed by assuming that a new sugar mill is permitted to be established in the Eastern region. The Chonburi Sugar Industry mill, which has ceased operation since the production year 2006/2007 in order to wait for relocation, was then assumed to be reopened. It was found that the mill received sugarcane at a very low quantity of 409,380 tons, while its demand is 615,420 tons, resulting in its capacity utilization of 66.52%. Meanwhile, Eastern Sugar and Cane mill, New Kwang Soon Lee mill, Rayong Sugar mill, and Chonburi Sugar and Trading mill, which are located in the same region, had capacity utilization of 88.39%, 100%, 99.98% and 71.89%, respectively. The results imply that the proposed approach is quite reliable. This approach can predict that Chonburi Sugar Industry mill might face problems of low capacity utilization and insufficient sugarcane supply. This finding is in good agreement with the fact that the mill has requested to cease its operation and wait for relocation.

Case 3 *The Cabinet Resolution:* This analysis was conducted in order to examine the results from the relocation and capacity expansion of Chonburi Sugar Industry mill from the Eastern region to the Northern region. By assuming that its operation was implemented by the production year 2008/2009, it was found that the mill's capacity utilization may be as low as 13.64%. This is in agreement with the fact that Nakhonsawan province has expressed its opinion of disagreement regarding the relocation of Chonburi Sugar Industry mill into Nongbua district of Nakhonsawan province. They gave reasons that the area is mostly mountainous. Meanwhile, the terrain is sandy and dry due to insufficient supply of water, making its unsuitable for sugarcane plantation, and that may result in insufficient sugarcane supply for the mill and other existing mills nearby the area (Ministry of Industry, 2011).

6.3 Impact of liberalization policy on inbound logistics

According to the study on impacts of sugar mill liberalization on inbound logistics by using the tools presented in Section 6.2 for analyzing with the three cases; namely, Case 1 The optimal current situation (the production year 2008/2009), Case 2 Adding a new sugar mill in the Eastern region, and Case 3 The Cabinet Resolution, the analysis results revealed the main impacts in four aspects.

6.3.1 The impact on the optimal capacity utilization

The study revealed that capacity utilization of a sugar mill can be high or low depending on the balance or imbalance between the sugarcane supply in each area group and quantity of sugarcane demand by the mill.

Case 1 *The optimal current situation (the production year 2008/2009)*: Quantity of overall sugarcane demand of all sugar mills in the country was 74,633,506 tons, while the overall sugarcane supply was 71,083,073 tons, resulting in the overall capacity utilization of all sugar mills equaled to 95.24%. Among all 46 sugar mills, 35 mills were found to have full utilization of 100%. The Eastern region was the region with the highest overall utilization at 99.95%. This is followed by the Northeastern, Northern, and Central regions, whose overall capacity utilization of their sugar mills were 96.76%, 96.69%, and 91.53%, respectively. The highest capacity utilization may be explained by the ceased operation of Chonburi Sugar Industry mill (and waiting for relocation) in the Eastern region.

Case 2 *Adding a new sugar mill in the Eastern region*: By adding Chonburi Sugar Industry mill into the system, the overall sugarcane demand of all sugar mills in the country will increase to 75,248,926 tons, while the quantity of sugarcane remains to be 71,083,073 tons. This caused the decreased overall capacity utilization down to 94.46%. The addition of Chonburi Sugar Industry mill in the Eastern region would reduce the overall capacity utilization in this region from 99.90% to be only 86.59%. The capacity utilization of Chonburi Sugar Industry mill would be only 66.52%. Meanwhile, the utilization of other nearby mills in the Eastern region would be decreased from 99.90% to 88.39%, 100% to 99.98%, 100% to 71.89%, and 76.00% to 32.29% for Eastern Sugar and Cane, Rayong Sugar, Chonburi Sugar and Trading and New Krungthai mills, respectively. However, capacity utilization in other regions would remain unchanged.

Case 3 *The Cabinet Resolution:* By assuming that the relocation and capacity expansion of the seven sugar mills according to the cabinet resolution has been implemented within the production year 2008/2009, it was found that the capacity expansion will result in an increase of sugarcane demand of all sugar mills in the country from 74,633,506 tons to 84,278,170 tons. However, the quantity of sugarcane supply would remain to be only 71,083,073 tons. Thus the overall capacity utilization of sugar mills in the country would reduce from 95.24% to only 84.34%. There could be some advantages happened from the relocation and/or capacity expansion of the seven sugar mills. According to the analysis results, Banrai, New Krungthai, Banpong, and Erawan mills should be able to fully utilize their capacity at 100%. However, Phitsanulok, New Kwang Soon Lee, and Chonburi Sugar Industry mills may have decreased utilizations of as low as 41.14%, 40.45%, and 13.64%, respectively due to the insufficiency of sugarcane supply.

In addition, this research has conducted sensitivity analysis in order to examine the situations when there are changes in sugarcane quantity from the prediction. In the case of 10% and 20% lower-than-prediction, it was found that the overall capacity utilization of all sugar mills in the country also decreased. On the contrary, when assuming that the overall sugarcane quantity in the country increases by 10% and 20%, it was found that the overall capacity utilization also increased. This change is particularly obvious with the case of 20% increase of sugarcane quantity.

The total supply becomes 85,299,692 tons, whereas the total demand of all sugar mills is only 84,278,170 tons. Therefore, if sugarcane quantity increases by 20%, it is more likely that all sugar mills may be able to fully utilize their capacity at 100%.

It can be concluded that, by the year that the implementation of the relocation and capacity expansion according to the cabinet resolution of these seven mills will be completed, the overall quantity of sugarcane production in Thailand should be at least 84,278,170 tons. This is to ensure that there will be consistently sufficient sugarcane supply for capacity of all sugar mills and that there will not be too high competition among existing mills. At present (the production year 2010/2011), the overall quantity of sugarcane production in Thailand is as high as almost 100 million tons. Therefore, unless there is too much capacity expansion in the future, quantity of sugarcane supply should be sufficient for the overall demand of all sugar mills in Thailand that has been increased due to the capacity expansion of the seven mills.

6.3.2 The impact on the optimal transportation distance

Regarding impacts on transportation distance, the results can be summarized according to the cases as follows:

Case 1 *The optimal current situation (the production year 2008/2009)*: The overall optimal average transportation distance from the growing areas to the sugar mills in the whole country is found to be 43.08 kilometers. This is considered appropriate because the Ministry of Agriculture and Cooperatives used to specify that the distance for sugarcane transportation should not exceed 50 kilometers (Nilpan, 2008). The reason is that, if the distance is longer the transportation cost will be too high. In this case, the average transportation distances in the Eastern, the Northern, the Central, and the Northeastern regions were found to be 41.55, 46.41, 34.71, and 47.80 kilometers, respectively.

Case 2 *Adding a new sugar mill in the Eastern region*: After adding Chonburi Sugar Industry mill in the Eastern region, it was found that the overall average transportation distance in the whole country would reduce from 43.08 to 42.95 kilometers. The average transportation distance in the Eastern region would decrease from 41.55 to 39.29 kilometers. Having examined average transportation distances of sugar mills nearby Chonburi Sugar Industry mill, it was found that three mills would have increasing transportation distances; i.e., New Kwang Soon Lee mill (increase from 35.14 to 48.19 kilometers), Rayong mill (increase from 28.38 to 34.42 kilometers), and Chonburi Sugar and Trading mill (increase from 18.32 to 49.97 kilometers). The increases in transportation distances of these mills are believed to be caused by insufficiency sugarcane supply in nearby areas, thus the mills have to obtain sugarcane from areas being farther away.

Case 3 *The Cabinet Resolution:* This case assumed that the implementation of the relocation and capacity expansion according to the cabinet resolution of the seven sugar mills have been completed. It was found that the overall average transportation distance in the whole country would decrease from 43.08 to 39.76 kilometers. Considering by region, almost all regions also had shorter average transportation distances. The average transportation distances in the Northern region, the Central region and the Northeastern region would decrease from 46.41 to 42.40, from 34.71 to 30.64, and from 47.80 to 43.41 kilometers, respectively. This finding is expected to be caused by the tool used for the analysis, which is developed for calculating for the minimum transportation cost. Therefore, when there is insufficient sugarcane supply to meet capacity of the mills, no transportation is made. That makes the average transportation distances shorter.

When conducting a *sensitivity analysis* with the case that sugarcane quantity becomes less than expectation, it was found that the average transportation distance tended to decrease. This is because insufficient sugarcane supply resulted in no transportation. On the contrary, when there is more sugarcane quantity than expectation, the average transportation distances tend to increase too. Keep in mind that the production increment is assumed to distribute evenly across the country. As long as there is a need for more sugarcane in one region, the mathematical model works its best to look for sugarcane from another region. As a result, mills in the Central and Northern regions, which are short of sugarcane, end up seeking sugarcane from plantation areas in the Northern region in order to fulfill their production capacity. Consequently, the transportation distance is inevitably increased. The overall average transportation distance therefore increased from 43.08 to 47.23 kilometers.

According to the results, it can be concluded that there should be a future plan to promote sugarcane plantation in areas around sugar mills so that sugarcane can be transported to the nearest sugar mill. It is found at present that there is no systematic management for sugarcane transportation across different sugar mills. This improper planning of sugarcane transportation can lengthen transportation distances to 160-250 kilometers (Ministry of Industry, 2003b). Such these far transportation distances incur excessive transportation costs.

6.3.3 The impact on the optimal transportation pattern

The analysis results can be discussed according to the assumed cases. For *Case 1*: the optimal current situation (the production year 2008/2009), it was found that sugarcane were supplied to sugar mills nearby first in order to yield optimum solution (minimum total transportation cost). For *Case 2*: by adding a new sugar mill in the Eastern region, it was found that the pattern of sugarcane transportation in the Eastern region had changed. This change is apparent for the patterns of transporting sugarcane to sugar mills locating near the added sugar mill (Chonburi Sugar Industry mill). Examples of such these mills are Rayong mill, Chonburi Sugar and Trading mill, and New Kwang Soon Lee mill. This is because some of the existing sugarcane supply was switched to feed the new sugar mill. Finally, *Case 3*: The Cabinet Resolution, it was found that the relocation and/or capacity expansion resulted in obvious change of transportation patterns. For example, the relocation of New Kwang Soon Lee mill would force the fields that used to supply sugarcane to this mill to supply to other mills that are located further away. Some sugarcane from these fields would go to the mills in the Central region. This is because sugar mills, which are located near these fields, have already fully utilized their capacity. Regarding the relocation of Banpong mill and Chonburi Sugar Industry mill to the Northern region, the pattern of transportation in that region would be changed due to this relocation. This is particularly true for areas around the new locations of the two mills, because some sugarcane fields will certainly switch to supply to these new mills due to the closer distances. In addition, the obvious change was also found from conducting a sensitivity analysis by assuming that overall sugarcane quantity in the country was more than prediction by 20%. Much sugarcane was then apparently transported across regions (i.e., from the Northeastern region to the Northern and the Central regions). This is probably because the Northeastern region is the region with the largest sugarcane growing area. Therefore, after assuming the 20% increase, sugarcane yield in this region became greater than demand of sugar mills in the region. Meanwhile, other regions still had insufficient sugarcane supply, thus sugarcanes from the Northeastern region were transported to other regions as well.

6.3.4 The impact on the optimal inbound logistics cost

The total inbound logistics cost consists of transportation cost from all growing fields to all sugar mills, the opportunity cost of sugar mills, and the opportunity cost of sugarcane farmers. The opportunity cost of sugar mills is incurred when the overall quantity of sugarcane supply is less than their production capacity or demand $(\sum_{i=1}^{m} S_i < \sum_{j=1}^{n} D_j)$. This cost can be calculated by multiplying the shortage quantity with the average sugar yield per ton of sugarcane at 110 kilograms/ton, and then multiplied with sugar price of 25 Baht/kilogram. The opportunity cost of sugarcane farmers happens when the overall sugarcane supply exceeds the overall sugarcane demand $(\sum_{i=1}^{m} S_i > \sum_{j=1}^{n} D_j)$. This cost can be calculated by multiplying the excessive quantity of sugarcane with the average cost of sugarcane 920 Baht/ton. In conclusion, the optimal inbound logistics cost of sugarcane and sugar industry can be summarized by the studied cases as follows:

Case 1 *The optimal current situation (the production year 2008/2009)*: The minimum total sugarcane transportation cost from all fields to all sugar mills in the country was 12,615,129,290 Baht. However, since the sugarcane supply in that production year was less than the sugarcane demand at 3,550,433 tons, there is an opportunity cost incurred to the sugar mills. The opportunity cost is 3,550,433 tons x 110 kilograms/ton x 25 Baht/kilogram = 9,763,690,750 Baht. Therefore, the total cost of inbound logistics system for this case was 22,378,820,040 Baht.

Case 2 *Adding a new sugar mill in the Eastern region*: After adding Chonburi Sugar Industry mill in the Eastern region, it was found that the minimum total sugarcane transportation cost in the country decreased to 12,577,936,513 Baht.

Quantity of the sugarcane supply was less than the sugarcane demand by 4,165,853 tons, resulted in an opportunity cost of the sugar mills from having insufficient sugarcane for their production. The opportunity cost is equal to 4,165,853 tons x 110 kilograms/ton x 25 Baht/ kilogram = 11,456,095,750 Baht. Therefore, the total cost of inbound logistics had increased to 24,034,032,263 Baht.

Case 3 *The Cabinet Resolution:* This case was analyzed by assuming that the relocation and/or capacity expansion of the seven mills approved by the cabinet resolution has been implemented in the production year 2008/2009. It was found that the optimal total sugarcane transportation cost in the country would reduce to 11,645,062,551 Baht, which is less than the cost of the optimal current situation. However, due to the expansion of these seven mills, the sugarcane supply would not be sufficient to match the increasing demand. The shortage is as much as 9,644,644 tons. This would result in an opportunity cost of sugar mills at 9,644,644 tons x 110 kilograms/ton x 25 Baht/kilogram = 26,522,771,000 Baht. Therefore, the total cost of the system would increase to be as high as 38,167,833,551 Baht.

Sensitivity Analysis was conducted for the cases when the sugarcane production became more or less than the predicted quantity by 10% and 20%. In the cases of the yield less than prediction by 10% and 20%, it was found that the minimum total sugarcane transportation cost in the country would decrease to 9,869,038,990 Baht and 8,553,244,923 Baht, respectively. The sugarcane supply became less than the sugarcane demand for 20,303,385 and 27,411,716 tons, respectively. Therefore, the opportunity costs of sugar mills for the two cases are equal to 20,303,385 tons x 110 kilograms/ton x 25 Baht/kilogram = 55,834,308,750 Baht and 27,411,716 tons x 110 kilograms/ton x 25 Baht/ kilogram = 75,382,219,000 Baht, respectively. The total cost of the system, when the yield had decreased by 10% and 20%, are 65,703,347,740 Baht and 83,935,463,923 Baht, respectively. On the contrary, for the case of the yield become higher than prediction by 10%, it was found that the total transportation cost would reduce to 14,088,622,274 Baht. In this case, the sugarcane supply would be less than the demand for 6,086,769 tons. The opportunity cost of sugar mills would be equal to 6,086,769 tons x 110 kilograms/ton x 25 Baht/kilogram = 16,738,614,750 Baht. As a result, the total cost of the system would be 30,827,237,024 Baht. However, when sugarcane yield became more than the predicted quantity by 20%, the optimal total transportation cost increased to 16,400,166,793 Baht. In this case, the sugarcane supply was greater than the sugarcane demand for 1,021,522 tons. This would result to an opportunity cost of sugarcane farmers, which was equal to 1,021,522 tons x 920 Baht/ton = 939,800,240 Baht. Therefore, the total cost of the inbound logistics for the whole country would be 17,339,967,033 Baht.

6.4 Suggestions and guideline for liberalization policy

These are always supporters and opponents of sugar mill liberalization policy regarding the new establishment, relocation, or capacity expansion of sugar mills. A past research surveyed the opinions among stakeholders of this industry (Siamwala et al., 1993). From the perspective of entrepreneurs of small sugar mills, they seemed to agree with the policy to allow relocation and/or capacity expansion. However, they disagreed to the policy to allow new establishment of sugar mills. They gave a reason that the new establishment would lead to higher competition for sugarcane in the area. Meanwhile, the entrepreneurs of large sugar mills totally disagreed to the sugar mill liberalization policy. Their reason was that the new establishment or relocation of sugar mills would have some impacts on the existing mills around the area. Sugarcane might become insufficient. Consequently, high competition for sugarcane would be unavoidable. Finally, in the perspective of entrepreneurs who wanted to establish new sugar mills, they certainly agreed to the policy to allow new establishment of sugar mills. However, once they have been allowed to establish their mills, they would turn to oppose the policy of new establishment. Sugar mill liberalization is therefore analogous to a two-sided coin, there are always persons who gain and who lose. Nevertheless, sugar mill liberalization is unavoidable eventually. Thus solutions for coping with this policy have to be prepared so that all stakeholders can get ready for the future change. For this purpose, the research would like to recommend some guidelines for sugar mill liberalization as follows:

1) In the future, some tools for quantitatively analyzing impacts of sugar mill liberalization should be developed. The tools would allow all relevant partners to understand the consequences of liberalization easily and clearly. The results from analyzing with the tools will become efficient information for preparing to cope with future change. This research has proposed such the tool. The tool has been proved to provide satisfactory results, which are consistent with the real circumstances.

2) A balance between the sugarcane supply and the sugarcane demand or capacity of sugar mills is the most important factor when making decisions about new establishment, relocation, and capacity expansion. Therefore, accuracy of the estimation on sugarcane quantity is highly influential for decision making. This is particularly true when the real sugarcane yield become less than the overall demand. Problems, such as high competition and low capacity utilization, will happen in the whole system. Thus attention should be also put on a tool for predicting sugarcane yield. There should also be plans or projects to promote and enhance efficiency of sugarcane farming so that the sugar mills will have sufficient sugarcane for their production capacity without having to compete too fiercely with each other.

3) According to the reviewed literature regarding the sugarcane and sugar industry and the results from this research's analyses, the transportation distances from some sugarcane fields to some sugar mills can be as far as 160 – 250 kilometers (Ministry of Industry, 2003b). Therefore, a future plan for better sugarcane transportation planning should be very important. Areas for growing sugarcane may be re-specified, and locations of sugar mills may be determined more appropriately.

6.5 Recommended future research

This research has studied the impacts of sugar mill liberalization on inbound logistics of cane and sugarcane production. For this purpose, the transportation model was applied as the tool for analyzing the impacts quantitatively. According to the findings of this research, some recommendations for future research can be made as follows:

1) Some data should be adjusted to be more detailed. For example, the data on sugarcane field in this research is aggregated at the district level due to the limitation of the software capability. In the future, this data may be made to have higher details by using boundaries of Tambol (sub-districts) or villages instead. This would allow the results to reflect the real circumstances more accurately. For this operation, the software used for calculation might have to be changed from LINDO to IBM ILOG CPLEX.

2) The model should be improved to better resemble the real situation. Currently, the transportation model allows a field to transport sugarcane to more than one mill. This is very unlikely in the real situation. In fact, each sugarcane field supplies its sugarcane to only one mill, with a characteristic of so-called "single source" distribution. Therefore, the future research should add a constraint into the model in order to force it to allow only single source transportation.

3) The results from the tool in this research are very satisfactory. However, the tool requires a complex and difficult procedure for inputting the data. Therefore, in the future, a form of Decision Support System (DSS) might be developed to facilitate the data input procedure. The DSS will enable users to see the impacts immediately after there is any change in the data. For example, changes in sugarcane supply, number of production days, production capacity, and the locations of mills. These changes are expected to happen after the relocation and capacity expansion of some sugar mills in the future. Such the DSS can be developed without much difficulty. All required data have already been collected in a form of GIS data from the responsible authorities. Data of sugar mill locations and sugarcane fields have been obtained from the Office of the Cane and Sugar Board. GIS data of transportation-related was obtained from the Permanent Secretariat Office of the Ministry of Transport. The remaining tasks are only to integrate these data with the developed mathematical model and create the user-friendly interface for the application. This would be sufficient to derive an effective decision support system that is highly beneficial to the Thai society.

REFERENCES

Chamnanhlaw,C. (2004). *Truck allocation in transporting sugarcane from field to industry*. Master's thesis. Khon Kaen University, Khon Kaen, Thailand.

Detpon, J. (1997). *An Analysis of Impacts of Sugar Policies in Thailand. Master's thesis*. Kasetsart University, Bangkok, Thailand.

Hansen, A., Barnes, Lyne, L. (1998). An integrated approach to simulating sugarcane harvest-to-mill delivery systems. *An ASAE Meeting Presentation*; Paper No. 986099.

Higgins, A. (2006). Scheduling of road vehicles in sugarcane transport: A case study at an Australian sugar mill. *European Journal of Operational Research 170*. 987-1000.

Higgins, A., Antony, G., Sandell, G., Davies, I., Prestwidge, D., Andrew, B. (2004). A framework for integrating a complex harvesting and transport system for sugar production. *Journal of Agricultural Systems*. 99-115.

Higgins, A., Muchow, R. (2003). Assessing the potential benefits of alternative cane supply arrangements in the Australian sugar industry. *Agricultural Systems* (76). 623-638.

Higgins, A., Muchow, R., Rudd, A., Ford, A. (1998). Optimizing harvest date in sugar production: A case study for the Mossman mill region in Australia I. *Development of operations research model and solution*. Field Crops Research. 153-162.

Intasen, S. (2001). *An Analysis of Land Suitability for Sugarcane and the Location of Sugar Mills in the Upper Central Plain*. Master's thesis. Ramkhamhaeng University, Bangkok, Thailand.

Ministry of Industry. (2003a). *Solving the problem of sugarcane and sugar prices in the entire system*. 27 April 2012. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2546&top_serlno=193536&rel_doc_seq=4. page 2.

Ministry of Industry. (2003b). *Enhancing production efficiency of sugarcane and sugar industry for global market competition*. 1 January 2012. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2546&top_serlno=194911&rel_doc_seq=4. page 2.

Ministry of Industry. (2007). *Requests for permissions regarding sugar mill relocation and capacity expansion*. 27 December 2011. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2550&top_serlno=214089&rel_doc_seq=19. page 2.

Ministry of Industry. (2008). *Three sugar groups have moved greatly by investing over ten billion baht for expanding their mills*. 13 November 2011. http://www.industry.go.th/ops/pio/sukhothai/Lists/annuity/Disp.aspx?List=7aadc3d2-0e41-46a9-b8fa-c8da61323bdd&ID=27

Ministry of Industry. (2009). *Adjustment of requests regarding relocation or requests existing capacity to the new location and capacity expansion*. 8 March 2011. http://www.cabinet.soc.go.th/doc_image/2554/9922665120.pdf

Ministry of Industry. (2011). *Requests for changes regarding moving the capacity to the new location, moving the existing capacity to the new location, and requests for capacity expansion*. 5 January 2012. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2554&top_serlno=99227297&rel_doc_seq=21. page 2.

Ministry of Interior. (2007). *Requests for permissions regarding sugar mill relocation and capacity expansion*. 27 April 2012. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2550&top_serlno=214089&rel_doc_seq=16

Ministry of Natural Resources and Environment. (2007). *Requests for permissions regarding sugar mill relocation and capacity expansion*. 27 April 2012. http://www.cabinet.soc.go.th/soc/docimage.jsp?meet_yy=2550&top_serlno=214089&rel_doc_seq=17

Ministry of Transport. (2007). *Transport fundamental geographic data set: Transport FGD*. [CD-ROM]

Mulwa, M.R., Emrouznejad, A., Murithi, F.M. (2008). Impact of liberalization on efficiency and productivity of sugar industry in Kenya. *Journal of Economic Studies*. 250-264.

Nilpan, B. (2008). *An efficient transport planning to deliver sugar cane to sugar mill*. Master's thesis. Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Noiwan, S. (2011). *Lessons from sugarcane situations and the flood crisis in Thailand.* Year 7 (issue 6), September-October, The Office of the Cane and Sugar Board, Thailand. page 3.

Office of Agricultural Economics. (2008). *Export, Sugar Exportations of Thailand in 2007-2009*. 15 June 2010. http://www.oae.go.th/oae_report/export_import/export.php

Office of the Cane and Sugar Board. (2005). *Results from a sugarcane growing survey using satellite images for the production year 2004/2005*. The Office of the Cane and Sugar Board, Thailand.

Office of the Cane and Sugar Board. (2008a). *Locations of sugar mills the production year during 2008/2009*. 19 August 2010. http://oldweb.ocsb.go.th/uploads/contents/11/attachfiles/HouseEng072552.pdf

Office of the Cane and Sugar Board. (2009a). *Manuals or guidelines regarding operation practices of governmental officers, Group 6: Re-formation sugarcane and sugar industry.* The Office of the Cane and Sugar Board, Thailand.

Office of the Cane and Sugar Board. (2009b). *Sugarcane fields in the production year during 2008/2009*. [CD-ROM].

Office of the Cane and Sugar Board. (2009c). *Report of the sugarcane fields in the production year during 2008/2009*. The Office of the Cane and Sugar Board, Thailand.

Office of the Cane and Sugar Board. (2009d). *Production capacities of permit by the government in the production year during 2008/2009*. The Office of the Cane and Sugar Board, Thailand.

Office of the Cane and Sugar Board. (2009e). *Report of working days of sugar mills in the production year during 2008/2009*. 19 August 2010. http://www. ocsb. go.th/th/cms/detail.php?ID=142&SystemModuleKey=production

Office of the Cane and Sugar Board. (2010). *Cabinet resolutions regarding establishment, relocation, and production capacity expansion of sugar mills.*

Prachachat Online. (2011). *The sugarcane mob was pleased with the government's decision to relocate the sugar mill*. 8 March 2011. http://www.prachachat.net/news_detail.php?newsid=1299584416&grpid=03&catid=00

Sakulkhemruethai, W. (2002). *The Impacts of Free Trade on the Sugar and Sugar Cane Industry in Thailand*. Master's thesis. Chiang Mai University, Chiang Mai, Thailand.

Sanglow, A. (2004). *An Analysis of Market Structure and Conduct of Sugar Industry in Thailand*. Master's thesis. Khon Kaen University, Khon Kaen, Thailand.

Sattayanikom, R. (2011). *Maintenance of sugarcane farms that were inundated*. Year 7 (issue 6), September-October, The Office of the Cane and Sugar Board, Thailand. page 4.

Semenzato, R. (1995). A simulation study of sugar cane harvesting. *Journal of Agricultural systems*. 427-437.

Siamwala, A., Netyarak, P., Hiranrak, W., Phuaphongsakon, N., Netyarak, H. (1993). *Future of Sugarcane and Sugar Industry*, Final Research Report. Proposed to the Cane and Sugar Board, Ministry of Industry.

Siamwala, A., Phuaphongsakon, N., Na-Ranong, W., Issawilanon, S., Pearce, D., Dunyawasinphong, S., Chansai, C., Supariyasin, A., Siwaranan, Y., Uprasit, U., Khunnathamdi, P., Keatifueangfu, W., Phueanpathom, T. (2000). *Sugarcane and Sugar Industry Research Project*, Suggestions on Production Expansion for Exportation Enhancement, Volume 1, Research Report, Complete Research Proposal, proposed to the Cane and Sugar Board, Ministry of Industry, Thailand Development Research Institute.

Sugar Journal. (1998a). *Policies regarding permission requests for establishing new sugar mills and expanding sugar production capacity in various countries*, 34(5), September- October, The Office of the Cane and Sugar Board, Thailand. pages 19-26.

Sugar Journal. (1998b). *Business relationship in Asia and attitude toward Asian economy development*, 34(6), November-December, The Office of the Cane and Sugar Board, Thailand. pages 11-21.

Suwansoon, N. (2002). *Optimal Locations and Sizes of Sugarcane Processing Plants in Thailand*. Master's thesis. Chiang Mai University, Chiang Mai, Thailand.

Taechasook, P. (2008). *A Decision Support System for Sugar Cane Harvest in Inbound Logistics of Mill Region*. Master's thesis. Khon Kaen University, Khon Kaen, Thailand.

The Secretariat of the Cabinet. (1989). *Cabinet resolutions regarding establishment, relocation, and production capacity expansion of sugar mills.* 27 December 2011. http://www.cabinet.soc.go.th/soc/Program2-3.jsp?top_serl=48171&key_word=น้ำตาล&owner_dep=&meet_date_dd=10&meet_date_mm=10&meet_date_yyyy=2532&doc_id1=&doc_id2=&meet_date_dd2=&meet_date_mm2=&meet_date_yyyy2

Tuampan, P. (2002). *Delivery Cost Structure of Sugar Cane*. Master's thesis. Chulalongkorn University, Bangkok, Thailand.

Tumcharoen, W. (2008). *Analyzing cost and lead time of harvesting and transportation the sugarcane to a factory for increase competitiveness: A study of the growers in Kanchanaburi and Suphanburi province*. Master's thesis. Mae Fah Luang University, Chiang Rai, Thailand.

APPENDICES

APPENDIX A
PREPARING DATA FOR ANALYSIS IN GEOGRAPHIC INFORMATION SYSTEM (SUGARCANE FIELDS)

Network Analyst feature calculates distances by finding the shortest path between two point features. Therefore, the polygon dataset of sugarcane field areas, obtained from the Office of the Cane and Sugar had to be converted to a point dataset. The field data that contain 388,104 records of polygons, covering the total area of 6,831,892 rais during the growing period of 2008/2009 is too large to handle. These fields were then grouped by district in Thailand, resulting in a total of 404 sugarcane field areas. Thus there were 404 groups of field areas to be used for distance calculation. Procedures for grouping field areas and converting polygons of these groups to point features are explained in details below.

1) Open ArcMap and select 404 districts in Thailand that will be used for grouping field areas and defining scope of this study (See Figure A.1).

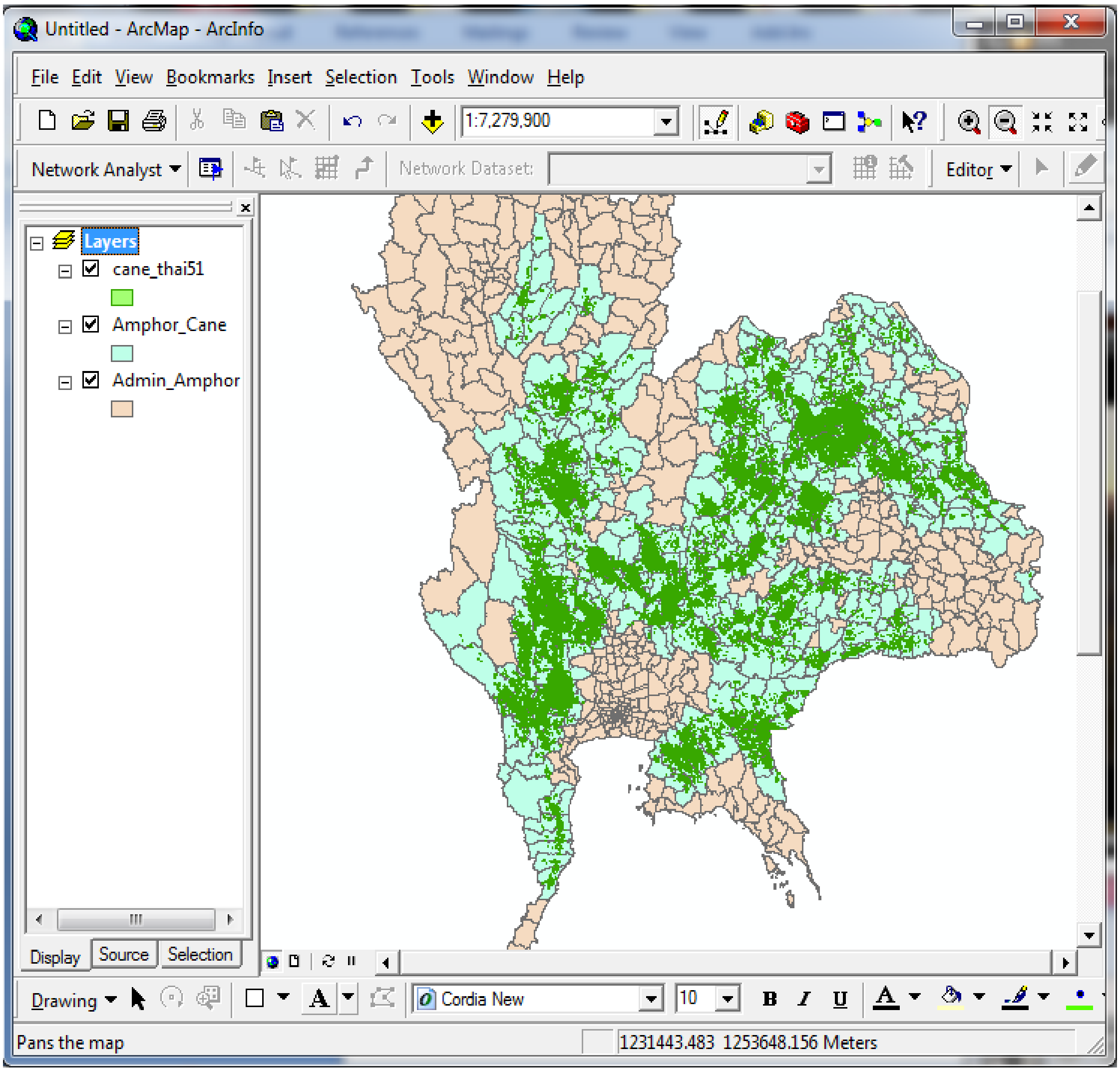


Figure A.1 Polygons of sugarcane field areas are displayed in ArcMap.

2) In order to convert polygon data to point data, this research used ET GeoWizards Extension, which is available for free download from www.freegeographytools.com. After being downloaded and installed in ArcGIS Desktop 9.3, ET GeoWizard tool can be accessed by clicking View → Toolbars → ET Geo Wizards (See Figure A.2).

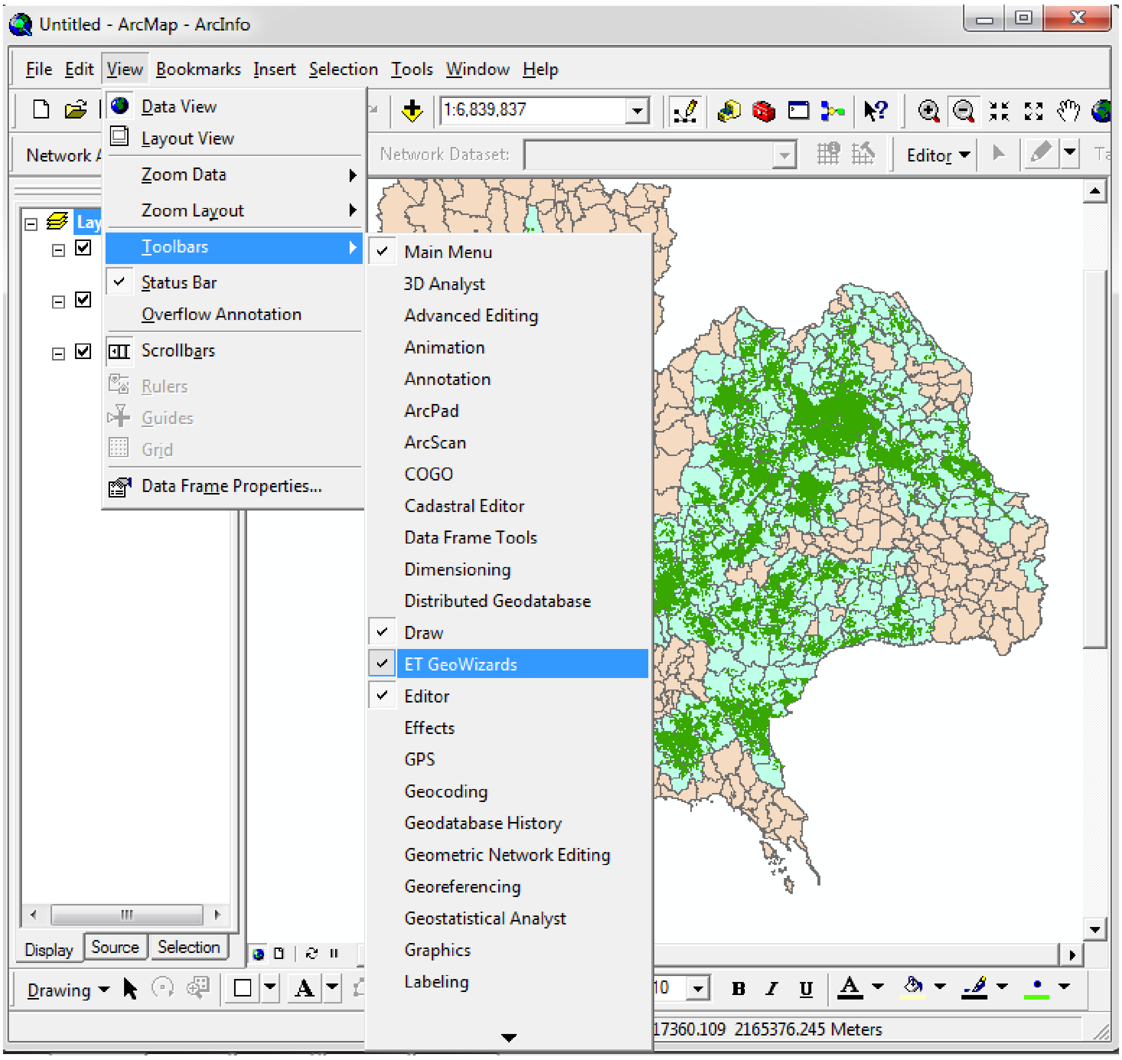


Figure A.2 Add functionality of ET GeoWizards

3) Click at ET GeoWizards tool to open GeoWizards window. To convert polygons to points, click Convert → Polygon to Point → Go (See Figure A.3).

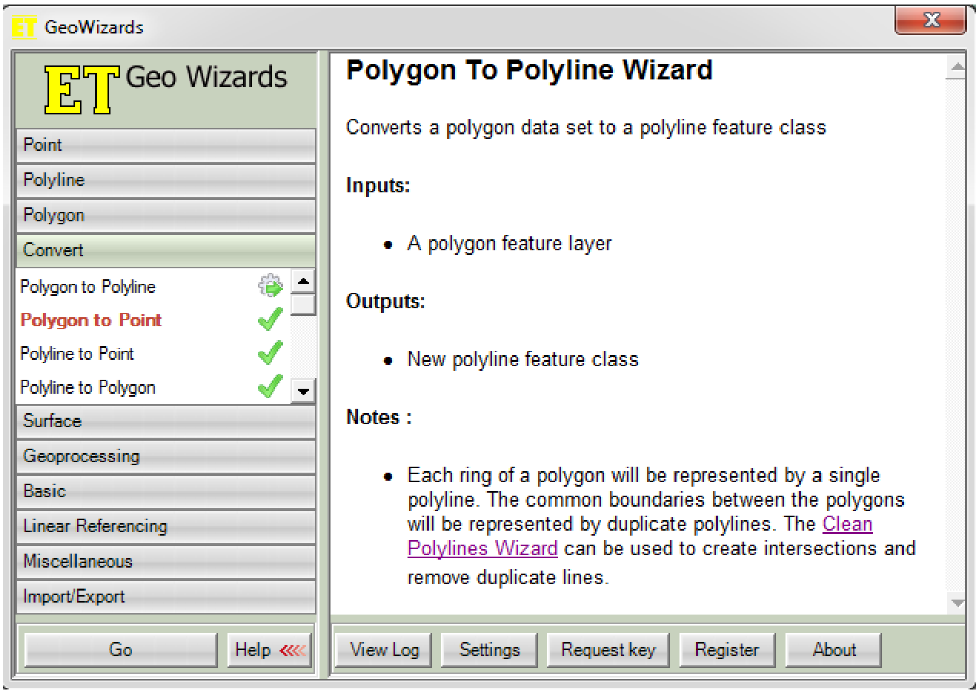


Figure A.3 Open function Polygon to Point Wizard

4) Select “Amphor_Cane” layer, which is the polygon shapefile of districts in Thailand, in the “Select polygon layer” drop down name. Then specify a Shapefile name in the “Specify output feature class or shapefile” box and click next (See Figure A.4).

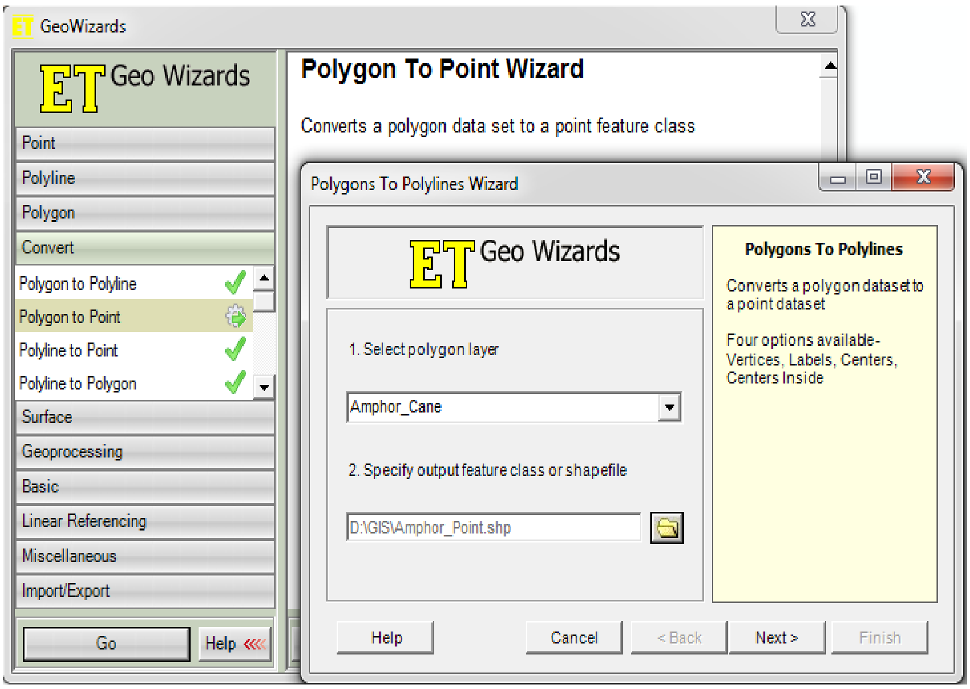


Figure A.4 Select input polygon layer and specify output point shapefile

5) There are four optional conversion algorithms in ET GeoWizards. In this research, the “Centers In” option (See Figure A.5) was applied. Details of all four options are explained below.

5.1) Vertices - the vertices of all polygons will be converted to points. If the "Remove duplicate points" option is selected the duplicate points created from the vertices of two adjacent polygons will be represented by one point. Note that if this option is used, the attempt to convert back these points to polygons will produce incorrect result

5.2) Labels - the Label point is always located inside the polygon. The algorithm makes sure that the point is not close to the boundary of the polygon. Points created using this algorithm are suitable for spatial transfer of attributes.

5.3) Centers - the Center points represent the centroid of a polygon. Therefore sometimes they might be located outside of the polygon

5.4) Centers In - points representing the centroids of the polygons. If the centroid occurs outside of the polygon, the point is moved to be in the polygon.

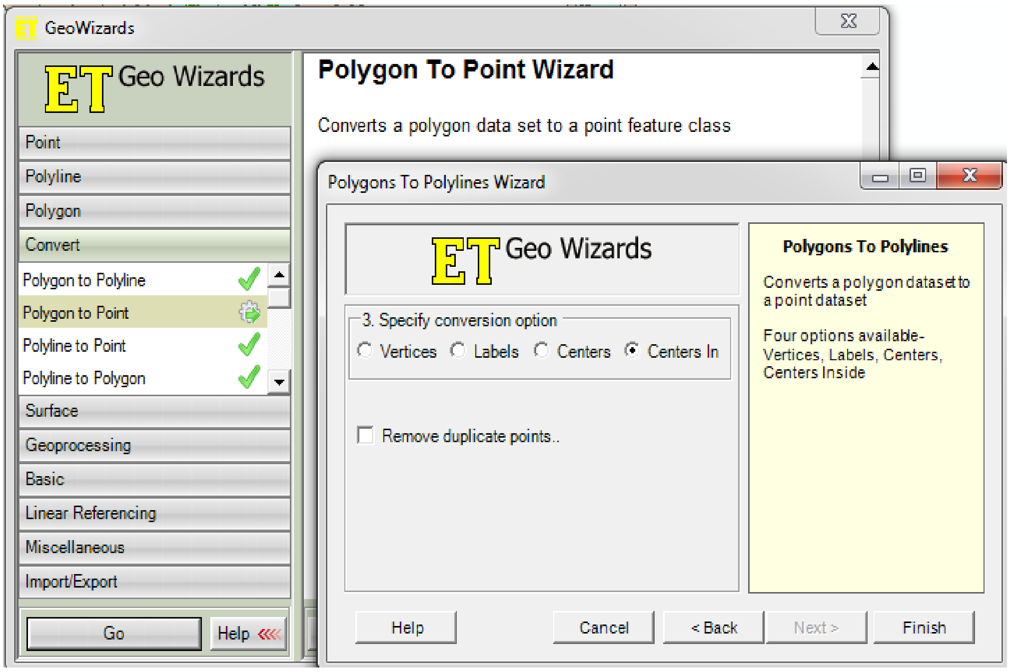


Figure A.5 Specify conversion option by selecting “Centers In”

6) When the operation is completed, the program will display "Function completed successfully" dialog (See Figure A.6).

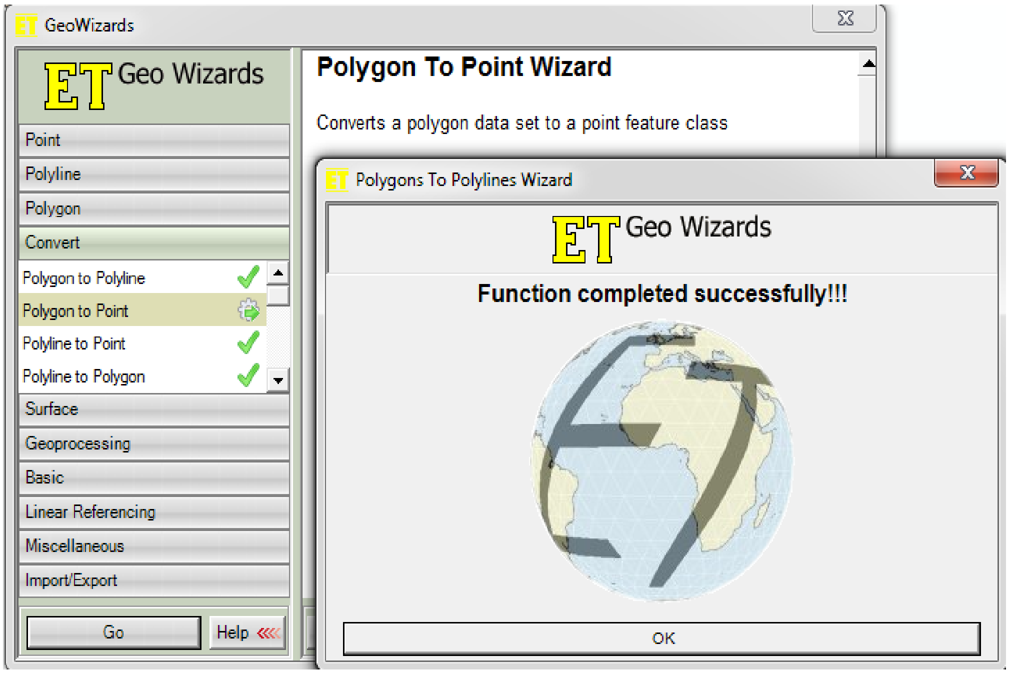


Figure A.6 Function completed successfully

7) The results contain centroids, which represent groups of sugarcane field areas. It can be added into ArcMap and displayed together with other data. In Figure A.7, we can see that the centroids of 404 districts are positioned within district polygons in Thailand (See Figure A.7).

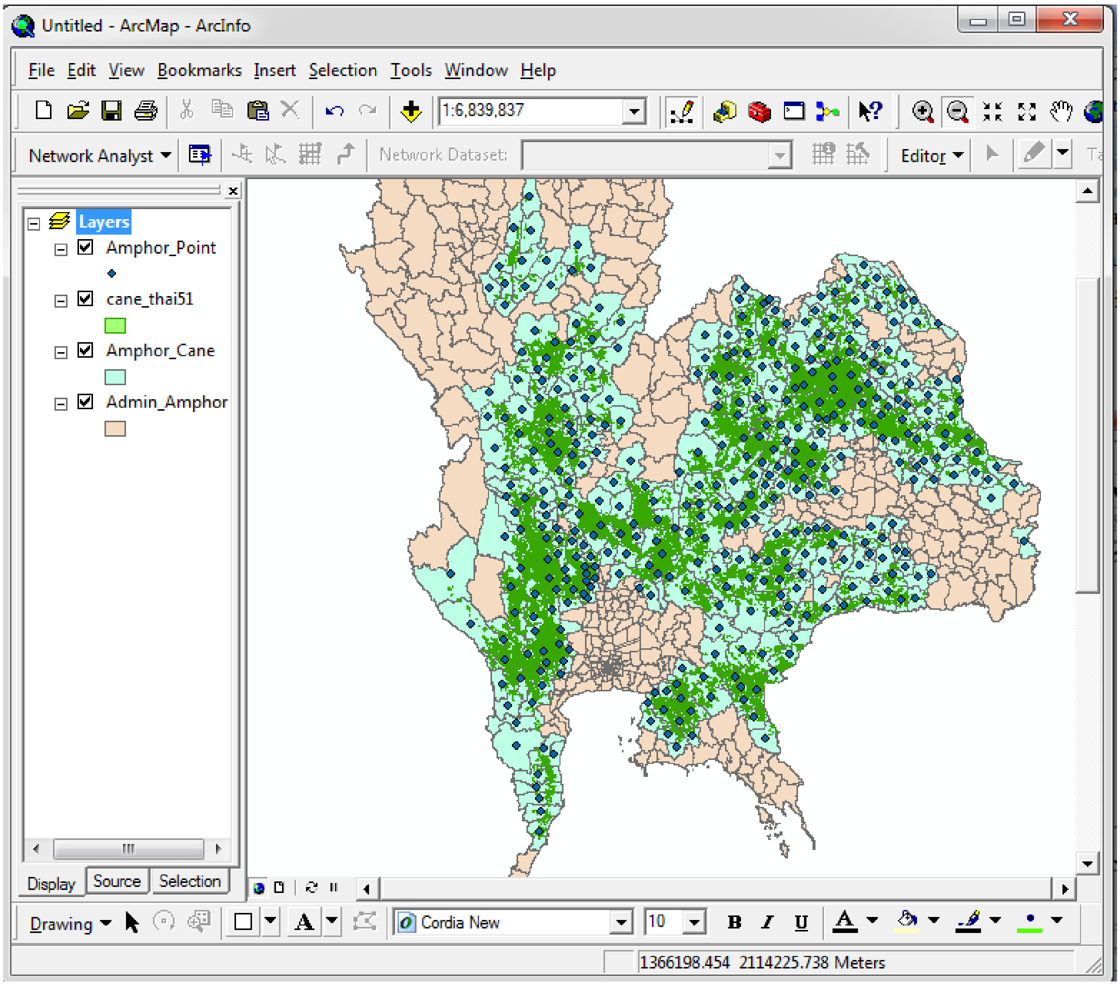


Figure A.7 The 404 groups of sugarcane field areas

8) The Figure A.7 reveals that sometimes centroids from data conversion process from polygon to point might be located outside areas of cane fields. If we are not satisfied with the result, we can move that point to a required position. To do this, we use Editor Function of ArcGIS, which can be accessed by clicking Editor → Start Editing (See Figure A.8).

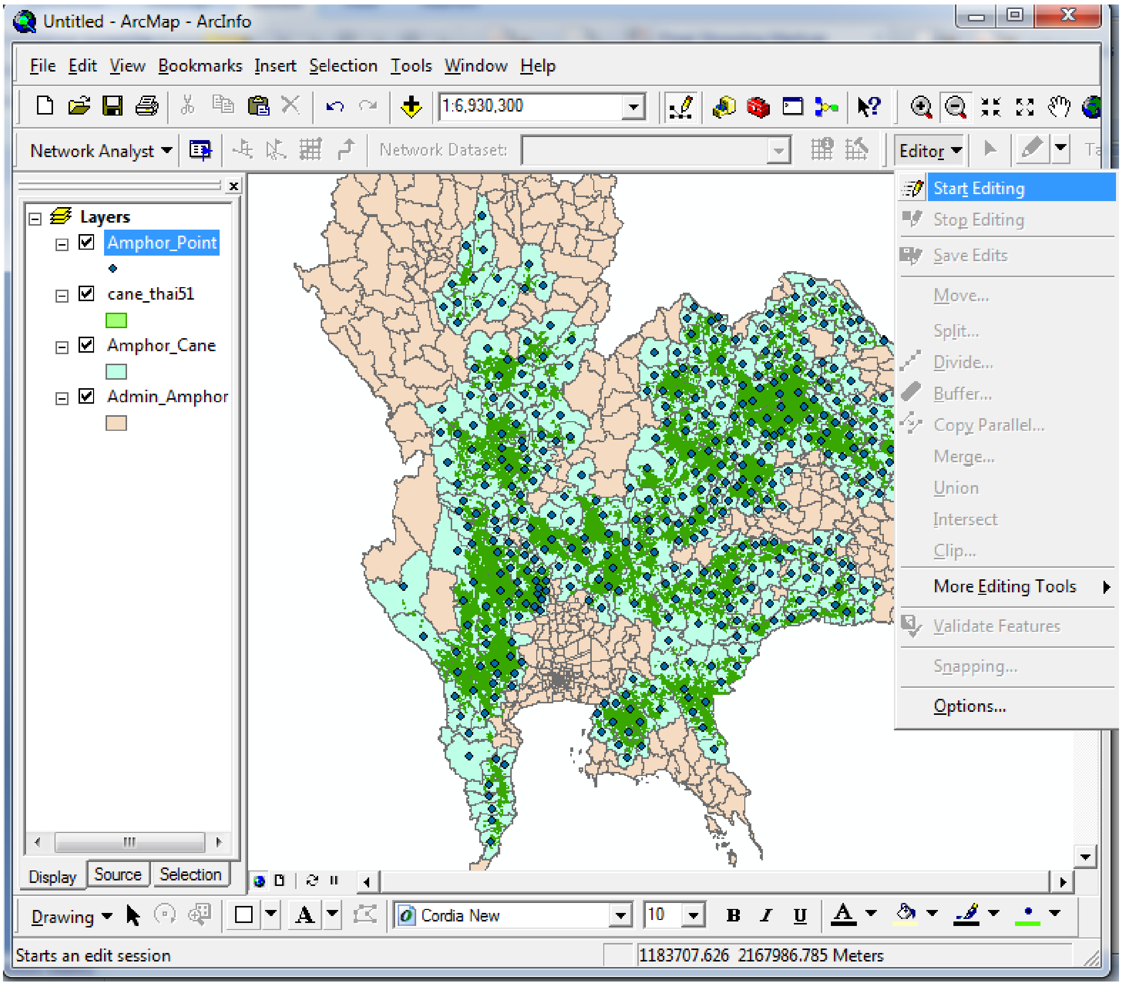


Figure A.8 Open Editor Function to start editing the point features

9) Move the point of cane fields located in a wrong position to a new and correct position (See Figure A.9). When finish editing, click Editor → Save edits → Stop Editing

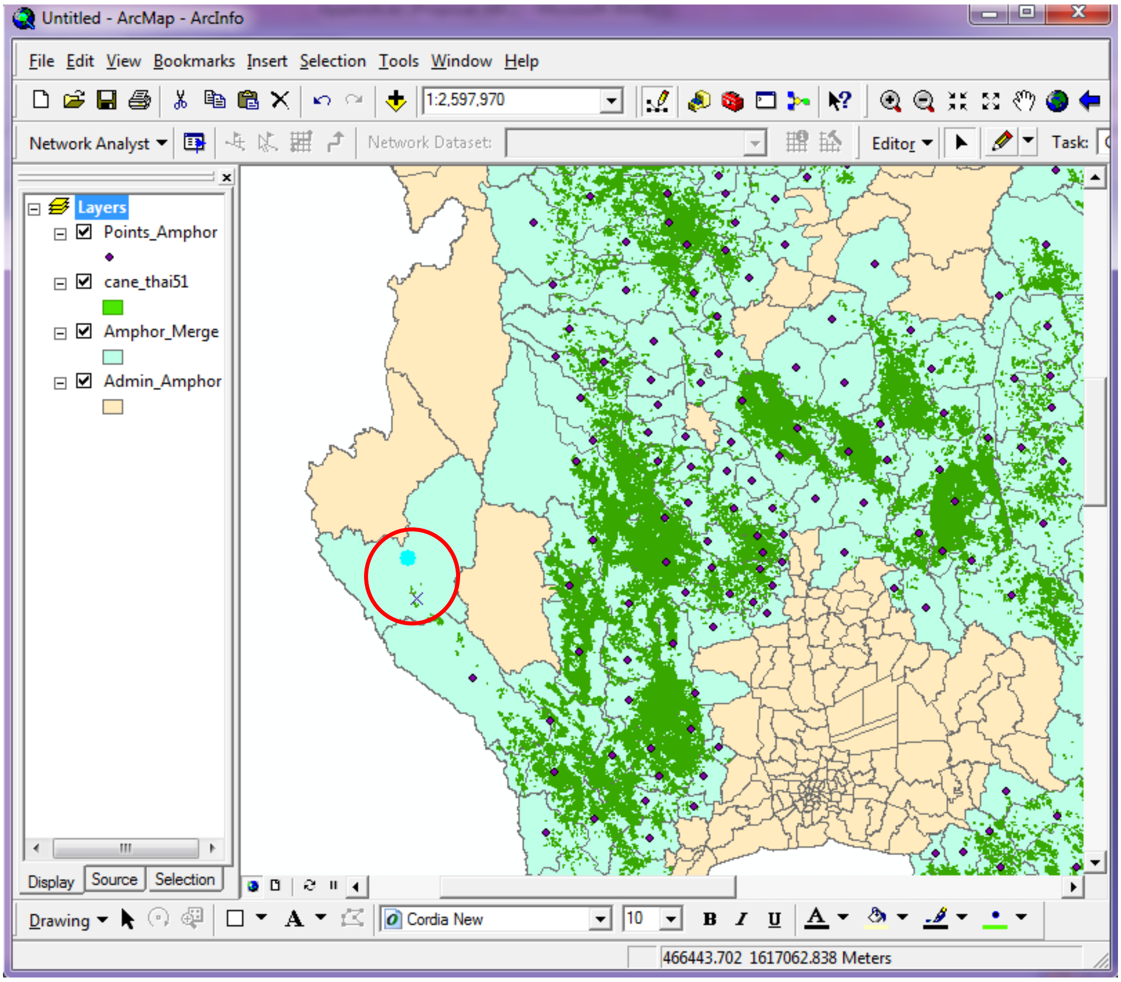


Figure A.9 Moving a point representing an area of cane fields

10) The incorrect point of sugarcane field has been moved (See Figure A.10 in circle). When finish editing, click Editor → Save edits → Stop Editing.

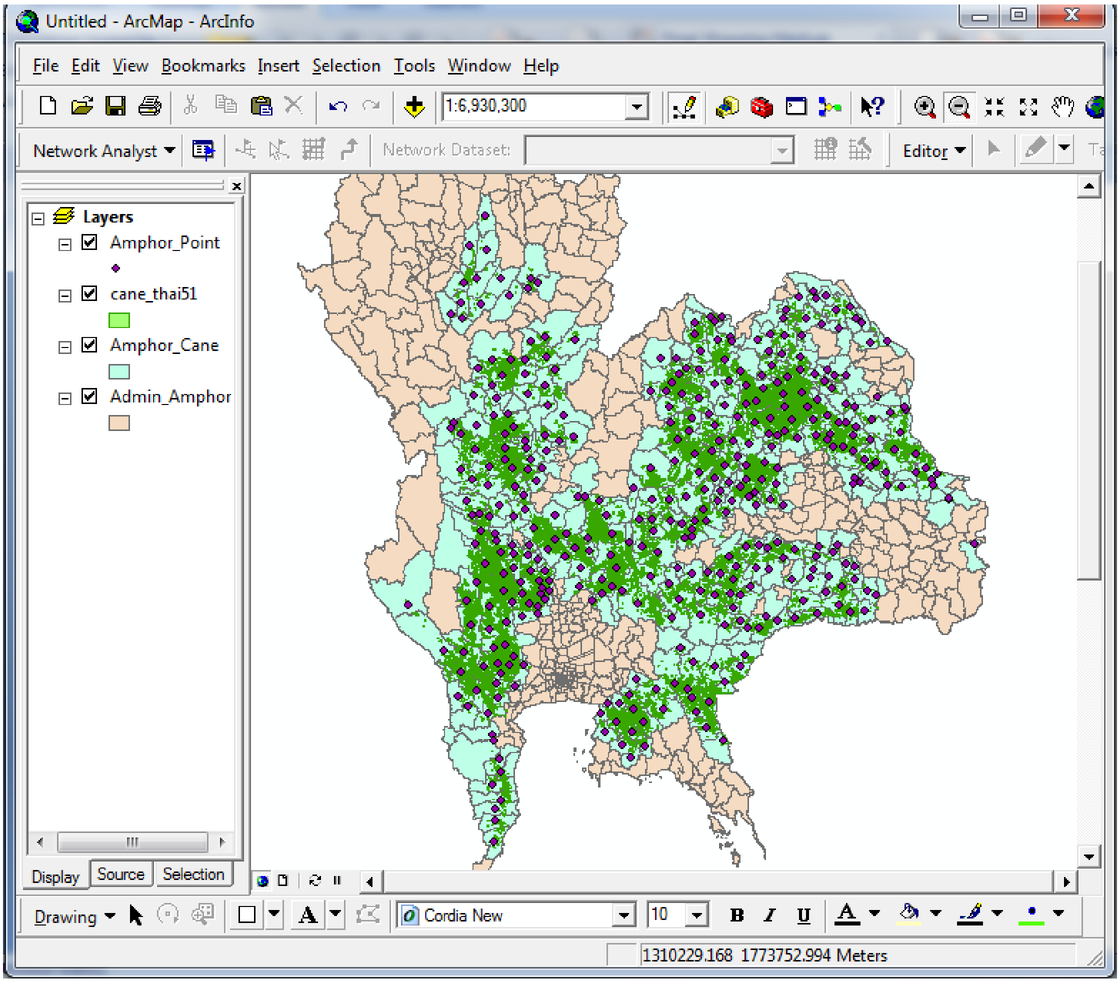


Figure A.10 The final 404 groups of sugarcane field areas

The detail sugarcane fields grouped by district in Thailand during the growing period of 2008/2009 were presented in Appendix B in the "District" column of Table B.1 (The estimate of sugarcane production in Thailand).

APPENDIX B
THE ESTIMATED SUGARCANE PRODUCTION IN THAILAND

Table B.1 The estimated sugarcane production in Thailand

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
1	Kamphaeng Phet	11.05	Mueang Kamphaeng Phet	60,198	665,188
2	Kamphaeng Phet	11.05	Sai Ngam	49,318	544,964
3	Kamphaeng Phet	11.05	Khlong Lan	3,474	38,388
4	Kamphaeng Phet	11.05	Khanu Woralaksaburi	23,893	264,018
5	Kamphaeng Phet	11.05	Khlong Khlung	34,278	378,772
6	Kamphaeng Phet	11.05	Phran Kratai	35,841	396,043
7	Kamphaeng Phet	11.05	Lan Krabue	37,437	413,679
8	Kamphaeng Phet	11.05	Sai Thong Watthana	44,546	492,233
9	Kamphaeng Phet	11.05	Pang Sila Thong	8,062	89,085
10	Kamphaeng Phet	11.05	King Amphoe Bueng Samakkhi	46,219	510,720
11	Kamphaeng Phet	11.05	King Amphoe Kosamphi Nakhon	5,844	64,576
12	Lampang	8.63	Mueang Lampang	13,204	113,951
13	Lampang	8.63	Mae Mo	426	3,676
14	Lampang	8.63	Ko Kha	3,247	28,022
15	Lampang	8.63	Soem Ngam	187	1,614
16	Lampang	8.63	Chae Hom	402	3,469
17	Lampang	8.63	Wang Nuea	597	5,152
18	Lampang	8.63	Mae Tha	4,141	35,737
19	Lampang	8.63	Sop Prap	1,770	15,275
20	Lampang	8.63	Hang Chat	2,038	17,588
21	Lampang	8.63	Mueang Pan	5,322	45,929

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
22	Nakhon Sawan	11.47	Mueang Nakhon Sawan	5,872	67,352
23	Nakhon Sawan	11.47	Krok Phra	4,312	49,459
24	Nakhon Sawan	11.47	Nong Bua	3,055	35,041
25	Nakhon Sawan	11.47	Banphot Phisai	17,102	196,160
26	Nakhon Sawan	11.47	Kao Liao	6,250	71,688
27	Nakhon Sawan	11.47	Takhli	70,031	803,256
28	Nakhon Sawan	11.47	Tha Tako	17,474	200,427
29	Nakhon Sawan	11.47	Phaisali	28,436	326,161
30	Nakhon Sawan	11.47	Phayuha Khiri	111,154	1,274,936
31	Nakhon Sawan	11.47	Lat Yao	2,174	24,936
32	Nakhon Sawan	11.47	Tak Fa	102,064	1,170,674
33	Nakhon Sawan	11.47	Mae Wong	6,044	69,325
34	Nakhon Sawan	11.47	King Amphoe Mae Poen	6,530	74,899
35	Nakhon Sawan	11.47	King Amphoe Chum Ta Bong	11,450	131,332
36	Phetchabun	11.20	Chon Daen	1,303	14,594
37	Phetchabun	11.20	Wichian Buri	108,607	1,216,398
38	Phetchabun	11.20	Si Thep	77,940	872,928
39	Phetchabun	11.20	Bueng Sam Phan	12,541	140,459
40	Phichit	12.50	Mueang Phichit	1,045	13,063
41	Phichit	12.50	Pho Prathap Chang	8,121	101,513
42	Phichit	12.50	Taphan Hin	594	7,425
43	Phichit	12.50	Pho Thale	2,568	32,100
44	Phichit	12.50	Sam Ngam	5,228	65,350
45	Phichit	12.50	King Amphoe Sak Lek	808	10,100
46	Phichit	12.50	King Amphoe Bueng Na Rang	23,071	288,388
47	Phichit	12.50	Wachirabarami	1,033	12,913
48	Phitsanulok	11.31	Mueang Phitsanulok	3,577	40,456
49	Phitsanulok	11.31	Chat Trakan	6,691	75,675
50	Phitsanulok	11.31	Bang Rakam	38,377	434,044
51	Phitsanulok	11.31	Bang Krathum	7,869	88,998

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
52	Phitsanulok	11.31	Phrom Phiram	5,039	56,991
53	Phitsanulok	11.31	Wat Bot	5,273	59,638
54	Phitsanulok	11.31	Wang Thong	9,833	111,211
55	Phitsanulok	11.31	Noen Maprang	3,458	39,110
56	Phrae	10.20	Rong Kwang	1,441	14,698
57	Phrae	10.20	Long	410	4,182
58	Phrae	10.20	Song	3,767	38,423
59	Phrae	10.20	Nong Muang Khai	299	3,050
60	Sukhothai	11.11	Mueang Sukhothai	1,725	19,165
61	Sukhothai	11.11	Ban Dan Lan Hoi	1,927	21,409
62	Sukhothai	11.11	Khiri Mat	15,889	176,527
63	Sukhothai	11.11	Kong Krailat	4,881	54,228
64	Sukhothai	11.11	Si Satchanalai	37,779	419,725
65	Sukhothai	11.11	Si Samrong	9,749	108,311
66	Sukhothai	11.11	Sawankhalok	73,450	816,030
67	Sukhothai	11.11	Si Nakhon	27,465	305,136
68	Sukhothai	11.11	Thung Saliam	9,259	102,867
69	Tak	11.49	Mueang Tak	1,283	14,742
70	Tak	11.49	King Amphoe Wang Chao	2,807	32,252
71	Uttaradit	10.87	Mueang Uttaradit	8,321	90,449
72	Uttaradit	10.87	Tron	12,143	131,994
73	Uttaradit	10.87	Tha Pla	2,725	29,621
74	Uttaradit	10.87	Nam Pat	2,871	31,208
75	Uttaradit	10.87	Phichai	10,878	118,244
76	Uttaradit	10.87	Thong Saen Khan	16,842	183,073
77	Ang Thong	11.81	Pho Thong	2,603	30,741
78	Ang Thong	11.81	Sawaeng Ha	8,619	101,790
79	Ang Thong	11.81	Wiset Chai Chan	995	11,751
80	Ang Thong	11.81	Samko	945	11,160
81	Chai Nat	11.02	Mueang Chai Nat	627	6,910
82	Chai Nat	11.02	Manorom	976	10,756
83	Chai Nat	11.02	Wat Sing	5,446	60,015

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
84	Chai Nat	11.02	Sapphaya	73	804
85	Chai Nat	11.02	Sankhaburi	9,211	101,505
86	Chai Nat	11.02	Hankha	9,786	107,842
87	Chai Nat	11.02	King Amphoe Nong Mamong	26,651	293,694
88	Chai Nat	11.02	King Amphoe Noen Kham	51,727	570,032
89	Kanchanaburi	10.85	Mueang Kanchanaburi	67,808	735,717
90	Kanchanaburi	10.85	Sai Yok	12,059	130,840
91	Kanchanaburi	10.85	Bo Phloi	107,165	1,162,740
92	Kanchanaburi	10.85	Tha Maka	54,235	588,450
93	Kanchanaburi	10.85	Tha Muang	74,114	804,137
94	Kanchanaburi	10.85	Thong Pha Phum	1,053	11,425
95	Kanchanaburi	10.85	Phanom Thuan	30,759	333,735
96	Kanchanaburi	10.85	Lao Khwan	56,295	610,801
97	Kanchanaburi	10.85	Dan Makham Tia	44,137	478,886
98	Kanchanaburi	10.85	Nong Prue	58,527	635,018
99	Kanchanaburi	10.85	Huai Krachao	29,163	316,419
100	Lop Buri	10.76	Mueang Lop Buri	5,171	55,640
101	Lop Buri	10.76	Phatthana Nikhom	82,277	885,301
102	Lop Buri	10.76	Khok Samrong	19,359	208,303
103	Lop Buri	10.76	Chai Badan	118,334	1,273,274
104	Lop Buri	10.76	Ban Mi	11,509	123,837
105	Lop Buri	10.76	Tha Luang	69,967	752,845
106	Lop Buri	10.76	Sa Bot	14,383	154,761
107	Lop Buri	10.76	Khok Charoen	38,383	413,001
108	Lop Buri	10.76	Lam Sonthi	31,553	339,510
109	Lop Buri	10.76	Nong Muang	94,896	1,021,081
110	Nakhon Pathom	11.52	Mueang Nakhon Pathom	16,560	190,771
111	Nakhon Pathom	11.52	Kamphaeng Saen	56,448	650,281
112	Nakhon Pathom	11.52	Don Tum	342	3,940
113	Phetchaburi	10.65	Nong Ya Plong	3,487	37,137

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
114	Phetchaburi	10.65	Cha-am	13,055	139,036
115	Phetchaburi	10.65	Tha Yang	9,672	103,007
116	Phetchaburi	10.65	Kaeng Krachan	377	4,015
117	Prachuap Khiri Khan	10.16	Mueang Prachuap Khiri Khan	6,419	65,217
118	Prachuap Khiri Khan	10.16	Kui Buri	5,110	51,918
119	Prachuap Khiri Khan	10.16	Pran Buri	7,918	80,447
120	Prachuap Khiri Khan	10.16	Hua Hin	17,454	177,333
121	Prachuap Khiri Khan	10.16	King Amphoe Sam Roi Yot	5,181	52,639
122	Ratchaburi	10.26	Mueang Ratchaburi	10,607	108,828
123	Ratchaburi	10.26	Chom Bueng	64,212	658,815
124	Ratchaburi	10.26	Suan Phueng	5,633	57,795
125	Ratchaburi	10.26	Ban Pong	30,842	316,439
126	Ratchaburi	10.26	Bang Phae	632	6,484
127	Ratchaburi	10.26	Photharam	34,625	355,253
128	Ratchaburi	10.26	Pak Tho	13,012	133,503
129	Ratchaburi	10.26	King Amphoe Ban Kha	1,651	16,939
130	Saraburi	11.47	Kaeng Khoi	7,213	82,733
131	Saraburi	11.47	Muak Lek	39,416	452,102
132	Saraburi	11.47	Wang Muang	41,707	478,379
133	Saraburi	11.47	Chaloem Phra Kiat	829	9,509
134	Sing Buri	11.83	Mueang Sing Buri	885	10,470
135	Sing Buri	11.83	Bang Rachan	20,545	243,047
136	Sing Buri	11.83	Khai Bang Rachan	16,894	199,856
137	Sing Buri	11.83	Tha Chang	273	3,230
138	Sing Buri	11.83	In Buri	1,670	19,756
139	Suphan Buri	10.92	Mueang Suphan Buri	1,656	18,084
140	Suphan Buri	10.92	Doem Bang Nang Buat	49,193	537,188

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
141	Suphan Buri	10.92	Dan Chang	115,130	1,257,220
142	Suphan Buri	10.92	Si Prachan	7,829	85,493
143	Suphan Buri	10.92	Don Chedi	8,918	97,385
144	Suphan Buri	10.92	Song Phi Nong	98,517	1,075,806
145	Suphan Buri	10.92	Sam Chuk	13,694	149,538
146	Suphan Buri	10.92	U Thong	65,263	712,672
147	Suphan Buri	10.92	Nong Ya Sai	103,612	1,131,443
148	Uthai Thani	10.35	Thap Than	339	3,509
149	Uthai Thani	10.35	Sawang Arom	1,714	17,740
150	Uthai Thani	10.35	Nong Chang	4,199	43,460
151	Uthai Thani	10.35	Nong Khayang	297	3,074
152	Uthai Thani	10.35	Ban Rai	181,580	1,879,353
153	Uthai Thani	10.35	Lan Sak	27,229	281,820
154	Uthai Thani	10.35	Huai Khot	9,265	95,893
155	Chachoengsao	8.15	Phanom Sarakham	1,434	11,687
156	Chachoengsao	8.15	Sanam Chai Khet	17,204	140,213
157	Chachoengsao	8.15	Plaeng Yao	8,577	69,903
158	Chachoengsao	8.15	Tha Takiap	30,986	252,536
159	Chanthaburi	10.12	Pong Nam Ron	3,052	30,886
160	Chanthaburi	10.12	Soi Dao	16,626	168,255
161	Chon Buri	9.15	Mueang Chon Buri	1,059	9,690
162	Chon Buri	9.15	Ban Bueng	43,682	399,690
163	Chon Buri	9.15	Nong Yai	22,353	204,530
164	Chon Buri	9.15	Phan Thong	1,327	12,142
165	Chon Buri	9.15	Phanat Nikhom	13,653	124,925
166	Chon Buri	9.15	Si Racha	3,137	28,704
167	Chon Buri	9.15	Bo Thong	52,266	478,234
168	Chon Buri	9.15	King Amphoe Ko Chan	11,869	108,601
169	Prachin Buri	9.36	Kabin Buri	17,959	168,096
170	Prachin Buri	9.36	Na Di	840	7,862
171	Rayong	9.53	Wang Chan	4,014	38,253
172	Rayong	9.53	Ban Khai	404	3,850

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
173	Rayong	9.53	Pluak Daeng	10,923	104,096
174	Sa Kaeo	8.19	Mueang Sa Kaeo	15,416	126,257
175	Sa Kaeo	8.19	Khlong Hat	40,204	329,271
176	Sa Kaeo	8.19	Ta Phraya	6,012	49,238
177	Sa Kaeo	8.19	Wang Nam Yen	21,240	173,956
178	Sa Kaeo	8.19	Watthana Nakhon	27,381	224,250
179	Sa Kaeo	8.19	Aranyaprathet	37,489	307,035
180	Sa Kaeo	8.19	Khao Chakan	18,951	155,209
181	Sa Kaeo	8.19	King Amphoe Khok Sung	13,786	112,907
182	Sa Kaeo	8.19	King Amphoe Wang Sombun	18,188	148,960
183	Amnat Charoen	10.27	Mueang Amnat Charoen	2,028	20,828
184	Amnat Charoen	10.27	Chanuman	15,189	155,991
185	Amnat Charoen	10.27	Pathum Ratchawongsa	2,857	29,341
186	Amnat Charoen	10.27	Senangkhanikhom	806	8,278
187	Buri Ram	9.93	Mueang Buri Ram	2,731	27,119
188	Buri Ram	9.93	Khu Mueang	10,586	105,119
189	Buri Ram	9.93	Krasang	910	9,036
190	Buri Ram	9.93	Nang Rong	5,962	59,203
191	Buri Ram	9.93	Nong Ki	13,342	132,486
192	Buri Ram	9.93	Lahan Sai	15,246	151,393
193	Buri Ram	9.93	Prakhon Chai	654	6,494
194	Buri Ram	9.93	Ban Kruat	7,478	74,257
195	Buri Ram	9.93	Lam Plai Mat	5,084	50,484
196	Buri Ram	9.93	Satuek	10,619	105,447
197	Buri Ram	9.93	Pakham	1,794	17,814
198	Buri Ram	9.93	Na Pho	51	506
199	Buri Ram	9.93	Nong Hong	16,698	165,811
200	Buri Ram	9.93	Non Suwan	983	9,761
201	Buri Ram	9.93	Chamni	395	3,922
202	Buri Ram	9.93	Non Din Daeng	936	9,294
203	Buri Ram	9.93	King Amphoe Ban Dan	4,241	42,113

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
204	Buri Ram	9.93	King Amphoe Khaen Dong	10,089	100,184
205	Chaiyaphum	10.15	Mueang Chaiyaphum	10,503	106,605
206	Chaiyaphum	10.15	Ban Khwao	4,128	41,899
207	Chaiyaphum	10.15	Khon Sawan	8,169	82,915
208	Chaiyaphum	10.15	Kaset Sombun	41,662	422,869
209	Chaiyaphum	10.15	Nong Bua Daeng	29,761	302,074
210	Chaiyaphum	10.15	Chatturat	14,333	145,480
211	Chaiyaphum	10.15	Bamnet Narong	7,347	74,572
212	Chaiyaphum	10.15	Nong Bua Rawe	4,299	43,635
213	Chaiyaphum	10.15	Thep Sathit	7,235	73,435
214	Chaiyaphum	10.15	Phu Khiao	181,046	1,837,617
215	Chaiyaphum	10.15	Ban Thaen	19,405	196,961
216	Chaiyaphum	10.15	Kaeng Khro	29,958	304,074
217	Chaiyaphum	10.15	Khon San	44,683	453,532
218	Chaiyaphum	10.15	Phakdi Chumphon	687	6,973
219	Chaiyaphum	10.15	Noen Sa-nga	3,806	38,631
220	Chaiyaphum	10.15	King Amphoe Sap Yai	2,382	24,177
221	Kalasin	10.25	Mueang Kalasin	8,819	90,395
222	Kalasin	10.25	Na Mon	15,643	160,341
223	Kalasin	10.25	Kuchinarai	34,997	358,719
224	Kalasin	10.25	Khao Wong	104	1,066
225	Kalasin	10.25	Yang Talat	2,831	29,018
226	Kalasin	10.25	Huai Mek	18,115	185,679
227	Kalasin	10.25	Sahatsakhan	7,055	72,314
228	Kalasin	10.25	Kham Muang	17,322	177,551
229	Kalasin	10.25	Tha Khantho	33,402	342,371
230	Kalasin	10.25	Nong Kung Si	43,173	442,523
231	Kalasin	10.25	Somdet	9,621	98,615
232	Kalasin	10.25	Huai Phueng	11,204	114,841
233	Kalasin	10.25	King Amphoe Khong Chai	28,641	293,570
234	Kalasin	10.25	King Amphoe Na Khu	133	1,363

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
235	Kalasin	10.25	King Amphoe Don Chan	11,315	115,979
236	Khon Kaen	9.79	Mueang Khon Kaen	16,689	163,385
237	Khon Kaen	9.79	Ban Fang	13,602	133,164
238	Khon Kaen	9.79	Phra Yuen	1,106	10,828
239	Khon Kaen	9.79	Nong Ruea	20,295	198,688
240	Khon Kaen	9.79	Chum Phae	20,147	197,239
241	Khon Kaen	9.79	Si Chomphu	26,916	263,508
242	Khon Kaen	9.79	Nam Phong	56,230	550,492
243	Khon Kaen	9.79	Ubolratana	10,190	99,760
244	Khon Kaen	9.79	Kranuan	53,590	524,646
245	Khon Kaen	9.79	Ban Phai	22,658	221,822
246	Khon Kaen	9.79	Pueai Noi	5,552	54,354
247	Khon Kaen	9.79	Phon	3,570	34,950
248	Khon Kaen	9.79	Waeng Yai	757	7,411
249	Khon Kaen	9.79	Waeng Noi	684	6,696
250	Khon Kaen	9.79	Nong Song Hong	10,493	102,726
251	Khon Kaen	9.79	Phu Wiang	11,919	116,687
252	Khon Kaen	9.79	Mancha Khiri	32,450	115,979
238	Khon Kaen	9.79	Phra Yuen	1,106	163,385
239	Khon Kaen	9.79	Nong Ruea	20,295	133,164
240	Khon Kaen	9.79	Chum Phae	20,147	10,828
241	Khon Kaen	9.79	Si Chomphu	26,916	198,688
242	Khon Kaen	9.79	Nam Phong	56,230	197,239
243	Khon Kaen	9.79	Ubolratana	10,190	263,508
244	Khon Kaen	9.79	Kranuan	53,590	550,492
245	Khon Kaen	9.79	Ban Phai	22,658	99,760
246	Khon Kaen	9.79	Pueai Noi	5,552	524,646
247	Khon Kaen	9.79	Phon	3,570	221,822
248	Khon Kaen	9.79	Waeng Yai	757	54,354
249	Khon Kaen	9.79	Waeng Noi	684	34,950
250	Khon Kaen	9.79	Nong Song Hong	10,493	7,411
251	Khon Kaen	9.79	Phu Wiang	11,919	6,696

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
252	Khon Kaen	9.79	Mancha Khiri	32,450	317,686
253	Khon Kaen	9.79	Chonnabot	3,542	34,676
254	Khon Kaen	9.79	Khao Suan Kwang	17,970	175,926
255	Khon Kaen	9.79	Phu Pha Man	9,509	93,093
256	Khon Kaen	9.79	King Amphoe Sam Sung	13,582	132,968
257	Khon Kaen	9.79	King Amphoe Khok Pho Chai	4,796	46,953
258	Khon Kaen	9.79	King Amphoe Nong Na Kham	936	9,163
259	Khon Kaen	9.79	King Amphoe Ban Haet	19,170	187,674
260	Khon Kaen	9.79	King Amphoe Non Sila	8,721	85,379
261	Loei	10.14	Mueang Loei	244	2,474
262	Loei	10.14	Na Duang	368	3,732
263	Loei	10.14	Wang Saphung	35,837	363,387
264	Loei	10.14	Phu Kradueng	3,956	40,114
265	Loei	10.14	Phu Luang	2,488	25,228
266	Loei	10.14	Pha Khao	21,882	221,883
267	Loei	10.14	King Amphoe Erawan	13,297	134,832
268	Loei	10.14	King Amphoe Nong Hin	16,305	165,333
269	Maha Sarakham	9.52	Mueang Maha Sarakham	522	4,969
270	Maha Sarakham	9.52	Kosum Phisai	56,910	541,783
271	Maha Sarakham	9.52	Chiang Yuen	923	8,787
272	Maha Sarakham	9.52	Borabue	6,407	60,995
273	Maha Sarakham	9.52	Na Chueak	5,771	54,940
274	Maha Sarakham	9.52	Na Dun	403	3,837
275	Maha Sarakham	9.52	King Amphoe Kut Rang	22,267	211,982
276	Maha Sarakham	9.52	King Amphoe Chuen Chom	9,737	92,696
277	Mukdahan	10.03	Mueang Mukdahan	39,628	397,469
278	Mukdahan	10.03	Nikhom Kham Soi	18,143	181,974
279	Mukdahan	10.03	Don Tan	28,156	282,405
280	Mukdahan	10.03	Dong Luang	6,574	65,937

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
281	Mukdahan	10.03	Khamcha-i	7,659	76,820
282	Mukdahan	10.03	Wan Yai	1,652	16,570
283	Mukdahan	10.03	Nong Sung	3,195	32,046
284	Nakhon Phanom	10.19	Tha Uthen	347	3,536
285	Nakhon Phanom	10.19	Ban Phaeng	108	1,101
286	Nakhon Phanom	10.19	That Phanom	1,218	12,411
287	Nakhon Phanom	10.19	Na Kae	472	4,810
288	Nakhon Phanom	10.19	Si Songkhram	1,458	14,857
289	Nakhon Phanom	10.19	Na Thom	358	3,648
290	Nakhon Ratchasima	9.93	Mueang Nakhon Ratchasima	5,933	58,915
291	Nakhon Ratchasima	9.93	Khon Buri	35,364	351,165
292	Nakhon Ratchasima	9.93	Soeng Sang	9,465	93,987
293	Nakhon Ratchasima	9.93	Khong	23,738	235,718
294	Nakhon Ratchasima	9.93	Ban Lueam	27,569	273,760
295	Nakhon Ratchasima	9.93	Chakkarat	25,616	254,367
296	Nakhon Ratchasima	9.93	Chok Chai	14,299	141,989
297	Nakhon Ratchasima	9.93	Dan Khun Thot	30,809	305,933
298	Nakhon Ratchasima	9.93	Kham Sakaesaeng	6,081	60,384
299	Nakhon Ratchasima	9.93	Bua Yai	21,356	212,065
300	Nakhon Ratchasima	9.93	Pak Thong Chai	38,432	381,630

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
301	Nakhon Ratchasima	9.93	Phimai	31,798	315,754
302	Nakhon Ratchasima	9.93	Huai Thalaeng	15,873	157,619
303	Nakhon Ratchasima	9.93	Chum Phuang	12,253	121,672
304	Nakhon Ratchasima	9.93	Sung Noen	10,118	100,472
305	Nakhon Ratchasima	9.93	Kham Thale So	73	725
306	Nakhon Ratchasima	9.93	Sikhio	19,210	190,755
307	Nakhon Ratchasima	9.93	Pak Chong	56,230	558,364
308	Nakhon Ratchasima	9.93	Nong Bunnak	19,902	197,627
309	Nakhon Ratchasima	9.93	Kaeng Sanam Nang	48,052	477,156
310	Nakhon Ratchasima	9.93	Wang Nam Khiao	17,775	176,506
311	Nakhon Ratchasima	9.93	King Amphoe Thepharak	7,001	69,520
312	Nakhon Ratchasima	9.93	King Amphoe Phra Thong Kham	14,146	140,470
313	Nakhon Ratchasima	9.93	King Amphoe Lam Thamenchai	181	1,797
314	Nakhon Ratchasima	9.93	King Amphoe Bua Lai	1,219	12,105
315	Nakhon Ratchasima	9.93	Chaloem Phra Kiat	3,799	37,724
316	Nong Bua Lam Phu	10.23	Mueang Nong Bua Lam Phu	4,666	47,733

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
317	Nong Bua Lam Phu	10.23	Na Klang	4,364	44,644
318	Nong Bua Lam Phu	10.23	Non Sang	172	1,760
319	Nong Bua Lam Phu	10.23	Si Bun Rueang	29,237	299,095
320	Nong Bua Lam Phu	10.23	Suwannakhuha	3,329	34,056
321	Nong Bua Lam Phu	10.23	Na Wang	5,752	58,843
322	Nong Khai	10.09	Tha Bo	474	4,783
323	Nong Khai	10.09	Bueng Kan	71	716
324	Nong Khai	10.09	Phon Charoen	1,244	12,552
325	Nong Khai	10.09	Phon Phisai	1,922	19,393
326	Nong Khai	10.09	So Phisai	1,730	17,456
327	Nong Khai	10.09	Si Chiang Mai	1,568	15,821
328	Nong Khai	10.09	Sangkhom	513	5,176
329	Nong Khai	10.09	Seka	5,859	59,117
330	Nong Khai	10.09	Bueng Khong Long	3,802	38,362
331	Nong Khai	10.09	Si Wilai	653	6,589
332	Nong Khai	10.09	King Amphoe Sakhrai	2,057	20,755
333	Nong Khai	10.09	King Amphoe Fao Rai	3,471	35,022
334	Nong Khai	10.09	King Amphoe Pho Tak	5,031	50,763
335	Roi Et	9.94	Phon Thong	29,372	291,958
336	Roi Et	9.94	Pho Chai	14,720	146,317
337	Roi Et	9.94	Nong Phok	13,740	136,576
338	Roi Et	9.94	Selaphum	4,401	43,746
339	Roi Et	9.94	Moei Wadi	3,390	33,697
340	Sakon Nakhon	10.29	Mueang Sakon Nakhon	1,571	16,166
341	Sakon Nakhon	10.29	Kut Bak	1,302	13,398
342	Sakon Nakhon	10.29	Phanna Nikhom	3,268	33,628
343	Sakon Nakhon	10.29	Phang Khon	201	2,068

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
344	Sakon Nakhon	10.29	Waritchaphum	1,341	13,799
345	Sakon Nakhon	10.29	Nikhom Nam Un	930	9,570
346	Sakon Nakhon	10.29	Kham Ta Kla	96	988
347	Sakon Nakhon	10.29	Ban Muang	6,580	67,708
348	Sakon Nakhon	10.29	Akat Amnuai	276	2,840
349	Sakon Nakhon	10.29	Sawang Daen Din	13,599	139,934
350	Sakon Nakhon	10.29	Song Dao	16,912	174,024
351	Sakon Nakhon	10.29	Tao Ngoi	2,287	23,533
352	Sakon Nakhon	10.29	Charoen Sin	3,228	33,216
353	Sakon Nakhon	10.29	Phu Phan	3,744	38,526
354	Si Sa Ket	10.2	Phrai Bueng	51	520
355	Si Sa Ket	10.2	Prang Ku	784	7,997
356	Si Sa Ket	10.2	Huai Thap Than	90	918
357	Si Sa Ket	10.2	Phu Sing	2,421	24,694
358	Si Sa Ket	10.2	Khukhan	548	5,590
359	Surin	10.07	Mueang Surin	1,428	14,380
360	Surin	10.07	Tha Tum	473	4,763
361	Surin	10.07	Chom Phra	1,357	13,665
362	Surin	10.07	Prasat	4,611	46,433
363	Surin	10.07	Kap Choeng	10,635	107,094
364	Surin	10.07	Rattanaburi	68	685
365	Surin	10.07	Sanom	529	5,327
366	Surin	10.07	Sikhoraphum	347	3,494
367	Surin	10.07	Sangkha	13,724	138,201
368	Surin	10.07	Lamduan	295	2,971
369	Surin	10.07	Samrong Thap	63	634
370	Surin	10.07	Buachet	18,825	189,568
371	Surin	10.07	King Amphoe Phanom Dong Rak	13,166	132,582
372	Surin	10.07	King Amphoe Si Narong	10,151	102,221
373	Surin	10.07	King Amphoe Khwao Sinarin	18	181

Table B.1 The estimated sugarcane production in Thailand (Continued)

No.	Province	Average Production (tons/rai)	District	Cultivated Area of Sugarcane (rais)	Supply (tons)
374	Ubon Ratchathani	10.26	Khemarat	2,502	25,671
375	Ubon Ratchathani	10.26	Trakan Phuet Phon	134	1,375
376	Ubon Ratchathani	10.26	Kut Khaopun	435	4,463
377	Ubon Ratchathani	10.26	Pho Sai	298	3,057
378	Ubon Ratchathani	10.26	Sirindhorn	68	698
379	Udon Thani	9.82	Mueang Udon Thani	28,057	275,520
380	Udon Thani	9.82	Kut Chap	19,342	189,938
381	Udon Thani	9.82	Nong Wua So	14,107	138,531
382	Udon Thani	9.82	Kumphawapi	45,655	448,332
383	Udon Thani	9.82	Non Sa-at	82,777	812,870
384	Udon Thani	9.82	Nong Han	10,784	105,899
385	Udon Thani	9.82	Thung Fon	1,281	12,579
386	Udon Thani	9.82	Chai Wan	32,036	314,594
387	Udon Thani	9.82	Si That	72,956	716,428
388	Udon Thani	9.82	Wang Sam Mo	91,435	897,892
389	Udon Thani	9.82	Ban Dung	12,515	122,897
390	Udon Thani	9.82	Ban Phue	19,452	191,019
391	Udon Thani	9.82	Nam Som	12,121	119,028
392	Udon Thani	9.82	Phen	1,016	9,977
393	Udon Thani	9.82	Sang Khom	199	1,954
394	Udon Thani	9.82	Nong Saeng	32,643	320,554
395	Udon Thani	9.82	Na Yung	6,584	64,655
396	Udon Thani	9.82	Phibun Rak	2,623	25,758
397	Udon Thani	9.82	King Amphoe Ku Kaeo	14,003	137,509
398	Udon Thani	9.82	King Amphoe Prachaksinlapakhom	938	9,211
399	Yasothon	10.49	Mueang Yasothon	454	4,762
400	Yasothon	10.49	Sai Mun	738	7,742
401	Yasothon	10.49	Kut Chum	2,195	23,026
402	Yasothon	10.49	Pa Tio	920	9,651
403	Yasothon	10.49	Loeng Nok Tha	16,488	172,959
404	Yasothon	10.49	Thai Charoen	1,341	14,067

APPENDIX C
DISTANCE MATRIX

The appendix shows an example on how to calculate the transportation distances from a group of 404 sugarcane fields to one sugar mill, which is New Kwang Soon Lee mill. Distances for all other sugar mills can be calculated with the same procedures. Here are detailed procedures for the distance calculation.

1) Add all data needed for distance calculation into the View of ArcMap. These are datasets of Transport FGDS (polyline layer), 404 groups of field areas (point layer), and position of New Kwang Soon Lee (point layer). These data were displayed together as shown in Figure C.1.

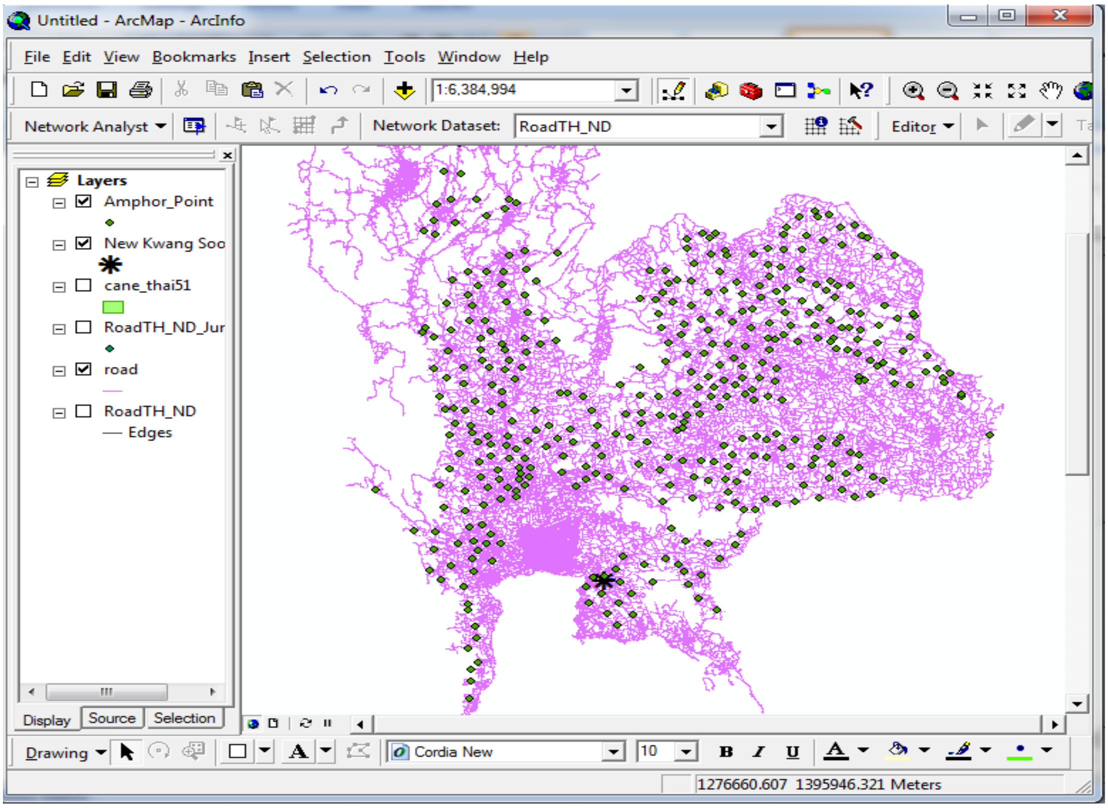


Figure C.1. Required datasets for distance calculation are displayed together

2) The calculation of distances from 404 groups of the sugarcane fields to the New Kwang Soon Lee can be conducted by using Network Analyst Extension. To start the calculation, click on the tool of Network Analyst in the Toolbars, and select "New Closest Facility", as shown in Figure C.2.

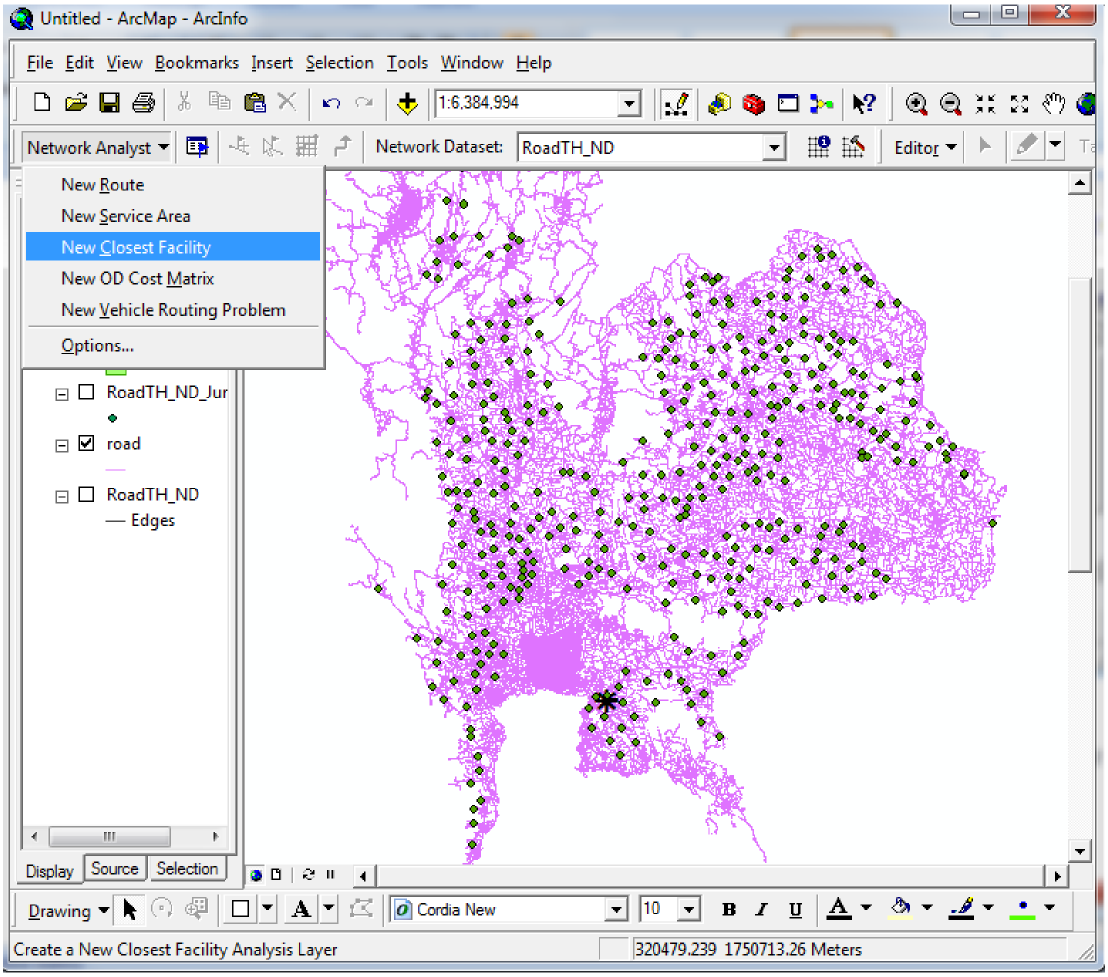


Figure C.2 Using New Closest Facility function of Network Analyst

3) The Closest Facility Layer function of Network Analyst Window can then be displayed as shown in Figure C.3.

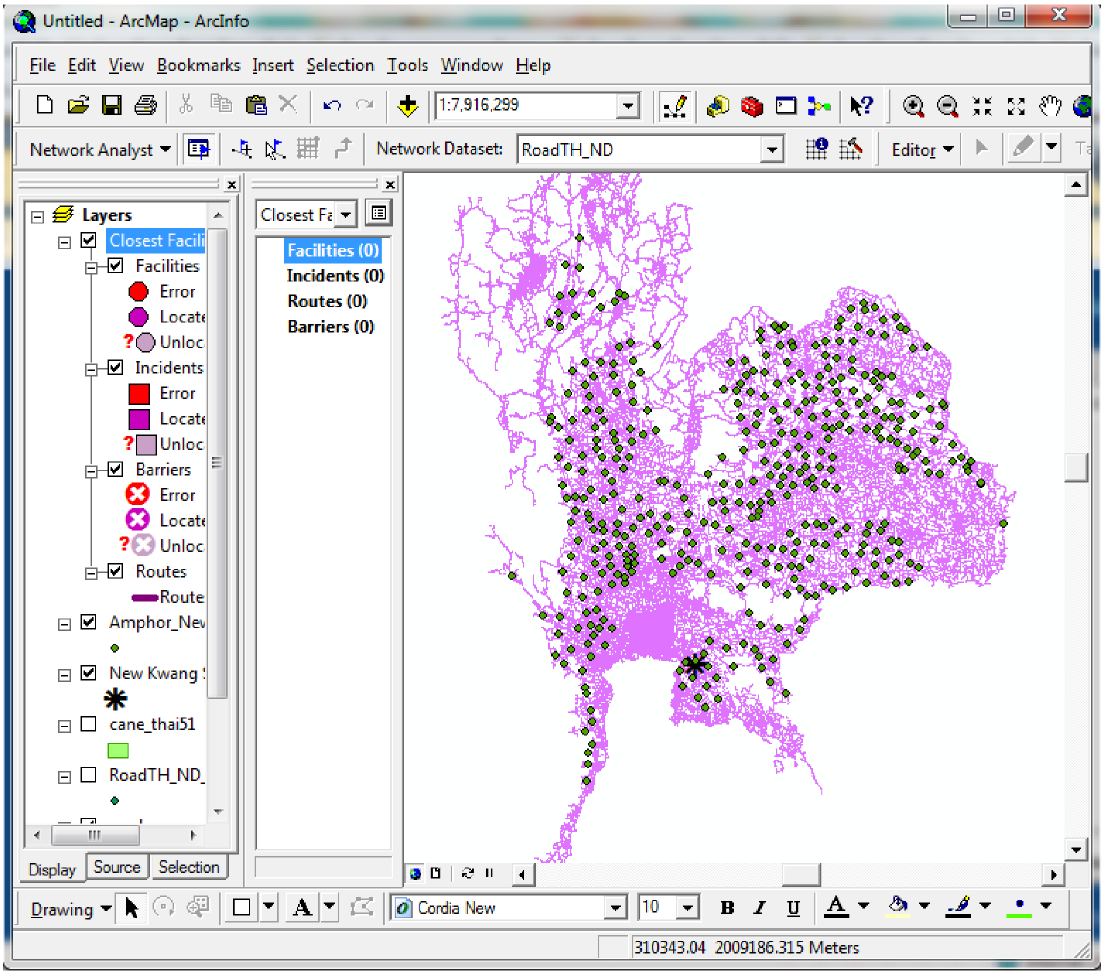


Figure C.3 The Closest Facility Layer function in Network Analyst Window

4) Click at the button  to open the Property Window of Closest Facility Layer. Then determine properties for the analysis. According to requirement of this research, two main sets of properties are needed to be specified here.

- Go to the Analysis Settings tab to specify locations that we want to do the distance calculation. In this case we want to find distances from groups of the sugarcane fields to a sugar mill. Therefore, in the Travel From section, we selected the "Incident to Facility" option as shown in Figure C.4.

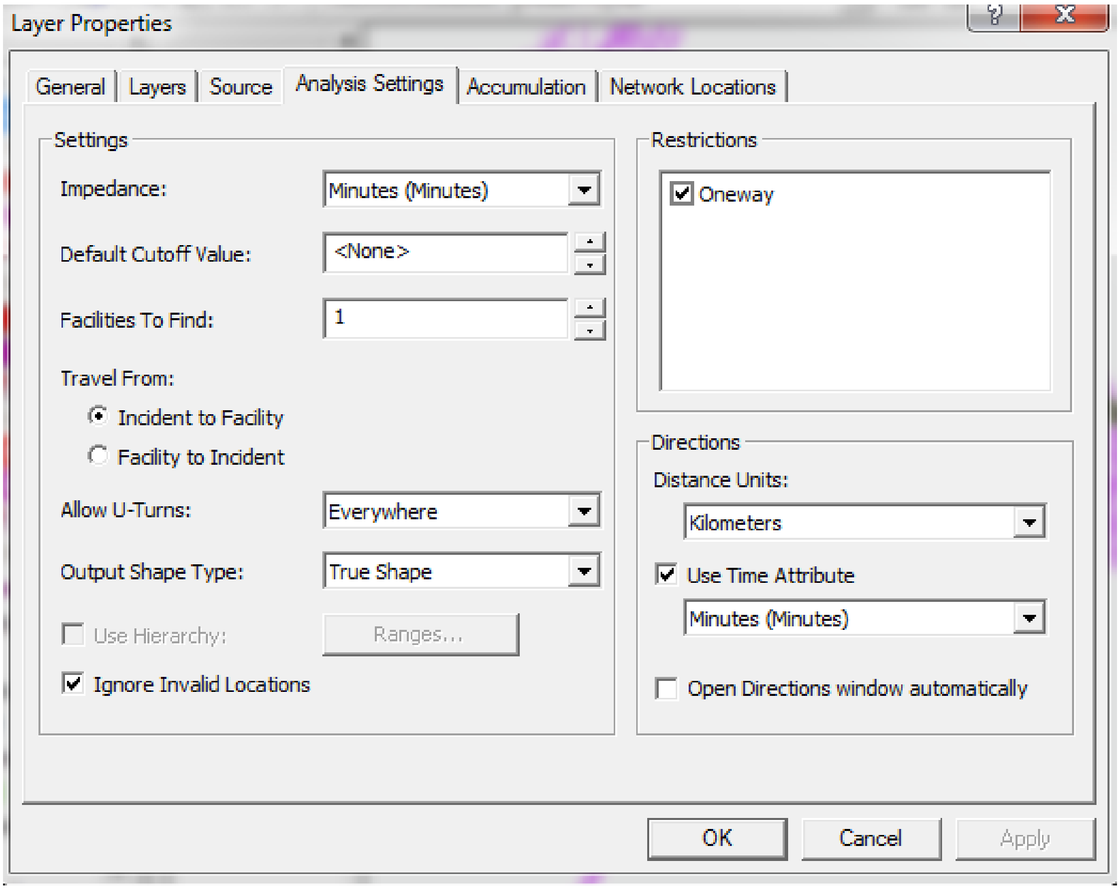


Figure C.4 Determining properties of distance calculation in the Analysis Settings tab

- Go to the Accumulation tab to specify types of outputs. The distance calculation of Network Analyst can give outputs in Meters and/or Minutes. Since this research requires only distances without time, thus we choose only “Meters” option here, as shown in Figure C.5. Then click OK to finish specifying the properties of distance calculation.

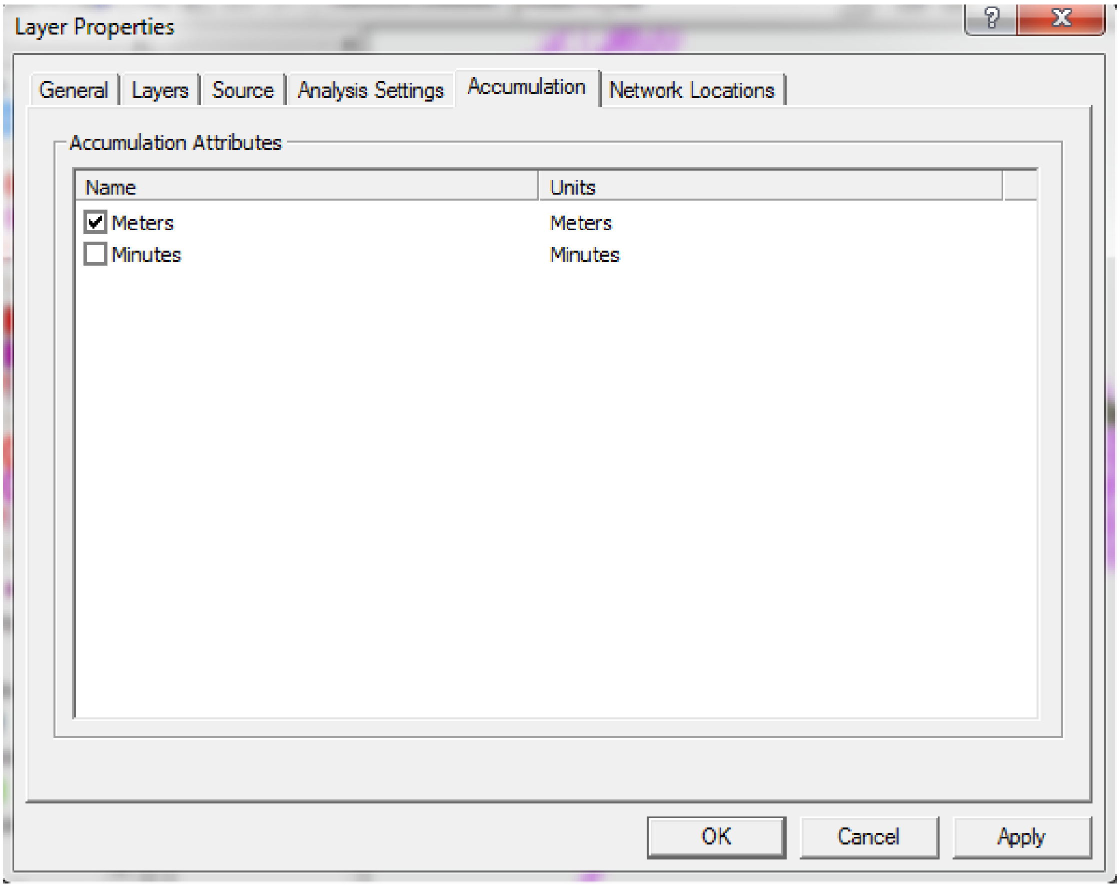


Figure C.5 Determining properties of distance calculation in the Accumulation tab

5) Then right-click at the Facilities item in Network Analyst Window, and choose Load Locations as shown in Figure C.6.

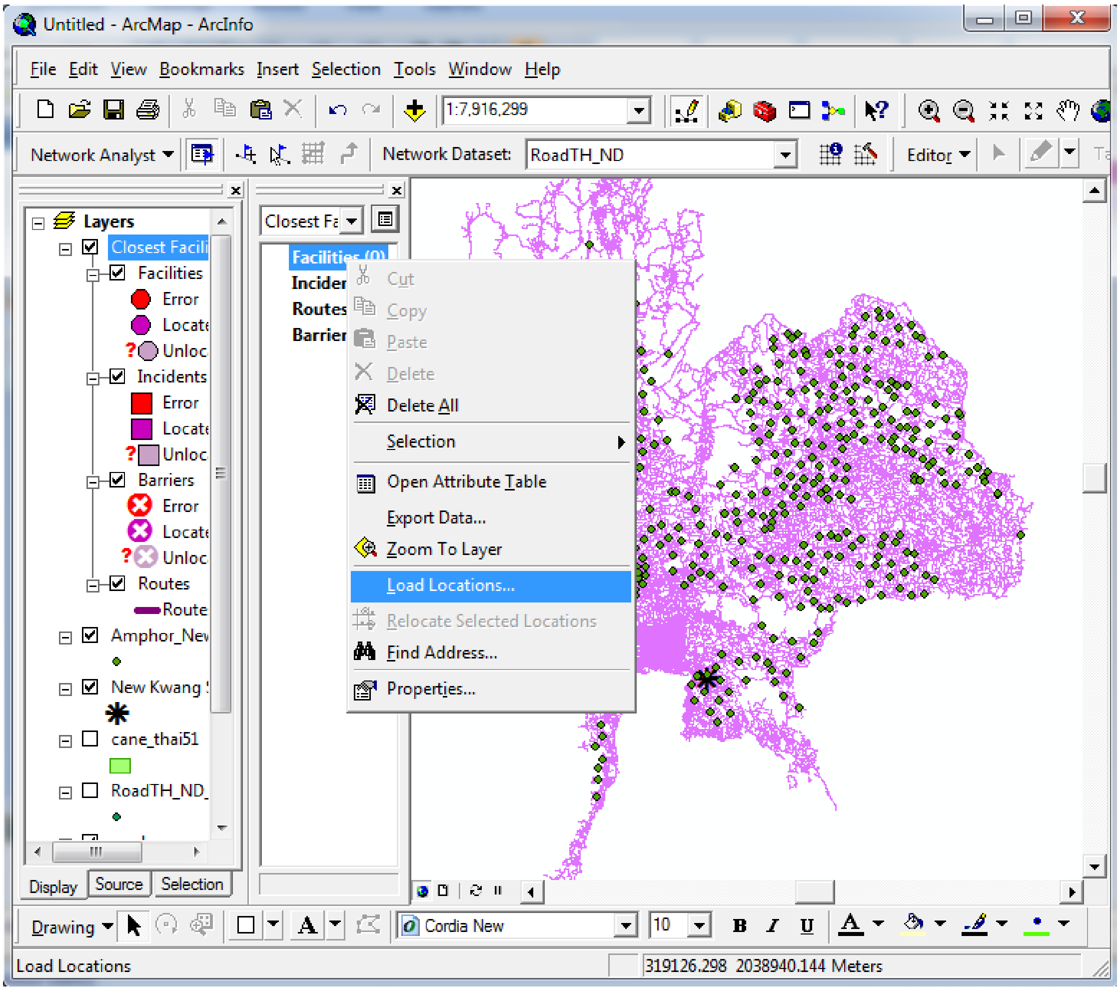


Figure C.6 Load locations of the facilities to be calculated for distances

6) Specify the location of the facility (i.e., the New Kwang Soon Lee), then click OK, as shown in Figure C.7.

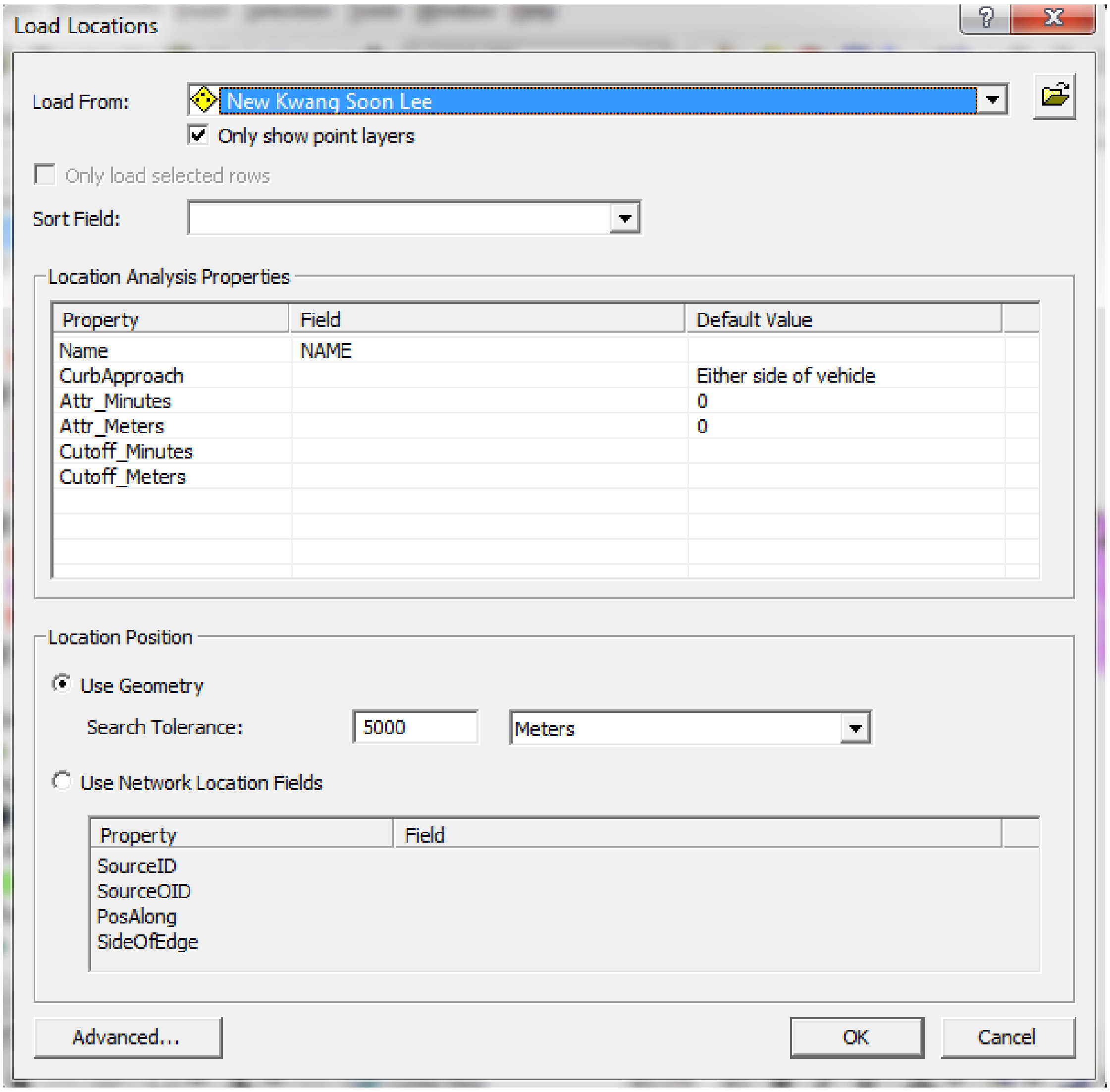


Figure C.7 Load Locations window for specifying the facility

7) Right-click at the Incidents item in the Network Analyst Window, and choose Load Locations as shown in Figure C.8.

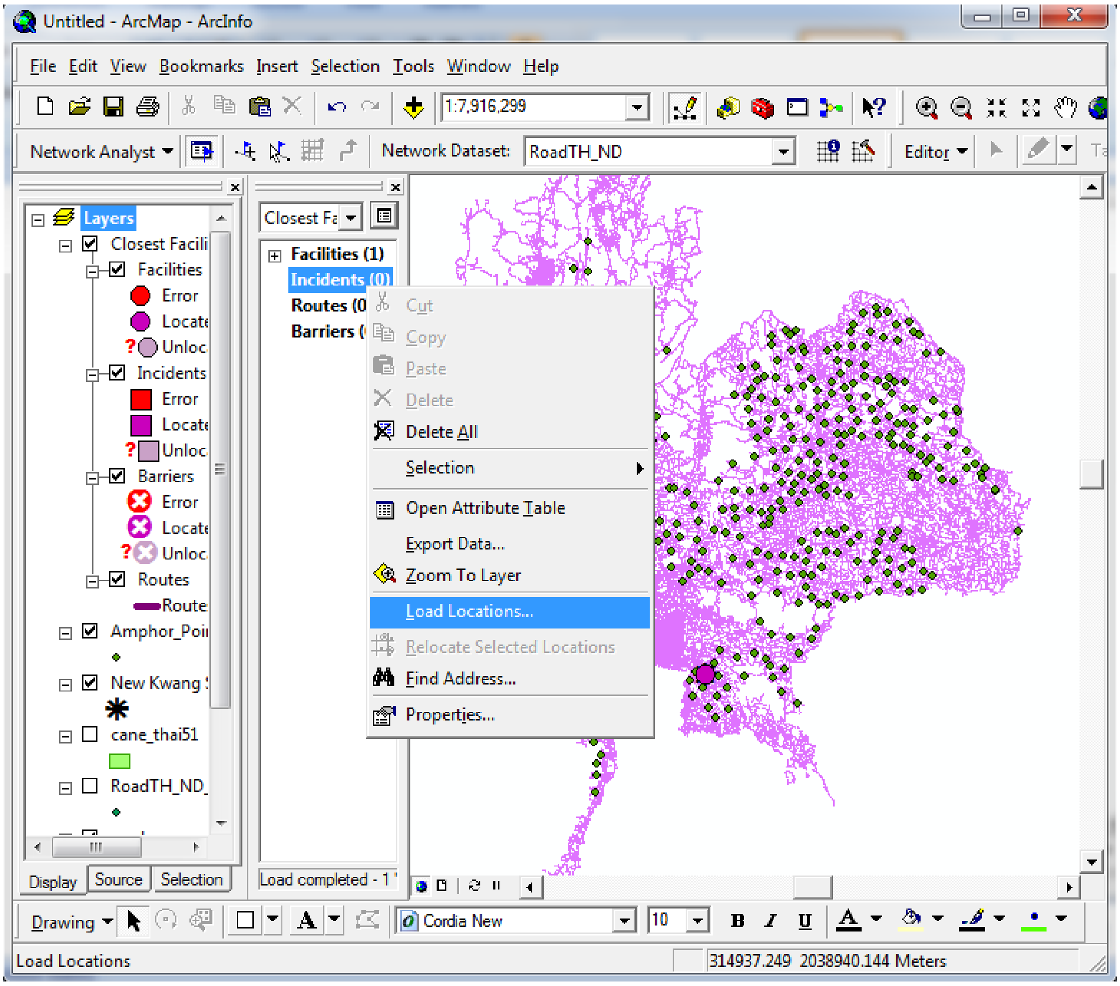


Figure C.8 Load locations of incidents, which are groups of cane fields

8) Specify locations of groups of cane fields as the incidents, and then click OK, as shown in Figure C.9.

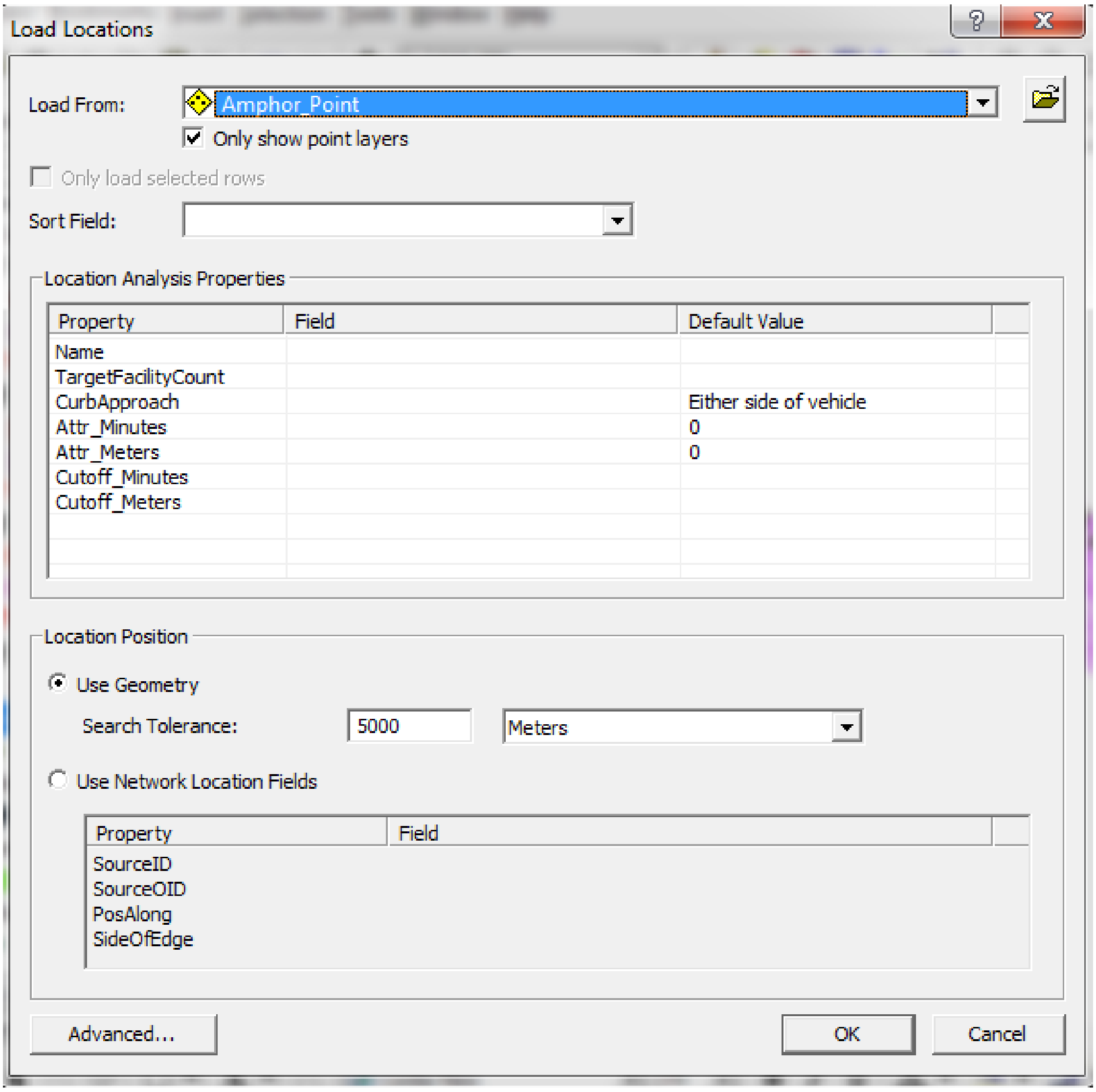


Figure C.9 Load locations of incidents from the layer of cane field groups

9) After finishing specifying locations of Facility and Incidents to be used for distance calculation, click at the Solve button  in order to find distances from all 404 groups of sugarcane fields to the New Kwang Soon mill. As shown in Figure C.10, it can be seen that after completing the distance calculation, the program will process and display results as routes from the groups of the sugarcane fields to the sugar mill.

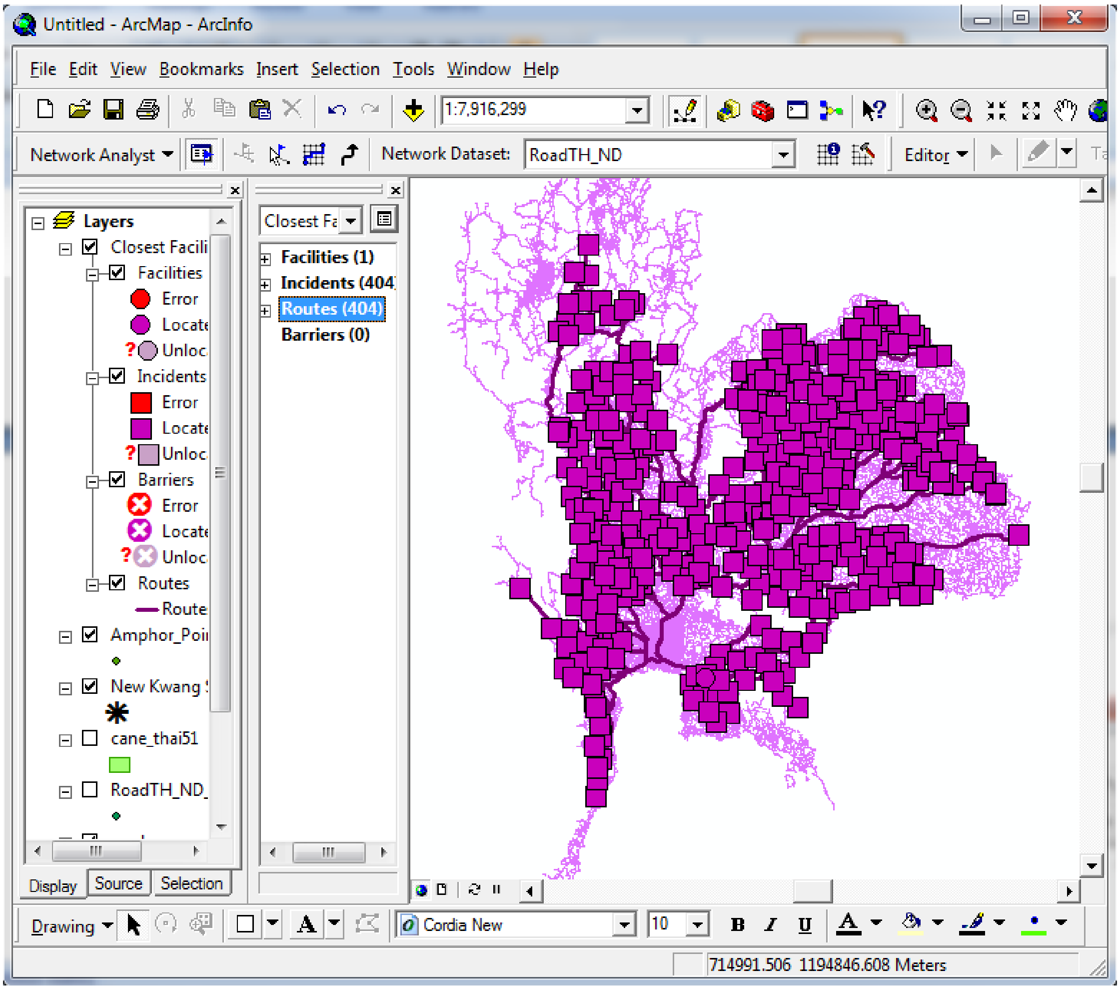


Figure C.10 Routes from field groups of sugarcane fields to New Kwang Soon Lee mill

10) Right-click at the Routes (404), and choose Open Attribute Table as shown in Figure C.11.

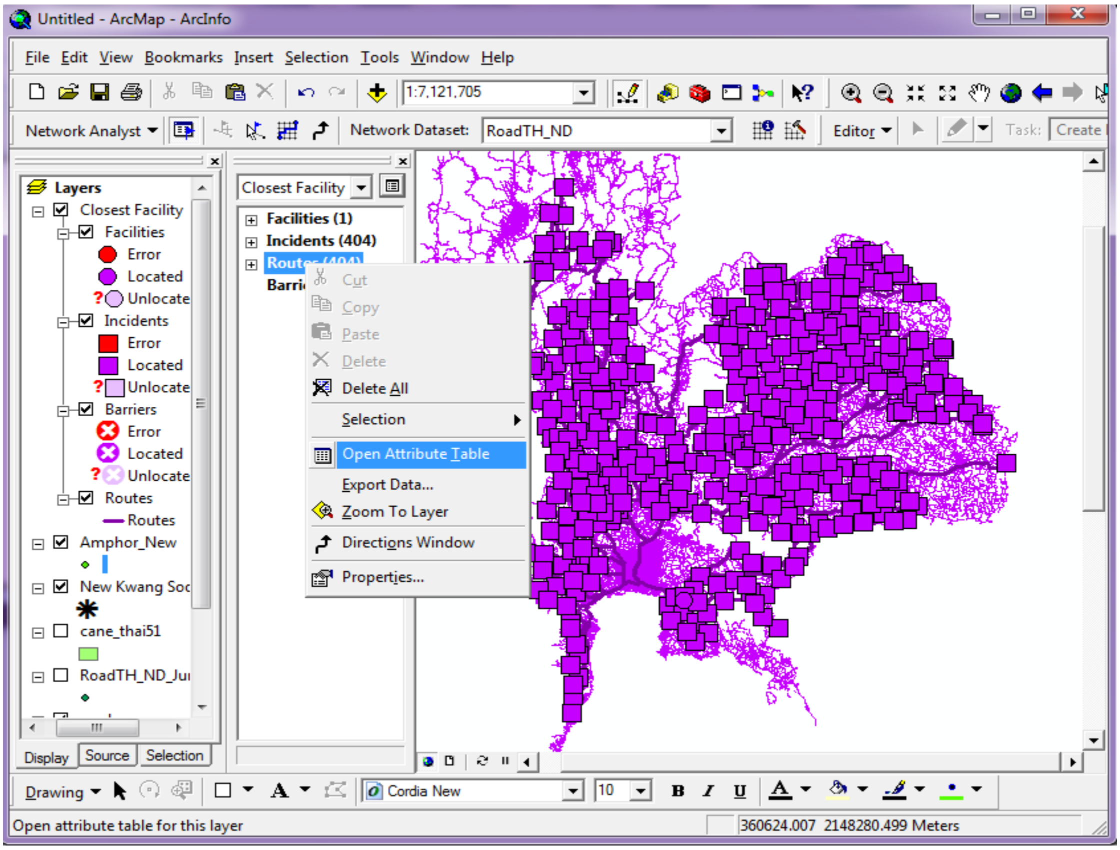
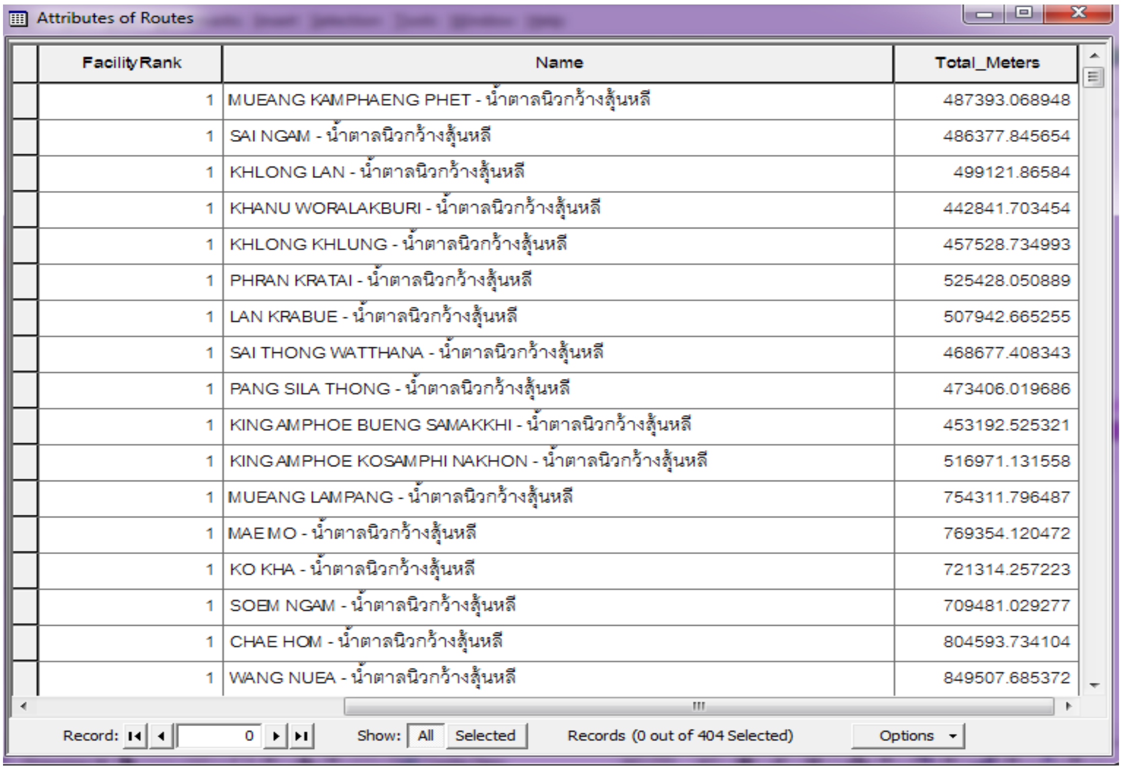


Figure C.11 Open Attribute Table

11) The distance data from the 404 groups of the sugarcane fields (Incidents) to New Kwang Soon Lee mill (Facilities) as shown in Figure C.12.



Attributes of Routes

FacilityRank	Name	Total_Meters
1	MUEANG KAMPHAENG PHET - น้ำตาลนิวกว้างสุ้นหลี	487393.068948
1	SAI NGAM - น้ำตาลนิวกว้างสุ้นหลี	486377.845654
1	KHLONG LAN - น้ำตาลนิวกว้างสุ้นหลี	499121.86584
1	KHANU WORALAKBURI - น้ำตาลนิวกว้างสุ้นหลี	442841.703454
1	KHLONG KHLUNG - น้ำตาลนิวกว้างสุ้นหลี	457528.734993
1	PHRAN KRATAI - น้ำตาลนิวกว้างสุ้นหลี	525428.050889
1	LAN KRABUE - น้ำตาลนิวกว้างสุ้นหลี	507942.665255
1	SAI THONG WATTHANA - น้ำตาลนิวกว้างสุ้นหลี	468677.408343
1	PANG SILA THONG - น้ำตาลนิวกว้างสุ้นหลี	473406.019686
1	KING AMPHOE BUENG SAMAKKHI - น้ำตาลนิวกว้างสุ้นหลี	453192.525321
1	KING AMPHOE KOSAMPHI NAKHON - น้ำตาลนิวกว้างสุ้นหลี	516971.131558
1	MUEANG LAMPANG - น้ำตาลนิวกว้างสุ้นหลี	754311.796487
1	MAE MO - น้ำตาลนิวกว้างสุ้นหลี	769354.120472
1	KO KHA - น้ำตาลนิวกว้างสุ้นหลี	721314.257223
1	SOEM NGAM - น้ำตาลนิวกว้างสุ้นหลี	709481.029277
1	CHAE HOM - น้ำตาลนิวกว้างสุ้นหลี	804593.734104
1	WANG NUEA - น้ำตาลนิวกว้างสุ้นหลี	849507.685372

Record: 0 Show: All Selected Records (0 out of 404 Selected) Options

Figure C.12 The distance data

12) Right-click at the Options, and choose Export in order to save distance data on each file which needed shown in Figure C.13.

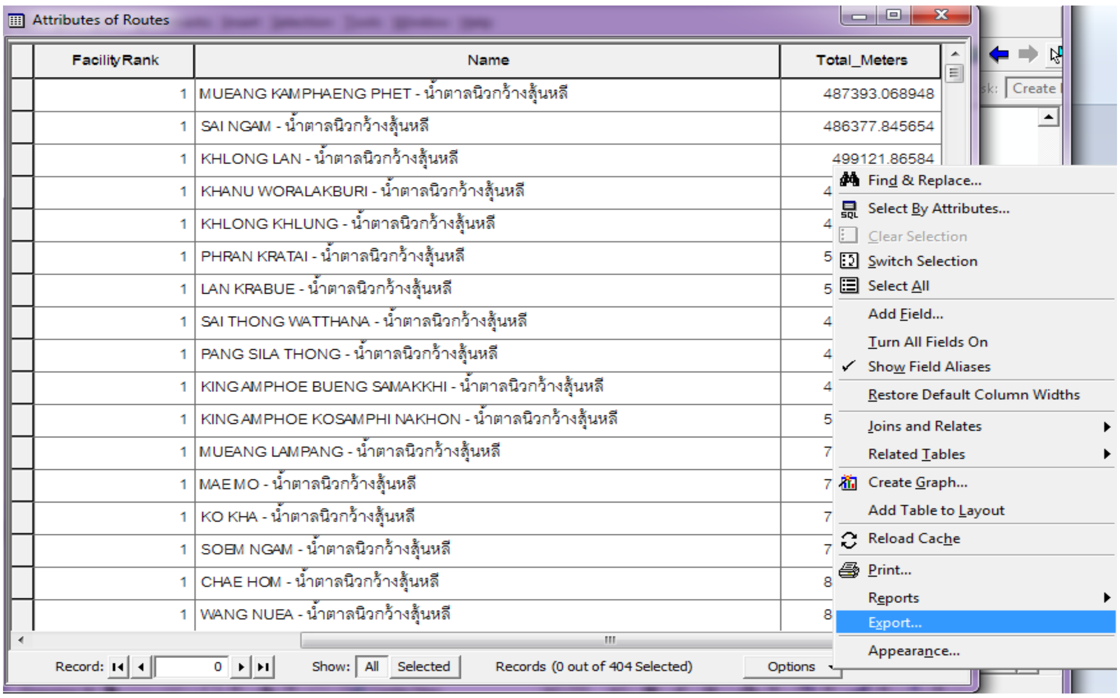


Figure C.13 Exporting of the data distance

13) Save as Distance Matrix.xls, as shown in Figure C.14.

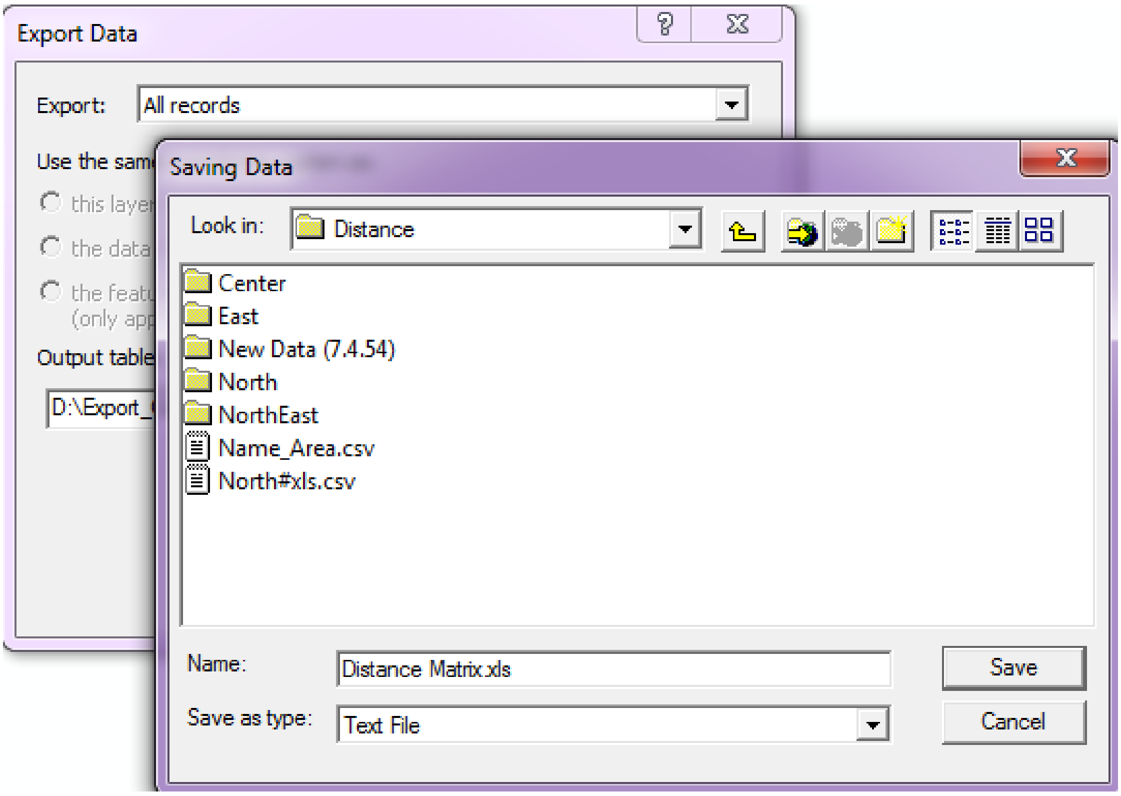


Figure C.14 To define output Text File

14) Processing Export CFRoutes table, as shown in Figure C.15.

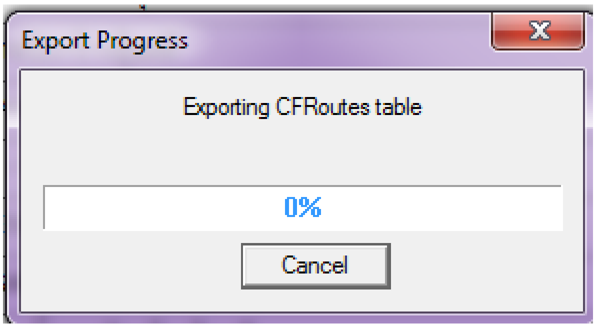


Figure C.15 Processing of export CFRoutes table

15) Export of the distance data as a Microsoft Excel file, as shown in Figure C.16. The distance may be converted from Meters to Kilometers. Distances for all other sugar mills can be calculated with the same procedures.

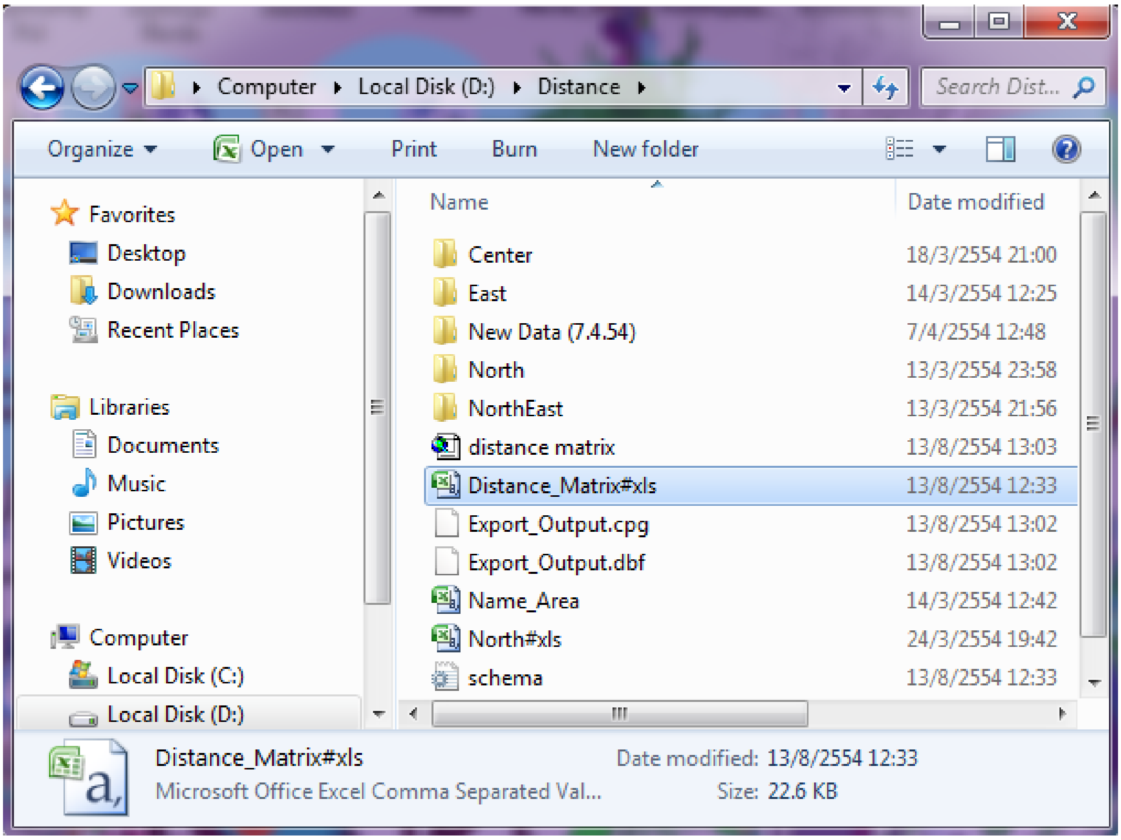


Figure C.16 Distance data in Microsoft Excel file

APPENDIX D
A PUBLICATION IN THE NATIONAL CONFERENCE ON INDUSTRIAL ENGINEERING 2010

การประชุมวิชาการวิศวกรรมอุตสาหการแห่งชาติ 2010
เพื่อเฉลิมพระเกียรติพระบาทสมเด็จพระเจ้าอยู่หัวฯ เนื่องในวโรกาสทรงพระชนมายุ 84 พรรษา

ผลกระทบของการเปิดเสรีโรงงานน้ำตาลที่มีต่อระบบโลจิสติกส์ขาเข้าของอ้อยและการผลิตน้ำตาล

Impact of Sugar Mill Liberalization on Inbound Logistics of Cane and Sugar Production

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บทคัดย่อ : ประเด็นการเปิดเสรีโรงงานน้ำตาลเป็นข่าวปรากฏตามสื่อสารมวลชนอยู่เป็นประจำ แม้ว่าขณะนี้ประเทศไทยจะมีโรงงานน้ำตาลที่ได้รับอนุญาตแล้วจำนวนมากถึง 47 แห่งกระจายอยู่ทั่วประเทศ การถกเถียงยังไม่สามารถหาข้อสรุปได้ว่าควรให้มีการเปิดเสรีโรงงานน้ำตาลหรือไม่ งานวิจัยนี้นำประเด็นดังกล่าวมาศึกษาวิเคราะห์ในมุมมองของการจัดการด้านโลจิสติกส์ว่าการเปิดเสรีจะส่งผลกระทบอย่างไรต่อกระบวนการโลจิสติกส์ขาเข้าของอ้อยสู่โรงงานและการผลิตน้ำตาลทรายของโรงงานในระบบบ โดยใช้กรณีศึกษาในพื้นที่ภาคตะวันออกเป็นตัวอย่างการวิเคราะห์ อาศัยข้อมูลจากระบบภูมิศาสตร์สารสนเทศ (Geographic Information Systems: GIS) ซึ่งแสดงทำเลที่ตั้งของโรงงานและกำลังการผลิต พื้นที่ปลูกอ้อย อัตราผลผลิต ประกอบกับมีตัวแบบจำลองคณิตศาสตร์เป็นเครื่องมือ ผลลัพธ์ที่ได้แสดงให้เห็นว่าการเปิดเสรีโรงงานน้ำตาลในพื้นที่ดังกล่าวอาจก่อให้เกิดการเปลี่ยนแปลงรูปแบบการขนส่งอ้อย และส่งผลกระทบต่ออัตราการใช้กำลังผลิตของโรงงานน้ำตาลทั้งหลายย ในเชิงนโยบายอาจจะมองได้ว่าการเปิดเสรีโรงงานน้ำตาลนั้นจะต้องคำนึงถึงสมดุลระหว่างหลายองค์ประกอบ และควรทำการศึกษาวิจัยอย่างจริงจังก่อนตัดสินใจ

ABSTRACT : The liberalization of sugar mill has been a hot issue debated on public media regularly. Although Thailand now has 47 sugar mills in service, the debate is still going on whether more sugar mills should be allowed. This research analyzed this issue from the perspective of its impact on sugar cane inbound logistics and the utilization of sugar mill production capacity. Using a case study of the eastern region, Geographic Information Systems database and a mathematical model, the results showed that the liberalization sugar mill in the eastern region would likely change the distribution pattern of sugar cane, increase the transportation distance, and lower the utilization of production capacity. However, the system transportation cost seems to be lower. Therefore, from the policy making perspective, the liberalization of sugar mill needs to consider the balance between several components of the industry. This is an important research question subject to serious further investigation before a good decision can be reached.

KEYWORDS : Sugar Cane; Sugar Mill; Liberalization; Inbound Logistics

1. ความเป็นมาและความสำคัญของปัญหางานวิจัย

จากกระแสของเศรษฐกิจโลกในปัจจุบันนี้มีแนวโน้มไปสู่ระบบเสรีมากขึ้น ซึ่งรวมถึงอุตสาหกรรมอ้อยและน้ำตาลทรายใน ประเทศไทยด้วย ทำให้เกิดคำถามที่ว่ารัฐบาลควรดำเนินนโยบายให้มีการตั้งโรงงานน้ำตาลขึ้นใหม่ ย้ายโรงงาน และ/หรือขยายกำลังผลิตได้อย่างเสรีหรือไม่ ด้วยเหตุนี้จึงทำให้มีการ

ถกเถียงกันอย่างกว้างขวางในหมู่นักวิชาการที่สนใจและผู้ที่มีผลประโยชน์เกี่ยวข้องกับอุตสาหกรรมนี้ โดยมีความคิดเห็นแตกต่างกันในมุมมองด้านผลประโยชน์เป็นสำคัญ [1] และถึงแม้ยังไม่สามารถหาข้อสรุปได้ แต่ทางคณะรัฐมนตรีก็มีการอนุญาตให้ย้ายโรงงานน้ำตาลทรายจากเขตที่มีปริมาณอ้อยไม่เพียงพอไปสู่เขตที่มี ปริมาณ อ้อยที่มากขึ้น และให้โอกาสขยายกำลังการผลิตได้ตามความเหมาะสมของปริมาณอ้อยในเขตที่ตั้งใหม่ รวมถึงอนุญาตให้โรงงานน้ำตาลที่มีอยู่เดิมที่ตั้งอยู่ในเขตที่มีปริมาณอ้อยเกินกว่า กำลังการผลิตของโรงงานที่มีอยู่ สามารถขยายกำลังการผลิตเพิ่มขึ้นได้ตามความเหมาะสมกับปริมาณอ้อยในบริเวณนั้นๆ ทั้งนี้เป็นการพิจารณาถึงปริมาณอ้อยที่จะทำการขนส่งเข้าโรงงานน้ำตาลเพื่อให้เหมาะสมกับกำลังการผลิต ซึ่งแสดงให้เห็นว่าที่ตั้งโรงงานน้ำตาลกับพื้นที่เพาะปลูกอ้อยมีความสัมพันธ์ต่อกัน ดังนั้นก่อนที่มีการเปิดเสรีโรงงานน้ำตาลขึ้นมาจริง สิ่งแรกที่ ควรศึกษา คือ วิเคราะห์ในมุมมองของการจัดการด้านโลจิสติกส์ว่าจะก่อให้เกิดผลกระทบอย่างไร เช่น รูปแบบการขนส่งอ้อย และอัตราการใช้กำลังผลิตของโรงงานน้ำตาล ซึ่งผลลัพธ์ที่ได้ใน เชิงนโยบายอาจจะมองได้ว่าการเปิดเสรีโรงงานน้ำตาลนั้นจะต้อง คำนึงถึงความสมดุลอะไรบ้าง

2. ทบทวนเอกสารงานวิจัย

อุตสาหกรรมอ้อยและน้ำตาลเป็นอุตสาหกรรมการเกษตรที่สำคัญ ที่มีความเชื่อมโยงกับการเพาะปลูกอ้อยซึ่งเป็นวัตถุดิบที่สำคัญ โดยที่ตั้งโรงงานน้ำตาลกับแหล่งเพาะปลูกอ้อยจะมีความสัมพันธ์ ต่อกัน [2] ดังนั้นพื้นที่ปลูกอ้อยจะต้องไม่ควรอยู่ห่างจากโรงงาน เพราะถ้าอยู่ไกลเกินไปจะเสียค่าขนส่งสูง [3] ในปัจจุบันปริมาณการขนส่งอ้อยเข้าสู่โรงงานน้ำตาลจะขึ้นอยู่กับกำลังการผลิตของ โรงงาน เพื่อให้ปริมาณอ้อยที่เข้าสู่กระบวนการผลิตน้ำตาลทราย เป็นไปอย่างต่อเนื่องและเต็มกำลังการผลิต [4] ซึ่งถ้าในอนาคตการค้าน้ำตาลในตลาดเป็นไปโดยเสรี ประเทศไทยซึ่งเป็น ประเทศ ผู้ผลิตและส่งออกน้ำตาลรายใหญ่ประเทศหนึ่งจะ สามารถส่งออกน้ำตาลได้มากขึ้น [5] เหตุผลเดียวกันถ้ามีการเปิดเสรีโรงงานน้ำตาลขึ้นก็จะมีการขยายกำลังในการผลิตเพิ่มมากขึ้นนซึ่งอาจทำให้เกิดปัญหามีผลผลิตอ้อยไม่เพียงพอต่อการหีบอ้อย จึงควรมีการขยายกำลังการผลิตอ้อยให้มากขึ้น [6] ซึ่งจากการทบทวนเอกสารและงานวิจัยที่ผ่านมาแสดงให้เห็นว่าที่ตั้งโรงงานน้ำตาลกับพื้นที่เพาะปลูกอ้อยมีความสัมพันธ์ต่อกัน ดังนั้นก่อนที่มีการเปิดเสรีโรงงานน้ำตาลขึ้นมาจริง จึงควรทำการศึกษา วิจัยก่อนการตัดสินใจ โดยงานวิจัยนี้เป็นการศึกษาถึงผลกระทบที่อาจก่อให้เกิดการเปลี่ยนแปลงรูปแบบการขนส่งอ้อย และอัตราการใช้กำลังผลิตจากการเปิดเสรีโรงงานน้ำตาล โดยใช้แบบจำลองคณิตศาสตร์โปรแกรมเชิงเส้นตรง (Linear Programming: LP) มาช่วยในการคำนวณการขนส่งจากพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาล [7-10] เพื่อคำนวณต้นทุนรวมของการขนส่งต่ำที่สุด อีกทั้งยังสามารถนำไปช่วยวิเคราะห์ถึงอัตราการใช้กำลังผลิตโดยรวมของโรงงานน้ำตาล จากการเปรียบเทียบปริมาณอ้อยที่แต่ละพื้นที่ปลูกอ้อยส่งเข้าไปยังโรงงานน้ำตาลกับปริมาณอ้อยที่โรงงานต้องการใช้ในการผลิต น้ำตาลได้อีกด้วย และมีการใช้ระบบสารสนเทศภูมิศาสตร์มาประยุกต์ใช้เพื่อศึกษาถึงผลกระทบที่อาจก่อให้เกิดการเปลี่ยนแปลงรูปแบบการขนส่งอ้อยจากการเปิดเสรีโรงงานน้ำตาล ในกรณีที่มีการเปลี่ยนแปลงจำนวนโรงงานน้ำตาล โดยการแสดงทำเลที่ตั้งของโรงงานและพื้นที่ปลูกอ้อย

3. ขั้นตอนการดำเนินงานวิจัย

เริ่มจากการกำหนดขอบเขตกรณีศึกษา จากนั้นทำการเก็บข้อมูล รวมถึงพัฒนาแบบจำลองคณิตศาสตร์โปรแกรมเชิงเส้นตรงของการขนส่ง เพื่อวิเคราะห์รูปแบบการกระจายอ้อยเข้าสู่โรงงานและนำปริมาณการขนส่งอ้อยไปคำนวณอัตราการใช้กำลังผลิตของโรงงานน้ำตาล (Utilization) แต่ละโรงงานในระบบ เพื่อศึกษาถึงผลกระทบที่เกิดจากการเปิดเสรีโรงงานน้ำตาล

3.1 กรณีศึกษา

ผู้วิจัยได้เลือกใช้กรณีศึกษาในพื้นที่ภาคตะวันออกเป็นตัวอย่างในการวิเคราะห์ข้อมูลในเบื้องต้น โดยภาคตะวันออกมีโรงงานอุตสาหกรรมอ้อยและน้ำตาล 5 แห่ง [11] และมีขนาดพื้นที่เพาะปลูกอ้อย 460,043 ไร่ โดยงานวิจัยนี้ทำการแบ่งพื้นที่เพาะปลูกออกเป็น 28 กลุ่ม ตามรายอำเภอที่ทำการปลูกอ้อยในภาคตะวันออก เพื่อความสะดวกในการคำนวณ

3.2 ตัวแบบจำลองคณิตศาสตร์

เนื่องจากงานวิจัยนี้เป็นการวิเคราะห์ในมุมมองของการจัดการด้านโลจิสติกส์ว่าการเปิดเสรีจะส่งผลกระทบอย่างไรต่อกระบวนการโลจิสติกส์ขาเข้าของอ้อยสู่โรงงาน การวิเคราะห์ด้านการขนส่งนั้นเป็นส่วนหนึ่งของกระบวนการโลจิสติกส์ด้วย

เมื่อพิจารณาถึงลักษณะของปัญหาที่กำลังทำการวิเคราะห์จึงเห็นว่าตัวแบบจำลองคณิตศาสตร์การขนส่ง (Transportation Problem) มีความเหมาะสมสามารรถนำมาใช้เป็นเครื่องมือในปริมาณอ้อยที่โรงงานแต่ละแห่งควรจะได้รับเพื่อให้ระบบมีต้นทุนการขนส่งที่ต่ำที่สุด แบบจำลองการขนส่งนั้นมีลักษณะไม่ซับซ้อนและง่ายต่อการทำความเข้าใจ ดังต่อไปนี้

Objective Function: Minimize Total Transportation Cost

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

Constrains $$\sum_{i=1}^{m} X_{ij} \le S_j \quad ; \forall_j \qquad (2)$$

$$\sum_{j=1}^{n} X_{ij} \ge D_i \quad ; \forall_i \qquad (3)$$

$$X_{ij} \ge 0 \qquad (4)$$

โดยที่

C_{ij} = ระยะทางการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย j ไปยังโรงงาน i (กิโลเมตร)

X_{ij} = ปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย j ไปยังโรงงาน i (ตัน)

D_i = ปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิต (ตัน)

S_j = ปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อย (ตัน)

i = โรงงานน้ำตาลในภาคตะวันออก; i = 1,2,3,4

j = กลุ่มพื้นที่เพาะปลูกอ้อยในภาคตะวันออก; j = 1, 2,…, 29 โดยที่ 29 คือ dummy location

m = จำนวนโรงงานน้ำตาลในภาคตะวันออก

n = จำนวนกลุ่มพื้นที่เพาะปลูกอ้อยในภาคตะวันออก

โดยในแบบจำลองนี้ฟังก์ชั่นวัตถุประสงค์ (1) คือ เพื่อให้ต้นทุนค่าขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงานอุตสาหกรรมอ้อยและน้ำตาลในภาคตะวันออกโดยรวมต่ำที่สุด เงื่อนไขใน (2) เป็นเงื่อนไขบังคับของปัญหาปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยใดๆ หมายถึงปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อยใดๆไปยังโรงงานน้ำตาลโดยรวมทั้งหมดจะต้องไม่เกินปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยนั้นๆ เงื่อนไขใน (3) เป็นเงื่อนไขบังคับของปัญหาปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิต หมายถึงปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาลโดยรวมทั้งหมดจะต้องไม่น้อยกว่าปริมาณความต้องการอ้อยที่โรงงานน้ำตาลต้องการในการผลิต และเงื่อนไขใน (4) หมายถึงจำนวนปริมาณอ้อยที่ส่งจากกลุ่มพื้นที่ส่งอ้อยไปยังโรงงานน้ำตาล ต้องไม่ติดลบ

เนื่องการใช้ตัวแบบการขนส่งมาทำการตัดสินใจแก้ปัญหานั้นจำเป็นที่ผลรวมของปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยต้องเท่ากับผลรวมของปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิต ($\sum_{j=1}^{n} S_j = \sum_{i=1}^{m} D_i$) ดังนั้นจึงจำเป็นต้องมีการปรับข้อมูลให้สามารถใช้กับตัวแบบได้ โดยใช้ตัวแปรสมมติ (Dummy Variable) ซึ่งในงานวิจัยนี้มีปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิตมากกว่าปริมาณอ้อยทั้งหมดจากกลุ่มพื้นที่เพาะปลูกอ้อยจึงทำการเติม Dummy Location ไปที่กลุ่มพื้นที่เพาะปลูกอ้อย เพื่อให้เกิดความสมดุลกันของปริมาณความต้องการอ้อยที่โรงงานต้องการและปริมาณอ้อยทั้งหมดจากกลุ่มพื้นที่เพาะปลูกอ้อยในการคำนวณ

เมื่อทำการแก้ปัญหาแล้ว จะทำให้ทราบถึงต้นทุนรวมในการขนส่งอ้อยจากพื้นที่เพาะปลูกอ้อยทุกแห่งไปยังโรงงานน้ำตาลแต่ละโรง ปริมาณอ้อยที่ได้นี้สามารถนำไปใช้วิเคราะห์คำนวณอัตราการใช้กำลังผลิตของโรงงานน้ำตาลแต่ละแห่งได้ โดยทำการเปรียบเทียบกับกำลังผลิตของโรงงานน้ำตาลนั่นเอง และเมื่อทำการสมมุติว่ามีการเพิ่มโรงงานน้ำตาลแห่งใหม่เข้าไปในระบบผลิต อันเนื่องมาจากนโยบายเปิดเสรีโรงงานน้ำตาลแล้ว ย่อมทำให้ สามารถวิเคราะห์ได้ถึงความเปลี่ยนแปลงหรือผลกระทบจากนโยบายดังกล่าว ต่อรูปแบบการขนส่งอ้อย ต้นทุนค่าขนส่งและอัตราการใช้กำลังการผลิตที่เปลี่ยนแปลงไปเนื่องจากมีความต้องการใช้อ้อยเพิ่มขึ้นในพื้นที่

3.3 การเก็บรวบรวมข้อมูล

ข้อมูลที่จำเป็นแบ่งเป็น 2 ส่วน ได้แก่ 1) ข้อมูลด้านการคมนาคม [12] ที่ช่วยแสดงให้เห็นถึงรูปแบบระยะทางการขนส่งจากพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาล ประกอบไปด้วยที่ตั้งโรงงานน้ำตาล พื้นที่เพาะปลูกอ้อย และถนน 2) ข้อมูลของผลผลิต เพื่อนำข้อมูลที่ได้ไปวิเคราะห์ถึงอัตรากำลังผลิตของโรงงาน ประกอบไปด้วยปริมาณผลผลิตอ้อยจากกลุ่มพื้นที่เพาะปลูก และปริมาณความต้องการใช้อ้อยที่โรงงานต้องการ [13 - 14]

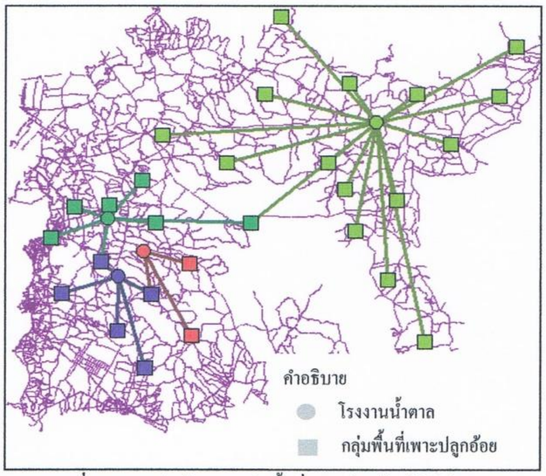
3.4 วิธีดำเนินงานวิจัย

เมื่อทำการเก็บรวบรวมข้อมูลด้านการคมนาคมครบแล้วจะทำให้ทราบถึงระยะทางการขนส่งจากพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาล รวมถึงปริมาณความต้องการใช้อ้อยที่โรงงาน

ต้องการในการผลิตจากการเก็บข้อมูลของผลผลิต จากนั้นจึงพัฒนาตัวแบบปัญหาการขนส่งและแก้ปัญหาด้วยเพื่อให้ทราบปริมาณอ้อยที่แต่ละกลุ่มพื้นที่ปลูกอ้อยทั้ง 29 กลุ่มต้องส่งให้แต่ละโรงงาน โดยการใช้โปรแกรม Excel's Solver หากโรงงานใดจำเป็นต้องได้รับอ้อยจากกลุ่มพื้นที่เพาะปลูกสมมติ (Dummy Location) ย่อมเป็นการบ่งชี้ว่าโรงงานแห่งนั้นไม่ได้รับอ้อยไปจริง หรือขาดแคลนปริมาณวัตถุดิบสำหรับใช้ผลิตน้ำตาลนั่นเอง ซึ่งจะได้กล่าวถึงรายละเอียดในส่วนต่อไป

4. ผลการวิจัย

จากการเก็บรวบรวมข้อมูลด้านการคมนาคมประกอบผลที่ได้จากการแก้ปัญหาตัวแบบการขนส่งด้วยโปรแกรม Excel's Solver ในสภาพปัจจุบันที่มีโรงงานน้ำตาลในพื้นที่เพียง 4 แห่ง แสดงรูปแบบการขนส่งอ้อยที่เหมาะสมที่สุด (Optimal Transportation Plan) จากพื้นที่เพาะปลูกไปยังโรงงานน้ำตาลแต่ละแห่งได้ดังภาพ ที่ 1 ซึ่งเป็นรูปแบบการขนส่งที่ก่อให้เกิดต้นทุนค่าขนส่งรวมของระบบต่ำที่สุด สำหรับระยะทางการขนส่งอ้อยรายงานเป็นค่าสถิติเชิงพรรณาไว้ในตารางที่ 1 ซึ่งเห็นได้ว่าระยะทางขนส่งที่ใกล้ที่สุดมีค่าเท่ากับ 8.77 กิโลเมตรเป็นการขนส่งอ้อยเข้าสู่โรงงานน้ำตาลนิวกว้างสุ้นหลี ส่วนระยะทางขนส่งที่อ้อยที่ไกล ที่สุดเกิดขึ้นที่โรงงานน้ำตาลอ้อยตะวันออกเท่ากับ 122.88 กิโลเมตร



ภาพที่ 1 การขนส่งอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงาน

ผลลัพธ์จาก Excel's Solver ยังบอกถึงปริมาณอ้อยที่แต่ละกลุ่มพื้นที่เพาะปลูกส่งให้กับโรงงานน้ำตาล จึงสามารถคำนวณได้ว่า โรงงานน้ำตาลแต่ละแห่งมีอัตราการใช้กำลังการผลิตเท่าไร ซึ่ง ผลลัพธ์สรุปไว้ในตารางที่ 2 จะเห็นได้ว่า ณ สภาพปัจจุบัน โรงงานน้ำตาลแต่ละแห่งมีอัตราการใช้กำลังการผลิตอยู่ในเกณฑ์สูงถึง 100% ทุกแห่ง ยกเว้นโรงงานอ้อยตะวันออก ซึ่งมีกำลังผลิตค่อนข้างมาก

ตารางที่ 1 ระยะทางการขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาล

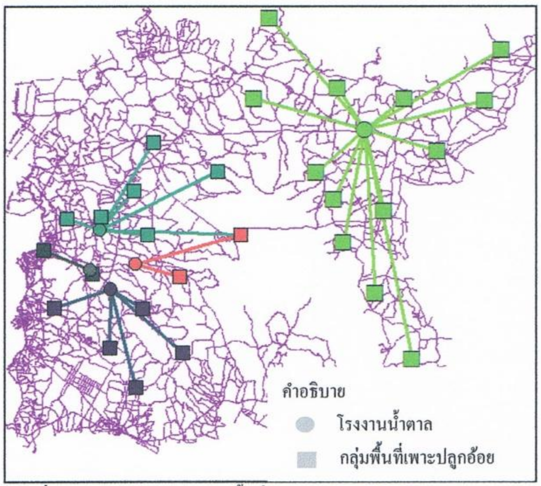
โรงงาน	ระยะทาง (กิโลเมตร)			
	Min	Mean	Max	S.D
อ้อยตะวันออก	29.56	51.81	122.88	26.95
นิวกว้างสุ้นหลี	8.77	41.58	70.91	20.09
น้ำตาลระยอง	25.93	28.37	53.59	14.69
สหการชลบุรี	11.35	17.26	49.97	14.70
รวม	8.77	41.40	122.88	27.64

ตารางที่ 2 อัตราการใช้กำลังการผลิตของโรงงานน้ำตาล

โรงงาน	ปริมาณอ้อยที่ได้รับ (ตัน)	กำลังการผลิตที่ต้องการ (ตัน/วัน)	Utilization (%)
อ้อยตะวันออก	2,168,693	2,265,228	95.74
นิวกว้างสุ้นหลี	609,026	609,026	100.00
น้ำตาลระยอง	589,360	589,360	100.00
สหการชลบุรี	622,258	622,258	100.00
รวม	3,989,337	4,085,872	97.64

เพื่อเป็นการวิเคราะห์ผลกระทบของการเปิดเสรีโรงงานน้ำตาล ต่อโลจิสติกส์ของระบบ จึงสมมุติว่ามีการเปิดโรงงานน้ำตาลเพิ่มขึ้นมาอีก 1 แห่ง และทำการวิเคราะห์เช่นเดิมเพื่อจะดูว่าเกิดความเปลี่ยนแปลงอย่างไรต่อรูปแบบการขนส่งอ้อยเข้าสู่โรงงานและอัตราการใช้กำลังการผลิตของแต่ละโรงงาน

เนื่องจากงานวิจัยนี้ได้เลือกใช้ภาคตะวันออกเป็นกรณีศึกษา โดยระหว่างปีการผลิต 2551/2552 โรงงานน้ำตาลอุตสาหการชลบุรีได้หยุดดำเนินการไป เพราะอยู่ในระหว่างการดำเนินการย้ายโรงงาน ผู้วิจัยจึงได้สมมุติว่าโรงงานดังกล่าวเป็นโรงงานที่เปิดใหม่เพิ่มขึ้นมาในระบบ ซึ่งทำให้มีโรงงานในพื้นที่ศึกษาทั้งสิ้น 5 โรง โดยใช้ข้อมูลกำลังการผลิตของโรงงานและจำนวนวันในการผลิตของโรงงานจากรายงานการผลิตของปี 2549/2550 แทน [15] ผลจากการแก้ปัญหาตัวแบบขนส่งและทำให้ได้รูปแบบการขนส่งอ้อยเข้าสู่โรงงานตามที่แสดงในภาพที่ 2 โดยมีค่าสถิติระยะทางการขนส่งตามตารางที่ 3 และมีค่าอัตราการใช้กำลังการผลิต (Utilization) ที่คำนวณได้เป็นไปตามตารางที่ 4



ภาพที่ 2 การขนส่งอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงาน หลังจากการเพิ่มโรงงาน

ตารางที่ 3 ระยะทางการขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานหลังจากการเพิ่มโรงงาน

โรงงาน	ระยะทาง (กิโลเมตร)			
	Min	Mean	Max	S.D
อ้อยตะวันออก	29.56	48.90	122.88	26.77
นิวกว้างสุ้นหลี	8.77	48.18	70.91	29.62
น้ำตาลระยอง	25.93	34.43	71.02	31.88
สหการชลบุรี	20.44	26.12	49.97	12.08
อุตสาหการชลบุรี	5.24	5.68	24.09	13.33
รวม	8.77	47.68	122.88	26.85

ตารางที่ 4 อัตราการใช้กำลังการผลิตของโรงงานน้ำตาลหลังจากการเพิ่มโรงงาน

โรงงาน	ปริมาณอ้อยที่ได้รับ (ตัน)	กำลังการผลิตที่ต้องการ (ตัน/วัน)	Utilization (%)
อ้อยตะวันออก	2,002,183	2,265,228	88.39
นิวกว้างสุ้นหลี	609,026	609,026	100.00
น้ำตาลระยอง	589,315	589,360	99.99
สหการชลบุรี	379,433	622,258	60.98
อุตสาหการชลบุรี	409,380	656,448	62.36
รวม	3,989,337	4,742,320	84.12

เมื่อทำการเปรียบเทียบรูปแบบการขนส่งระหว่างก่อน (ภาพที่ 1) และหลังการเพิ่มโรงงานน้ำตาล (ภาพที่ 2) เนื่องจากสมมุติว่ามีการเปิดเสรี จะเห็นว่ารูปแบบการขนส่งอ้อยเปลี่ยนแปลงไป เนื่องจากมีการกระจายปริมาณการขนส่งอ้อยไปยังโรงงานที่เพิ่มเข้ามาใหม่ในระบบ เมื่อเปรียบเทียบระยะทางการขนส่งเฉลี่ยซึ่งคำนวณแบบถ่วงน้ำหนัก (Weighted Average) ระหว่างค่าในตารางที่ 1 และ 3 พบว่าระยะทางการขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาลหลังจากการ เพิ่ม โรงงานมีแนวโน้มไกลขึ้นกว่าเดิม ยกเว้นโรงงานน้ำตาล อ้อย ตะวันออกที่มีระยะทางการขนส่งเฉลี่ยลดลง

ในมุมมองของการใช้กำลังผลิตนั้น อาจกล่าวได้ว่าการเปิดเสรีโรงงานน้ำตาลที่มีขนาดเท่ากับโรงงานอุตสาหการชลบุรี ภายใต้สภาวะผลผลิตอ้อยที่เท่าเดิม จะส่งผลกระทบทางลบทำให้โรงงานบางแห่งใช้กำลังการผลิตได้ต่ำลงอย่างมาก ซึ่งย่อมส่งผลอันไม่พึงปรารถนาในทางธุรกิจ

อย่างไรก็ตาม หากพิจารณาจากแง่ของค่าขนส่งโดยรวมของระบบ ตามตารางที่ 5 ซึ่งคำนวณจากการใช้ระยะทางขนส่งและปริมาณอ้อยที่ขนส่งไปยังโรงงานน้ำตาล โดยสมมติให้ต้นทุนค่าขนส่งต่อหน่วยน้ำหนักของอ้อยมีค่าเท่ากันไม่ว่าจะขนส่งจากพื้นที่ใดไปโรงงานใด โดยเพียงแต่แปรผันตามระยะทางการขนส่งเท่านั้น พบว่าต้นทุนค่าขนส่งของระบบลดลง 5,387,482 ในหน่วยของ ตัน-กิโลเมตร คูณด้วยค่าขนส่งต่อตันต่อกิโลเมตร

ตารางที่ 5 เปรียบเทียบต้นทุนค่าขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาล

โรงงาน	ต้นทุนค่าขนส่ง (ตัน-กม.)	
	ก่อนเพิ่มโรงงาน	หลังเพิ่มโรงงาน
อ้อยตะวันออก	112,366,507	97,900,207
นิวกว้างสุ้นหลี	25,323,897	29,342,473
น้ำตาลระยอง	16,722,715	20,288,010
สหการชลบุรี	10,741,036	9,910,059
อุตสาหการชลบุรี	-	2,325,924
รวม	165,154,155	159,766,673

5. สรุปและข้อเสนอแนะ

การวิจัยนี้เป็นการวิเคราะห์ผลกระทบของนโยบายการเปิดเสรีโรงงานน้ำตาลในมุมมองของการจัดการด้านโลจิสติกส์ว่าจะส่งผลกระทบอย่างไรบ้างต่อกระบวนการโลจิสติกส์ขาเข้าของอ้อยสู่โรงงานและการผลิตน้ำตาลทรายของโรงงาน โดยการใช้ตัวแบบจำลองปัญหาการขนส่งเป็นเครื่องมือ ผลลัพธ์ที่ได้แสดงให้เห็นว่าการเปิดเสรีโรงงานน้ำตาลในพื้นที่กรณีศึกษา อาจก่อให้เกิดการเปลี่ยนแปลงรูปแบบการขนส่งอ้อย ระยะทางการขนส่งอ้อยมีแนวโน้มไกลขึ้น และส่งผลกระทบทางลบต่ออัตราการใช้กำลังผลิตของโรงงานน้ำตาล เนื่องจากการเพิ่มโรงงานเข้า

ไปในระบบทำให้ปริมาณความต้องการอ้อยเพิ่มมากขึ้น แต่ปริมาณผลผลิตอ้อยจากพื้นที่เพาะปลูกเท่าเดิม แต่หากพิจารณาในแง่ของต้นทุนค่าขนส่งของทั้งระบบ การเปิดเสรีอาจมีผลทำให้ต้นทุนค่าขนส่งลดต่ำลงได้ เนื่องจากอ้อยจำนวนมากไม่จำเป็นต้อง ถูกขนส่งไปไกล ดังนั้นการเปิดเสรีโรงงานน้ำตาลจึงควรต้องพิจารณาสมดุลระหว่างหลายองค์ประกอบ ได้แก่ สมดุลระหว่างปริมาณอ้อยในพื้นที่กับกำลังการผลิต สมดุลระหว่างต้นทุนค่าขนส่งกับต้นทุนการผลิตน้ำตาล อย่างไรก็ตามการวิจัยนี้ใช้กรณีศึกษาที่ยังมีขอบเขตจำกัดในพื้นที่ภาคตะวันออกเท่านั้น ดังนั้นข้อเสนอแนะเกี่ยวกับงานวิจัยที่จะทำในอนาคตจึงควรเพิ่มเติมได้ใน 2 ประเด็นสำคัญ ได้แก่

1) การศึกษาในครั้งนี้มีการรวมกลุ่มพื้นที่เพาะปลูกอ้อย เป็นรายอำเภอ ทำให้ข้อมูลอาจจะหยาบเกินไป ทั้งนี้เนื่องมาจากขีดความสามารถในการแก้ปัญหาของ Excel's Solver ถูกจำกัดด้วยจำนวนตัวแปรที่ไม่มากนัก การศึกษาในอนาคตควรพยายามแยกไร่อ้อยให้ละเอียดมากขึ้นเพื่อจำลองสภาพความเป็นจริงได้ดีขึ้น และจำเป็นต้องเปลี่ยน Solver

2) การศึกษาในครั้งนี้เป็นการศึกษาโดยมีขอบเขตของงานอยู่ที่ภาคตะวันออกของประเทศไทย ทำให้ผลการศึกษาไม่ครอบคลุมทุกพื้นที่ นอกจากนี้ โรงงานน้ำตาลที่อยู่ในระหว่างรอยต่อของภาคตะวันออกกับภาคอื่น อาจได้รับอ้อยจากกลุ่มพื้นที่เพาะปลูกในภาคอื่นด้วย ดังนั้นในงานวิจัยที่จะศึกษาในอนาคตจะเพิ่มขอบเขตในการศึกษาเป็นกลุ่มพื้นที่เพาะปลูกอ้อยทั้งประเทศไทยเพื่อให้ผลการศึกษาครอบคลุมทุกพื้นที่

6. กิตติกรรมประกาศ

ขอขอบพระคุณ ศูนย์เทคโนโลยีสารสนเทศและการสื่อสาร สำนักงานปลัดกระทรวงคมนาคมที่เอื้อเฟื้อชุดข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม และขอขอบพระคุณสำนักงานคณะกรรมการอ้อยและน้ำตาลทราย (สอน.) สำหรับความเอื้อเฟื้อในเรื่องข้อมูลและเอกสารอ้างอิงที่ใช้ในงานวิจัยนี้

7. บรรณานุกรม

[1] อัมมาร สยามวาลา, ประยงค์ เนตยารักษ์, วรวุฒิ หิรัญรักษ์, นิพนธ์ พัวพงศกร, หัทยา เนตยารักษ์, 2536. อนาคตอุตสาหกรรมอ้อยและน้ำตาลไทย, รายงานวิจัยฉบับสมบูรณ์ สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย กระทรวงอุตสาหกรรม

[2] ศรัณย์นพ อินทเสน, 2544. การวิเคราะห์หาความเหมาะสมของพื้นที่ปลูกอ้อยโรงงานและที่ตั้งโรงงานน้ำตาล ในเขตที่ราบภาคกลางตอนบน, วิทยานิพนธ์ปริญญาโท, มหาวิทยาลัยรามคำแหง

[3] วีรมน ธรรมเจริญ, 2551. การวิเคราะห์ต้นทุนและระยะเวลาของการเก็บเกี่ยวและขนส่งอ้อยไปสู่โรงงาน เพื่อกำหนดแนวทางในการเพิ่มขีดความสามารถในการแข่งขัน: ศึกษาผู้ปลูกจังหวัดกาญจนบุรีและจังหวัดสุพรรณบุรี, วิทยานิพนธ์ปริญญาโท, มหาวิทยาลัยแม่ฟ้าหลวง

[4] พรรณวิภา เตชะสุข, 2551. การพัฒนาระบบสนับสนุนการตัดสินใจการเก็บเกี่ยวอ้อยสำหรับระบบโลจิสติกส์ขาเข้าของอุตสาหกรรมอ้อยและน้ำตาลทราย, วิทยานิพนธ์ปริญญาโท, มหาวิทยาลัยขอนแก่น

[5] พรชัย ท้วมปาน, 2545. โครงสร้างต้นทุนการขนส่งอ้อย, วิทยานิพนธ์ปริญญาโท, จุฬาลงกรณ์มหาวิทยาลัย

[6] ณัฐพร สุวรรณสูนย, 2545. ทำเลที่ตั้งและขนาดที่เหมาะสมของโรงงานน้ำตาลทรายในประเทศไทย, วิทยานิพนธ์ปริญญาโท, มหาวิทยาลัยเชียงใหม่

[7] Hansen A, Barnes A, Lyne L.1998, An integrated approach to simulation sugarcane harvest to mill delivery. International Meeting Presentation; Paper No. 986099.

[8] Diaz J and Perez I. 2000, Simulation and optimization of sugar cane transportation in harvest season. Winter Simulation Conference, 1114-1117

[9] Higgins A, Antony G, Sandell G, Davies I, Prestwidge D, Andrew B.,2004.A framework for integrating a complex harvesting and transport system for sugar production, Journal of Agricultural Systems, 99–115.

[10] Higgins A, 2006. Scheduling of road vehicles in sugarcane transport : A case study at an Australian sugar mill, European Journal of Operational Research 170, 987–1000.

[11] สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย, 2551. ที่ตั้งของโรงงานน้ำตาลในประเทศไทย.

[12] สำนักงานปลัดกระทรวงคมนาคม, 2550. ข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม (Transport Fundamental Geographic Data Set : Transport FGDS).

[13] สำนักคณะกรรมการอ้อยและน้ำตาลทราย, 2552. รายงานผลการสำรวจพื้นที่ปลูกอ้อยประจำปีการผลิต 2551/2552.

[14] สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย, 2551. กำลังการผลิตที่โรงงานน้ำตาลได้รับอนุญาต.

[15] สำนักคณะกรรมการอ้อยและน้ำตาลทราย, 2550. รายงานผลการสำรวจพื้นที่ปลูกอ้อยประจำปีการผลิต 2549/2550.

APPENDIX E

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การประชุมวิชาการข่ายงานวิศวกรรมอุตสาหการ ประจำปี 2554
20-21 ตุลาคม 2554

การวิเคราะห์ผลกระทบด้านโลจิสติกส์จากการย้ายโรงงานและขยายกำลังการผลิตของโรงงานน้ำตาลทรายด้วยตัวแบบจำลองคณิตศาสตร์

Analysis of the Impacts on Logistics Resulting from the Relocation and Capacity Expansion of Sugar Mills by Using Mathematical Models

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บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลกระทบจากการเปิดเสรีโรงงานน้ำตาล เนื่องจากอุตสาหกรรมอ้อยและน้ำตาลในประเทศไทยได้ถูกควบคุมโดยพระราชบัญญัติอ้อยและน้ำตาล พ.ศ.2527 มาเป็นระยะเวลานาน ทำให้ในปัจจุบันมีการวิเคราะห์ถึงสภาวะอุตสาหกรรมอ้อยและน้ำตาลทรายของไทยว่า สมควรมีการดำเนินการปรับปรุงโครงสร้างระบบอุตสาหกรรมอ้อยและน้ำตาลทรายขึ้นมาใหม่ โดยลดการปกป้องคุ้มครองและควบคุมจากรัฐบาลเพื่อให้สอดคล้องกับกระแสของเศรษฐกิจที่มีแนวโน้มปรับไปสู่ระบบการค้าเสรี โดยการอนุญาตให้มีการตั้งโรงงานขึ้นมาใหม่ หรือแม้แต่การขยายกำลังการผลิตได้ งานวิจัยนี้จึงนำมติของคณะรัฐมนตรีที่มีการเห็นชอบเมื่อวันที่ 10 ตุลาคม พ.ศ. 2550 ที่เกี่ยวข้องกับการย้ายโรงงานและการขยายกำลังการผลิตของโรงงานน้ำตาลมาเป็นกรณีศึกษาสำหรับการวิเคราะห์ผลกระทบของการเปิดเสรีโรงงานน้ำตาลทราย โดยมีการประยุกต์ใช้ตัวแบบจำลองทางคณิตศาสตร์และระบบสารสนเทศภูมิศาสตร์ มาเป็นเครื่องมือในการวิเคราะห์ทำการเปรียบเทียบผลลัพธ์ที่เกิดขึ้นก่อนและหลังจากการเห็นชอบตามมติดังกล่าว โดยเน้นศึกษาในส่วนของรูปแบบการขนส่งอ้อย และอัตราการใช้กำลังการผลิตของโรงงานน้ำตาลในระบบ ผลจากการศึกษาพบว่า ภาคเหนือและภาคตะวันออกควรมีการส่งเสริมการปลูกอ้อยเพื่อให้เกิดความสมดุลระหว่างความต้องการใช้อ้อยในพื้นที่และอุปทานของอ้อยที่เกิดขึ้นในอนาคต

คำหลัก โรงงานน้ำตาล, การเปิดเสรี, รูปแบบการขนส่งอ้อย, อัตราการใช้กำลังการผลิต, ตัวแบบคณิตศาสตร์

1. บทนำ

อุตสาหกรรมอ้อยและน้ำตาลทรายได้พัฒนาตัวเองมาเป็นระยะเวลานานจากการเป็นผู้นำเข้าน้ำตาลในระยะแรกจนก้าวขึ้นเป็นผู้ส่งออกรายใหม่ของโลกในปัจจุบัน และสามารถทำรายได้ให้กับรัฐในรูปของเงินตราต่างประเทศเป็นจำนวนปีละหลายหมื่นล้านบาท ในปี พ.ศ. 2551 การส่งออกน้ำตาลสามารถนำเงินตราเข้าประเทศได้กว่า 47,600 ล้านบาท จากการส่งออกน้ำตาลประมาณ 5,000,000 ตัน [1] อุตสาหกรรมนี้จึงมีความสำคัญต่อระบบเศรษฐกิจของประเทศไทยเป็นอย่างมาก ทำให้รัฐบาลเข้ามามีบทบาทและให้ความสำคัญกับการแก้ไขปัญหาที่เกิดขึ้นในอุตสาหกรรมนี้มาโดยตลอด ในปัจจุบันอุตสาหกรรมนี้ได้ถูกควบคุมตามพระราชบัญญัติอ้อยและน้ำตาลทราย พ.ศ. 2527 มาเป็นระยะเวลากว่า 20 ปี ทำให้มีการวิเคราะห์ถึงสภาวะอุตสาหกรรมอ้อยและน้ำตาลทรายของไทยว่า สมควรมีการดำเนินการปรับปรุงโครงสร้างระบบอุตสาหกรรมอ้อยน้ำตาลทรายขึ้นมาใหม่ โดยการยกเลิกระบบผูกขาด หรือแม้กระทั่งให้รัฐบาลเข้าไปแทรกแซงอุตสาหกรรมนี้น้อยที่สุด [2] เนื่องมาจากทุกวันนี้กระแสของเศรษฐกิจโลกมีแนวโน้มไปสู่ระบบเสรีมากขึ้น ทำให้พบว่าถ้ายังคงมีการปกป้องคุ้มครองอุตสาหกรรมนี้ จะทำให้ขาดแรงจูงใจในการพัฒนาเพิ่มศักยภาพ และแข่งขันได้ในตลาดการค้าเสรี ด้วยเหตุนี้จึงทำให้มีงานวิจัยต่างๆ ทำการศึกษาถึงผลกระทบจากการเปิดเสรีของอุตสาหกรรมนี้ [3 - 5] เพื่อให้เกิดการเตรียมความพร้อมกับการเปลี่ยนแปลงในอนาคต แต่ยังไม่มีงานวิจัยใดทำการวิเคราะห์ผลกระทบเชิงปริมาณอย่างชัดเจน งานวิจัยนี้ได้ทำการศึกษาผลกระทบของการเปิดเสรีโรงงานน้ำตาล ซึ่งรวมไปถึงการตั้งโรงงานใหม่ การย้ายโรงงานเดิม และขยายกำลังการผลิตของโรงงาน โดยใช้กรณีศึกษาจากมติเห็นชอบของคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายโรงงานและการขยายกำลังการผลิตของโรงงานน้ำตาล เมื่อวันที่ 10 ตุลาคม พ.ศ. 2550 [6] เพื่อสมมติเหตุการณ์ให้เสมือนจริง หากเมื่อมีการเปิดเสรีโรงงานน้ำตาลขึ้นมา โดยเน้นการวิเคราะห์ในมุมมองของผลกระทบที่มีต่อรูปแบบการขนส่งอ้อย และอัตราการใช้กำลังผลิตของโรงงานน้ำตาล ซึ่งได้ประยุกต์ใช้ตัวแบบจำลองคณิตศาสตร์การขนส่ง (Transportation Problem) มาช่วยในการวิเคราะห์รูปแบบและปริมาณการขนส่งอ้อยจากไร่ไปยังโรงงานน้ำตาลแต่ละแห่ง เพื่อให้ต้นทุนรวมค่าขนส่งของระบบต่ำที่สุด โดยอาศัยระบบภูมิศาสตร์สารสนเทศเป็นเครื่องมือสำหรับคำนวณหาระยะทางจากพื้นที่เพาะปลูกไปยัง

โรงงาน รวมถึงแสดงให้เห็นรูปแบบการขนส่งอ้อย โดยการแสดงทำเลที่ตั้งของโรงงานและพื้นที่ปลูกอ้อยอีกด้วย ซึ่งผลลัพธ์ที่ได้ช่วยให้พิจารณาได้ว่านโยบายการเปิดเสรีโรงงานน้ำตาลจากมติคณะรัฐมนตรีดังกล่าวอาจส่งผลกระทบอย่างไรต่อระบบโลจิสติกส์ขาเข้าของอุตสาหกรรมผลิตน้ำตาลทราย

2. ระเบียบวิธีวิจัย

งานวิจัยนี้นำตัวแบบจำลองคณิตศาสตร์การขนส่ง (Transportation Problem) มาใช้เป็นเครื่องมือในการวิเคราะห์คำนวณรูปแบบการกระจายอ้อยและปริมาณอ้อยที่เหมาะสมซึ่งโรงงานแต่ละแห่งควรจะได้รับเพื่อให้ระบบมีต้นทุนการขนส่งโดยรวมต่ำที่สุด โดยอาศัยโปรแกรมคอมพิวเตอร์ทางด้านระบบสารสนเทศภูมิศาสตร์ (Geographic Information System, GIS) สำหรับคำนวณหาระยะทางการขนส่งจากพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาล และแสดงรูปแบบการส่งขนโดยการแสดงทำเลที่ตั้งของโรงงานและพื้นที่ปลูกอ้อย

2.1 ข้อมูล

งานวิจัยนี้ทำการวิเคราะห์ข้อมูลของปีการผลิต 2551/2552 ซึ่งโรงงานน้ำตาลทั่วประเทศมีอยู่ทั้งหมด 47 โรงงาน แบ่งออกเป็น 4 ภูมิภาค ได้แก่ ภาคตะวันออก 5 โรงงาน (โรงงานอุตสาหกรรมน้ำตาลชลบุรีหยุดการผลิต เพื่อรอการย้ายที่ตั้งโรงงาน) ภาคเหนือ 9 โรงงาน ภาคกลาง 17 โรงงาน และภาคตะวันออกเฉียงเหนือ 16 โรงงาน [7] ประเทศไทยมีพื้นที่ปลูกอ้อยรวมทั้งประเทศ 6,831,892 ไร่ แต่เนื่องจากข้อมูลมีจำนวนมาก ด้วยข้อจำกัดของโปรแกรมการคำนวณ ผู้วิจัยจึงได้ทำการรวมกลุ่มไร่อ้อยเหล่านี้เป็นรายอำเภอทั้งสิ้น 404 อำเภอ [8] จากนั้นเพื่อเป็นการวิเคราะห์ให้เห็นถึงผลกระทบจากการเปิดเสรีโรงงานน้ำตาล ผู้วิจัยจึงนำมติของคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายโรงงานและการขยายกำลังการผลิตของโรงงานน้ำตาล เมื่อวันที่ 10 ตุลาคม พ.ศ. 2550 มาเป็นกรณีศึกษาสำหรับการวิเคราะห์ผลกระทบที่เกิดขึ้น ประกอบไปด้วยการย้ายสถานที่ตั้งโรงงานและขยายกำลังการผลิตของโรงงานน้ำตาลนิวกรุงไทย น้ำตาลบ้านโป่ง และน้ำตาลนิวกว้างสุ้นหลี รวมทั้งการขยายกำลังการผลิตของโรงงานน้ำตาลพิษณุโลกและน้ำตาลบ้านไร่ ในที่นี้รวมไปถึงโรงงานอุตสาหกรรมน้ำตาลชลบุรีที่หยุดการผลิตในปี 2551/2552 เพื่อย้ายสถานที่ตั้งและขยายกำลังการผลิตด้วย การปฏิบัติตามมติคณะรัฐมนตรีดังกล่าว จะทำให้กำลังการผลิตของโรงงานน้ำตาลในภาพรวมเพิ่มสูงขึ้น 54,805 ตันอ้อย/วัน จากเดิมที่มีอยู่ 731,207 ตันอ้อย/วัน สำหรับปีการผลิต 2551/2552

2.2 ตัวแบบจำลองคณิตศาสตร์การขนส่ง

เนื่องจากงานวิจัยนี้เป็นการวิเคราะห์ผลกระทบของการเปิดเสรีโรงงานน้ำตาลทรายที่มีต่อรูปแบบการขนส่งอ้อยและอัตราการใช้กำลังการผลิตของโรงงานด้วยตัวแบบจำลองคณิตศาสตร์ เมื่อพิจารณาถึงลักษณะของปัญหาที่กำลังทำการวิเคราะห์จึงเห็นว่าตัวแบบจำลองคณิตศาสตร์การขนส่ง (Transportation Problem) มีความเหมาะสมสามารถนำมาประยุกต์ใช้เป็นเครื่องมือ [9 - 11] ในการคำนวณหาปริมาณอ้อยที่โรงงานแต่ละแห่งควรจะได้รับเพื่อให้ระบบมีต้นทุนการขนส่งที่ต่ำที่สุด อีกทั้งยังสามารถนำไปช่วยวิเคราะห์ถึงอัตราการใช้กำลังผลิตโดยรวมของโรงงานน้ำตาล จากการเปรียบเทียบปริมาณอ้อยที่แต่ละพื้นที่ปลูกอ้อยส่งเข้าไปยังโรงงานน้ำตาลกับปริมาณอ้อยที่โรงงานต้องการใช้ในการผลิตน้ำตาลได้อีกด้วย โดยมีรายละเอียดของแบบจำลองดังนี้

Objective Function: Minimize Total Transportation Cost

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

Constrains

$$\sum\nolimits_{j=1}^{n} X_{ij} \le S_i \quad ; \forall_i \qquad (2)$$

$$\sum\nolimits_{i=1}^{m} X_{ij} \ge D_j \quad ; \forall_j \qquad (3)$$

$$X_{ij} \ge 0 \qquad (4)$$

โดยที่

C_{ij} = ระยะทางการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย *i* ไปยังโรงงาน *j* (กิโลเมตร)

X_{ij} = ปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย *i* ไปยังโรงงาน *j* (ตัน)

D_j = ปริมาณความต้องการอ้อยของโรงงาน i (ตัน)

S_i = ปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อย (ตัน)

i = กลุ่มพื้นที่เพาะปลูกอ้อย; i = 1,2,…,*m*

j = โรงงานน้ำตาล; j = 1, 2,…,*n*

m = จำนวนกลุ่มพื้นที่เพาะปลูกอ้อย

n = จำนวนโรงงานน้ำตาล

ฟังก์ชั่นวัตถุประสงค์ *(1)* ต้องการให้รูปแบบการขนส่งมีต้นทุนค่าขนส่งโดยรวมจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาลต่ำที่สุด เงื่อนไขใน *(2)* เป็นเงื่อนไขบังคับปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อยใดๆ ไปยังโรงงานน้ำตาลต้องไม่เกินปริมาณอ้อยที่ผลิตได้ เงื่อนไขใน *(3)* เป็นเงื่อนไขบังคับว่าโรงงานน้ำตาลแต่ละแห่งจะต้องได้รับปริมาณอ้อยเพียงพอสอดคล้องกับกำลังการผลิตที่มีอยู่ สุดท้ายเงื่อนไขใน *(4)* หมายถึงจำนวนปริมาณอ้อยที่ส่งจากกลุ่มพื้นที่ส่งอ้อยไปยังโรงงานน้ำตาลต้องไม่ติดลบ

ตัวแบบจำลองนี้ตั้งสมมุติฐานว่าต้นทุนค่าขนส่งต่อหน่วยน้ำหนักของอ้อยมีค่าเท่ากันไม่ว่าจะขนส่งจากพื้นที่ใดไปโรงงานใด โดยเพียงแต่แปรผันตามระยะทางการขนส่งเท่านั้น จึงสามารถแทนต้นทุนได้ด้วยระยะทาง C_{ij} โดยตรง

เพื่อให้ตัวแบบจำลองสามารถหาคำตอบได้เสมอ จึงจำเป็นที่ผลรวมของปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยต้องเท่ากับผลรวมของปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิต

กล่าวคือ $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j$ จากข้อมูลในงานวิจัยนี้ พบว่าปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิตมากกว่าปริมาณอ้อยทั้งหมดจากกลุ่มพื้นที่เพาะปลูกอ้อย ดังนั้นจึงจำเป็นต้องเพิ่ม Dummy Location ไปที่กลุ่มพื้นที่เพาะปลูกอ้อย เพื่อสมมุติว่ามีปริมาณอ้อยเพียงพอ ทำให้เกิดความสมดุลระหว่างปริมาณความต้องการอ้อยที่โรงงานต้องการและปริมาณอ้อยที่ผลิตได้จากกลุ่มพื้นที่เพาะปลูกอ้อย

2.3 การรวบรวมข้อมูล

การรวบรวมข้อมูลในงานวิจัยนี้ คือ การเตรียมข้อมูลสำหรับตัวแบบจำลองคณิตศาสตร์เพื่อแทนค่าพารามิเตอร์ลงในตัวแบบจำลอง ข้อมูลแบ่งออกเป็น 3 ส่วนสำคัญ ดังนี้

1) ปริมาณผลผลิตอ้อย (Supply)

ในการคำนวณหาปริมาณผลผลิตอ้อยต้องใช้ข้อมูลพื้นฐาน 2 ชุด คือ ข้อมูลพื้นที่เพาะปลูกอ้อยเป็นรายอำเภอ และข้อมูลอัตราผลผลิตอ้อยเฉลี่ยต่อไร่ในประเทศไทยสำหรับปีการผลิต 2551/52 จากนั้นนำข้อมูลทั้งสองมาคูณกัน

2) ระยะทางการขนส่งอ้อยไปยังโรงงาน (Distance Matrix)

ในการคำนวณหาระยะทางการขนส่งอ้อยจากพื้นที่เพาะปลูกไปยังโรงงานน้ำตาลแต่ละโรงนั้น งานวิจัยนี้ใช้โปรแกรม ArcMap ด้วยคำสั่ง Network Analyst ในการคำนวณหาระยะทาง โปรแกรมดังกล่าวจำเป็นต้องมีข้อมูลระบบสารสนเทศภูมิศาสตร์ 3 ชุด ได้แก่ ข้อมูลพื้นที่เพาะปลูกอ้อย ข้อมูลด้านเส้นทางคมนาคม (Transport Fundamental Geographic Data Set: Transport FGDS) [12] และข้อมูลที่ตั้งโรงงานน้ำตาล

3) ปริมาณความต้องการใช้อ้อย (Demand)

ในการคำนวณหาปริมาณความต้องการใช้อ้อย สามารถคำนวณได้จากข้อมูลพื้นฐาน 2 ชุด คือ ข้อมูลกำลังการผลิตที่โรงงานน้ำตาลได้รับอนุญาต และข้อมูลจำนวนวันที่แต่ละโรงงานได้ทำการผลิตน้ำตาลสำหรับปีการผลิต 2551/52 จากนั้นนำข้อมูลทั้งสองมาคูณกัน

เมื่อทำการเตรียมข้อมูลในส่วนของพารามิเตอร์ต่าง ๆ เรียบร้อยแล้ว จึงพัฒนาตัวแบบจำลองทางคณิตศาสตร์ขึ้น และใช้โปรแกรม LINDO (Linear Interactive Discrete Optimizer) เป็น Solver ในการแก้ปัญหาเพื่อหาผลลัพธ์

2.4 วิธีวิเคราะห์ข้อมูล

หลังจากแก้ปัญหาด้วยแบบจำลองคณิตศาสตร์การขนส่งโดยใช้โปรแกรม LINDO (Linear Interactive Discrete Optimizer) แล้ว จะทำให้ทราบถึงรูปแบบการขนส่งอ้อยและปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกแต่ละแห่งไปยังโรงงานน้ำตาลแต่ละโรง ซึ่งสามารถนำผลลัพธ์ที่ได้มาวิเคราะห์ถึงผลกระทบจากการเปิดเสรีโรงงานน้ำตาลในมุมมองโลจิสติกส์ขาเข้าของอ้อยสู่โรงงาน โดยแบ่งออกเป็น 2 ประเด็น ดังนี้

1) รูปแบบการขนส่งอ้อย

วิเคราะห์ถึงการเปลี่ยนแปลงหรือผลกระทบที่มีต่อระบบการขนส่งอ้อยจากการเปิดเสรีโรงงานน้ำตาล โดยการใช้โปรแกรม ArcMap ในการแสดงรูปแบบการขนส่งอ้อยจากกลุ่มพื้นที่เพาะปลูกไปยังแต่ละโรงงาน ซึ่งโปรแกรมดังกล่าวจะแสดงรูปแบบการขนส่งออกมาเป็นแผนที่ และเพื่อเป็นการวิเคราะห์ถึงผลกระทบที่มีต่อระบบการขนส่งอ้อยจากการเปิดเสรีโรงงานน้ำตาล จึงใช้กรณีศึกษาจากมติคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายและการขยายกำลังการผลิตของโรงงาน แล้วทำการเปรียบเทียบรูปแบบการขนส่งก่อนที่จะมีมติคณะรัฐมนตรีดังกล่าว

2) อัตราการใช้กำลังการผลิต

เมื่อทราบถึงปริมาณอ้อยที่โรงงานแต่ละแห่งควรจะได้รับจากพื้นที่เพาะปลูกแล้ว สามารถนำปริมาณอ้อยที่ได้นี้ไปใช้วิเคราะห์คำนวณอัตราการใช้กำลังผลิตของโรงงานน้ำตาลแต่ละแห่งได้ ซึ่งทำการเปรียบเทียบกับกำลังผลิตของโรงงานน้ำตาล โดยที่ปริมาณอ้อยรวมที่ได้รับจากทุกกลุ่มพื้นที่เพาะปลูกหารด้วยกำลังการผลิตของโรงงานและคูณด้วย 100 เพื่อเทียบเป็นเปอร์เซ็นต์ และเพื่อเป็นการวิเคราะห์ถึงผลกระทบที่มีต่ออัตราการใช้กำลังการผลิตจากการเปิดเสรีโรงงานน้ำตาล จึงใช้กรณีศึกษาจากมติคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายและการขยายกำลังการผลิตของโรงงานแล้ว ทำการเปรียบเทียบข้อมูลก่อนและหลัง โดยผลต่างที่ได้จากการคำนวณ คือ ผลกระทบของการเปิดเสรีโรงงานน้ำตาลนั่นเอง

3. การวิเคราะห์และผลลัพธ์

3.1 กรณีโรงงานน้ำตาลในสภาพปัจจุบัน

โรงงานน้ำตาลทั่วประเทศในปัจจุบันมีอยู่ทั้งหมด 47 โรงงาน แบ่งออกเป็น 4 ภูมิภาค ได้แก่

ภาคเหนือ	จำนวน	9	โรงงาน
ภาคกลาง	จำนวน	17	โรงงาน
ภาคตะวันออกเฉียงเหนือ	จำนวน	16	โรงงาน
ภาคตะวันออก	จำนวน	5	โรงงาน
	รวมทั้งสิ้น	47	โรงงาน

ทั้งนี้โรงงานอุตสาหกรรมน้ำตาลชลบุรีหยุดการผลิตไปในปี 2551/2552 เพื่อรอย้ายสถานที่ตั้งโรงงานไปยังจังหวัดนครสวรรค์ งานวิจัยนี้จึงทำการคำนวณกรณีโรงงานน้ำตาลในสภาพปัจจุบันเพียง 46 โรงงาน

เมื่อทำการแก้ปัญหาด้วยแบบจำลองคณิตศาสตร์การขนส่งโดยใช้โปรแกรม LINDO สามารถแสดงรูปแบบการขนส่งอ้อยที่เหมาะสมที่สุด (Optimal Transportation Plan) จากพื้นที่เพาะปลูกไปยังโรงงานน้ำตาลแต่ละแห่งในสภาพปัจจุบันที่ก่อให้เกิดต้นทุนการขนส่งโดยรวมต่ำที่สุด ตามที่แสดงในรูปที่ 1

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รูปที่ 1 รูปแบบการขนส่งอ้อยที่ต้นทุนค่าขนส่งรวมต่ำที่สุด ในสภาพปัจจุบัน

ตารางที่ 1 ระยะทางการขนส่งอ้อยจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานก่อนมีมติคณะรัฐมนตรี

ภาค	ระยะทาง (กิโลเมตร)			
	Min	Mean	Max	S.D
ตะวันออก	8.77	41.55	112.15	26.02
เหนือ	1.72	47.73	128.65	27.99
กลาง	2.09	36.08	158.46	31.85
ตะวันออกเฉียงเหนือ	0.56	47.83	210.28	38.34
รวม	0.56	43.47	210.28	35.16

สำหรับระยะทางการขนส่งอ้อยรายงานเป็นค่าสถิติไว้ในตารางที่ 1 โดยแยกระยะทางการขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานออกเป็นตามภาคที่มีโรงงานน้ำตาล พบว่าระยะทางขนส่งเฉลี่ยในภาพรวมมีค่าเท่ากับ 43.47 กิโลเมตร โดยภาคกลางเป็นภาคที่มีระยะทางการขนส่งเฉลี่ยต่ำที่สุดมีค่าเท่ากับ 36.08 กิโลเมตร ซึ่งจากการแก้ปัญหาด้วยแบบจำลองคณิตศาสตร์ยังบอกถึงปริมาณอ้อยที่แต่ละกลุ่มพื้นที่เพาะปลูกส่งให้กับโรงงานน้ำตาล จึงสามารถคำนวณอัตราการใช้กำลังการผลิตได้ โดยสามารถสรุปอัตราการใช้กำลังการผลิตของแต่ละภาคไว้ในตารางที่ 2 ซึ่งจะเห็นได้ว่า ณ สภาพปัจจุบันโรงงานน้ำตาลแต่ละแห่งมีอัตราการใช้กำลังการผลิตอยู่ในเกณฑ์สูงเกือบ 100% โดยเฉพาะภาคตะวันออกที่มีอัตราการใช้กำลังการผลิตสูงถึง 99.95% น่าจะเป็นผลมาจากการที่โรงงานอุตสาหกรรมน้ำตาลชลบุรีหยุดการดำเนินการผลิตไป

ตารางที่ 2 อัตราการใช้กำลังการผลิตของโรงงานน้ำตาลก่อนมีมติคณะรัฐมนตรี

ภาค	ปริมาณอ้อยที่ได้รับ (ตัน)	กำลังการผลิต (ตัน/วัน)	Utilization (%)
ตะวันออก	3,989,236	3,991,414	99.95
เหนือ	18,480,165	19,113,395	96.69
กลาง	21,780,530	23,810,827	91.47
ตะวันออกเฉียงเหนือ	26,833,142	27,717,870	96.81
รวม	71,083,073	74,633,506	95.24

3.2 กรณีโรงงานน้ำตาลจากมติของคณะรัฐมนตรี

เพื่อเป็นการวิเคราะห์ผลกระทบของการเปิดเสรีโรงงานน้ำตาล จึงสมมติกรณีศึกษาจากมติของคณะรัฐมนตรีเมื่อวันที่ 16 ตุลาคม พ.ศ. 2550 เกี่ยวกับการขยายกำลังการผลิตและย้ายสถานที่ตั้งโรงงานน้ำตาลทั้ง 5 โรง โดยสามารถแบ่งที่ตั้งของโรงงานใหม่ออกเป็น 4 ภูมิภาค ดังนี้

ภาคเหนือ	จำนวน	10	โรงงาน
ภาคกลาง	จำนวน	17	โรงงาน
ภาคตะวันออกเฉียงเหนือ	จำนวน	16	โรงงาน
ภาคตะวันออก	จำนวน	4	โรงงาน
	รวมทั้งสิ้น	47	โรงงาน

ทั้งนี้โรงงานอุตสาหกรรมน้ำตาลชลบุรีที่แต่เดิมอยู่ในภาคตะวันออกได้ย้ายไปตั้งที่อำเภอหนองบัว จังหวัดนครสวรรค์ในภาคเหนือและขยายกำลังการผลิตเพิ่มขึ้นด้วย

โดยรูปแบบการขนส่งอ้อยจากกรณีศึกษามติของคณะรัฐมนตรี สามารถแสดงให้เห็นตำแหน่งที่ตั้งของโรงงานน้ำตาลที่ได้รับปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกในแต่ละแห่งได้จากรูปที่ 2 ซึ่งพบว่ามีรูปแบบการขนส่งที่เปลี่ยนแปลงไป อันเป็นผลมาจากการย้ายที่ตั้งโรงงานและขยายกำลังการผลิต ค่าสถิติระยะทางการขนส่งตามตารางที่ 3 แสดงให้เห็นว่าระยะทางขนส่งเฉลี่ยในภาพรวมมีค่าเท่ากับ 39.76 กิโลเมตร และอัตราการใช้กำลังการผลิต (Utilization) ที่คำนวณได้เป็นไปตามตารางที่ 4

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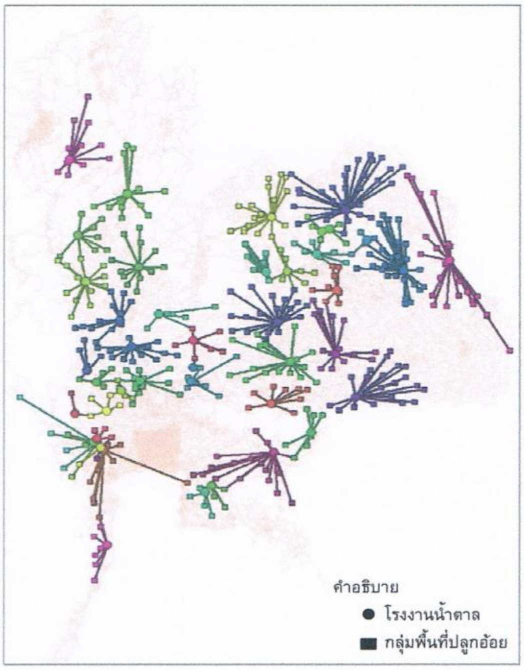

รูปที่ 2 รูปแบบการขนส่งอ้อยที่ต้นทุนค่าขนส่งรวมต่ำที่สุด กรณีศึกษาจากมติคณะรัฐมนตรี

ตารางที่ 3 ระยะทางการขนส่งจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงาน หลังมีมติคณะรัฐมนตรี

ภาค	ระยะทาง (กิโลเมตร)			
	Min	Mean	Max	S.D
ตะวันออก	11.35	56.09	148.78	38.56
เหนือ	1.72	40.41	128.65	27.25
กลาง	1.93	32.68	158.46	32.40
ตะวันออกเฉียงเหนือ	0.56	43.41	210.28	37.04
รวม	0.56	39.76	210.28	35.16

ตารางที่ 4 อัตราการใช้กำลังการผลิตของโรงงานน้ำตาล หลังมีมติคณะรัฐมนตรี

ภาค	ปริมาณอ้อยที่ได้รับ (ตัน)	กำลังการผลิต (ตัน/วัน)	Utilization (%)
ตะวันออก	4,158,047	5,299,988	78.45
เหนือ	15,850,360	23,504,085	67.44
กลาง	24,635,246	27,012,863	91.20
ตะวันออกเฉียงเหนือ	26,439,420	28,461,234	92.90
รวม	71,083,073	84,278,170	84.34

3.3 ผลกระทบของการย้ายและขยายกำลังการผลิตตามมติคณะรัฐมนตรี

เมื่อเปรียบเทียบผลลัพธ์ที่ได้จากกรณีก่อนและหลังการปฏิบัติตามมติคณะรัฐมนตรี ทำให้สามารถเข้าใจผลกระทบที่ต่อระบบโลจิสติกส์ขาเข้า ใน 2 ประเด็นหลัก ดังนี้

1) *รูปแบบการขนส่งอ้อย*

เปรียบเทียบรูปแบบการขนส่งระหว่างรูปที่ 1 และ 2 พบว่า รูปแบบการขนส่งอ้อยที่เหมาะสมมีการเปลี่ยนแปลงไป เนื่องจากมีการย้ายที่ตั้งโรงงานและขยายกำลังการผลิต หากเปรียบเทียบระยะทางการขนส่งเฉลี่ยซึ่งคำนวณแบบถ่วงน้ำหนัก (Weighted Average) ระหว่างค่าในตารางที่ 1 และ 3 พบว่าระยะทางการขนส่งเฉลี่ยจากกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาลโดยรวมมีแนวโน้มลดลงจาก 43.47 กิโลเมตร เป็น 39.76 กิโลเมตร มีเพียงภาคตะวันออกเท่านั้นที่มีแนวโน้มระยะทางเฉลี่ยสูงขึ้นจาก 41.55 กิโลเมตร เป็น 56.09 กิโลเมตร ซึ่งน่ามาจากการย้ายที่ตั้งและขยายกำลังการผลิตของโรงงานน้ำตาลนิวกว้างสุ้นหลี

2) *อัตราการใช้กำลังการผลิต*

เมื่อเปรียบเทียบผลในตารางที่ 2 และ 4 พบว่า กำลังการผลิตในแต่ละภาคเพิ่มสูงขึ้น โดยเฉพาะอย่างยิ่งในภาคเหนือ เนื่องจากการที่โรงงานอุตสาหกรรมน้ำตาลชลบุรีย้ายสถานที่ตั้งไปยังจังหวัดนครสวรรค์ อีกทั้งโรงงานน้ำตาลพิษณุโลกขอขยายกำลังการผลิต ทำให้ปริมาณความต้องการอ้อยในพื้นที่เพิ่มสูงขึ้นจาก 19,113,395 ตันอ้อย/วัน เป็น 23,504,085 ตันอ้อย/วัน จึงส่งผลกระทบทางลบต่ออัตราการใช้กำลังผลิตในภาคเหนือเป็นอย่างมาก ทำให้อัตราการใช้กำลังผลิตเหลือเพียง 67.44% จาก 96.69% รองลงมาคือภาคตะวันออกที่มีการขยายกำลังการผลิตของโรงงานน้ำตาลนิวกว้างสุ้นหลีทำให้มีปริมาณความต้องการอ้อยเพิ่มขึ้นจาก 3,991,414 ตันอ้อย/วัน เป็น 5,299,988 ตันอ้อย/วัน ส่งผลให้อัตราการใช้กำลังผลิตลดต่ำลง จากที่เคยสูงอยู่ที่ระดับ 96.69% เหลือเพียง 67.44%

ซึ่งผลที่ได้จากงานวิจัยทำให้สรุปได้ในเบื้องต้นว่าภาคเหนือและภาคตะวันออกของประเทศไทยควรมีการส่งเสริมให้มีการปลูกอ้อย หรือพัฒนาประสิทธิภาพการเพาะปลูกอ้อยให้มีผลผลิตเฉลี่ยต่อไร่สูงขึ้น เพื่อรองรับความต้องการใช้อ้อยในพื้นที่ของโรงงาน ในกรณีที่มีการตั้งโรงงานขึ้นมาใหม่ หรือขยายกำลังการผลิต จากการเปิดเสรีโรงงานน้ำตาลในอนาคต

4. สรุป

การวิจัยนี้เป็นการวิเคราะห์เชิงปริมาณของผลกระทบจากการย้ายโรงงานและขยายกำลังการผลิตโรงงานน้ำตาลทรายที่มีต่อโลจิสติกส์ขาเข้า โดยเน้นที่รูปแบบการขนส่งอ้อยที่เหมาะสมและอัตราการใช้กำลังการผลิตของโรงงานน้ำตาล โดยการใช้ตัวแบบจำลองคณิตศาสตร์และระบบภูมิศาสตร์สารสนเทศเป็นเครื่องมือในการวิเคราะห์ และมีมติคณะรัฐมนตรีที่เห็นชอบให้มีการย้ายโรงงานและการขยายกำลังการผลิตของโรงงานน้ำตาลที่กำลังจะเกิดขึ้นจริงในไม่ช้ามาเป็นกรณีศึกษา ผลที่ได้จากการศึกษา

ขั้นต้นแสดงให้เห็นว่า ระยะทางมีการขนส่งเปลี่ยนแปลงไปอย่างเห็นได้ชัด ในพื้นที่ซึ่งกำลังการผลิตสูงกว่าปริมาณอ้อยพบว่าระยะทางการขนส่งมีค่าสูงขึ้น เนื่องจากต้องหาปริมาณอ้อยให้เพียงพอต่อการผลิต สำหรับอัตราการใช้กำลังการผลิต (Utilization) ของโรงงานน้ำตาลจะสูงหรือต่ำขึ้นอยู่กับปริมาณผลผลิตอ้อยของแต่ละกลุ่มพื้นที่ที่ป้อนให้กับโรงงานเปรียบเทียบกับปริมาณความต้องการใช้อ้อยของโรงงานนั้นๆ ดังนั้นเมื่อมีการย้ายที่ตั้งโรงงานหรือขยายกำลังการผลิตจึงควรมีวิธีการดำเนินการส่งเสริมการปลูกอ้อยในพื้นที่ที่จะไปขอตั้งใหม่หรือขยายกำลังการผลิต เพื่อให้สามารถมีอ้อยเข้าสู่โรงงานได้เพียงพอกับกำลังการผลิตอย่างสม่ำเสมอ และไม่ก่อให้เกิดการแย่งอ้อยกันของโรงงานที่ตั้งอยู่เดิม

ในอีกทางหนึ่ง พื้นที่เดิมที่เคยมีโรงงานน้ำตาลตั้งอยู่ เมื่อจำนวนโรงงานน้ำตาลลดต่ำลงก็จะทำให้อัตราการใช้กำลังการผลิตของโรงงานในพื้นที่เดิมเพิ่มสูงขึ้น หากว่าปริมาณอ้อยมีมากกว่ากำลังการผลิตย่อมส่งผลกระทบต่อราคารับซื้ออ้อย เนื่องจากอ้อยมีลักษณะล้นตลาด อาจทำให้ชาวไร่ในพื้นที่เดิมได้รับความเดือดร้อนอันเป็นข้อกังวลของชาวไร่อ้อยในพื้นที่ทุกครั้งที่จะมีการย้ายโรงงานออกจากพื้นที่ไป ดังนั้นการย้ายโรงงานหรือขยายกำลังการผลิตของโรงงานจึงเปรียบเสมือนเหรียญสองด้าน ซึ่งจะต้องมีทั้งผู้ได้ประโยชน์และเสียประโยชน์อย่างแน่นอน จึงควรต้องมีเครื่องมือในการวิเคราะห์ผลกระทบที่น่าเชื่อถือได้ ประเมินผลกระทบที่อาจจะเกิดขึ้นได้อย่างเป็นรูปธรรมให้ทุกฝ่ายเข้าใจได้ง่าย ก่อนอนุมัติให้ดำเนินการอย่างหนึ่งอย่างใดลงไป ซึ่งในงานวิจัยนี้ได้เสนอวิธีการเชิงปริมาณเพื่อให้สามารถนำไปประยุกต์ใช้ได้โดยง่ายและมีข้อมูลพร้อมอยู่แล้ว

อย่างไรก็ตาม ตัวแบบจำลองคณิตศาสตร์ต้องใช้ข้อมูลป้อนเข้าจำนวนหนึ่ง ซึ่งมีความไม่แน่นอนแฝงอยู่ เช่น ปริมาณผลผลิตอ้อย อันเป็นปัจจัยสำคัญสำหรับการพิจารณาอนุมัติให้เปิดปิด หรือย้ายโรงงาน ดังนั้นข้อเสนอแนะของงานวิจัยในอนาคตจึงควรทำการวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) เพิ่มเติมเพื่อศึกษาถึงผลกระทบในกรณีที่ผลผลิตอ้อย (รวมถึงข้อมูลอื่นๆ) เปลี่ยนแปลงไปจากที่ประมาณการไว้ จะได้ทราบถึงขอบเขตของผลกระทบจากการเปิดเสรีโรงงานน้ำตาลที่อาจเป็นไปได้ ซึ่งทำให้ได้ผลลัพธ์ที่มีความละเอียดชัดเจนและรัดกุมมากยิ่งขึ้น ช่วยให้ทุกฝ่ายที่เกี่ยวข้องในอุตสาหกรรมอ้อยและน้ำตาลทรายตัดสินใจและวางแผนรับมือกับการเปิดเสรีได้อย่างถูกต้องและทันท่วงที มีระยะเวลาเพียงพอในการเตรียมตัวและปรับตัวก่อนการเข้าสู่การเปิดเสรีอย่างจริงจัง

กิตติกรรมประกาศ

ขอขอบพระคุณ ศูนย์เทคโนโลยีสารสนเทศและการสื่อสาร สำนักงานปลัดกระทรวงคมนาคมที่เอื้อเฟื้อชุดข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย (สอน.) สำหรับความเอื้อเฟื้อข้อมูลและเอกสารอ้างอิงจำนวนมากในการทำงานวิจัยโครงการนี้ อีกทั้งศูนย์ผู้เชี่ยวชาญด้านระบบขนส่ง จราจรและโลจิสติกส์ (T-LEX Center) คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหิดล ที่อนุเคราะห์สถานที่ คอมพิวเตอร์และโปรแกรมต่างๆ ที่จำเป็นสำหรับการทำงานวิจัย

เอกสารอ้างอิง

[1] สำนักงานเศรษฐกิจการเกษตร (2551). *สถิติการส่งออก.* www.oae.go.th.

[2] สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย. (2552). *คู่มือหรือคำสั่งเกี่ยวกับวิธีปฏิบัติงานของเจ้าหน้าที่รัฐ กลุ่มที่ 6 การปรับโครงสร้างอุตสาหกรรมอ้อยและน้ำตาลทราย.* ห้องสมุดสำนักงานคณะกรรมการอ้อยและน้ำตาลทราย

[3] จินตนา เดชผล. (2540). *การวิเคราะห์ผลกระทบของนโยบายอุตสาหกรรมน้ำตาลในประเทศไทย.* วิทยานิพนธ์ปริญญาโท. มหาวิทยาลัยเกษตรศาสตร์

[4] วิไลลักษณ์ สกุลเขมฤทัย. (2545). *ผลกระทบของการค้าเสรีที่มีอุตสาหกรรมอ้อยและน้ำตาลไทย.* วิทยานิพนธ์ปริญญาโท. มหาวิทยาลัยเชียงใหม่

[5] อภิรมย์ เลี้ยงชีพเสริมสุข. (2535). *การแทรกแซงของรัฐในทางกฎหมายต่อภาคเศรษฐกิจอ้อยและน้ำตาล. วิทยานิพนธ์ปริญญาโท.* มหาวิทยาลัยธุรกิจบัณฑิตย์

[6] สำนักงานคณะกรรมการอ้อยและน้ำตาล. (2551). *มติของคณะรัฐมนตรีที่เกี่ยวข้องกับการตั้ง การย้าย และขยายกำลังในการผลิตของโรงงานน้ำตาล.* www.ocsb.go.th

[7] สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย.(2551). *ที่ตั้งของโรงงานน้ำตาลในประเทศไทย.* ห้องสมุดสำนักงานคณะกรรมการอ้อยและน้ำตาลทราย

[8] สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย. (2552). *รายงานผลการสำรวจพื้นที่ปลูกอ้อยประจำปีการผลิต 2551/52.* ห้องสมุดสำนักงานคณะกรรมการอ้อยและน้ำตาลทราย

[9] ณัฐพร สุวรรณสูนย. (2545). *ทำเลที่ตั้งและขนาดที่เหมาะสมของโรงงานน้ำตาลทรายในประเทศไทย.* วิทยานิพนธ์ปริญญาโท. มหาวิทยาลัยเชียงใหม่

[10] Higgins A, Antony G, Sandell G, Davies I, Prestwidge D, Andrew B. 2004. A framework for integrating a complex harvesting and transport system for sugar production, *Journal of Agricultural Systems*, 99–115.

[11] Higgins A. 2006. Scheduling of road vehicles in sugarcane transport: A case study at an Australian sugar mill. *European Journal of Operational Research 170.* 987–1000

[12] สำนักงานปลัดกระทรวงคมนาคม. (2550). *ข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม (Transport Fundamental Geographic Data Set: Transport FGDS).* [CD-ROM]

APPENDIX F
A PUBLICATION IN THE 8th NATIONAL TRANSPORT CONFERENCE

การประชุมวิชาการ การขนส่งแห่งชาติ ครั้งที่ 8
พัฒนาการขนส่งหลายรูปแบบสู่ความเป็นเลิศทางเศรษฐกิจระดับโลก

(NTC8-047)

การวิเคราะห์ความอ่อนไหวของผลกระทบจากนโยบายเปิดเสรีโรงงานน้ำตาลเนื่องจากความไม่แน่นอนของผลผลิตอ้อย

SENSITIVITY ANALYSIS ON THE IMPACTS OF SUGAR MILL LIBERALIZATION POLICY RESULTING FROM THE UNCERTAINTY OF THE AMOUNT OF CANE PRODUCTION

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บทคัดย่อ:

ในอุตสาหกรรมอ้อยและน้ำตาลทราย มีกระบวนการสำคัญที่เกี่ยวข้อง 3 ขั้นตอน ได้แก่ โลจิสติกส์ขาเข้า การผลิตภายในโรงงานน้ำตาลทราย และโลจิสติกส์ขาออก สำหรับโลจิสติกส์ขาเข้าถือว่าเป็นกระบวนการที่สำคัญมาก เป็นการนำอ้อยซึ่งเป็นวัตถุดิบเข้าสู่โรงงาน เป็นจุดเริ่มต้นของกระบวนการผลิตน้ำตาลทราย คิดเป็นต้นทุนโลจิสติกส์ที่มีมูลค่าสูงมาก การวางแผนเพาะปลูกอ้อยและบริหารกำลังการผลิตของโรงงานน้ำตาลให้สอดคล้องกันจึงเป็นสิ่งจำเป็นอย่างยิ่งที่ช่วยให้อุตสาหกรรมนี้มีประสิทธิภาพ ตลอดเวลาที่ผ่านมารัฐบาลมีการพิจารณานโยบายเปิดเสรีโรงงานน้ำตาล ซึ่งมีทั้งเสียงคัดค้านและสนับสนุน เหตุผลที่มักจะถูกหยิบยกขึ้นมาพิจารณาก็คือเรื่องของสมดุลระหว่างปริมาณอ้อยและกำลังการผลิตน้ำตาลทรายในแต่ละพื้นที่ การวิจัยนี้ทำการศึกษาวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) ของผลกระทบจากนโยบายเปิดเสรีโรงงานน้ำตาล อันเนื่องมาจากความไม่แน่นอนของปริมาณผลผลิตอ้อยที่มักจะเกิดขึ้นอยู่เสมอ โดยอาศัยข้อมูลจากระบบสารสนเทศภูมิศาสตร์และตัวแบบจำลองทางคณิตศาสตร์เป็นเครื่องมือในการวิเคราะห์ ภายใต้สมมุติฐานของ 3 สถานการณ์หลัก คือ 1) กรณีผลผลิตเป็นไปตามที่คาดการณ์ไว้ 2) กรณีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ และ 3) กรณีปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ กรณีศึกษาที่ทำการวิเคราะห์กรณีการยื่นคำขอย้ายที่ตั้งโรงงานและเพิ่มกำลังการผลิตน้ำตาลทรายเมื่อปี พ.ศ. 2550 เน้นที่ความอ่อนไหวที่มีต่อรูปแบบการขนส่งอ้อยเข้าสู่โรงงาน และอัตราการใช้ประโยชน์กำลังผลิตของแต่ละโรงงาน

คำสำคัญ: อ้อย, โรงงานน้ำตาล, โลจิสติกส์ขาเข้า, การเปิดเสรี, การวิเคราะห์ความอ่อนไหว

1. บทนำ

อุตสาหกรรมอ้อยและน้ำตาลของไทยเป็นอุตสาหกรรมหนึ่งที่ได้รับการกล่าวถึงเรื่องการเปิดเสรีเป็นอย่างมาก ทำให้มีการวิเคราะห์ว่าสมควรมีการดำเนินการปฏิรูปโครงสร้างระบบอุตสาหกรรมอ้อยและน้ำตาลขึ้นมาใหม่ โดยลดการปกป้องคุ้มครองและควบคุม หรือแม้กระทั่งให้รัฐบาลเข้าไปแทรกแซงอุตสาหกรรมนี้น้อยที่สุด [1] เพื่อให้อุตสาหกรรมนี้มีแนวโน้มไปสู่ระบบเสรีมากขึ้น โดยงานวิจัยนี้เน้นศึกษาเรื่องผลกระทบจากการเปิดเสรีโรงงานน้ำตาล เช่น การตั้งโรงงานน้ำตาลขึ้นใหม่ ย้ายโรงงาน และ/หรือขยายกำลังผลิตได้อย่างเสรี โดยไม่ถูกควบคุมจากรัฐบาล และถึงแม้ในปัจจุบันจะยังไม่สามารถหาข้อสรุปเรื่องนี้ได้ แต่ทางคณะรัฐมนตรีก็มีการอนุญาตให้ย้ายโรงงานน้ำตาลจากเขตที่มีปริมาณอ้อยไม่เพียงพอไปสู่เขตที่มีปริมาณอ้อยที่มากขึ้น รวมถึงสามารถขยายกำลังการผลิตตามความเหมาะสมของปริมาณอ้อย ทั้งนี้เป็นการพิจารณาถึงปริมาณอ้อยที่จะทำการขนส่งเข้าโรงงานน้ำตาลเพื่อให้เหมาะสมกับกำลังการผลิต ซึ่งจะเห็นได้ชัดว่าปริมาณอ้อยเป็นปัจจัยสำคัญต่อการอนุมัติให้มีการย้าย/ตั้งใหม่ หรือขยายกำลังการผลิตของโรงงานน้ำตาล ดังนั้นการเปลี่ยนแปลงพื้นที่เพาะปลูก หรือปริมาณผลผลิตอ้อยย่อมส่งผลกระทบต่อปริมาณการผลิตน้ำตาลโดยตรง

ในปัจจุบันพบว่าปริมาณผลผลิตอ้อยมักจะมีความความไม่แน่นอนเกิดขึ้นอยู่เสมอ ซึ่งมีผลโดยตรงต่อการผลิตน้ำตาล ดังนั้นการวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) จากความไม่แน่นอนของปริมาณผลผลิตอ้อยจึงน่าสนใจศึกษาเป็นอย่างยิ่ง งานวิจัยนี้จึงทำการวิเคราะห์ภายใต้สมมุติฐานของ 3 สถานการณ์หลัก คือ กรณีผลผลิตเป็นไปตามที่คาดการณ์ไว้ กรณีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ และกรณีปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ โดยใช้กรณีศึกษาจากมติของคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายโรงงานและการขยายกำลังการผลิตของโรงงานน้ำตาลที่จะเกิดขึ้นจริง ซึ่งผลลัพธ์ที่ได้ช่วยให้พิจารณาได้ว่าความอ่อนไหว (Sensitivity Analysis) จากความไม่แน่นอนของปริมาณผลผลิตอ้อยจะส่งผลกระทบต่อนโยบายการเปิดเสรีโรงงานน้ำตาลในอนาคตหรือไม่

2. งานวิจัยที่เกี่ยวข้อง

สำหรับอุตสาหกรรมอ้อยและน้ำตาลทรายนั้นอ้อยและน้ำตาลมีความสัมพันธ์กันมาก ดังนั้นไม่ว่าจะเป็นการย้ายการตั้งโรงงานขึ้นใหม่ การขยายกำลังการผลิต หรือแม้กระทั่งการเปลี่ยนแปลงพื้นที่เพาะปลูกหรือปริมาณอ้อยย่อมส่งผลกระทบต่อปริมาณการผลิตน้ำตาลโดยตรง จึงทำให้มีงานวิจัยศึกษาวิเคราะห์ถึงความต้องการอ้อยในประเทศไทยจากการขยายตัวของอุตสาหกรรมอ้อยและน้ำตาล [2] รวมทั้งปัจจัยที่มีผลกระทบต่อปริมาณการผลิตอ้อย [3] เพื่อให้ที่ตั้งโรงงานมีความเหมาะสมกับพื้นที่ปลูกอ้อย [4] เนื่องจากอุตสาหกรรมอ้อยและน้ำตาลเป็นอุตสาหกรรมแปรรูปสินค้าทางทางการเกษตร โดยมีอ้อยเป็นวัตถุดิบหลักในการผลิต ดังนั้นปริมาณอ้อยที่เข้าสู่โรงงานจึงมีความสำคัญมาก ทำให้มีงานวิจัยต่างๆ ศึกษาตั้งแต่การวางแผนเพาะการเก็บเกี่ยวอ้อย [5] เพื่อการพัฒนาวิธีการเพิ่มประสิทธิภาพในการเก็บเกี่ยว [6] และจัดสรรการขนส่งอ้อยเข้าสู่โรงงาน [7] เพื่อให้เกิดประสิทธิภาพในการผลิตจากการที่มีปริมาณอ้อยเพียงพอต่อความต้องการมากที่สุด ซึ่งพบว่ามีวิธีการแก้ปัญหาที่นิยมใช้ คือ การโปรแกรมเชิงเส้นตรง (Linear Programming) โดยฟังก์ชั่นวัตถุประสงค์ (Objective Function) จะเป็นปัญหาค่าต่ำสุด (Minimization Problems) ซึ่งงานวิจัยนี้ได้นำมาประยุกต์ใช้เป็นเครื่องมือในการคำนวณหารูปแบบการขนส่งจากพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาลเพื่อให้ระบบมีต้นทุนการขนส่งต่ำที่สุด อีกทั้งยังประยุกต์ใช้โปรแกรมทางด้านระบบสารสนเทศภูมิศาสตร์ (Geographic Information System: GIS) สำหรับคำนวณหาระยะทางการขนส่งจากพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาลอีกด้วย

3. ระเบียบวิธีวิจัย

3.1 ข้อมูล

งานวิจัยนี้ได้ทำการวิเคราะห์ข้อมูลของปีการผลิต 2551/2552 เพื่อนำมาเป็นข้อมูลพื้นฐานในการวิเคราะห์ โดยโรงงานน้ำตาลทั่วประเทศมีอยู่ทั้งหมด 47 โรงงาน [8] และมีพื้นที่ปลูกอ้อยรวมทั้งประเทศ 6,831,892 ไร่ แต่เนื่องจากข้อมูลมีจำนวนมาก ด้วยข้อจำกัดของโปรแกรมการคำนวณ ผู้วิจัยจึงได้ทำการรวมกลุ่มไร่อ้อยเหล่านี้เป็นรายอำเภอได้ทั้งสิ้น 404 อำเภอ [9]

3.2 ตัวแบบจำลองคณิตศาสตร์การขนส่ง

เนื่องจากงานวิจัยนี้เป็นการวิเคราะห์ผลกระทบของการเปิดเสรีโรงงานน้ำตาล ซึ่งเน้นวิเคราะห์ความอ่อนไหวของปริมาณผลผลิตอ้อยที่มีต่อรูปแบบการขนส่งอ้อยเข้าสู่โรงงาน และอัตราการใช้ประโยชน์กำลังผลิตของแต่ละโรงงาน เมื่อพิจารณาถึงลักษณะของปัญหาที่กำลังทำการวิเคราะห์จึงเห็นว่าตัวแบบจำลองคณิตศาสตร์การขนส่ง (Transportation Problem) มีความเหมาะสมสามารถนำมาประยุกต์ใช้เป็นเครื่องมือในการวิเคราะห์ได้ โดยมีรายละเอียดของแบบจำลองดังนี้

Objective Function: Minimize Total Transportation Cost

$$\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

Constrains

$$\sum_{j=1}^{n} X_{ij} \le S_i \quad ; \quad \forall_i \qquad (2)$$

$$\sum_{i=1}^{m} X_{ij} \ge D_j \quad ; \quad \forall_j \qquad (3)$$

$$X_{ij} \ge 0 \qquad (4)$$

โดยที่

C_{ij} = ระยะทางการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย i ไปยังโรงงาน j (กิโลเมตร)

X_{ij} = ปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อย i ไปยังโรงงาน j (ตัน)

D_j = ปริมาณความต้องการอ้อยของโรงงาน j (ตัน)

S_i = ปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อย i (ตัน)

i = กลุ่มพื้นที่เพาะปลูกอ้อย; $i = 1,2,\ldots,m$

j = โรงงานน้ำตาล; $j = 1, 2,\ldots,n$

m = จำนวนกลุ่มพื้นที่เพาะปลูกอ้อย

n = จำนวนโรงงานน้ำตาล

ฟังก์ชั่นวัตถุประสงค์ *(1)* ต้องการให้รูปแบบการขนส่งมีต้นทุนค่าขนส่งโดยรวมจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาลต่ำที่สุด เงื่อนไขใน *(2)* เป็นเงื่อนไขบังคับปริมาณอ้อยที่ทำการขนส่งจากกลุ่มพื้นที่เพาะปลูกอ้อยใดๆ ไปยังโรงงานน้ำตาลต้องไม่เกินปริมาณอ้อยที่ผลิตได้ เงื่อนไขใน *(3)* เป็นเงื่อนไขบังคับว่าโรงงานน้ำตาลแต่ละแห่งจะต้องได้รับปริมาณอ้อยเพียงพอสอดคล้องกับกำลังการผลิตที่มีอยู่ สุดท้ายเงื่อนไขใน *(4)* หมายถึงจำนวนปริมาณอ้อยที่ส่งจากกลุ่มพื้นที่ส่งอ้อยไปยังโรงงานน้ำตาลต้องไม่ติดลบ

ตัวแบบจำลองนี้ตั้งสมมุติฐานว่าต้นทุนค่าขนส่งต่อหน่วยน้ำหนักของอ้อยมีค่าเท่ากันไม่ว่าจะขนส่งจากพื้นที่ใดไปโรงงานใดเพียงแต่แปรผันตามระยะทางการขนส่งเท่านั้น จึงสามารถแทนต้นทุนด้วยระยะทาง C_{ij} ได้โดยตรง และเพื่อให้ตัวแบบจำลองสามารถหาคำตอบได้เสมอ จึงจำเป็นที่ผลรวมของปริมาณอ้อยจากกลุ่มพื้นที่เพาะปลูกอ้อยต้องเท่ากับผลรวมของปริมาณความต้องการอ้อยที่โรงงานต้องการในการผลิต กล่าวคือ $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j$ เพื่อให้เกิดความสมดุลระหว่างปริมาณความต้องการอ้อยที่โรงงานต้องการและปริมาณอ้อยที่ผลิตได้จากกลุ่มพื้นที่เพาะปลูกอ้อย ซึ่งผลลัพธ์ที่ได้จากตัวแบบจำลองนำมาวิเคราะห์ออกเป็น 3 ประเด็น ดังนี้

1) รูปแบบการขนส่งอ้อย วิเคราะห์ถึงผลกระทบที่มีต่อระบบการขนส่งอ้อย โดยการเปรียบเทียบระยะทางเฉลี่ยจากกลุ่มพื้นที่เพาะปลูกอ้อยไปยังโรงงานน้ำตาล

2) อัตราการใช้กำลังการผลิต นำปริมาณอ้อยที่โรงงานแต่ละแห่งได้รับมาใช้คำนวณอัตราการใช้กำลังผลิตของโรงงานน้ำตาลแต่ละแห่งได้ โดยการเปรียบเทียบกับกำลังผลิตของโรงงานน้ำตาล ซึ่งปริมาณอ้อยรวมที่ได้รับจากทุกกลุ่มพื้นที่เพาะปลูกหารด้วยกำลังการผลิตของโรงงานและคูณด้วย 100 เพื่อเทียบเป็นเปอร์เซ็นต์

3) การวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) นำผลของกรณีที่ปริมาณผลผลิตเป็นไปตามที่คาดการณ์ไว้มาเป็นข้อมูลพื้นฐาน (Base Case) หลังจากนั้นทดลองเปลี่ยนปริมาณผลผลิตอ้อยภายใต้สมมุติฐาน 3 สถานการณ์ คือ กรณีผลผลิตเป็นไปตามที่คาดการณ์ไว้ กรณีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ (+10% และ +20%) และกรณีปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ (-%10 และ -20%) แล้วนำผลที่ได้มาเปรียบเทียบกับ “Base Case” เพื่อวิเคราะห์ผลตาม 1) และ 2)

3.3 การรวบรวมข้อมูล

การรวบรวมข้อมูลในงานวิจัยนี้ คือ การเตรียมข้อมูลสำหรับตัวแบบจำลองคณิตศาสตร์เพื่อแทนค่าพารามิเตอร์ลงไป โดยข้อมูลแบ่งออกเป็น 3 ส่วนสำคัญ ดังนี้

1) ปริมาณผลผลิตอ้อย (Supply); S_i คำนวณได้จากการนำข้อมูลพื้นที่เพาะปลูกอ้อยเป็นรายอำเภอ และข้อมูลอัตราผลผลิตอ้อยเฉลี่ยต่อไร่มาคูณกัน โดยสำหรับปีการผลิต 2551/52 ประเทศไทยมีการประมาณการผลผลิตอ้อยทั้งหมด 71,083,073 ตัน และเพื่อเป็นการวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) อันเนื่องมาจากความไม่แน่นอนของปริมาณผลผลิตอ้อย จึงทำการศึกษาในกรณีที่ปริมาณอ้อยมีการเปลี่ยนแปลง 3 กรณี คือ กรณีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ 10% (78,191,401 ตัน) และ 20% (85,299,692 ตัน) และกรณีปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ 10% (63,974,785 ตัน) และ 20% (56,866,454 ตัน)

2) ระยะทางการขนส่งอ้อย (Distance Matrix); C_{ij} คำนวณหาระยะทางการขนส่งอ้อยจากพื้นที่เพาะปลูกไปยังโรงงานน้ำตาลโดยการใช้โปรแกรม ArcMap ซึ่งจำเป็นต้องมีข้อมูลระบบสารสนเทศภูมิศาสตร์ 3 ชุด ได้แก่ ข้อมูลพื้นที่เพาะปลูกอ้อย ข้อมูลด้านเส้นทางคมนาคม [10] และข้อมูลที่ตั้งโรงงาน

3) ปริมาณความต้องการใช้อ้อย (Demand); D_j คำนวณได้จากการนำข้อมูลกำลังการผลิตที่โรงงานน้ำตาลได้รับอนุญาต และข้อมูลจำนวนวันที่แต่ละโรงงานได้ทำการผลิตน้ำตาลสำหรับปีการผลิต 2551/52 มาคูณกัน

ข้อมูลในส่วนของพารามิเตอร์ที่คำนวณได้จะถูกนำมาจัดเก็บเป็นฐานข้อมูลโดยใช้โปรแกรม Microsoft Access เพื่อให้สามารถเข้าถึงและประมวลผลโดยใช้ Visual Basic ในการสร้าง Formulation หลังจากนั้นจึงใช้โปรแกรม LINDO ทำการ Solve เพื่อหาผลลัพธ์

4. ผลการศึกษาและวิเคราะห์ผล

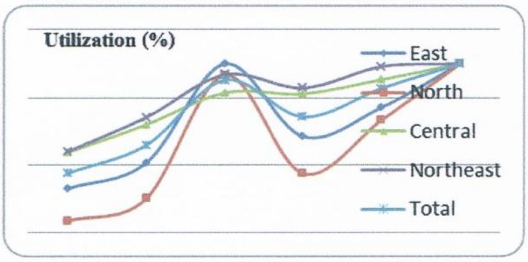
4.1 กรณีที่ 1: ปริมาณผลผลิตเป็นไปตามที่คาดการณ์ไว้

ผลลัพธ์ที่ได้จากการแก้ปัญหาในกรณีปริมาณผลผลิตเป็นไปตามที่คาดการณ์ไว้ แสดงไว้ในภาพที่ 1 ซึ่งพบว่า ณ สภาพปัจจุบันระยะทางการขนส่งเฉลี่ยโดยรวมอยู่ที่ 43.37 กิโลเมตร ส่วนอัตราการใช้กำลังการผลิตจากภาพที่ 2 อยู่ในเกณฑ์สูงเกือบ 100% โดยเฉพาะภาคตะวันออกที่มีอัตราการใช้กำลังการผลิตสูงถึง 99.95% และถึงแม้ภาคกลางจะมีอัตราการใช้กำลังการผลิตต่ำที่สุด แต่ก็สูงถึง 91.47% ซึ่งผลที่ได้นี้จะนำมาเป็นข้อมูลพื้นฐาน (Base Case) ในการเปรียบเทียบ

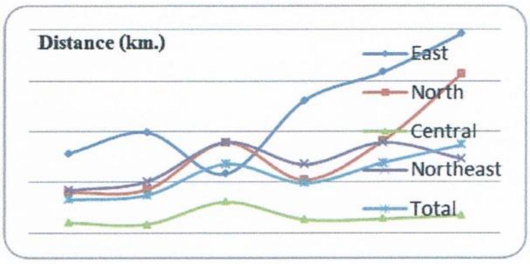
สำหรับการวิเคราะห์ถึงผลกระทบของการเปิดเสรีโรงงานน้ำตาลจากมติของคณะรัฐมนตรี (Cabinet) เมื่อวันที่ 16 ตุลาคม พ.ศ. 2550 ที่เกี่ยวข้องกับการย้ายโรงงานและขยายกำลังการผลิตพบว่าโรงงานน้ำตาลนิวกรุงไทยย้ายที่ตั้งจาก อ.ท่ามะกา ไปที่ อ.บ่อพลอย จ.กาญจนบุรี และขยายกำลังการผลิตจาก 8,385 เป็น 20,400 ตันอ้อย/วัน โรงงาน

น้ำตาลบ้านโป่ง ย้ายที่ตั้งจากราชบุรีไปที่สุโขทัย และขยายกำลังการผลิตจาก 9,131 เป็น 18,000 ตันอ้อย/วัน โรงงานน้ำตาลนิวกว้างสุ้นหลี ย้ายที่ตั้งจากชลบุรีไปที่ สระแก้ว และขยายกำลังการผลิตจาก 6,479 เป็น 24,000 ตันอ้อย/วัน โรงงานน้ำตาลพิษณุโลก ขยายกำลังการผลิตจาก 12,000 เป็น 22,000 ตันอ้อย/วัน โรงงานน้ำตาลบ้านไร่ ขยายกำลังการผลิตจาก 12,000 เป็น 2,000 ตันอ้อย/วัน ในที่นี้รวมไปถึงโรงงานอุตสาหกรรมน้ำตาลชลบุรีย้ายที่ตั้งจากชลบุรี ไปยังนครสวรรค์ และขยายกำลังการผลิตจาก 5,800 เป็น 36,000 ตันอ้อย/วัน ไปยังขยายกำลังการผลิตด้วย โดยการปฏิบัติตามมติคณะรัฐมนตรีดังกล่าว จะทำให้กำลังการผลิตของโรงงานน้ำตาลในภาพรวมเพิ่มสูงขึ้น 54,805 ตันอ้อย/วัน จากเดิมที่มีอยู่ 731,207 ตันอ้อย/วัน ในปีการผลิต 2551/2552 [11] ซึ่งส่งผลให้ระยะทางการขนส่งเฉลี่ยจากภาพที่ 1 ของกลุ่มพื้นที่ปลูกอ้อยไปยังโรงงานน้ำตาลโดยรวมมีแนวโน้มลดลงจาก 43.47 เป็น 39.76 กิโลเมตร และมีอัตราการใช้กำลังการผลิตจากภาพที่ 2 โดยรวมลดลงด้วย เนื่องมาจากความต้องการปริมาณอ้อยในระบบเพิ่มขึ้นจากเดิม

จากนั้นวิเคราะห์เปรียบเทียบผลกระทบจากความไม่แน่นอนของปริมาณผลผลิตอ้อยภายใต้สมมุติฐาน 3 สถานการณ์หลัก ซึ่งสามารถวิเคราะห์ออกเป็น 2 ส่วนคือ รูปแบบการขนส่งซึ่งคำนวณแบบถ่วงน้ำหนัก (Weighted Average) และอัตราการใช้กำลังผลิตโดยรวม ดังภาพที่ 1 และ 2 ตามลำดับ



ภาพที่ 1 ความอ่อนไหวของระยะทางขนส่งเฉลี่ยตามการเปลี่ยนแปลงของปริมาณผลผลิตอ้อย



ภาพที่ 2 ความอ่อนไหวของอัตราการใช้กำลังผลิตตามการเปลี่ยนแปลงของปริมาณผลผลิตอ้อย

4.2 กรณีที่ 2: ปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้

เมื่อวิเคราะห์ถึงผลกระทบจากการที่ปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ โดยการเปรียบเทียบกับข้อมูลพื้นฐาน (Base Case) ในภาพที่ 1 และ 2 พบว่า ยิ่งปริมาณผลผลิตอ้อยสูงขึ้นระยะทางเฉลี่ยก็มีแนวโน้มเพิ่มสูงขึ้นจาก 43.47 เป็น 43.73 เป็น 47.23 กิโลเมตรตามลำดับ ซึ่งน่าจะมาจากกลุ่มพื้นที่เพาะปลูกอ้อยกระจายอยู่ทั่วไป รวมทั้งโรงงานน้ำตาลบางแห่งมีปริมาณอ้อยบริเวณรอบๆโรงงานไม่เพียงพอต่อความต้องการ จึงทำให้ต้องมีการขนส่งอ้อยจากพื้นที่ที่ไกลออกไปมายังโรงงานเพื่อให้เพียงพอต่อการผลิต ซึ่งเป็นสาเหตุให้ระยะทางการขนส่งเฉลี่ยมีค่าสูงขึ้น เมื่อวิเคราะห์ถึงความอ่อนไหวของอัตราการใช้กำลังการผลิตพบว่า เมื่อปริมาณผลผลิตอ้อยสูงขึ้นอัตราการใช้กำลังการผลิตก็มีแนวโน้มสูงขึ้นด้วยเช่นกัน

4.3 กรณีที่ 3: ปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้

เมื่อวิเคราะห์ถึงผลกระทบจากการที่ปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ โดยการเปรียบเทียบกับข้อมูลพื้นฐาน (Base Case) ในภาพที่ 1 และ 2 พบว่า ระยะทางเฉลี่ยมีแนวโน้มลดลงจาก 43.47 เป็น 37.44 เป็น 36.51 ตามลำดับ ซึ่งน่ามาจากปริมาณผลผลิตอ้อยมีไม่เพียงพอต่อการผลิต เมื่อมองถึงอัตราการใช้กำลังการผลิตพบว่ายิ่งมีปริมาณผลผลิตอ้อยน้อยลงเท่าใด อัตราการใช้กำลังการผลิตของโรงงานก็มีแนวโน้มลดลงเช่นกัน

5. สรุปผล

งานวิจัยนี้เป็นการวิเคราะห์ความอ่อนไหว (Sensitivity Analysis) ของผลกระทบจากนโยบายเปิดเสรีโรงงานน้ำตาล อันเนื่องมาจากความไม่แน่นอนของปริมาณผลผลิตภายใต้สมมุติฐาน คือ 1) กรณีผลผลิตเป็นไปตามที่คาดการณ์ไว้ 2) กรณีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ และ 3) กรณีปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้ กรณีศึกษาจากมติของคณะรัฐมนตรีที่เกี่ยวข้องกับการย้ายสถานที่ตั้งโรงงานและขยายกำลังการผลิตที่จะเกิดขึ้นในอนาคต โดยใช้ข้อมูลปริมาณผลผลิตอ้อยในปีการผลิต 2551/52 เป็นข้อมูลพื้นฐาน จากการศึกษาขั้นต้นแสดงให้เห็นว่า เมื่อปริมาณอ้อยสูงขึ้น ระยะทางในการขนส่งเฉลี่ยกลับมีแนวโน้มเพิ่มขึ้นด้วย ทั้งนี้น่าจะมาจากพื้นที่เพาะปลูกอ้อยกระจายอยู่ทั่วไป เมื่อปริมาณอ้อยที่ทำการศึกษาเพิ่มขึ้นจากเดิมแต่อาจมีโรงงานน้ำตาลบางแห่งที่มีปริมาณผลผลิตอ้อยบริเวณรอบๆโรงงานไม่เพียงพอต่อความต้องการก็ได้ จึงทำให้ต้องมีการขนส่งอ้อยจากพื้นที่ที่ไกลออกไปมายังโรงงานเพื่อให้เพียงพอต่อการผลิต ดังนั้นถ้าในอนาคตมีการย้าย การตั้งโรงงาน หรือขยายกำลังการผลิตเนื่องจากการเปิดเสรีโรงงานน้ำตาล สิ่งแรกที่ควรต้องพิจารณา คือ สมดุลระหว่างปริมาณอ้อยในพื้นที่กับกำลังการผลิต เนื่องจากพื้นที่ปลูกอ้อยไม่ควรอยู่ห่างจากโรงงาน เพราะถ้าอยู่ไกลเกินไปจะเสียค่าขนส่งสูง ซึ่งแสดงให้เห็นว่าปริมาณอ้อยมีความสำคัญต่อโรงงานน้ำตาลมาก และเมื่อวิเคราะห์ถึงอัตราการใช้กำลังการผลิต (Utilization) ของโรงงานน้ำตาล พบว่าอัตราการใช้กำลังการผลิตจะสูงหรือต่ำขึ้นอยู่กับปริมาณผลผลิตอ้อยของแต่ละกลุ่มพื้นที่ที่ป้อนให้กับโรงงานเปรียบเทียบกับปริมาณความต้องการใช้อ้อยของโรงงานนั้นๆ เมื่อปริมาณผลผลิตอ้อยน้อยกว่าที่คาดการณ์ไว้จึงทำให้โรงงานน้ำตาลมีอัตราการใช้กำลังผลิตไม่เต็มที่ ซึ่งถ้าไม่มีการศึกษาในดีก่อนที่มีการเปิดเสรีโรงงาน อาจก่อให้เกิดการแย่งอ้อยกันในพื้นที่ และอาจเป็นสาเหตุที่ทำให้โรงงานน้ำตาลบางแห่งหยุดดำเนินการไปในที่สุด ตรงกันข้ามเมื่อมีปริมาณผลผลิตอ้อยสูงกว่าที่คาดการณ์ไว้ จะทำให้โรงงานน้ำตาลมีอัตราการใช้กำลังผลิตที่สูงขึ้น ซึ่งอาจก่อให้เกิดการขยายกำลังการผลิต หรือการตั้งโรงงานน้ำตาลขึ้นใหม่จากการเปิดเสรีโรงงานน้ำตาลได้ในอนาคต

กิตติกรรมประกาศ

ขอขอบพระคุณ ศูนย์เทคโนโลยีสารสนเทศและการสื่อสาร สำนักงานปลัดกระทรวงคมนาคมที่เอื้อเฟื้อชุดข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม และสำนักงานคณะกรรมการอ้อยและน้ำตาลทราย (สอน.) สำหรับความเอื้อเฟื้อในเรื่องข้อมูลและเอกสารอ้างอิงที่ใช้ในงานวิจัยนี้

เอกสารอ้างอิง

1) สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย, (2552). คู่มือหรือคำสั่งเกี่ยวกับวิธีปฏิบัติงานของเจ้าหน้าที่รัฐ กลุ่มที่ 6 การปรับโครงสร้างอุตสาหกรรมอ้อยและน้ำตาลทราย. สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย
2) อัจฉรา ทศรฐ, 2522. การวิเคราะห์ความต้องการอ้อยในประเทศไทย. วิทยานิพนธ์ปริญญาโท มหาวิทยาลัยเกษตรศาสตร์.
3) จิราภรณ์ พ้นภัย, 2542. การคาดคะเนอุปทานอ้อยในประเทศไทย. วิทยานิพนธ์ปริญญาโท มหาวิทยาลัยรามคำแหง.
4) ศรัณย์นพ อินทเสน, 2544. การวิเคราะห์หาความเหมาะสมของพื้นที่ปลูกอ้อยโรงงานและที่ตั้งโรงงานน้ำตาล ในเขตที่ราบภาคกลางตอนบน. วิทยานิพนธ์ปริญญาโท มหาวิทยาลัยรามคำแหง.
5) Higgins A, Muchow R, Rudd A, Ford A. (1998). Optimizing harvest date in sugar production: A case study for the Mossman mill region in Australia I. Development of operations research model and solution. Field Crops Research.153 – 162.
6) Higgins A, Muchow R. (2003). Assessing the potential benefits of alternative cane supply arrangements in the Australian sugar industry. Agricultural Systems (76). 623-638.

7) บุริม นิลแป้น, 2551. การวางแผนการขนส่งอ้อยเข้าสู่โรงงานน้ำตาลอย่างมีประสิทธิภาพ. วิทยานิพนธ์ปริญญาโท มหาวิทยาลัยเทคโนโลยีสุรนารี.

8) สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย. (2551). ที่ตั้งของโรงงานน้ำตาลในประเทศไทย. สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย

9) สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย. (2552). รายงานผลการสำรวจพื้นที่ปลูกอ้อยประจำปีการผลิต 2551/52. สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย

10) สำนักงานปลัดกระทรวงคมนาคม. (2550). ข้อมูลพื้นฐานเชิงพื้นที่ด้านเส้นทางคมนาคม (Transport Fundamental Geographic Data Set: Transport FGDS). [CD-ROM]

11) สำนักงานคณะกรรมการอ้อยและน้ำตาล, (2551). มติของคณะรัฐมนตรีที่เกี่ยวข้องกับการตั้ง การย้าย และขยายกำลังในการผลิตของโรงงานน้ำตาล. วันที่ 21 มิถุนายน พ.ศ. 2554. www.ocsb.go.th

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PUBLICATION / PRESENTATION

Conference 2011, Chonburi, October 20-21, 2011.

Supattra Samueanpho and Somchai Pathomsiri, 2012. Sensitivity Analysis on the Impacts of Sugar Mill Liberalization Policy Resulting from the Uncertainty of the Amount of Cane Production, Proceedings of the 8th National Transport Conference: NTC8, Chonburi, March 15-16, 2012.