SUGARCANE TRANSPORTATION MANAGEMENT USING NETWORK AND MULTI-OBJECTIVE DECISION ANALYSES

Warunee Aunphoklang

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geoinformatics

Suranaree University of Technology

Academic Year 2012

การจัดการการขนส่งอ้อยโดยใช้การวิเคราะห์โครงข่าย
และการตัดสินใจแบบหลายวัตถุประสงค์

นางสาววารุณี อ้วนโพธิ์กลาง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาภูมิสารสนเทศ
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2555

SUGARCANE TRANSPORTATION MANAGEMENT USING NETWORK AND MULTI-OBJECTIVE DECISION ANALYSES

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's Degree.

Thesis Examining Committee

Suwit Ong.

(Assoc. Prof. Dr. Suwit Ongsomwang)

Chairperson

S. Sarapirome

(Asst. Prof. Dr. Sunya Sarapirome)

Member (Thesis Advisor)

S. Dasananda

(Asst. Prof. Dr. Songkot Dasananda)

Member

(Dr. Dusdi Chanlikit)

Member

(Prof. Dr. Sukit Limpijumnong)

Vice Rector for Academic Affairs

P. Manyum

(Assoc. Prof. Dr. Prapun Manyum)

Dean of Institute of Science

วารุณี อ้วนโพธิ์กลาง : การจัดการการขนส่งอ้อยโดยใช้การวิเคราะห์โครงข่ายและการตัดสินใจแบบหลายวัตถุประสงค์ (SUGARCANE TRANSPORTATION MANAGEMENT USING NETWORK AND MULTI-OBJECTIVE DECISION ANALYSES) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.สัญญา สราภิรมย์, 160 หน้า.

ในปัจจุบันการจัดการการขนส่งอ้อยในประเทศไทยนั้นจะขึ้นอยู่กับการตัดสินใจที่ไม่มีกฎเกณฑ์และไม่เป็นระบบ ด้วยเหตุนี้ทำให้ประสิทธิภาพในการขนส่งค่อนข้างต่ำและมีการสูญเสียต้นทุนในการขนส่งเป็นจำนวนมากโดยไม่จำเป็น โดยพื้นที่ปลูกอ้อยในภาคตะวันออกเฉียงเหนือมีขนาดใหญ่ที่สุดเมื่อเทียบกับภูมิภาคอื่นของประเทศ และมีพื้นที่ปลูกอ้อยกระจายอยู่ใน 228 อำเภอจากทั้งหมด 321 อำเภอ มีโรงงานน้ำตาลทราย 16 โรงงานจากทั้งหมด 47 โรงงานทั่วประเทศ การศึกษาครั้งนี้จึงมีวัตถุประสงค์ในการประยุกต์ใช้การวิเคราะห์โครงข่ายและการโปรแกรมเชิงเส้นเพื่อจัดการการขนส่งอ้อยที่เหมาะสมในภาคตะวันออกเฉียงเหนือของประเทศไทย ซึ่งมีวัตถุประสงค์หลักในการศึกษา คือ (1) การจัดแบ่งส่วนการขนส่งอ้อยจากรายแปลงไปยังชุดโรงงานที่เหมาะสมเพื่อให้มีต้นทุนในการขนส่งน้อยที่สุดและ (2) การจัดแบ่งส่วนการขนส่งอ้อยจากรายแปลงไปยังชุดโรงงานที่เหมาะสมเพื่อให้มีต้นทุนและผลกระทบต่อสิ่งแวดล้อมในการขนส่งน้อยที่สุด เพื่อจัดการกับข้อมูลรายแปลงที่มีเป็นจำนวนมากในภูมิภาค การศึกษาครั้งนี้จึงแบ่งวิธีการศึกษาออกเป็น 2 ขั้นตอน โดยขั้นตอนแรกเป็นการจัดแบ่งส่วนผลผลิตอ้อยจากระดับอำเภอไปยังชุดโรงงานที่เหมาะสม ขั้นตอนที่สองใช้ผลลัพธ์จากขั้นตอนแรกเป็นข้อมูลนำเข้าในการจัดแบ่งส่วนอ้อยจากแต่ละรายแปลงไปยังชุดโรงงานที่เหมาะสมของแต่ละอำเภอ

ผลการศึกษาสำหรับวัตถุประสงค์แรก ต้นทุนในการขนส่งรวมระดับอำเภอและรายแปลง คือ 1,466,641,682.33 บาท และ 1,551,454,082.19 บาท ตามลำดับ สำหรับวัตถุประสงค์ที่สองที่มีการพิจารณาผลกระทบสิ่งแวดล้อมนั้น ต้นทุนในการขนส่งรวมระดับอำเภอและรายแปลง คือ 1,478,985,242.38 บาท และ 1,570,661,893.68 บาท ตามลำดับ ผลลัพธ์จากทั้งสองขั้นตอนของสองวัตถุประสงค์นั้นสอดคล้องกับสมมุติฐานการวิจัย โดยการพิจารณาแบบหลายวัตถุประสงค์ที่มีการนำผลกระทบสิ่งแวดล้อมมาคิดร่วมด้วยนั้นมีต้นทุนในการขนส่งที่สูงกว่าการพิจารณาแบบวัตถุประสงค์เดี่ยวที่ไม่ได้คิดผลกระทบสิ่งแวดล้อม การคิดผลกระทบสิ่งแวดล้อมร่วมด้วยเป็นสาเหตุในการเปลี่ยนเส้นทางการขนส่งและเปลี่ยนการจัดแบ่งส่วนอ้อยเข้าโรงงานซึ่งมีผลต่อต้นทุนในการขนส่งรวม

จากการศึกษานี้ทำให้ได้วิธีการและเทคนิคที่เหมาะสมในการจัดแบ่งส่วนการขนส่งอ้อยที่ดีที่สุดจากรายแปลงไปยังโรงงานเมื่อทำงานร่วมกับข้อมูลรายแปลงที่มีจำนวนมากในพื้นที่ศึกษา

ซึ่งเทคนิคที่ได้คือการวิเคราะห์โครงข่ายและการโปรแกรมเชิงเส้นในระดับอำเภอและระดับรายแปลง โดยแบบรูปการขนส่งที่ดีที่สุดที่เป็นผลมาจากเทคนิคนี้ให้ผลลัพธ์ที่ดีกว่าเมื่อเทียบกับวิธีการจัดแบ่งส่วนอื่นที่ไม่เป็นระบบ และรูปแบบการขนส่งจากงานวิจัยนี้สามารถนำมาประยุกต์ใช้ในการจัดแบ่งส่วนโควตาอ้อยจากรายแปลงไปยังชุดโรงงานที่เหมาะสมพร้อมกับผลประโยชน์ที่พึงพอใจ

สาขาวิชาการรับรู้จากระยะไกล	ลายมือชื่อนักศึกษา วารุณี ช้วนโพธิ์กลาง
ปีการศึกษา 2555	ลายมือชื่ออาจารย์ที่ปรึกษา [illegible]

WARUNEE AUNPHOKLANG : SUGARCANE TRANSPORTATION MANAGEMENT USING NETWORK AND MULTI-OBJECTIVE DECISION ANALYSES. THESIS ADVISOR : ASST. PROF. SUNYA SARAPIROME, Ph.D. 160 PP.

SUGARCANE TRANSPORTATION/ NETWORK ANALYSIS/ LINEAR PROGRAMMING

Currently, the sugarcane transportation management in Thailand has been relied only on arbitrary and unsystematic decisions. This can lead to low efficiency and great loss in unnecessary transportation cost. The sugarcane cropping area in the Northeast region of Thailand is the biggest compared to others. The sugarcane areas distribute in 228 districts out of 321. There are 16 sugar factories to serve the region out of total 47 nationwide. The purpose of the study was to apply Network Analysis and Linear Programming to perform transportation management of sugarcane produced in the Northeast region of Thailand. The main objectives of the study were (1) to minimize the total transportation cost by proper allotting sugarcane from plots to certain sets of factories, and (2) to minimize the total transportation cost and environmental impact by proper allotting sugarcane from plots to certain sets of factories. To deal with a very large number of plots in the region, the methodology comprised 2 steps. The first step was to allot total sugarcane product from districts to certain sets of factories. The second step used the results from the first step as input to allot sugarcane from each plot to a certain set of factories specific for each district.

As a result for the first objective of the study, the minimum total transportation costs in district and plot levels were 1,466,641,682.33 baht and 1,551,454,082.19 baht, respectively. For the second objective, the minimum total transportation costs in district and plot levels were 1,478,985,242.38 baht and 1,570,661,893.68 baht, respectively. The results from both steps of both objectives were consistent with the research hypotheses. The multi objectives decision with environmental impact consideration required higher total transportation cost than the single objective without environmental impact. Adding environmental impact caused the changes in transport routes and factories allotment that affected the total transportation cost.

This study was successful in providing proper methods and techniques to optimize pattern of sugarcane transportation management from plots to factories when dealing with huge amount of plots in the region. The technique obtained were Network Analysis and Linear Programming in district and plot levels. The optimized transportation pattern resulted from using this technique provided better result compared to any non-systematic methods. The transportation pattern achieved from the study could be applied to quota allotment from plots to certain sets of factories with acceptable benefit.

School of Remote Sensing — Student's Signature Warunee Aunphoklang

Academic Year 2012 — Advisor's Signature S. Sarapirome

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my advisor, Asst. Prof. Dr. Sunya Sarapirome, for his helps with valuable instructions, guidance, and suggestions to complete this dissertation. Without his constructive devotion and support, this thesis would not be finished successfully.

I would like to thank the chairman and other members of this thesis committee; Asst. Prof. Dr. Suwit Ongsomwang, Asst. Prof. Dr. Songkot Dasananda, and Dr. Dusdi Chanlikit for their constructive comments.

I would also like to thank the Office of the Cane and Sugar Board, Thailand Transport Portal, and Land Development Department for supporting the data needed for the research and thank to experts in providing opinion on environmental impact of factories via questionnaires.

Special thanks go to Mr. Patiwat Littidej for guidance and teaching me the essential techniques. My warm thanks are due to my friends from the School of Remote Sensing for their kind help and moral support that made me stay with much joy and happy moments. I would also like to express my apology that I could not mention one by one personally.

Finally, I would like to thank my father and mother, who have been enduring a source of inspiration to grow academically and professionally. Thanks also go to all of former teachers, my friends, and everyone who have taught and helped me.

Warunee Aunphoklang

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

Page

CONTENTS (Continued)

Page

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF ABBREVIATIONS

EI	=	Environmental Impact
GIS	=	Geographic Information Systems
ISO	=	International Organization for Standardization
km	=	Kilometer
LP	=	Linear Programming
m	=	Meter
MADA	=	Multi-attribute Decision Analysis
MCDA	=	Multi-criteria Decision Analysis
MODA	=	Multi-objective Decision Analysis
NA	=	Network Analysis
NE	=	Northeast region, Thailand
OCSB	=	Office of the Cane and Sugar Board
O-D	=	Origin-Destination
TC	=	Transportation Cost

CHAPTER I

INTRODUCTION

1.1 Background of the Problem

Sugar industry is one of the important industries in Thailand which can make high income for both agricultural and industry sectors. Sugarcane is a raw material for sugar production. It is an agricultural product that has rather low value comparing with its weight. Therefore, the cost of sugar production depends more on the cost of sugarcane transportation from cropping areas to factories. Currently, in Thailand there are 2 types of sugarcane markets, which are immediate or spot market and future forward market. However, the trading is much more likely to be the future forward market than the immediate one. The future forward market is operated in form of quota which is managed in advance. This kind of market is to ensure that factories will have sufficient sugarcane quota to support when the annual grinding season comes (พรชัย ท้วมปาน, 2545). The sugarcane quota management is carried out by an agreement between factories and leaders of sugarcane growers. The leaders of growers take responsibility in gathering sugarcane from cropping areas and transporting them to the factories according to their quota provided. As mentioned above, the rate of sugarcane transportation cost (TC) to its cost as raw material is considered very high even comparing to other kinds of industrial raw materials.

According to information surveyed by the Office of the Cane and Sugar Board (OCSB) in the production year 2008/2009 (สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย, 2552), it revealed that the biggest amount of sugarcane was produced in the Northeast (NE) region of Thailand. The cropping areas of the region that supplied 25,889,583 tons of sugarcane to factories were as big as 2,595,468 rais which were totally the biggest amount and area compared to other regions. These areas were distributed in all provinces of the region. There have been 16 sugar factories in the region out of total 47 nationwide.

Currently, the sugarcane transportation management of the region relies only on leader decisions. The decision can be unsystematic and low efficiency. This can lead to great loss in TC unnecessary.

At present, the Network Analysis (NA) as a function in the Geographic Information System (GIS) and Linear Programming (LP) as a tool in Multi-criteria Decision Analysis (MCDA) have been known very well as tools to assist this kind of management. With their proper applications the loss can be significantly reduced. The efficient sugarcane allotments in a given area to a certain set of factories can be performed using this technology and operation.

In addition, environmental impact (EI) from factories and their related activities now becomes globally hot issue. It could be more fashionable if it is added as another objective for consideration in allotment analysis. Therefore, apart from using TC as one of analytical objectives, this study aims at including EI from sugarcane transportation and sugar factories as another analytical objective for efficient sugarcane allotment management. For this reason, the criteria in MCDA for this case become objectives, not attributes. The Multi-objectives Decision Analysis (MODA) is then strongly required as the solution of this problem.

From above reasons discussed, the objective of this research is to apply NA and LP to performing transportation management of sugarcane produced in the NE region. The optimization of the MODA through the LP is minimization of TC alone and both TC and EI. To deal with this kind of problem, the capacity limitation or the quota of factories, if available, can be brought to consider as well.

1.2 Research Objectives

The goal of the research is to properly manage sugarcane transportation in the NE region of Thailand using NA and multi-objective functions based on the constraint of factory-allotted amount declared by the OCSB, with and without EI consideration. Two objectives of the research are set as follows:

(1) to minimize TC by proper allotting sugarcane from each plot to certain sets of factories; and

(2) to minimize TC and EI by proper allotting sugarcane from each plot to certain sets of factories.

1.3 Research Hypotheses

(1) The cost of sugarcane transportation from each plot to factories achieved from the study is the minimum compared to other non-systematic transportation allotments.

(2) There is the difference of allotments based on consideration with and without EI.

1.4 Basic Assumptions

The basic assumptions of the study are as follows.

(1) Network Analysis relied on the shortest distance.

(2) Dijkstra’s algorithm was used for Network Analysis through ArcGIS 9.xx.

(3) Linear Programming was performed through the Microsoft Excel spreadsheet.

(4) No types of trucks were considered in transportation management.

(5) Sugarcane plots available in the production year 2009/2010 within the study area, gathered by the OCSB, were used for the study.

(6) Roads with at least two lanes of all-season service capability were used for Network Analysis in case information on prohibited roads for sugarcane transportation is not available.

(7) The existing industrial standards of factories in year 2010 were considered for environmental impact. However, some factories might be on the application processes for standards that will not be taken to account for the study.

1.5 Scope of the Study

(1) The study area covers the whole Northeast region of Thailand as described in section 1.6.

(2) Due to huge amount of the records of sugarcane plots in the region, the allotment was performed first from all districts and further to each plot of district by district.

(3) Actual information on the quota provided for farmers in the region cannot be referred to or used in the study because of information restriction of the OCSB and lacking of spatial and attribute data organization.

(4) Sugarcane allotments for factories announced by the OCSB for the 2009-2010 were used in LP analysis for sugarcane transportation management.

1.6 Study Area

1.6.1 Geographic location

The study area is the Northeast region of Thailand, commonly referred to as Isan. The region consists of 19 provinces which include totally 321 districts (Table 1.1). It covers approximately 160,000 km^2 and is located on the Khorat Plateau, which is bordered by the Lao People's Democratic Republic in the north and the east, Northern and Central regions of Thailand in the west, and Cambodia in the south.

Table 1.1 Provinces, numbers of districts, sugarcane cropping areas, and numbers of sugar factories in the Northeastern region (2008/2009).

Province	No. of District	Cropping areas (Rais)	No. of factories	Name of Factory
1) Nakhon Ratchasima	32	458,961	3	- Korach Industry - Angvian Industry (Ratchasima) - N.Y. (Khonburi)
2) Khon Kaen	25	359,772	2	- Khon Kaen - Mitr Phu Viang
3) Ubon Ratchathani	25	3,169	-	-
4) Buri Ram	23	100,427	1	- Burirum

Table 1.1 (Continued).

Province	No. of District	Cropping areas (Rais)	No. of factories	Name of Factory
5) Si Sa Ket	22	3,624	-	-
6) Roi Et	20	60,452	-	-
7) Udon Thani	20	467,263	3	- Rerm Udom - Kaset Phol - Kumpawapi
8) Kalasin	18	228,001	2	- E – Saan Sugar Industry - Mitr Kalasin
9) Sakon Nakhon	18	51,850	-	-
10) Surin	17	70,563	1	- Surin
11) Nong Khai	17	27,285	-	-
12) Chaiyaphum	16	395,719	1	- United Farmer & Industry
13) Loei	14	88,046	-	-
14) Maha Sarakham	13	93,384	1	- Wangkanai
15) Nakhon Phanom	12	3,829	-	-
16) Yasothon	9	20,547	-	-
17) Mukdahan	7	98,341	1	- Saharuang
18) Amnat Charoen	7	19,942	-	-
19) Nong Bua Lam Phu	6	44,293	1	- Arawan
Total	**321**	**2,595,468**	**16**	

1.6.2 Physical geographic characteristics

The area apparently tilts from the Phetchabun mountain range in the west of the region down towards the Mekong River. The plateau consists of two main basins i.e. Khorat basin which is drained by the Mun and Chi rivers, while Sakon

Nakhon basin in the north is drained by the Loei and Songkhram rivers. They are separated by the Phu Phan mountain range. The soil is mostly sandy, with substantial salt deposits in parts.

1.6.3 Land use

Rice is the main crop of the region covering approximately 60% of the cultivated land. However, farmers have been increasingly diversifying into cassava, sugarcane, and other crops. Compared to other regions, sugarcane in this region plays more important role. According to the survey by the OCSB in the production year 2008/2009, there are 2,595,468 rais of sugarcane cropping areas and 16 sugar factories in the NE. Sugarcane cropping areas, numbers of factories and their names in each province are listed in Table 1.1. Table 1.2 shows the sugarcane allotments for factories initially announced in the production year 2009/2010 by the OCSB.

The study area, locations of sugar factories, and sugarcane cropping areas are displayed in Figure 1.1. The community areas and road network in the study area are displayed in Figure 1.2.

Table 1.2 The sugarcane allotments for factories initially announced in the production year 2009/2010 by the OCSB.

No.	Factory (Province)	Sugarcane allotments by OCSB (Tons)
1	Kumphawapi sugar factory (Udon Thani)	1,509,000
2	Kaset Phol sugar factory (Udon Thani)	1,442,000
3	Khon Kaen sugar factory (Khon Kaen)	2,488,000
4	Rermudom sugar factory (Udon Thani)	1,246,000
5	Burirum sugar factory (Buri Ram)	1,206,000

Table 1.2 (Continued).

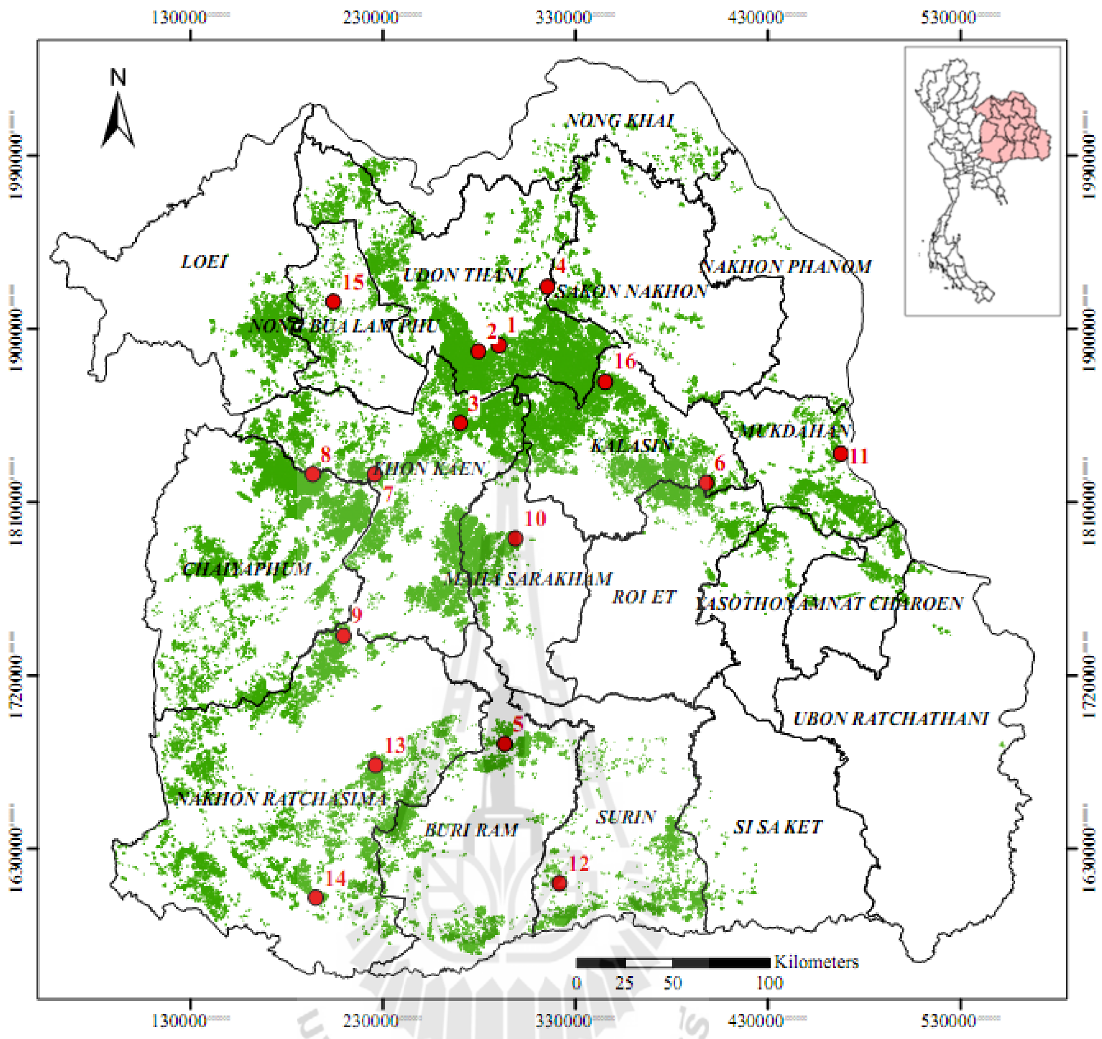
No.	Factory (Province)	Sugarcane allotments by OCSB (Tons)
6	Mitr Kalasin sugar factory (Kalasin)	2,149,000
7	Mitr Phuviang sugar factory (Khon Kaen)	2,798,000
8	United Farmer & Industry sugar factory (Chaiyaphum)	2,931,000
9	Angvian Industry sugar factory (Nakhon Ratchasima)	1,217,000
10	Wangkanai sugar factory (Maha Sarakham)	166,000
11	Saharuang sugar factory (Mukdahan)	1,066,000
12	Surin sugar factory (Surin)	1,209,000
13	Korach Industry sugar factory (Nakhon Ratchasima)	2,418,000
14	N.Y. sugar factory (Nakhon Ratchasima)	1,900,000
15	Arawan sugar factory (Nong Bua Lam Phu)	1,032,000
16	E – Saan Sugar Industry factory (Kalasin)	1,113,000
	Total sugarcane quantity	**25,890,000**

1.7 Benefits of the Study

(1) Achieving proper methods and techniques to optimize pattern of sugarcane transportation from plots to factories. The optimization is to minimize TC with and without EI considerations. The technique obtained can solve problem on dealing with huge amounts of plots existing in the big region.

(2) Achieving optimized transportation pattern, routes and allotments, from plots to factories resulted from using NA and MODA which provide better result compared to any non-systematic methods.

(3) Achieving the transportation pattern can be applied to quota allotment from plots to certain sets of factories.

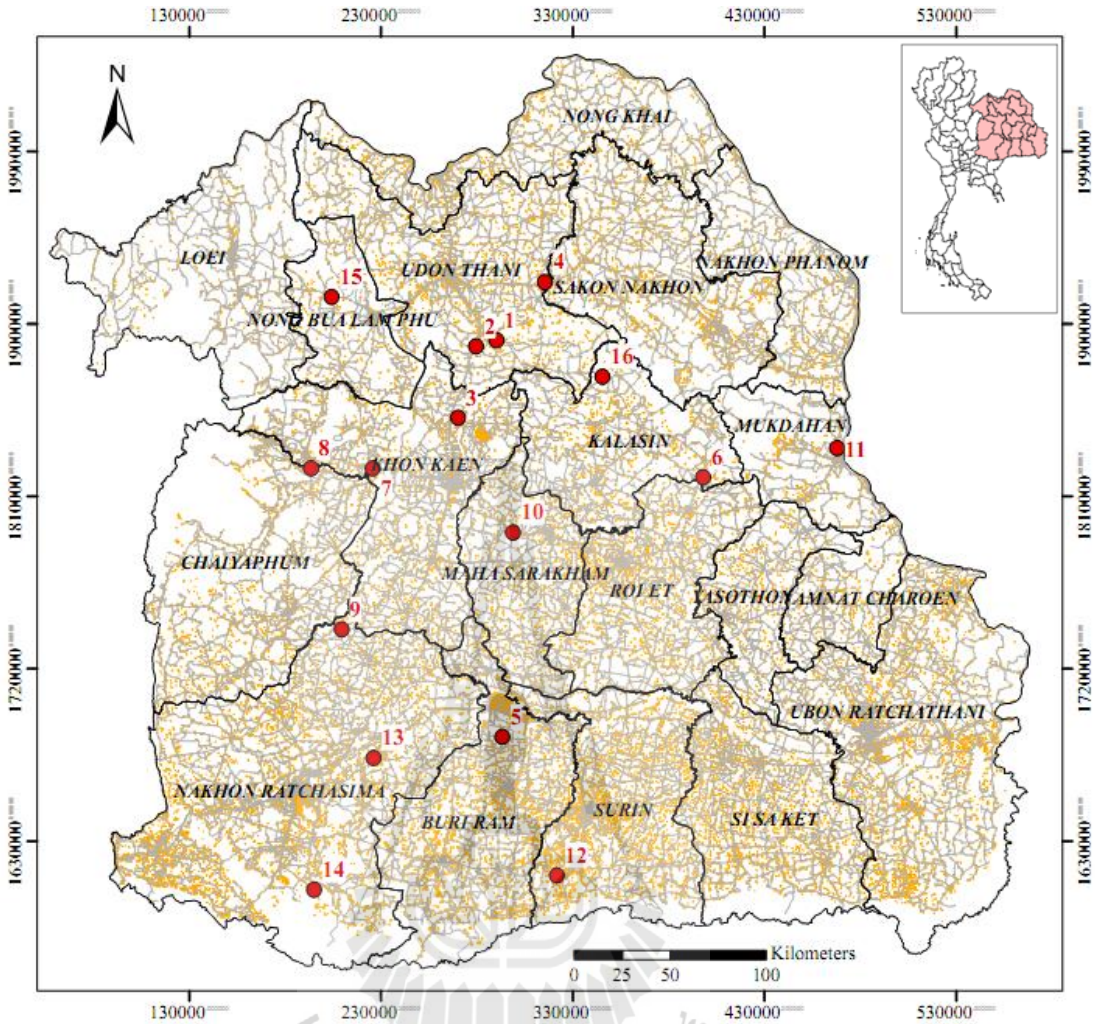


: Sugarcane cropping areas   : Province boundary

Number of sugar factory

1	: Kumpawapi (Udon Thani)	**9**	: Angvian Industry (Nakhon Ratchasima)
2	: Kaset Phol (Udon Thani)	**10**	: Wangkanai (Maha Sarakham)
3	: Khon Kaen (Khon Kaen)	**11**	: Saharuang (Mukdahan)
4	: Rerm Udom (Udon Thani)	**12**	: Surin (Surin)
5	: Burirum (Buri Ram)	**13**	: Korach Industry (Nakhon Ratchasima)
6	: Mitr Kalasin (Kalasin)	**14**	: N.Y. (Nakhon Ratchasima)
7	: Mitr Phu Viang (Khon Kaen)	**15**	: Arawan (Nong Bua Lam Phu)
8	: United Farmer & Industry (Chaiyaphum)	**16**	: E – Saan Sugar Industry (Kalasin)

Figure 1.1 Provinces, locations of sugar factories, and sugarcane cropping areas in the study area.



■ : Community areas

□ : Province boundary

— : Road network

<u>Number of sugar factory</u>

1 : Kumpawapi (Udon Thani)
2 : Kaset Phol (Udon Thani)
3 : Khon Kaen (Khon Kaen)
4 : Rerm Udom (Udon Thani)
5 : Burirum (Buri Ram)
6 : Mitr Kalasin (Kalasin)
7 : Mitr Phu Viang (Khon Kaen)
8 : United Farmer & Industry (Chaiyaphum)
9 : Angvian Industry (Nakhon Ratchasima)
10 : Wangkanai (Maha Sarakham)
11 : Saharuang (Mukdahan)
12 : Surin (Surin)
13 : Korach Industry (Nakhon Ratchasima)
14 : N.Y. (Nakhon Ratchasima)
15 : Arawan (Nong Bua Lam Phu)
16 : E – Saan Sugar Industry (Kalasin)

Figure 1.2 The community areas and road network in the study area.

CHAPTER II

LITERATURE REVIEW

2.1 Theory of Network Analysis and Shortest Path Problem

A network is a line coverage, which is topology-based and has the appropriate attributes for the flow of objects such as traffic (Chang, 2002). The network model is essentially adaptation of the vector data model. The vector network model is made up of the same arc (line segments) and node elements as any other vector data model but with the addition of special attributes, e.g. impedance which can be time, distance, fuel used, traffic volume, etc. (Heywood, Cornelius, and Carver, 2002).

NA is a special type of line analysis involving a set of interconnected lines. NA can be used to answer at least four types of questions which are address geocoding, optimum routing, finding closest facilities, and resource allocation (Verbyla, 2002). However, Evans and Minieka (1992) stated that NA is used to serve varieties of requirements performing on line network. The requirements present in terms of problems encountered in its widespread applications include many types, namely Shortest Path, Minimum Spanning Tree, Maximum Flow, and Minimum Cost Flow.

In this study, the NA dealt only with the shortest path problem. The Closest facility analysis which is the function of ArcGIS 9.x was used to solve the shortest path problem through Dijkstra's algorithm.

Shortest Path Problem

- **Dijkstra's Algorithm**

The Dijkstra's Algorithm was discovered by Edsger Wybe Dijkstra, a Netherland's mathematician, for computing shortest path distance of weighted graph (Evans, Minieka, 1992). Dijkstra's algorithm is a label-setting algorithm in that a label is permanent at all iterations. The main idea underlying the Dijkstra shortest-path algorithm is explained as the following steps.

Step 1: Initially, all arcs and vertices are unlabeled. Assign a number $d(x)$ to each vertex x to denote the tentative length of the shortest path from s to x that uses only labeled vertices as intermediate vertices. Initially, set $d(s) = 0$ and $d(x) = \infty$ for all $x \neq s$. Let y denotes the last vertex that was labeled. Label vertex s and let $y = s$.

Step 2: For each unlabeled vertex x, redefine $d(x)$ as follows:

$$d(x) = min\{d(x), d(y) + a(y, x)\}.$$

This can be performed efficiently by scanning the forward star of node y since only these nodes will be affected. If $d(x) = \infty$ for all unlabeled vertices x, then stop because no path exists from s to any unlabeled vertex. Otherwise, label the unlabeled vertex x with the smallest value of $d(x)$. Also label the arc directed into vertex x from a labeled vertex that determined the value of $d(x)$ in the above minimization. Let $y = x$.

Step 3: If vertex t has been labeled then stop, since a shortest path from s to t has been discovered. This path consists of the unique path of labeled arcs from s to t. If vertex t has not been labeled yet, repeat step 2.

Example of the performance of the Dijkstra's shortest-path algorithm from node *s* to node *t* can be displayed as a diagram in Figure. 2.1.

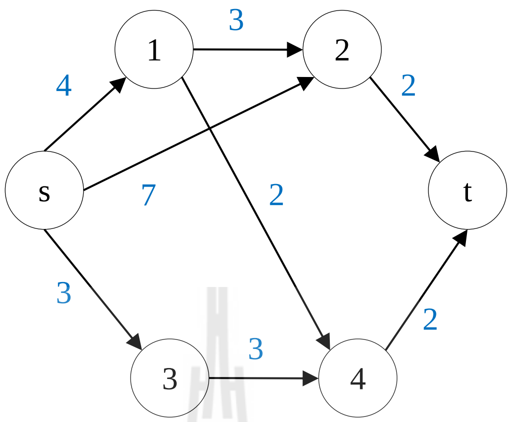


Figure 2.1 Example of the shortest-path network.

Step 1: Initially, only node *s* is permanently labeled, $d(s) = 0$. Assign tentative distances $d(x) = \infty$ for all $x \neq s$. Let $y = s$.

Step 2: Recomputed tentative distances for the unlabeled nodes in forward star of y as follows:

$$d(1) = min\{d(1), d(s) + a(s, 1)\} = min\{\infty, 0 + 4\} = 4,$$

$$d(2) = min\{d(2), d(s) + a(s, 2)\} = min\{\infty, 0 + 7\} = 7,$$

$$d(3) = min\{d(3), d(s) + a(s, 3)\} = min\{\infty, 0 + 3\} = 3.$$

Since the minimum distance on any unlabeled node is $d(3) = 3$, we label node 3 and arc $(s, 3)$. The current shortest-path arborescence consists of arc $(s, 3)$ as shown in Figure 2.2(a). Let $y = 3$.

Step 3: Vertex *t* has not been labeled, so return to step 2.

Step 2:

$$d(4) = min\{d(4), d(3) + a(3, 4)\} = min\{\infty, 3 + 3\} = 6.$$

The minimum tentative distance on the unlabeled node is $d(1) = 4$. Label node 1 and arc $(s, 1)$, which determined $d(1)$. The current shortest-path arborescence consists of arcs $(s, 3)$ and $(s, 1)$ as shown in Figure 2.2(b). Let $y = 1$.

Step 3: Vertex t has not been labeled, so return to step 2.

Step 2:

$$d(2) = min\{d(2), d(1) + a(1, 2)\} = min\{7, 4 + 3\} = 7,$$

$$d(4) = min\{d(4), d(1) + a(1, 4)\} = min\{6, 4 + 2\} = 6.$$

The minimum tentative distance on the unlabeled node is $d(4) = 6$. Label node 4 and arc (1, 4) or (3, 4), since both determined $d(4)$. Let us arbitrarily select arc (3, 4). Hence the current shortest-path arborescence becomes arcs $(s, 3)$, $(s, 1)$ and (3, 4) as shown in Figure 2.2(c). Let $y = 4$.

Step 3: Vertex t has not been labeled, so return to step 2.

Step 2:

$$d(\mathrm{t}) = min\{d(t), d(4) + a(4, t)\} = min\{\infty, 6 + 2\} = 8.$$

The minimum tentative distance label is $d(2) = 7$. Label node 2 and arc $(s, 2)$, which determined $d(2)$. The current shortest-path arborescence consists of arcs $(s, 3)$, $(s, 1)$, (3, 4) and $(s, 2)$ as shown in Figure 2.2(d). Let $y = 2$.

Step 3: Vertex t has not been labeled, so return to step 2.

Step 2:

$$d(t) = min\{d(t), d(2) + a(2, t)\} = min\{8, 7 + 2\} = 9.$$

Thus, vertex t has been labeled at last. Also, arc $(4, t)$, which determined $d(t)$, is labeled. The final shortest-path arborescence consists of arcs $(s, 3)$, $(s, 1)$, (3, 4), $(s, 2)$ and $(4, t)$ as shown in Figure 2.2(e).

Step 3: Vertex t has been labeled then stop.

A shortest path from node s to t consists of arcs (s, 3), (3, 4), and (4, t) with a length of 3 + 3 + 2 = 8.

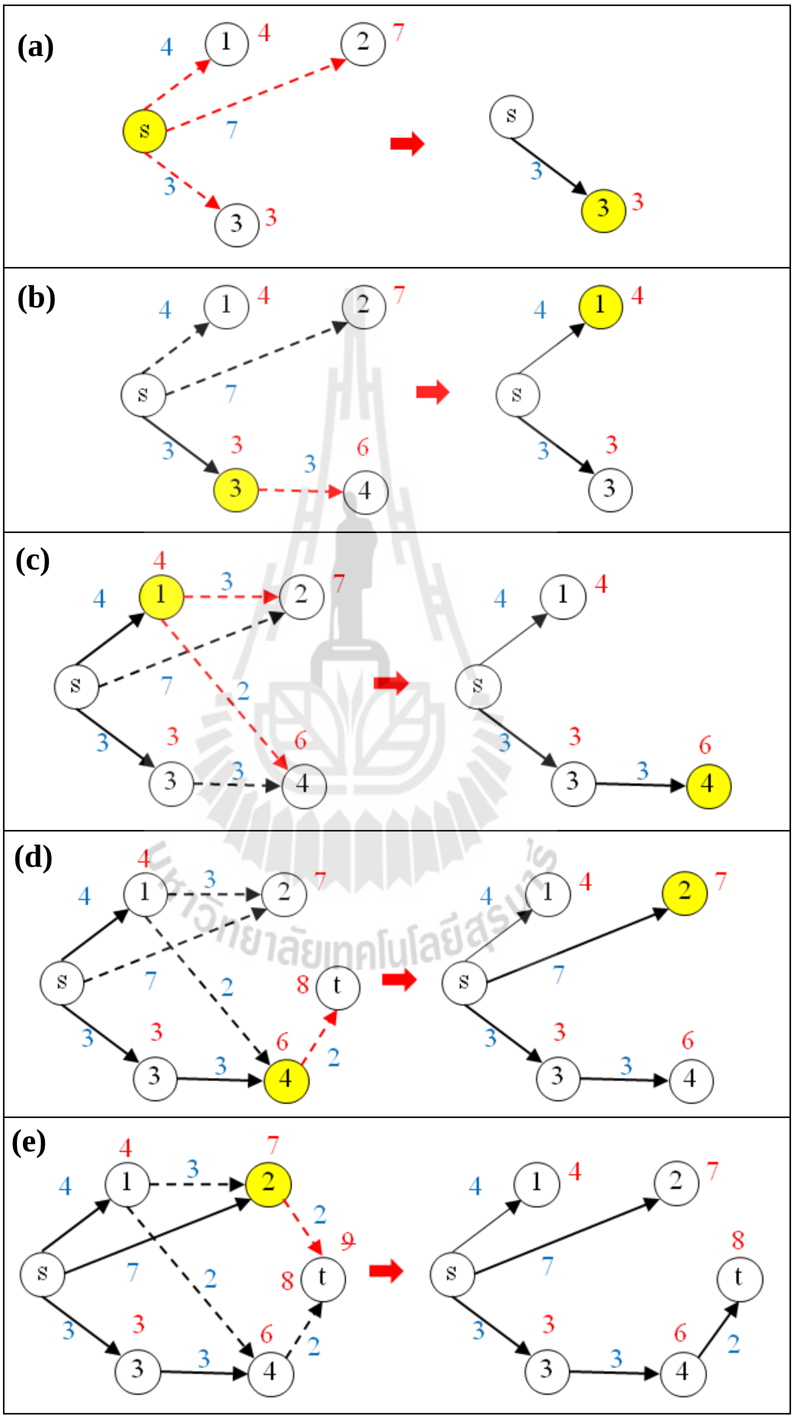


Figure 2.2 Growing a shortest-path arborescence.

The results of shortest path analysis are listed in the Closest Facility matrix.

- **Closest Facility**

ESRI (2006) describes in detail that closest facilities can specify how many to find and whether the direction of travel is toward or away from them. Once the closest facilities are found, it can display the best route to or from them, returns the travel cost for each route, and displays directions to each facility.

The closest facility and OD cost matrix solvers perform very similar analyses. The main difference, however, exists. OD cost matrix is in the output and the computation speed. The OD cost matrix solver is designed for quickly solving large M x N problems and as a result does not internally contain information that can be used to generate true shapes of routes and driving directions. If you need driving directions or true shapes of routes, use the closest facility solver.

The closest facility analysis layer stores all the inputs, parameters, and results of closest facility analysis.

(1) Facilities feature layer: this layer stores the network locations that are used as facilities in the closest facility analysis. These are used as the starting or ending points in closest facility analyses.

(2) Incidents feature layer: the layer stores network locations used as incidents for closest facility analysis. These are used as starting or ending points in closest facility analyses. Whether starting or ending points, incidents are always on the opposite end of a route from the connected facility.

(3) Barriers feature layer: barriers are used in closest facility analysis to denote points where a closest facility route cannot traverse.

(4) Routes feature layer: the routes layer stores the resultant paths of the closest facility analysis.

2.2 Theory of Multi-criteria Decision Analysis (MCDA)

The generic classification of Multi-criteria Decision Analysis (MCDA) is organized into two sections dealing with multi-attribute and multi-objective spatial decision problem. The aim of Multi-attribute Decision Analysis (MADA) is to choose the best or the most preferred alternative, to rank the alternatives in descending order of preference. In MADA methods the attributes serve as both decision variables and decision criteria, whereas in the Multi-objective Decision Analysis (MODA) approaches, a distinction is made between decision criteria (objective functions) and decision variables. The MODA decision rules define the set of alternatives in terms of a decision model consisting of a set of objective functions and a set of constraints imposed on the decision variables (Malczewski, 1999).

The processes of objective decision analyses in this research were in two forms i.e. single objective analysis and multi-objective analysis. Both used the same type of decision rule which is minimized optimization function in the LP.

2.2.1 Linear Programming

Bazaraa, Jarvis, and Sherali (1990) explained the general concept of the LP, which is concerned with the optimization (minimization or maximization) of a linear function while satisfying a set of linear equality and/or inequality of constraints or restrictions. The concept explanation begins by formulating a particular type of a LP problem. The following example case presents minimization as the optimization function. As seen, any general LP problem can be expressed in canonical form:

minimize

$$c_1x_1 + c_2x_2 + \cdots + c_nx_n; \tag{1}$$

subject to

$$\left.\begin{aligned}
&a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq b_1;\\
&a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq b_2;\\
&\qquad\qquad\vdots\\
&a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m;
\end{aligned}\right\} \tag{2}$$

and $$x_1, x_2, \ldots, x_n \geq 0. \tag{3}$$

LP consists of the following three parts.

(1) Objective function: here $c_1x_1 + c_2x_2 + \cdots + c_nx_n$ is the objective function (or criterion function) to be minimized and will be denoted by z. The coefficients $c_1, c_2, \ldots, c_n$ are the (known) cost coefficients and $x_1, x_2, \ldots, x_n$ are the decision variables (unknown) to be determined.

(2) Constraint set: the inequality $\sum_{j=1}^{n} a_{ij}x_j \geq b_i$ denotes the *i*th constraint set. In practice, the condition of constraints can be ≥ or = or ≤ as long as it serves the objective of optimization.

The coefficients a_{ij} for *i* = 1, 2, …, *m*, *j* = 1, 2, …, *n* are called the technological coefficients. The coefficients are usually expressed in matrix form of *A*.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

The column vector whose ith component is b_i, which is referred to as the right-hand-side vector, represents the minimal requirement to be satisfied.

(3) Non-negativity constraints: the constraints $x_1, x_2, \dots, x_n \geq 0$ are the non-negativity constraints. A set of variables $x_1, \dots, x_n$ satisfying all the constraints is called a feasible point or a feasible vector. The set of all such points constitutes the feasible region or feasible space.

LP can be a decision rule for both single objective function and multi-objectives function. This research proposed the LP as the decision rule for two purposes which are to minimize the total TC (the single objective function) and to minimize TC and EI (the multi-objectives function). These two purposes can be described as follows.

2.2.2 Linear Programming for minimizing the total transportation cost

This single objective analysis is to minimize the total TC from districts to factories or from plots to factories. The transportation problem considers *m* origin points (districts or plots), where district or plot *i* has a supply of s_i units of particular amount of sugarcane. In addition, there are *n* destination points (sugar factories), where factory *j* requires d_j units of sugarcane. We assume that $s_{i\,,}\, d_j > 0$. Associated with each link (*i*, *j*), from district or plot *i* to factory *j*, there is a unit cost c_{ij} for transportation. The problem is to determine a feasible "shipping pattern" from origin to destination that minimizes the total TC.

Let x_{ij} be the number of sugarcane units along link (*i, j*) from district or plot *i* to factory *j*. Further assume that the problem is balanced, that is, the total supply equals the total demand. Hence,

$$\sum_{i=1}^{m} s_i = \sum_{j=1}^{n} d_j. \tag{4}$$

This study used TC from NA as input of LP model to find minimized cost of sugarcane transportation to factories. For district level, c_{ij} is the TC from representative point of district *i* to the sugar factory *j*. For the plot level, c_{ij} is the TC of the sugarcane cropping plot *i* to the sugar factory *j*. The LP model working as the transportation optimization function can be expressed as the following equations.

Minimize:

$$TC = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} . \tag{5}$$

Subject to constraints:

$$\sum_{j=1}^{n} x_{ij} = s_i \qquad \text{for } \forall_i; \tag{6}$$

$$\sum_{i=1}^{m} x_{ij} \leq d_j \qquad \text{for } \forall_j; \tag{7}$$

$$x_{ij} \geq 0 \qquad \text{for } \forall_{i,j}; \tag{8}$$

where TC is total cost of sugarcane transportation (Baht),

c_{ij} is the cost of sugarcane transportation from district/plot *i* to sugar factory *j* (Baht/ton),

x_{ij} is the quantity of sugarcane at district/plot *i* to sugar factory *j* (Tons),

s_i is the quantity of sugarcane production at district/plot *i* (Tons),

d_j is the factory allotment for factory *j* , that receive from the OCSB (Tons),

i is district/plot, *i* = 1, 2, 3, .., *m*., and

j is sugar factory, *j* = 1, 2, 3, .., *n*.

The Equation (5) is the minimized objective function of the total TC from districts/plots to sugar factories under constraints expressing in Equation (6), (7), and (8).

The Equation (6) expresses that the sum of quantity of sugarcane transported from one district/plot to various sugar factories must be the same quantity of sugarcane production in that district/plot (one-to-many).

The Equation (7) expresses that the total quantity of sugarcane from various districts/plots to a sugar factory (many-to-one) shall not exceed the factory capacity or quota.

The Equation (8) is the non-negativity constraint. The equation expresses the general limitation of the LP model that the amount of transported sugarcane cannot be negative.

2.2.3 Linear Programming for minimizing transportation cost and environmental impact

This process is multi-objective analysis which aims to optimize pattern of transportation to obtain minimum total cost of transportation and normalized EI. Hence, the optimize function can be performed using LP as a decision rule and can be expressed in forms of equations as follows.

Minimize:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} + \sum_{i=1}^{m} \sum_{j=1}^{n} E_{ij} x_{ij}. \quad (9)$$

Subject to constraints:

$$\sum_{j=1}^{n} x_{ij} = s_i \quad \text{for } \forall_i; \quad (10)$$

$$\sum_{i=1}^{m} x_{ij} \leq d_j \quad \text{for } \forall_j; \quad (11)$$

$$x_{ij} \geq 0 \qquad \text{for } \forall_{i,j}; \qquad (12)$$

where Z is the total of normalized sugarcane TC and EI,

c_{ij} is the normalized sugarcane TC from district/plot i to sugar factory j,

x_{ij} is the normalized quantity of sugarcane at district/plot i to sugar factory j,

E_{ij} is the normalized score of EI for district/plot i to factory j,

s_i is the normalized quantity of sugarcane production at district/plot i,

d_j is the normalized factory allotment for factory j by the OCSB,

i is district/plot, i = 1, 2, 3, .., m., and

j is sugar factory, j = 1, 2, 3, .., n.

The Equation (9) is the objective function to find optimal solution of the sum total cost of sugarcane transported to sugar factories and sum total of EI indicators. This equation is operated under constraints expressed as Equations (10), (11), and (12).

The Equation (10) expresses that the summary of quantity of sugarcane transported from one district/plot to various sugar factories must be the same quantity of sugarcane production in that district/plot (one-to-many).

The Equation (11) expresses that the total quantity of sugarcane from various districts/plots to a sugar factory (many-to-one) shall not exceed the factory capacity or quota.

The Equation (12) is the non-negativity constraint. The equation expresses the general limitation of the LP model that the amount of transported sugarcane cannot be negative.

2.3 Environmental Impact Consideration

Environmental impact (EI) means the possible adverse effects caused by a development, industrial, or infrastructural project or by the release of a substance in the environment (BusinessDictionary, 2010).

Sugar factory can cause EI as well as other kinds of factory. Its effluents, when discharged into the environment, cause a serious health hazard to the rural and semi-urban populations that use stream and river water for agriculture and domestic purposes, with reports of fish mortality and damage to the paddy crops due to wastewaters entering agricultural land (Baruah, Sharma, and Borah, 1993, quoted in Ayyasamy et al., 2008). They cause an obnoxious odor and unpleasant color when release into the environment without proper treatment. Within such an environment, the crop growth and yield and the soil health will be reduced (Ayyasamy et al., 2008; Baskaran, Ganesh, Chidambaram, and Sundaramoorthy, 2009). Herrera (1999) reported quite clear that national, state and federal environmental standards related to the sugar agroindustry are those dealing with conservation of water resources, pollution and emission released into the air, disposal of liquid wastes or waste waters and solid wastes, noise and odors. Also, general parameters of pollutants and measurement units were mentioned. สำนักวิเคราะห์ผลกระทบสิ่งแวดล้อม (ม.ป.ป.)

reported that in Thailand sugar factory can cause EI with the same set of pollutants mentioned above.

Solomon (2005) studied about environmental pollution and its management in sugar industry in India. The liquid and gaseous effluents produced from sugar industry have adverse impact on ecosystem and environment. The control strategy for environmental excellence was implementation of Environmental Management System (EMS). The system is a structured program of continuous environmental improvement that follows procedure drawn from established business management practice. For example, ISO 14001 was set up as a new international EMS standard to improve the environmental solution for sugar industry. The efficient EMS can be utilized for smoother and pragmatic implementation of cleaner production technologies and waste treatment.

Wei and Xu (2004) studied about eco-friendly management of sugar industry effluents in Guangxi, China. They focused on the environmental changes brought by the growing sugar industry of Guangxi province in southwestern China. Special attention in this study was given to the treatment of effluents from sugarcane based wastewater distilleries. The estimation in Guangxi, each year around 2.2 million tones distillery effluent are generated, and that such wastewater contributes 380,000 tons of Chemical Oxidation Demand (COD), accounting for 73% of the total COD from industry wastewater of the province. Therefore, this study has suggested a management options for treatment of these wastes into 5 parts which are: (1) reuse or reduce the processing water, (2) centralized use and treatment of the distillery effluents, (3) installation of organic complex fertilizer plants, (4) use of anaerobic digestion system, coupled with the use of treated effluent for fertilizer and irrigation purposes, and (5) zero effluent technology. However, it is important to note that either of these treatment options requires considerable amount of budget to minimize the significant adverse EI on the society.

Chansoontorn, Naksrimork, and Norasatworachai (2010) studied about the problems that can happen in supply chain of sugar production. The case study is of Sugar Co., Ltd., which is an institute in the supply chain of sugar production. This case could indicate real problems in the sugar production industry. The problems were impacts on environment, community, society, and the country. In part of community impact, it was chiefly caused by sugarcane transportation. There were impacts from truck and method of transportation. If truck had less efficiency, it could lead to using more fuel and be no friendly with an environment by increasing sound and more CO_2. Inappropriate transportation could cause EI e.g. no covering of sugarcane loading tray while transporting can lead to dust dispersion and over load of sugarcane could cause road damage.

From the above reviews, it confirms that the EI generated from a factory and transportation is necessary to be included as one of the important objectives in sugarcane allotment management. The work on quantitative evaluation of EI possibility generated from a specific sugar factory is however somewhat rare. Instead, the works have been carried out more on effects of particular pollutants discharged from factory. Therefore, to quantitatively estimate the EI possibility generated from a specific sugar factory, a set of variables should be involved. This includes ISO certification achievement (Solomon, 2005), community impact from transportation route (Chansoontorn, Naksrimork, and Norasatworachai, 2010), size related to productivity of a factory (Ozkan, Erguder, and Demirer, 2010). ISO certification achievement indicates that a factory can implement environmental management system (EMS) to improve economic and environmental performance. The routes passing through more communities could cause more EI along the transport routes such as dust, noise, and smoke. Bigger size factory has higher capacity and tend to practically generate more waste to impact the environment.

To integrate the minimized EI factors as one of the objective function in this study, the quantitative scoring EI of each factory based on those variables mentioned above was set up and operated.

2.4 Previous Studies

The study of ณัฐพร สุวรรณศูนย์ (2543) aimed at investigating the optimal locations, sizes, and number of the sugarcane processing factories. She used LP for the analysis of transportation and sugarcane production costs in 3 different scenarios including: (1) current scenario, (2) sugarcane production based on potential production areas scenario, and (3) optimum sugarcane production based on potential sugar factories. The above findings suggested that the adjustment of sugarcane production according to their potential and requirement of those optimal factory locations which have actual operating capacities at fairly acceptable levels or the relocations of sugar factories to their optimal locations would provide significant economic return to the industry. The constructed LP model in this study could provide more detailed information on optimal locations, sizes and number of factories as well as sugarcane production. This study dealt only with non-spatial data analysis.

ภูวนาท แสนนา และ วรรธนะ กระภูพันธ์ (2550) studied the transportation and network planning to reduce logistic cost for sugarcane industry in the Northeast region of Thailand. This project collected capacity of transportation and sugarcane area of each Tambol (sub-district) in 5 provinces - Khon Kaen, Chaiyaphum, Nakhon Ratchasima, Kalasin, and Udon Thani. The study employed the NA to find the shortest distance network between the sugar factories and center point of each Tambol, to find the mass of sugarcane loaded on the upcountry highway, to find the mass of transported sugarcane and the bottle-neck of transportation. The study recommended how to reduce logistic cost of sugarcane industry in the Northeast region of Thailand.

Pontawepitanun (2004) applied Geo-informatics to sugarcane industry zoning in Eastern, Thailand. Land suitability of sugarcane in the study area was identified by GIS overlay analysis. The NA and LP were used to economically zone by considering transportation cost, distance and sugarcane quantity from each tambon to target factories, and factory capacity. Finally, by considering land suitability and economic zone, the optimum transferred sugarcane stations were located.

W. X. Ping, Fang, Qun, Yu, R. M. Ping, and Ding (2004) integrated the merits of the map overlay method and the geographic information system (GIS). The GIS based map overlay method was developed to analyze the environmental vulnerability around railway and its impact on the environment. The analysis relied on the comprehensive assessment of railway EI and the optimization of railway alignment from Yichang to Wanzhou. EI assessments of two railway alignments were conducted and the optimal alignment with less impact was selected.

Milan, Fernandez, and Aragones (2006) presented a mixed integer LP model to solve the problem of cost minimization of sugarcane removal and its transport from the fields to the sugar mill at operational level. To exemplify the use of the model a real case was considered. The mill of example processes sugarcane from around 239 fields situated in the Holguin province (Cuba). The model presented was capable of solving the problem of cost minimization of sugarcane transport from fields to the mill for a working day. The model determines the capacities of the road and rail transport facilities for transporting sugarcane to ensure an uninterrupted supply of it to the mill. Moreover, a scheduling of road transports and harvesting quotas of cutting means is derived from optimal solution that makes the daily task of mills managers easier. The real problem can become more complex than the case-example shown. Therefore, to solve this kind of complex model on daily basis would be to combine, in a tailor-made software package, the possibilities given by specific systems for solving mixed integer linear programming models with the knowledge and the experience of people who are familiar with the "cutting–loading–transportation" system for sugarcane that allows potential users of the model to make a more flexible allocation of harvesting and road transportation means.

Monprapussorn, Thaitakoo, Banomyong, and Watts (2007) applied GIS and MCDA for hazardous waste transport sustainability. This paper provides a holistic framework of decision making process based on the sustainability paradigm for hazardous waste transport by incorporating factors and criteria in line with economic, environment and social dimension. Using GIS to manage and organize complex data sources and then derived weights and scores via MCDA to evaluate risks involved.

Nagar and Tawfik (2007) presented an approach for analyzing and prototyping urban road network routes based on multiple criteria. They demonstrated the concept of multi-criteria assessment of road networks on Liverpool city center. The study aimed at optimizing the road network design to meet TC, safety, land use, aesthetic, and environmental considerations. A multi-criterion based analysis of urban road network routes and spatial layouts enabled local accessibility of the road network for the set criteria, global accessibility of the road network, and the finding of optimum path between two points in a network. The cost function was designed with the objective of determining the cost of the road according to the multi-objectives criteria. The cost function was applied to all the possible roads to reach the destination from a starting point. The selection of optimum path was based on the cost of path. To analyze the road network design according to different criteria, the weights were assigned to each of the criteria, such as distance, safety, comfort, and aesthetics.

Chen, Wang, and Lin (2008) studied about a multi-objectives GIS for route selection of nuclear waste transport. This research was developed a multi-objectives GIS with ESRI ArcView GIS 3.x interface to finding an appropriate route with multiple objectives using an actual road-network. Possible transportation routes between the Institute of Nuclear Energy Research (INER) and the harbor were numerous. The carrier had to pass through several villages/towns by local roads, expressways, or freeways before reaching the storage destination (harbor). The three model objectives were minimizing travel time, minimizing transportation risk, and minimizing the exposed population. Dijkstra’s algorithm was applied to resolve the shortest route problem in the multi-objectives linear model using Avenue of ArcView 3.x. The result of optimal route with minimal travel time is 106.44 min by mainly using the freeway and the expressway for transportation rather than local roads. Optimal route with minimal transportation risk could have 720 vehicles per hour and taking multiple turns so as to be evacuated from the congested traffic area as soon as possible. The optimal route with minimal exposed population is 12,819 residents which is very far away from the heavily populated area or the capital area. Hence, the compromised route with multi-objective optimization of minimal travel time is 326.55 min, minimal transportation risk is 875.98 vehicles per hour and minimal exposed population is 16,124 residents.

Keshkamat, Looijen, and Zuidgeetst (2009) evaluated transport route planning alternatives of the Via Baltica project in Poland using the formulated spatial decision support system. The study presented a holistic and coherent spatial multi-criteria NA method for the generation of optimal routing alternatives under 4 different policy visions. The equal vision, all themes had the same weight. In the social vision the highest weight was given to the theme of social impact and safety. In the ecology vision the highest weight was given to the theme ecology. And in the economy vision the highest weight was given to the theme economic costs and benefits. The weights were calculated based on a ranking of the four themes, namely transport efficiency, ecology, social impact and safety, and economic costs and benefits. The suitability maps of the four visions and a pre-processed road vector layer were firstly brought in to the GIS. Thus four different routes having the same origin and destination have been generated. The total route lengths of the various vision-optimal routes were compared. It could be seen that the optimal route is about 6-13% or 20-40 km shorter than the route that Polish Government preferred.

Paiva and Morabito (2009) presented an optimization model to support decisions in the aggregate production planning of sugar and ethanol milling companies. The mixed integer programming proposed was based on industrial process selection and production lot-sizing models. The aim was to help the decision makers in selecting the industrial processes used to produce sugar, ethanol and molasses, as well as determining the quantities of sugarcane crushed, the selection of sugarcane suppliers and sugarcane transport suppliers, and the final product inventory strategy. The aggregate production planning approach was divided into two stages. The first stage involves preliminary calculus of three matrices. This first stage of the approach was only a pre-calculus to prepare the input data for the optimization model. The second stage was the referred optimization model of the mixed integer programming model. The objective function was maximizes the total variable revenue of all agro-industrial stages of the mill. The case study is Santa Clotilde Mill (SCM) in the Northeast of Brazil. The present case study had been taken using data from the 2004/2005 harvesting season. The most important result was the total variable revenue result, the objective function result. Analyzing this important issue, they found that the model total variable revenue was 7.11% higher than the result obtained by the SCM plan for this season. These results encouraged the use of this model to support decisions in the aggregate production planning. Managers could adopt a decreasing planning horizon strategy, firstly solving the model considering all weeks of the harvesting season and then, by the time the data of each week became available, resolving the model considering only the weeks that remained until the end of the season. With this strategy, the aggregate production planning and analysis turned into a routine and the impact of data uncertainty was minimized. This strategy is being applied in SCM in the 2007/2008 season.

Zhou and Ping (2009) studied about evaluation of the current situation and planning of the green space system in Huaibei city using GIS based NA. The basic research materials were urban current land use, green space current situation, green space system planning and satellite images of Huaibei in 2006. Supported by GIS, the research chose the main urban area in Huaibei with an area greater than 10 km^2 of afforestation space as the node. According to the analytic approach of the network, the research established the idealized ecological networks, compared their network structure integrality, and then chose the best network. Through this research, it indicates that combining the NA and landscape pattern analysis with the help of GIS technology, cannot merely appraise the current situation of the green space system and planning. It can adjust the planning of the ecological network of the city, makes the ecological networking of the city more diverse and steady.

Scarpari and Beauclair (2010) were to develop an optimized planning model for sugarcane farming using a LP tool. The program language used was General Algebraic Modeling System (GAMS) as this system was seen to be an excellent tool to allow profit maximization and harvesting time schedule optimization in the sugar mill studied. The goal of this work was to develop a model for the scheduling optimization of the sugarcane harvest operation, analyzing the season months (May-December) using a LP tool. This study was undertaken in Piracicaba, State of São Paulo, Brazil during 2003/04. The functional objective of program was to define harvesting times to maximize the enterprise profit for 30 homogeneous areas being considered. The result of the optimized harvesting schedule, there was a homogeneous pattern in crop production that results in excellent integration of harvesting with milling requirements. Following this crop harvesting schedule, the maximum gross income realizable is US$ 25.6 million. The highest marginal returns for the crop were in the months of August, September, and October. Due to the high price of sugar and alcohol fuel ($Pacu_j$ and $PTalc_{i,j}$) already at the beginning of harvest (May), higher values of ATR (total recoverable sugars of homogeneous area) was interesting and the use of ripeners in early maturing varieties was recommended. This study has shown that optimized agricultural planning promotes a homogeneous distribution of raw material along the months of crop obtaining the maximum possible profit. An easy-to-use management tool was the best way to explore several harvesting options to maximize profits. The use of a yield-predicting model would give better support in the scenarios creation for optimization, mainly the maturation of sugarcane.

CHAPTER III

RESEARCH PROCEDURES

The final achievement of this research aims at minimizing objective functions for proper sugarcane allotment from cropping plots to a set of factories existing in the region. The objective functions include minimization of TC alone and both TC and EI. From the survey information operated by the OCSB, the number of plots distributing in the region becomes so tremendous amount that the limitation of LP software is reached. To solve this foreseen problem, the analytical process is better separated into 2 levels. The first level is to allot sugarcane from district level to a certain set of factories. The second level uses the results from the first level as input in order to allot sugarcane from each plot of each district to that certain set of factories.

The conceptual framework of this research is illustrated in Figure 3.1. It includes data collection, 2 levels of data analysis, and hypothesis evaluation. Data analysis for the first objective, to minimize TC, both district and plot levels dealt with only distance from them to factories. For the second objective, to minimize TC and EI, both levels dealt with distance from them to factories and EI which were separated to be impacts caused by transportation passing through communities, less industrial standard of factories, and productivity of factories. The research procedure in detail is described as follows.

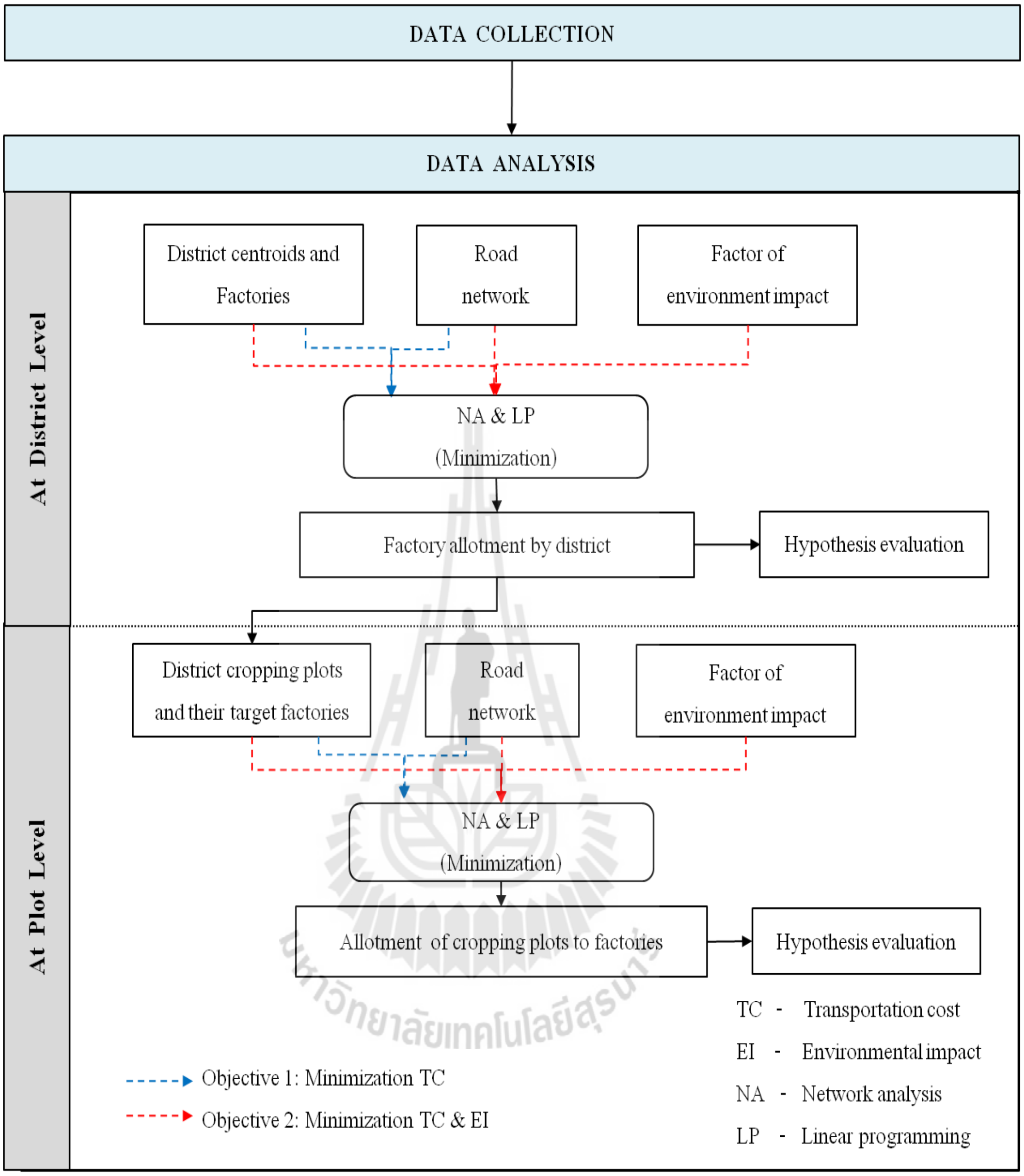


Figure 3.1 Conceptual framework of the study.

3.1 Data Collection, Refinement, and Manipulation

Input data required for the research as listed in Table 3.1 were collected. The EI related information includes routes of transportation passing through communities, industrial standard achievements, and productivity of factories.

These data as input for analytical processes were firstly refined and manipulated in order that they could be used properly and effectively to serve the research objectives, for example, cleaning polygons of cropping area data, district and cropping plot centroids determination, and topological check for road network data layer.

Table 3.1 Main required data and their sources.

Type of data	Source	Year
1) Sugarcane cropping plots	OCSB	2009
2) Sugar factory locations	OCSB	2009
3) Official factory allotment	OCSB	2009/2010
4) Road network	Ministry of Transport	N.A.
5) Transportation cost (baht/km/ton)	Thai Transportation and Logistics Association (TTLA)	2010
6) Lands use	Land Development Department	2007
7) EI related information	Sugar factories in the region	N.A.

3.1.1 The data layer of sugarcane cropping areas

The problem found in the sugarcane cropping areas was the repetitive polygons. More than one polygon was overlapped in the same plot. The rule “must not overlap” was then applied to data editing. This rule is used when an area cannot belong to two or more polygons (ESRI, 2006). In such problem, the overlapped data of cropping areas were merged or deleted. After polygon cleaning, the sugarcane quantity in each plot was calculated by multiplying the standard quantity per rai with a plot area (rais) and resulted in tons. The estimated production of sugarcane is proposed to be 10 tons per rai by the OCSB.

3.1.2 The data layer of the road network

The topological structure of the road network data layer was seriously checked. The problem found most often is that the lines are not connected especially at the crossroads or intersection, incurred unable to the NA. Topological rules added were "must not overlap" and "must not intersect". The rule of "must not overlap" is used where line segments should not be duplicated. For the rule "must not intersect", line features from the same feature class should not cross or overlap each other, where the intersection of lines should only occur at endpoints (ESRI, 2006). Line connectivity was another problem recognized and solved. The complet topological-checked road network data layer was further used to create network dataset for the NA.

3.1.3 The data layer of the centroids of sugarcane cropping areas in districts and plots

The centroids of sugarcane cropping areas in districts were identified for district level while centroids of plots were for plot level. These points were used as the origins of the NA in both levels. The centroid of each plot was identified by the *Feature to point* with the constraints that each centroid should be within its plot. Centroid of sugarcane cropping areas in each district was identified with weights which were quantities of sugarcane in plots of district by means of the *Mean center* as expressed in Equation (13).

$$\bar{X}_w = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}, \ \ \bar{Y}_w = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}, \tag{13}$$

where $\bar{X}_w$, $\bar{Y}_w$ is position of the district centroid,

w_i is weight of the plot *i*,

x_i, y_i is position of the plot *i*,

n is number of all plots, and

i is plot *i*.

3.1.4 The data layer of environmental impacts

Table 3.2 shows the summary of the normalization of each EI dataset.

(1) EI along routes caused by transportation passing through community areas with the buffer distance of 100 meters. These areas were adopted from land use data of 2007 prepared by the Land Development Departmen. Within this distance, dust, noise, and smoke can affect to the communities. The total length of road passing through the buffer zone was determined by the "Identity function" in the ArcGIS 9.x program.

The total length of buffered distances along the transportation routes was normalized to be in the range of 0-1 by means of the benefit-criterion linear scale transformation. The higher score indicates the higher impact. The equation for the normalization can be written as:

$$x'_{ij} = \frac{x_{ij}}{x_{max}}, \tag{14}$$

where x'_{ij} is the normalized buffered distance from the district/plot *i* to factory *j*,

x_{ij} is the raw score of buffered distance from district/plot i to factory j,

x_{max} is the maximum raw score,

i is the district/plot, i = 1, 2, 3, .., m., and

j is the sugar factory, j = 1, 2, 3, .., n.

(2) Factories with higher industrial standard cause less EI. The standard of all 16 factories was achieved by expert interviews via questionnaires. The questionnaire and result of the interview are shown in Appendix A and Table B.2 in Appendix B, respectively. Also, these scores were normalized to be between 0-1 by means of cost-criterion linear scale transformation. The less normalized score indicates the less impact which is consistent with the minimized objective function. The optimal equation can be expressed as:

$$x'_j = 1 - \frac{x_j}{x_{max}}, \tag{15}$$

where x'_j is the normalized industrial standard score for factory j,

x_j is raw score of industrial standard for factory j,

x_{max} is maximum raw score, and

j is sugar factory, j = 1, 2, 3, .., n.

(3) EI caused by the productivity of factories. The bigger factories inevitably provide more waste from production and wastewater discharge. This study assumed that factories with higher productivity have more chance to cause higher

impact. Productivity of factories was collected and normalized by means of the benefit-criterion linear scale transformation as shown in Table 3.2.

Table 3.2 Summary of the normalization of EI.

No.	Data layer of EI	Linear scale transformation	Normalization equation
1	EI caused by transportation routes.	Maximum score with benefit criterion.	$x'_{ij} = \frac{x_{ij}}{x_{max}}$
2	EI caused by industrial standard of factories.	Maximum score with the cost criterion.	$x'_{j} = 1 - \frac{x_{j}}{x_{max}}$
3	EI caused by the productivity of factories.	Maximum score with the benefit criterion.	$x'_{j} = \frac{x_{j}}{x_{max}}$

3.2 Data Analysis

As mentioned above, the analysis was divided into two levels (district/plot) for both objective functions. In each level of objective function, the NA was performed to obtain the least cost path from each district/plot to factories. This output from the NA was used as input into the LP with the constraints mentioned. The LP performance resulted in proper allotment of sugarcanes from each district/plot to a certain set of factories. The procedure can be explained as follows.

3.2.1 Single objective function: Minimizing the total transportation cost

This objective function is the minimization of total TC from district and plot levels to factories. The process resulted in providing allotment of sugarcanes from each district/plot to a certain set of factories including the shortest paths for all original nodes to destination nodes.

At district level.

Figure 3.2 shows the framework of single objective function in district level when the EI was neglected in the LP.

(1) Network analysis

Closet facility function of the NA was performed. Input data of the analysis were data layers of the centroids of cropping area in districts (228 points) as the origins, the locations of sugar factories (16 points) as the destinations, and road network. The impedance was the route length (distances). Analytical results were the shortest path of each origin and destination (O-D). The standard TC (1.19 baht/km/ton) as shown in Table 3.3 which averaged from costs in the NE region was used to multiply with the distance of each path and resulted as c_{ij} (baht/ton). The shortest paths multiplied with the standard TC were use for further LP analysis.

(2) Linear programming

The LP took the TC (c_{ij}) from district i to sugar factory j in the previous level and amount of sugarcane in the district to minimize the total TC as expressed in Equation (5).

Results of the process were the minimum total TC and allotment(s) from each district to a set of optimal factories in service.

At plot level

Figure 3.3 shows the framework of plot level operation without EI consideration.

Table 3.3 The standard TC in the NE region.

No.	From Bankok to…			TC of 10 wheel (Baht)	TC of Trailer (Baht)	Average TC of 10 wheel (Baht/km)	Average TC of Trailer (Baht/km)
	Province	District	Distance (km)				
1	Kalasin	Muang	513	10,474.00	15,291.00	20.42	29.81
2	Khon Kaen	Muang	444	9,341.00	13,673.00	21.04	30.80
3	Chaiyaphum	Muang	329	7,454.00	10,976.00	22.66	33.36
4	Nakhon Phanom	Muang	805	15,268.00	22,139.00	18.97	27.50
5	Nakhon Ratchasima	Muang	256	6,255.00	9,264.00	24.43	36.19
6	Buri Ram	Muang	429	9,095.00	13,321.00	21.20	31.05
7	Maha Sarakham	Muang	470	9,768.00	14,282.00	20.78	30.39
8	Mukdahan	Muang	723	13,921.00	20,216.00	19.25	27.96
9	Yasothon	Muang	578	11,541.00	16,815.00	19.97	29.09
10	Roi Et	Muang	510	10,425.00	15,220.00	20.44	29.84
11	Si Sa Ket	Muang	568	11,377.00	16,581.00	20.03	29.19
12	Sakon Nakhon	Muang	723	13,921.00	20,216.00	19.25	27.96
13	Surin	Muang	451	9,456.00	13,837.00	20.97	30.68
14	Nong Khai	Muang	618	12,198.00	17,753.00	19.74	28.73
15	Nong Bua Lam Phu	Muang	607	12,017.00	17,495.00	19.80	28.82
16	Amnat Charoen	Muang	633	12,444.00	18,105.00	19.66	28.60
17	Udon Thani	Muang	564	11,311.00	16,487.00	20.05	29.23
18	Ubon Ratchathani	Muang	645	12,641.00	18,386.00	19.60	28.51
19	Loei	Muang	553	11,131.00	16,229.00	20.13	29.35
	Average TC of each truck (Baht/km)					**20.44**	**29.85**
	Average TC of each truck per Ton (Baht/km/ton)*					**1.02**	**1.36**
	Standrad TC of all trucks in NE region (Baht/km/ton)					**1.19**	

Note * - loading of 10 wheel is 20 tons

- loading of trailer is 22 tons

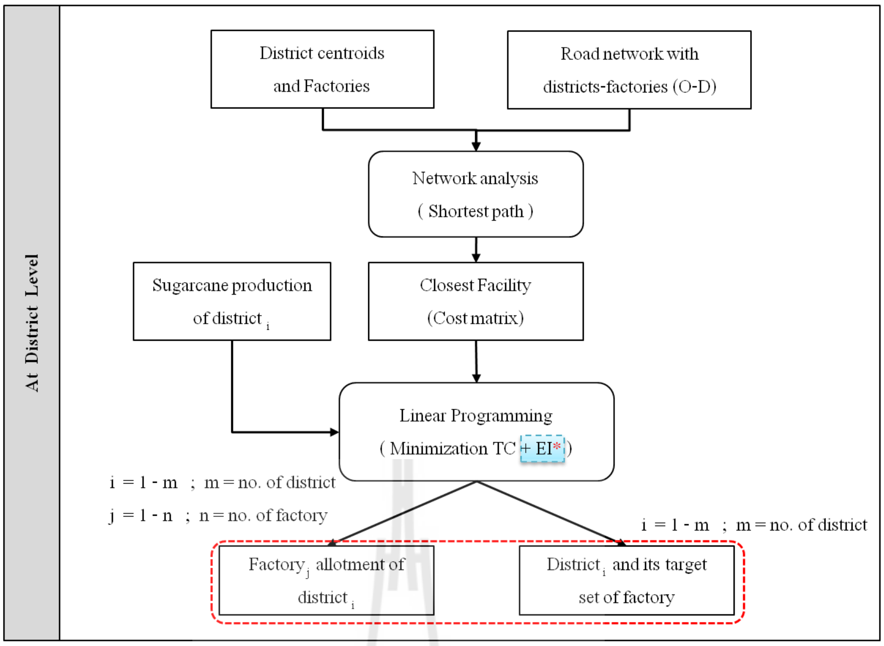


Figure 3.2 Conceptual framework of the optimization at district level of the single objective and multi-objective functions.

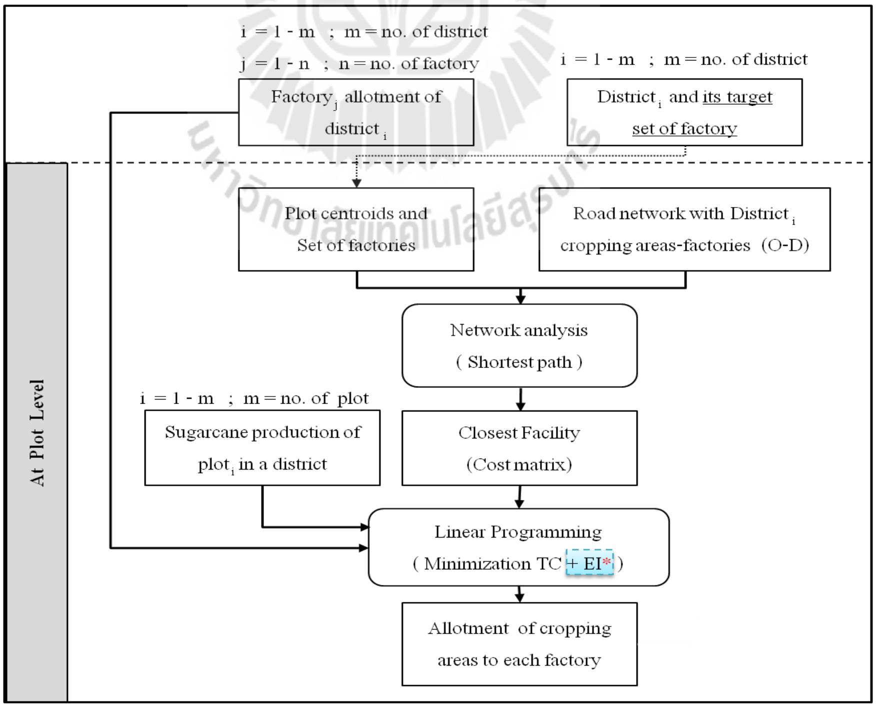


Figure 3.3 Conceptual framework of the optimization at plot level of the single objective and multi-objective functions.

(1) Network analysis

The result of the LP optimization in the first level in term of the optimal factories of each district (destination) was brought to perform with the centroids of plots in that district (origin). The results were the shortest path for each O-D. These paths were then multiplied with the standard TC for further analysis using the LP.

(2) Linear programming

The cost of each O-D from the NA was input for the LP operation. The process was the same with the district level but the centroids (*i*) and sugarcane amount of plots in each district were used instead. The factory destination and its allotment of each district from the result of the district level were used as constraints. The program was operated on district by district.

The results were the minimum total TC of sugarcane from all plots to factories, optimal factory or a set of optimal factories in service of each plot, and the allotment(s) of each plot to factory(s).

3.2.2 Multi-objectives function: Minimizing transportation cost and environmental impact

This step is the process in MODA aiming to make the allotment of sugarcane transportations at minimum cost and EI. The analytical steps were the same as the single objective function but involved with the EI as the frameworks shown in Figures 3.2 and 3.3.

At district level

(1) Network analysis

O-D in this level was the same as district level of the single objective function. The difference was only the impedance which additionally included length of road passing through the buffer zone of communities for each O-D. Thus, each O-D distances resulted from process must be subtracted by length of road passing through the buffer zone before using in TC calculation. The subtracted distance was the actual distance of each O-D. The standard TC which averaged from costs in the NE region were used to multiply with the distance of each path and resulted as c_{ij} (baht/ton). The shortest paths multiplied with the standard TC were use for further LP analysis.

(2) Linear programming

The LP took the TC (c_{ij}) from district i to sugar factory j in the previous NA and amount of sugarcane in the district to minimize the total TC and EI as expressed in Equation (9). In this step, before input to the LP, EI was normalized using Equations (14) and (15) while c_{ij} and x_{ij}variables were normalized using Equations (14).

Results of the process according to Equation (9) were the minimum total TC and EI including allotment(s) from each district to a set of optimal factories in service. The normalized results of TC and allotments were multiplied with their maximum actual values to obtain the actual values used for further analysis.

At plot level

At this level the processes were still the same as district level.

(1) Network analysis

The result of the LP optimization in the district level in term of the optimal factories of each district (destination) was brought to perform with the centroids of plots in that district (origin). Impedance of NA was additionally included length of road passing through the buffer zone of communities for each O-D. The results were the shortest path for each O-D. Thus, each O-D distances resulted from process must be subtracted by length of road passing through the buffer zone before using in TC calculation. The subtracted distance was the actual distance of each O-D. These paths were then multiplied with the standard TC and resulted as c_{ij} (baht/ton). The shortest paths multiplied with the standard TC were use for further LP analysis.

(2) Linear programming

The cost of each O-D (c_{ij}) from the NA was input for the LP operation. The process was the same with the district level but the centroids (i) and sugarcane amount of plots in each district were used instead. The factory destination and its allotment of each district from the result of the district level were used as constraints. The program was operated on district by district. In this step, before input to the LP, EI was normalized using Equations (14) and (15) while c_{ij} and x_{ij} variables were normalized using Equations (14).

The results were the minimum total TC and EI of sugarcane from all plots to factories, optimal factory or a set of optimal factories in service of each plot, and the allotment(s) of each plot to factory(s). The normalized results of TC and allotments were multiplied with their maximum actual values to obtain the actual values used for further analysis.

3.2.3 Hypotheses evaluation

The hypothesis evaluation of the study was carried out to obtain the new results and compared to the old ones.

(1) The cost of sugarcane transportation from each plot to factories achieved from the study is the minimum compared to other non-systematic transportation allotments.

There are 3 trials-i.e. the random matching of plot allotments in a district to one sugar factory with different transportation route from the study result; the random matching of plot allotments in a district to a set of sugar factories with different transportation routes; the random matching of plots allotments in a district to a set of sugar factories while factory allotments were kept the same.

(2) There is the difference of allotments based on consideration with and without EI.

Comparison on the study results of the single and multi-objective functions would prove whether the hypothesis is accepted.

CHAPTER IV

RESULTS AND DISCUSSION

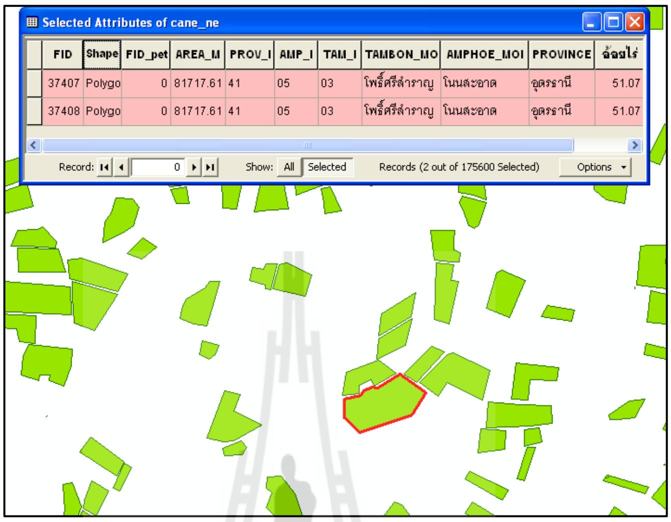
Chapter IV reported and discussed results of sugarcane transportation management using network and multi-objective decision analyses according to major steps of methodology. These included 3 steps: (1) data collection, refinement, and manipulation (2) single objective function in district and plot levels, and (3) multi-objectives function in district and plot levels.

4.1 Results of Data Collection, Refinement, and Manipulation

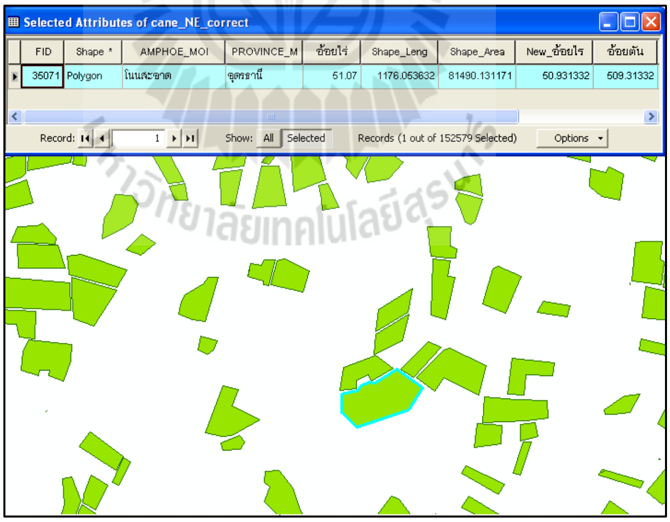
4.1.1 The data layer of sugarcane cropping areas

The problem found in the data layer of sugarcane cropping areas, received from OCSB, was the presence of repetitive polygons. There were duplications in the same plots. To solve the problem, the duplicated polygons were merged or deleted. The data layer of sugarcane cropping areas before being edited had around 175,600 records and became 152,579 records when edited. After polygon cleaning, the sugarcane quantity in each plot was calculated by multiplying the standard quantity per rai (10 tons) with a plot area (rais) and resulted in tons unit kept in a new field of attribute data.

Figure 4.1 shows the edit resulted of the data layer of sugarcane cropping areas. When selected a duplicated plot in the original data layer, it contained two attribute records as shown in Figure 4.1(a). When edited, only one record left as shown in Figure 4.1(b).



(a) The original data layer of sugarcane cropping areas.



(b) The edited data layer of sugarcane cropping areas.

Figure 4.1 Results of data refinement in sugarcane cropping areas layer: (a) 2 attribute records in one plot of the original data, and (b) only one record left for each plot with sugarcane quantity.

4.1.2 The data layer of road network

The most problem found was that the lines were not connected especially at the crossroads or intersection, incurred unable to the NA. When edited, a number of records was increased from 95,100 road segments of the original data to be 97,989 segments due to nodes being added at the junctions.

Furthermore, the network dataset was built for the NA, resulting in 3 layers of original road network, road junction, and road edges datasets as shown in Figure 4.2.

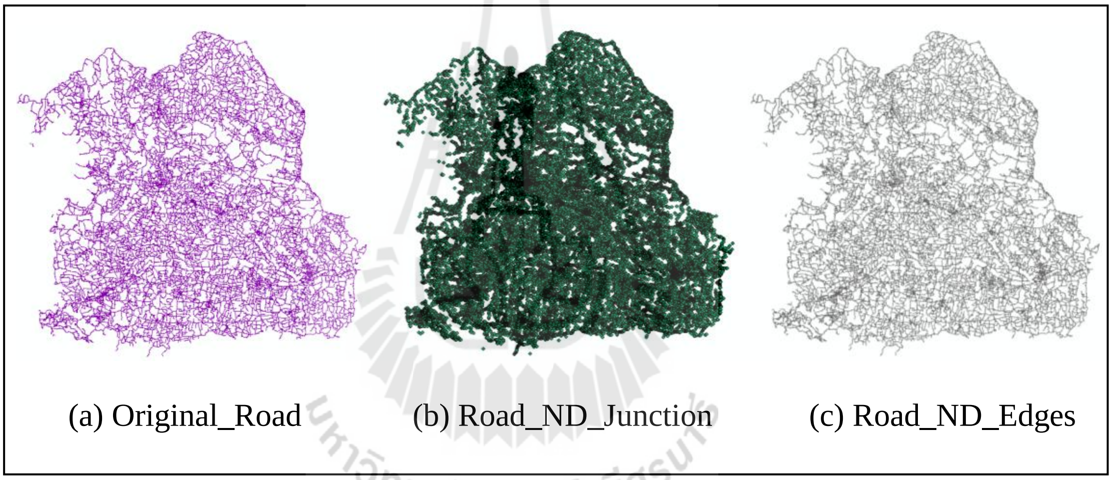


Figure 4.2 Network dataset for used in the NA: (a) original road, (b) road network junction, and (c) road edges dataset.

4.1.3 The data layer of the centroids of sugarcane cropping areas in districts and plots

The centroid of sugarcane cropping areas in each district was prepared using *Mean center* function as described in section 3.1.3 of Chapter III. The result was the mean point data representing the cropping plot areas of each district as shown in Figure 4.3. There were 228 centroids shown as red points in Figure 4.3. Some districts had no centroids because of having no sugarcane cropping areas.

The centroid of each plot was identified by the *Feature to point* function with the constraints that each centroid should be within its plot. The result of transforming was shown as an example in Figure 4.4.

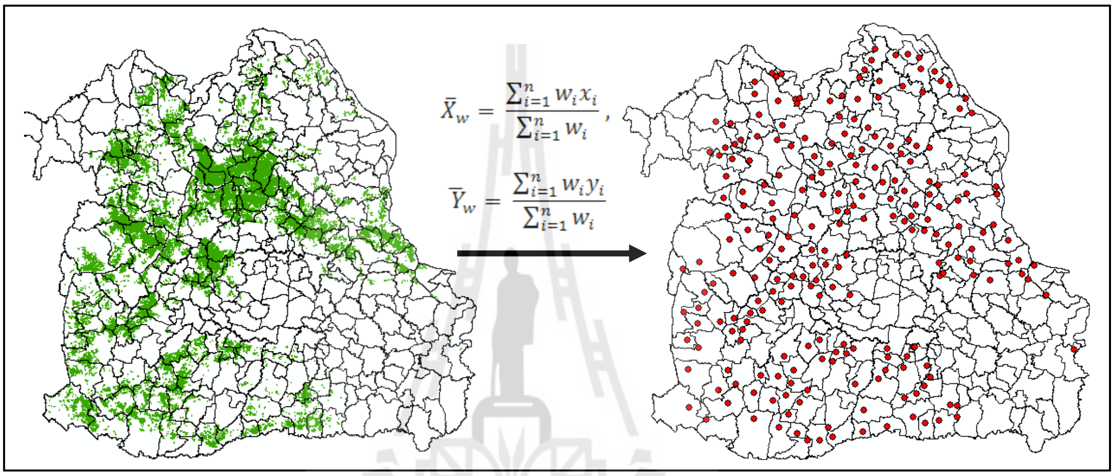


Figure 4.3 Centroids of sugarcane cropping areas of each district by the *Mean center* function.

Figure 4.4 Transformed sugarcane cropping areas into centroids.

4.1.4 The data layer of environmental impacts

(1) EI along routes caused by transportation passing through 100 m-buffer distance from communities was taken into account. As an example, Figure 4.5 depicts the length of road passing through 100 m-buffer zone. The length of buffered distances along each transportation route was normalized to be in the range of 0-1 by means of the benefit-criterion linear scale transformation as expressed in Equation (14). The normalized EI was used for further LP analysis of multi objectives function (Table B.1 in Appendix B).

(2) Factories with higher industrial standard cause less EI. Industrial standard information of all 16 factories in the NE region was collected and illustrated in Table 4.1. The Industrial standard information was prioritized as optimal scores in aspect of EI based on expert opinions via the questionnaire (Appendix A) as expressed in Table B.2 and Table B.3 in Appendix B. The questionnaires were sent to 10 experts but only 7 were returned. These scores were normalized to be between 0-1 by means of cost-criterion linear scale transformation expressed in Equation (15). The results were listed in Table 4.2, and used for further LP analysis of multi-objective function.

(3) EI cause by the productivity of factories was normalized by means of the benefit-criterion linear scale transformation. Table 4.3 shows the productivity and normalized productivity score of each factory. This was used for further LP analysis of multi objectives function.

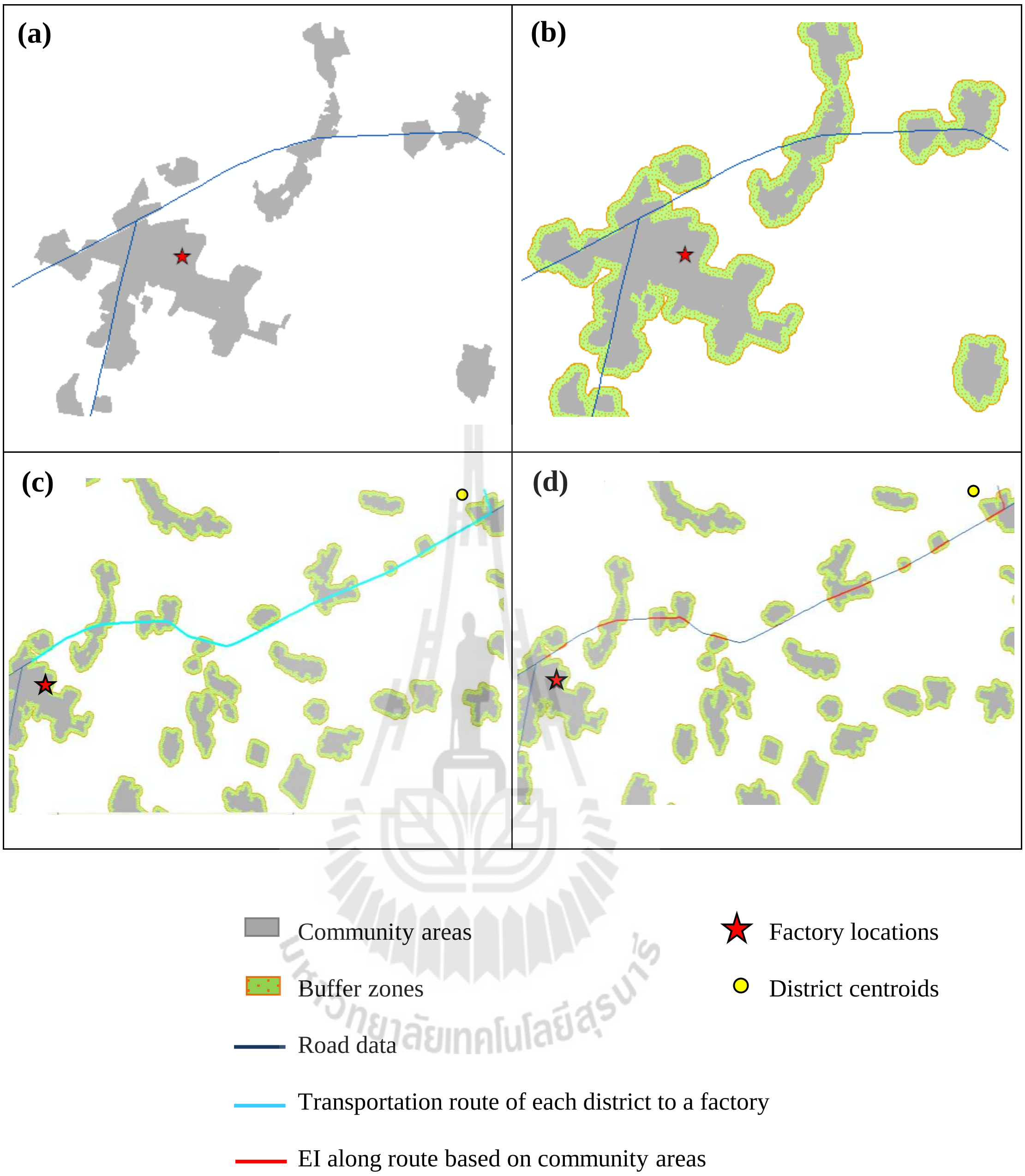


Figure 4.5 EI along transport routes: (a) transport routes passing communities, (b) 100 m-buffer zones from communities, (c) transport routes and district centroids, and (d) EI along route based on community areas.

Table 4.1 Industrial standard information of sugar factories in the NE region.

No.	Name of factories	ISO 9000	ISO 9001	ISO 9000:2008	ISO 9001:2000	ISO 9001:2008	ISO 9002	ISO 14001	ISO 14001:2004	GMP	HACCP	GMP/HACCP	HALAL	TIS.	TIS. 56-2553	Thailand Brand	Board of Investment	Kosher
1	Kumphawapi sugar factory (Udon Thani)				/					/			/	/		/		
2	Kaset Phol sugar factory (Udon Thani)				/					/			/					
3	Khon Kaen sugar factory (Khon Kaen)	/								/	/		/					
4	Rermudom sugar factory (Udon Thani)	/								/			/		/			
5	Burirum sugar factory (Buri Ram)	/											/					
6	Mitr Kalasin sugar factory (Kalasin)	/						/		/	/							
7	Mitr Phuviang sugar factory (Khon Kaen)	/						/		/	/							
8	United Farmer & Industry sugar factory (Chaiyaphum)	/						/		/	/							
9	Angvian Industry sugar factory (Nakhon Ratchasima)						/	/		/	/		/					
10	Wangkanai sugar factory (Maha Sarakham)																	
11	Saharuang sugar factory (Mukdahan)	/			/				/	/	/	/	/	/	/			
12	Surin sugar factory (Surin)			*														
13	Korach Industry sugar factory (Nakhon Ratchasima)				/				/	/	/		/					
14	N.Y. sugar factory (Nakhon Ratchasima)		/			/				/	/	/	/		/		/	/
15	Arawan sugar factory (Nong Bua Lam Phu)		*	/									/		/			
16	E – Saan Sugar Industry factory (Kalasin)	/								/	/		/	/				

Note: * is in process

From: ไทยชูการ์ มิลเลอร์ (2553)

Table 4.2 Normalized industrial standard scores for sugar factories in the NE region.

No.	Factory	Normalize industrial standard score
1	Kumphawapi sugar factory (Udon Thani)	0.48
2	Kaset Phol sugar factory (Udon Thani)	0.69
3	Khon Kaen sugar factory (Khon Kaen)	0.58
4	Rermudom sugar factory (Udon Thani)	0.59
5	Burirum sugar factory (Buri Ram)	0.81
6	Mitr Kalasin sugar factory (Kalasin)	0.53
7	Mitr Phuviang sugar factory (Khon Kaen)	0.53
8	United Farmer & Industry sugar factory (Chaiyaphum)	0.53
9	Angvian Industry sugar factory (Nakhon Ratchasima)	0.45
10	Wangkanai sugar factory (Maha Sarakham)	1.00
11	Saharuang sugar factory (Mukdahan)	0.00
12	Surin sugar factory (Surin)	0.90
13	Korach Industry sugar factory (Nakhon Ratchasima)	0.44
14	N.Y. sugar factory (Nakhon Ratchasima)	0.05
15	Arawan sugar factory (Nong Bua Lam Phu)	0.61
16	E – Saan Sugar Industry factory (Kalasin)	0.48

Table 4.3 Normalized productivity scores of sugar factories in the NE region.

No.	Factory	Productivity of factories (tons/day)	Normalize productivity score
1	Kumphawapi sugar factory (Udon Thani)	12,000	0.33
2	Kaset Phol sugar factory (Udon Thani)	12,000	0.33
3	Khon Kaen sugar factory (Khon Kaen)	20,400	0.57
4	Rermudom sugar factory (Udon Thani)	20,582	0.57
5	Burirum sugar factory (Buri Ram)	12,000	0.33
6	Mitr Kalasin sugar factory (Kalasin)	20,000	0.56
7	Mitr Phuviang sugar factory (Khon Kaen)	20,000	0.56
8	United Farmer & Industry sugar factory (Chaiyaphum)	18,000	0.50
9	Angvian Industry sugar factory (Nakhon Ratchasima)	36,000	1.00
10	Wangkanai sugar factory (Maha Sarakham)	15,453	0.43
11	Saharuang sugar factory (Mukdahan)	14,000	0.39
12	Surin sugar factory (Surin)	16,000	0.44
13	Korach Industry sugar factory (Nakhon Ratchasima)	24,000	0.67
14	N.Y. sugar factory (Nakhon Ratchasima)	13,690	0.38
15	Arawan sugar factory (Nong Bua Lam Phu)	8,117	0.23
16	E – Saan Sugar Industry factory (Kalasin)	15,000	0.42

4.2 Results of Data Analyses

4.2.1 Single objective function: Minimizing the total transportation cost

Results from this analysis can be used as the policy for sugarcane allotment transshipped to factories at minimum costs. In this study, the analysis was divided into two levels: district level, and plot level.

At district level

(1) Network analysis

Closet facility function of the NA was performed on input data which were centroids of cropping areas (228 points) of districts as the origins and locations of sugar factories (16 points) as the destinations. From NA, there were 16 shortest paths from each district centroid to each factory. This resulted in totally 3,648 shortest paths. Figure 4.6 shows an example of the result which was the shortest paths from Kranuan district in Khon Kaen province to all sugar factories. These distances were listed in Table 4.4.

The unit of shortest path was kilometer(s). They were transformed into the matrix expressing path from each original (district) to destination (factory) and then multiplied by the distance of each path and the standard TC (baht/km/ ton). Their unit became baht/ton. These TC (baht/ton) or c_{ij} were input for optimization to obtain the minimum cost of sugarcane transportation from districts to sugar factories in the LP analysis.

(2) Linear programming

According to Equation (5), c_{ij} from district i to sugar factory j obtained from the previous level was identified in LP to inimize the total TC in sugarcane transportation management from each district to each sugar factory.

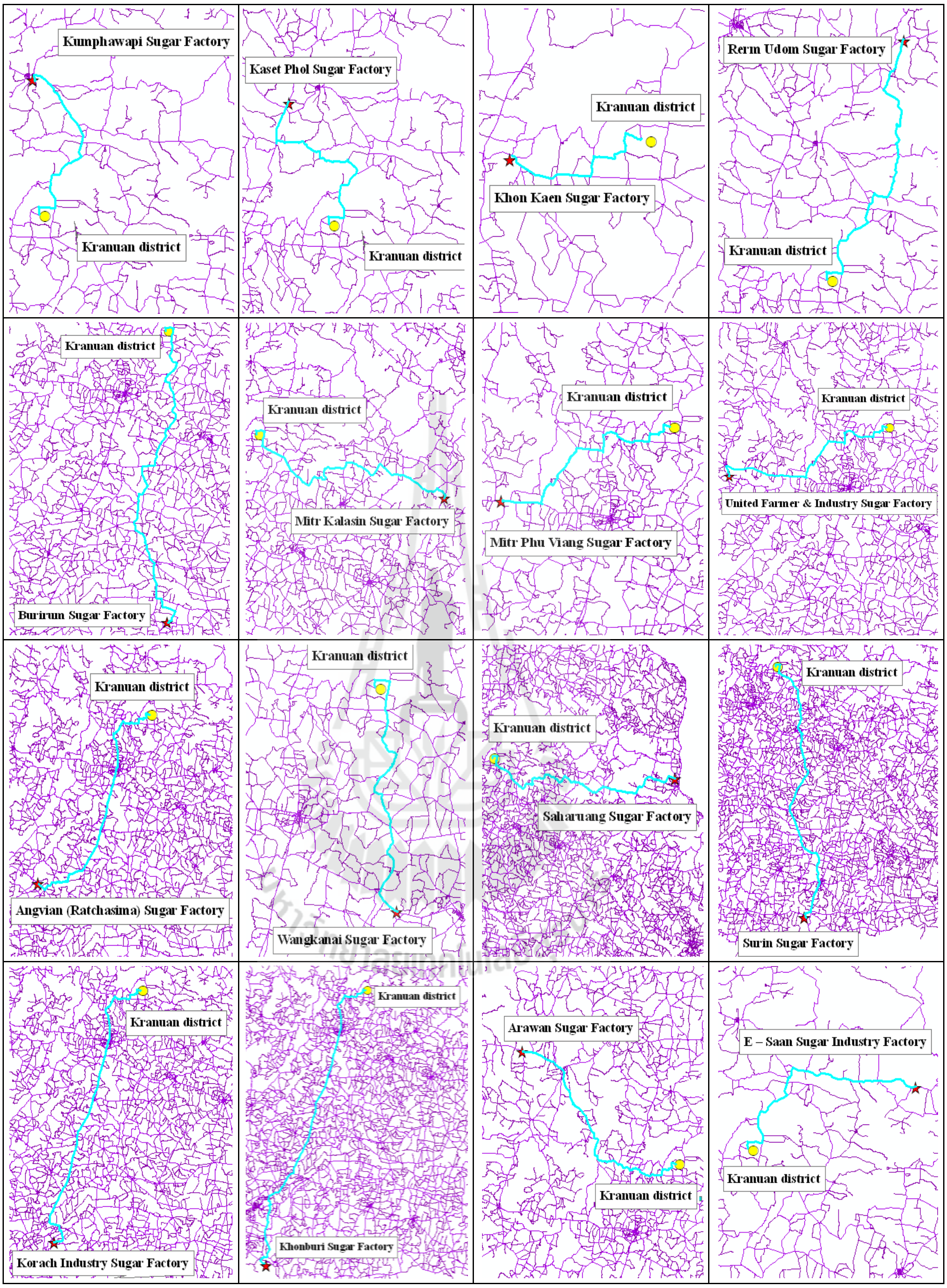


Figure 4.6 Examples of the shortest paths from the Kranuan district in Khon Kaen province to all sugar factories.

Table 4.4 The 16 shortest paths of Kranuan district in Khon Kaen province from NA.

No.	Shortest paths of Kranuan district to sugar factory	Distance (km.)
1	Kumphawapi sugar factory (Udon Thani)	59.03
2	Kaset Phol sugar factory (Udon Thani)	70.75
3	Khon Kaen sugar factory (Khon Kaen)	30.33
4	Rermudom sugar factory (Udon Thani)	95.29
5	Burirum sugar factory (Buri Ram)	209.65
6	Mitr Kalasin sugar factory (Kalasin)	154.66
7	Mitr Phuviang sugar factory (Khon Kaen)	100.33
8	United Farmer & Industry sugar factory (Chaiyaphum)	144.04
9	Angvian Industry sugar factory (Nakhon Ratchasima)	180.86
10	Wangkanai sugar factory (Maha Sarakham)	86.41
11	Saharuang sugar factory (Mukdahan)	236.45
12	Surin sugar factory (Surin)	301.47
13	Korach Industry sugar factory (Nakhon Ratchasima)	232.11
14	N.Y. sugar factory (Nakhon Ratchasima)	316.09
15	Arawan sugar factory (Nong Bua Lam Phu)	144.23
16	E – Saan Sugar Industry factory (Kalasin)	79.06

Results of the process were the minimum total TC and allotment(s) from each district to a set of optimal factories in service. Table 4.5 shows the brief results. The complete results are shown in Table C.1 in Appendix C. The minimum total TC of district level in NE region of a single objective function was 1,466,641,682.33 baht. In 214 districts, there was a pair of allotment from each district to one sugar factory. Others, 14 districts, were allotment from each district to a set of sugar factories which were 2 or 3 factories as shown in Table 4.6.

For these 14 districts, the allotment in plot level was performed from each plot to a certain set of factories using LP analysis. The factory destinations and their allotments of each district from the result became constraints of the process. The result returned in optimum allotments from each plot to which factory(s) resulted in the minimum total TC.

Table 4.5 A part of single objective result from LP analysis at district level.

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s)	Transportation cost in district level (Ci) (Baht)
Kranuan	1	-	-	535,044.40	-	-	-	-	-	-	-	-	-	-	-	-	-	535,044.40	19,313,496.80
Krasang	2	-	-	-	-	-	-	-	-	-	-	-	9,109.84	-	-	-	-	9,109.84	656,055.12
Kap Choeng	3	-	-	-	-	-	-	-	-	-	-	-	101,040.35	-	-	-	-	101,040.35	4,454,411.17
Kut Rang	4	-	-	-	-	225,429.89	-	-	-	-	-	-	-	-	-	-	-	225,429.89	29,801,425.52
Ku Kaeo	5	121,553.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	121,553.20	5,244,222.14
Khewa Sinarin	6	-	-	-	-	-	-	-	-	-	-	-	427.29	-	-	-	-	427.29	29,604.31
Khaen Dong	7	-	-	-	-	110,698.53	-	-	-	-	-	-	-	-	-	-	-	110,698.53	1,118,364.88
Khok Pho Chai	8	-	-	-	-	-	-	905.30	-	48,484.87	-	-	-	-	-	-	-	49,390.16	3,289,206.37
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Nong Saeng	219	-	331,369.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	331,369.23	6,574,169.19
Nong Hong	220	-	-	-	-	-	-	-	-	-	-	-	-	170,453.64	-	-	-	170,453.64	8,957,581.39
Nong Han	221	78,147.35	-	-	29,998.64	-	-	-	-	-	-	-	-	-	-	-	-	108,145.99	3,923,651.83
Huai Thalaeng	222	-	-	-	-	-	-	-	-	-	-	-	-	131,573.13	-	-	-	131,573.13	4,652,276.59
Huai Thapthan	223	-	-	-	-	-	-	-	-	-	-	-	896.89	-	-	-	-	896.89	121,728.89
Huai Phueng	224	-	-	-	-	-	111,312.06	-	-	-	-	-	-	-	-	-	-	111,312.06	4,562,594.51
Huai Mek	225	-	-	191,277.25	-	-	-	-	-	-	-	-	-	-	-	-	-	191,277.25	10,657,389.56
Wan Yai	226	-	-	-	-	-	-	-	-	-	-	19,489.65	-	-	-	-	-	19,489.65	584,633.57
Akat Amnuai	227	-	-	-	2,744.53	-	-	-	-	-	-	-	-	-	-	-	-	2,744.53	298,378.16
Ubonrat	228	-	-	101,907.62	-	-	-	-	-	-	-	-	-	-	-	-	-	101,907.62	2,930,677.39
Factory Allotted Capacity (dj)		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,209,000**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**	**Total Cost**	**1,466,641,682.33**
Allotted Quantity		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,051,843**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**		

Table 4.6 Summary of allotments from 14 districts to a set of factories at district level analysis of a single objective function.

No.	District	Sets of optimal factory	Allotted amount (Tons)
1	Khok Pho Chai	- Mitr Phu Viang (Khon Kaen)	905.30
	(Khon Kaen)	- Angvian Industry (Nakhon Ratchasima)	48,484.87
2	Non Sila	- Burirum (Burirum)	17,917.34
	(Khon Kaen)	- Korach Industry (Nakhon Ratchasima)	74,339.62
3	Kut Chap	- Kaset Phol (Udon Thani)	85,920.25
	(Udon Thani)	- Arawan (Nong Bua Lamphu)	121,662.15
4	Kosum Phisai	- Mitr Phu Viang (Khon Kaen)	375,858.42
	(Maha Sarakham)	- Wangkanai (Maha Sarakham)	160,416.28
5	Chok Chai	- Korach Industry (Nakhon Ratchasima)	4,333.06
	(Nakhon Ratchasima)	- N.Y. (Nakhon Ratchasima)	128,938.75
6	Tha Khantho	- Kumpawapi (Udon Thani)	287,797.17
	(Kalasin)	- Khon Kaen (Khon Kaen)	34,167.63
7	Thep Sathit	- Angvian Industry (Nakhon Ratchasima)	9,541.58
	(Chaiyaphum)	- Korach Industry (Nakhon Ratchasima)	64,525.12
8	Nikhom Kham Soi	- Mitr Kalasin (Kalasin)	46,019.43
	(Mukdahan)	- Saharuang (Maha Sarakham)	144,574.40
9	Non Sa-at	- Kaset Phol (Udon Thani)	361,623.57
	(Udon Thani)	- Khon Kaen (Khon Kaen)	266,058.91
10	Mueang Amnat Charoen	- Mitr Kalasin (Kalasin)	6,370.51
	(Amnat Charoen)	- Surin (Surin)	13,730.79
11	Wang Saphung	- Mitr Phu Viang (Khon Kaen)	151,739.37
	(Loei)	- United Farmer & Industry (Chaiyaphum)	143,519.16
		- Arawan (Nong Bua Lamphu)	64,262.43
12	Wang Sam Mo	- Kumpawapi (Udon Thani)	274,220.57
	(Udon Thani)	- E – Saan Sugar Industry (Kalasin)	639,048.11
13	Sahatsakhan	- Mitr Kalasin (Kalasin)	55,201.09
	(Kalasin)	- E – Saan Sugar Industry (Kalasin)	15,431.87
14	Nong Han	- Kumpawapi (Udon Thani)	78,147.35
	(Udon Thani)	- Rerm Udom (Udon Thani)	29,998.64

At plot level

(1) Network analysis

In this step, NA in plot level of 14 districts which had more than one destination (sugar factory) was performed. The results in the process were the shortest paths from each plot to a set of optimal factories. These paths were then multiplied with the standard TC (1.19 baht/km/ton) and became TC (baht/ton) or c_{ij} for further LP analysis to find the optimal path for sugarcane transport from each cropping plot to optimal factories that could obtain the minimum TC.

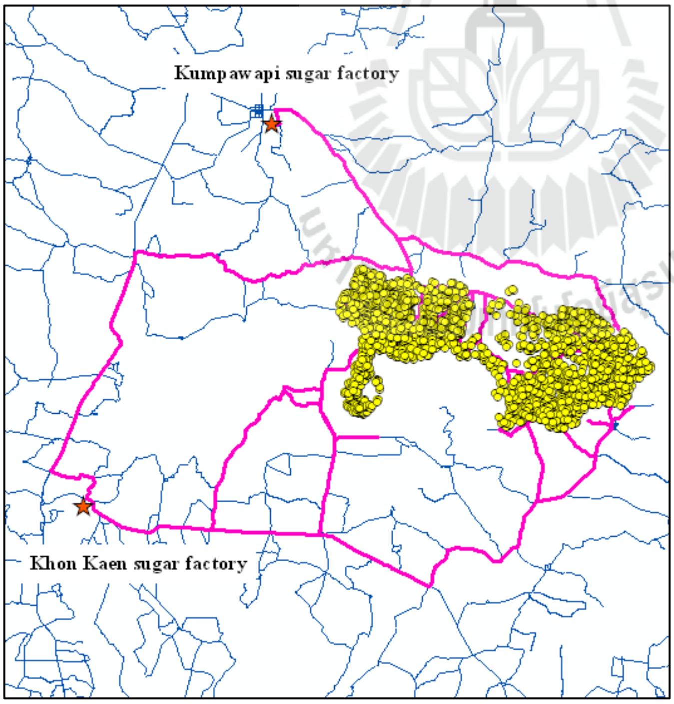
For other districts which sugarcane were allotted to only one optimal factory, the TC in plot level of districts was estimated by multiplying distance from NA with the standard TC (baht/km/ton) and became TC (baht/ton) or c_{ij}. The path for sugarcane allotment from each plot to an optimal factory had only one path, no LP analysis was required. Therefore, the result of NA in plot level was the distance of shortest path for each plot to a set of optimal factories.

Figure 4.7 shows an example case of Tha Khantho district in Kalasin province. From the district level analysis, it had a set of optimal factories, Kumpawapi (Udon Thani province) and Khon Kaen (Khon Kaen province), for sugarcane allotment. Each plot had shortest path to both factories as shown in Figure 4.7.

(2) Linear programming

TC from previous level of 14 districts, which had sugarcane allotments to a set of factories, were used as input to the LP to find an optimal path from each plot to a sugar factory that provided minimum total TC. Quantities of sugarcane allotment in Table 4.6 were used as constraints of decision rule for LP in plot level of each district.

To minimize total TC, the results of this level were a set of optimal factories of each plot, the allotments of each plot to factories, and total TC of each district in plot level. The result of allotment process could be summarized and displayed as maps of 14 districts as shown in Figures 4.8-4.21. The sugarcane allotment to each factory in the NE region was summarized and shown in Figure 4.22. The plot groups allotted to optimal factories were separated by colors. The minimum total TC of plot level in NE region of a single objective function was 1,551,454,082.19 baht. Table 4.7 shows the total TC of each district at plot level.



Name	Total_length_KM
118607 - น้ำตาลกุมภวาปี	36.19201
118607 - น้ำตาลขอนแก่น	45.333765
118609 - น้ำตาลกุมภวาปี	36.287067
118609 - น้ำตาลขอนแก่น	45.238708
118633 - น้ำตาลกุมภวาปี	37.640978
118633 - น้ำตาลขอนแก่น	43.884797
118645 - น้ำตาลกุมภวาปี	36.730119
118645 - น้ำตาลขอนแก่น	44.795656
118850 - น้ำตาลกุมภวาปี	36.221539
118850 - น้ำตาลขอนแก่น	52.796093
143129 - น้ำตาลกุมภวาปี	55.046275
143129 - น้ำตาลขอนแก่น	71.056631
143130 - น้ำตาลกุมภวาปี	56.211428
143130 - น้ำตาลขอนแก่น	69.552743
143131 - น้ำตาลกุมภวาปี	53.062312
143131 - น้ำตาลขอนแก่น	67.09149
143132 - น้ำตาลกุมภวาปี	51.246093
143132 - น้ำตาลขอนแก่น	68.907709

Figure 4.7 Results from NA in plot level of Tha Khantho district in Kalasin province.

(1) Khok Pho Chai district in Khon Kaen province had the sugarcane product of 49,390.16 tons. They were allotted for 2 factories, Mitr Phu Viang (Khon Kaen) and Angvian Industry (Nakhon Ratchasima), as shown in Figure 4.8. The amounts of sugarcane allocated were 905.30 and 48,484.87 tons, respectively. The total TC was 3,362,609.07 baht.

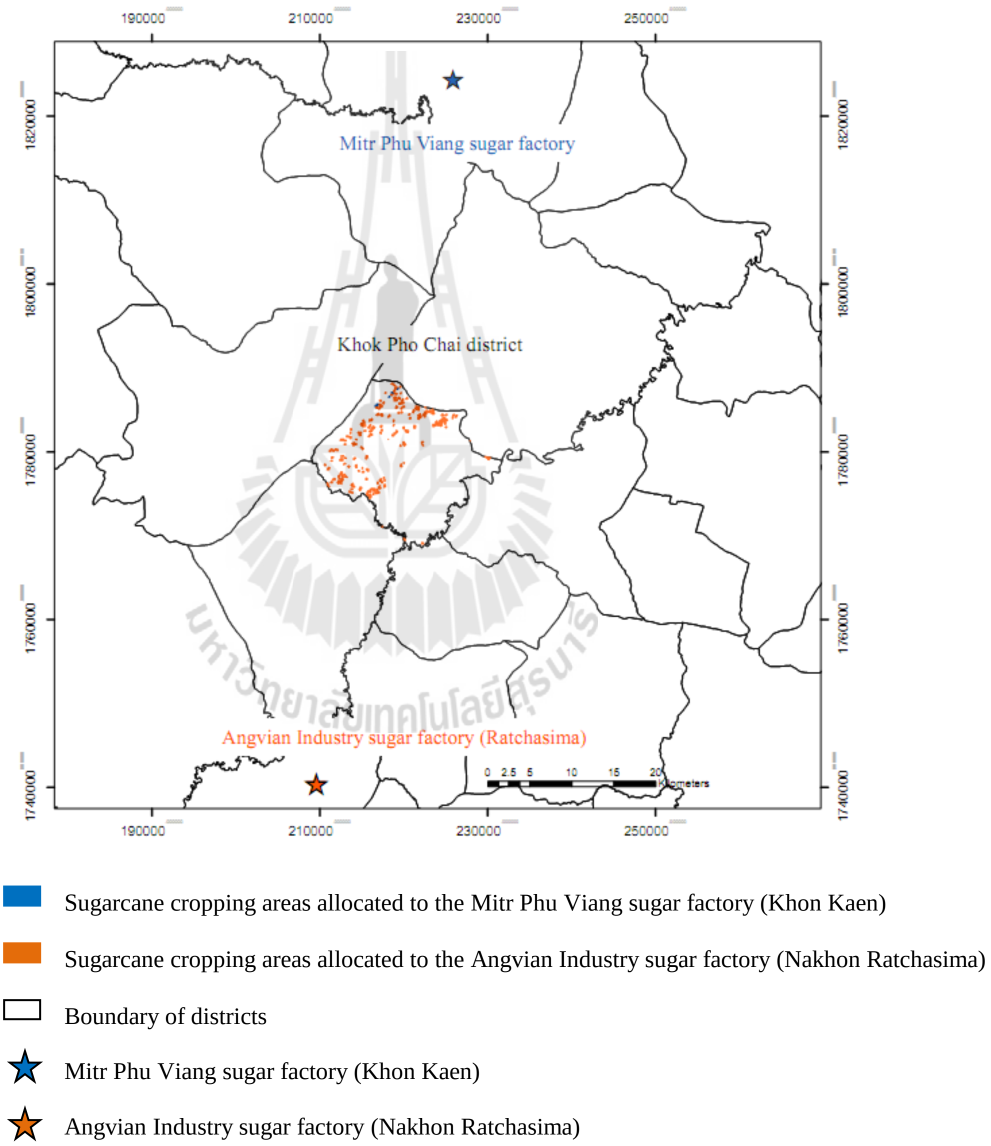


Figure 4.8 Sugarcane allocations from cropping plots in Khok Pho Chai district in Khon Kaen province to a set of optimal factories at minimum TC.

(2) Non Sila district in Khon Kaen province had the sugarcane product of 92,256.96 tons. They were allotted for 2 factories, Burirum (Burirum) and Korach Industry (Nakhon Ratchasima), as shown in Figure 4.9. The amounts of sugarcane allocated were 17,917.34 and 74,339.62 tons, respectively. The total TC was 12,564,278.35 baht.

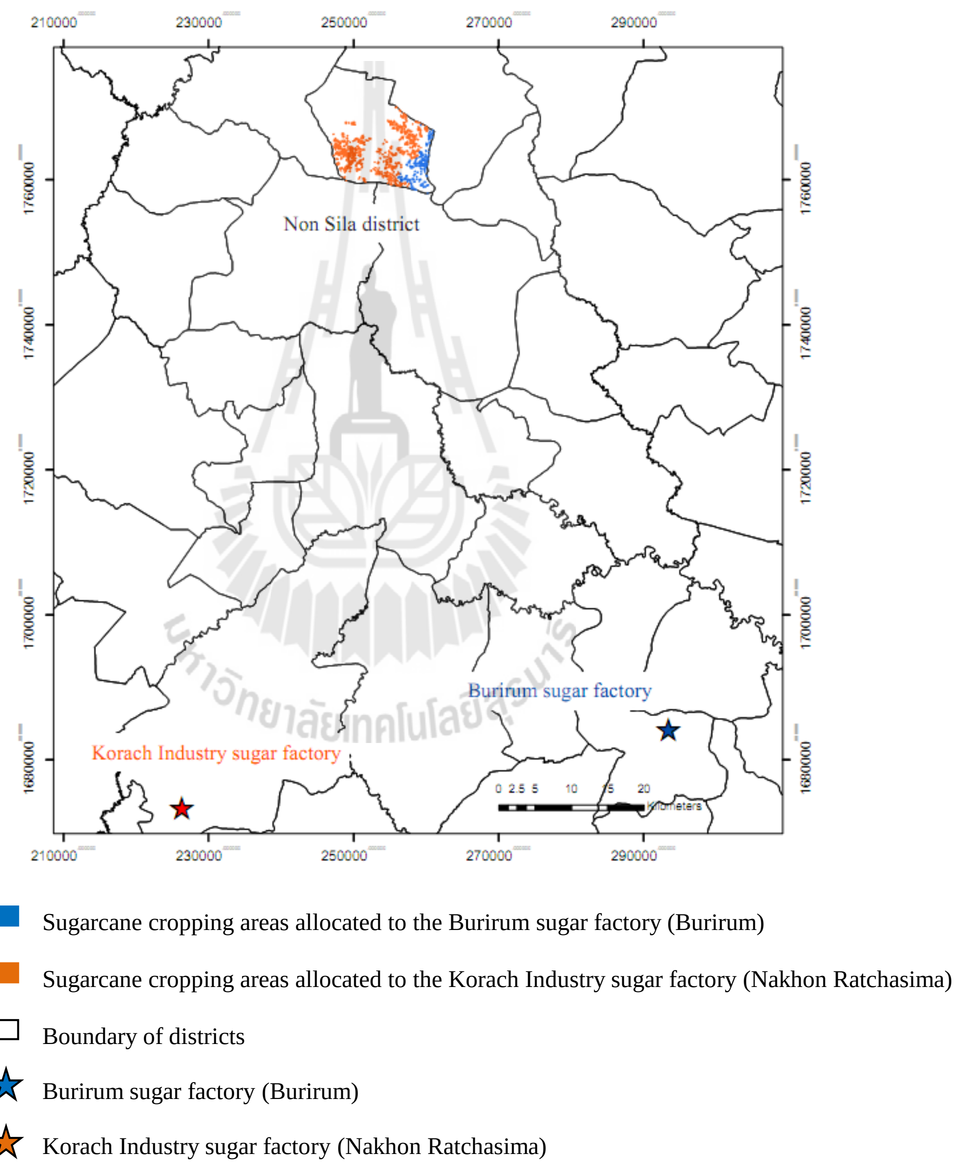


Figure 4.9 Sugarcane allocations from cropping plots in Non Sila district in Khon Kaen province to a set of optimal factories at minimum TC.

(3) Kut Chap district in Udon Thani province had the sugarcane product of 207,582.40 tons. They were allotted for 2 factories, Kaset Phol (Udon Thani) and Arawan (Nong Bua Lam Phu), as shown in Figure 4.10. The amounts of sugarcane allocated were 85,920.25 and 121,662.15 tons, respectively. The total TC was 15,389,480.37 baht.

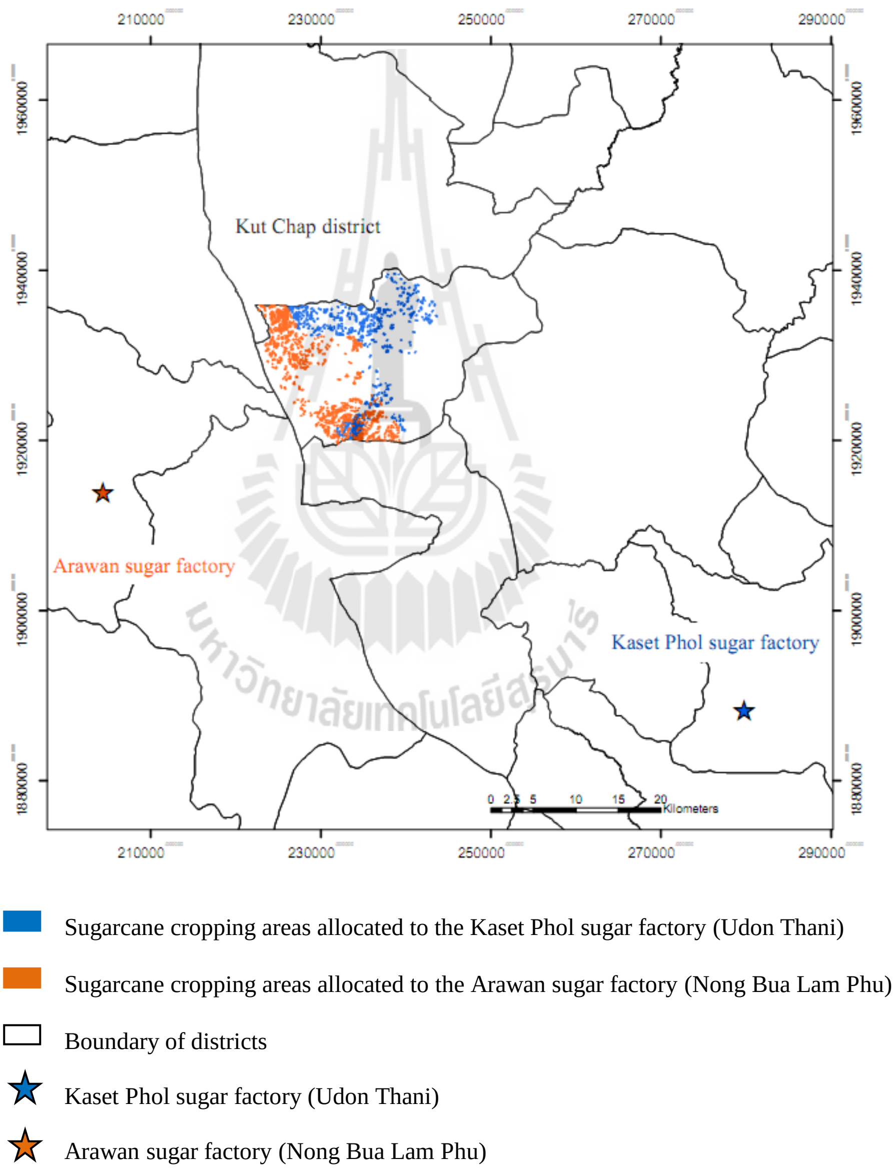


Figure 4.10 Sugarcane allocations from cropping plots in Kut Chap district in Udon Thani province to a set of optimal factories at minimum TC.

(4) Kosum Phisai district in Maha Sarakham province had the sugarcane product of 536,274.70 tons. They were allotted for 2 factories, Mitr Phu Viang (Khon Kaen) and Wangkanai (Maha Sarakham), as shown in Figure 4.11. The amounts of sugarcane allocated were 375,858.42 and 160,416.28 tons, respectively. The total TC was 38,448,631.11 baht.

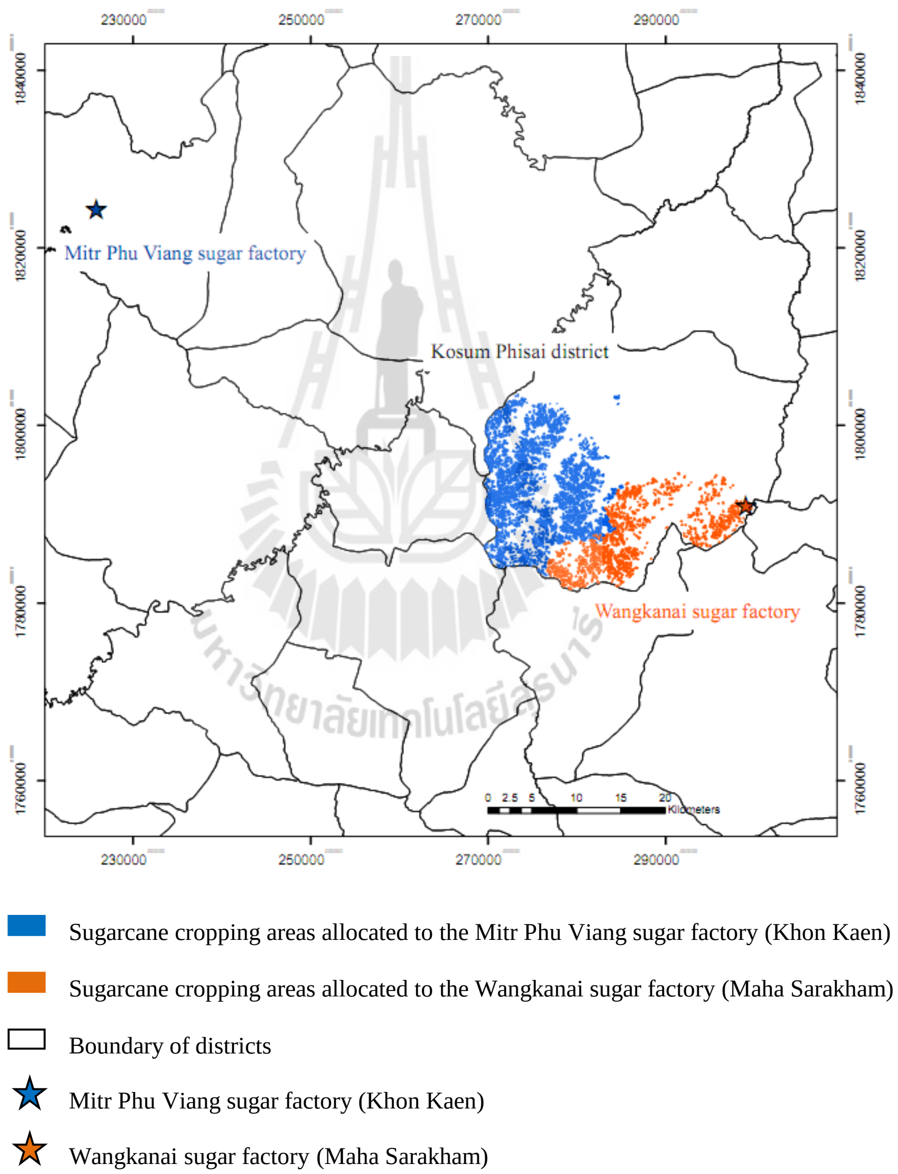


Figure 4.11 Sugarcane allocations from cropping plots in Kosum Phisai district in Maha Sarakham province to a set of optimal factories at minimum TC.

(5) Chok Chai district in Nakhon Ratchasima province had the sugarcane product of 133,271.81 tons. They were allotted for 2 factories, Korach Industry (Nakhon Ratchasima) and N.Y. (Nakhon Ratchasima), as shown in Figure 4.12. The amounts of sugarcane allocated were 4,333.06 and 128,938.75 tons, respectively. The total TC was 7,122,735.29 baht.

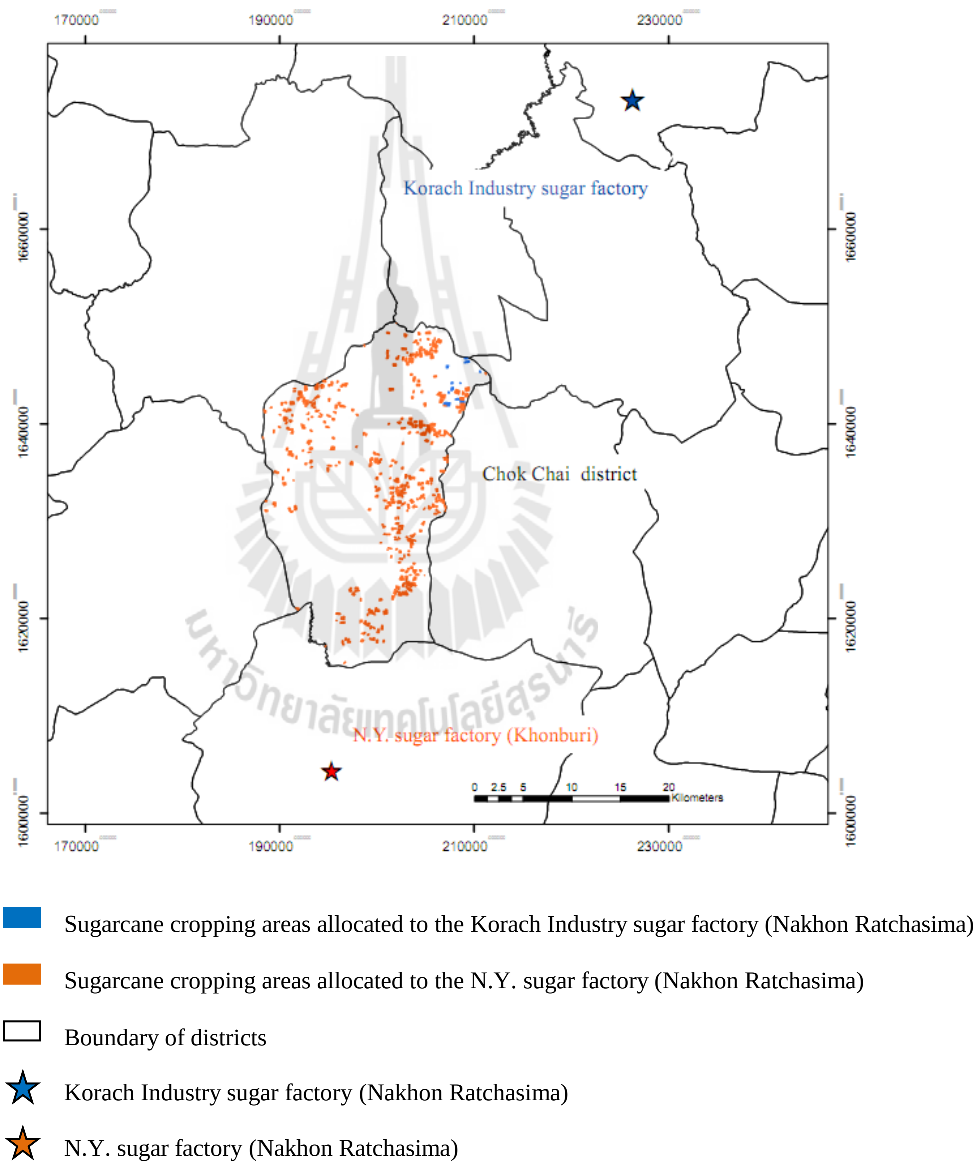
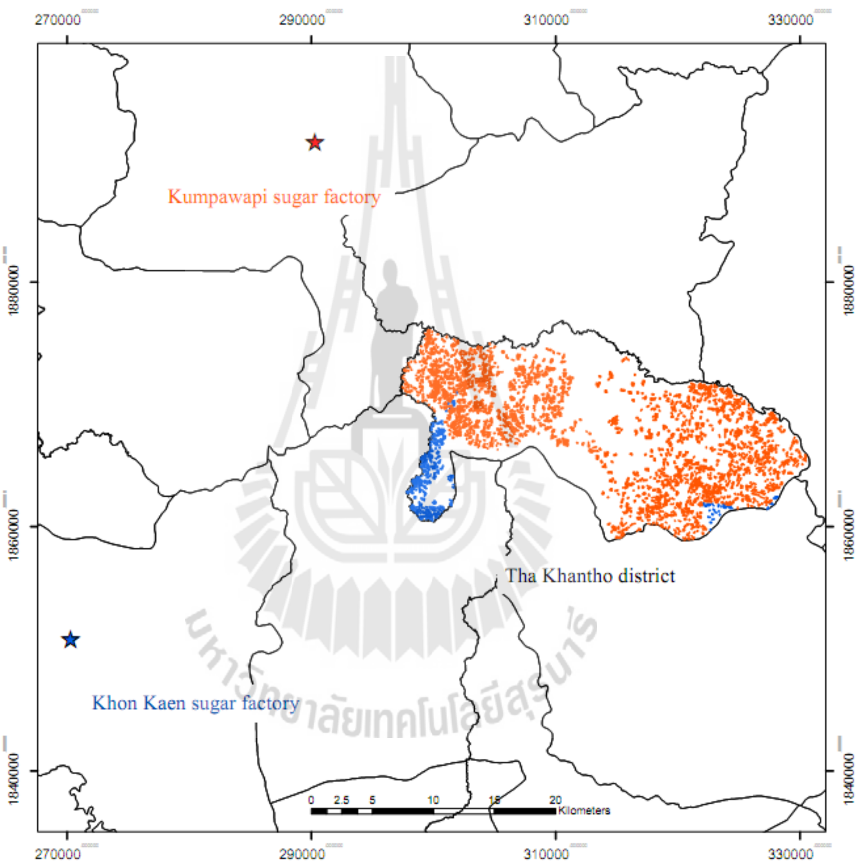


Figure 4.12 Sugarcane allocations from cropping plots in Chok Chai district in Nakhon Ratchasima province to a set of optimal factories at minimum TC.

(6) Tha Khantho district in Kalasin province had the sugarcane product of 321,964.81 tons. They were allotted for 2 factories, Khon Kaen (Khon Kaen) and Kumpawapi (Udon Thani), as shown in Figure 4.13. The amounts of sugarcane allocated were 34,167.63 and 287,797.17 tons, respectively. The total TC was 16,656,171.74 baht.



Sugarcane cropping areas allocated to the Khon Kaen sugar factory (Khon Kaen)

Sugarcane cropping areas allocated to the Kumpawapi sugar factory (Udon Thani)

Boundary of districts

Khon Kaen sugar factory (Khon Kaen)

Kumpawapi sugar factory (Khon Kaen)

Figure 4.13 Sugarcane allocations from cropping plots in Tha Khantho district in Kalasin province to a set of optimal factories at minimum TC.

(7) Thep Sathit district in Chaiyaphum province had the sugarcane product of 74,066.70 tons. They were allotted for 2 factories, Korach Industry (Nakhon Ratchasima) and Angvian Industry (Nakhon Ratchasima), as shown in Figure 4.14. The amounts of sugarcane allocated were 64,525.12 and 9,541.58 tons, respectively. The total TC was 13,244,508.31 baht.

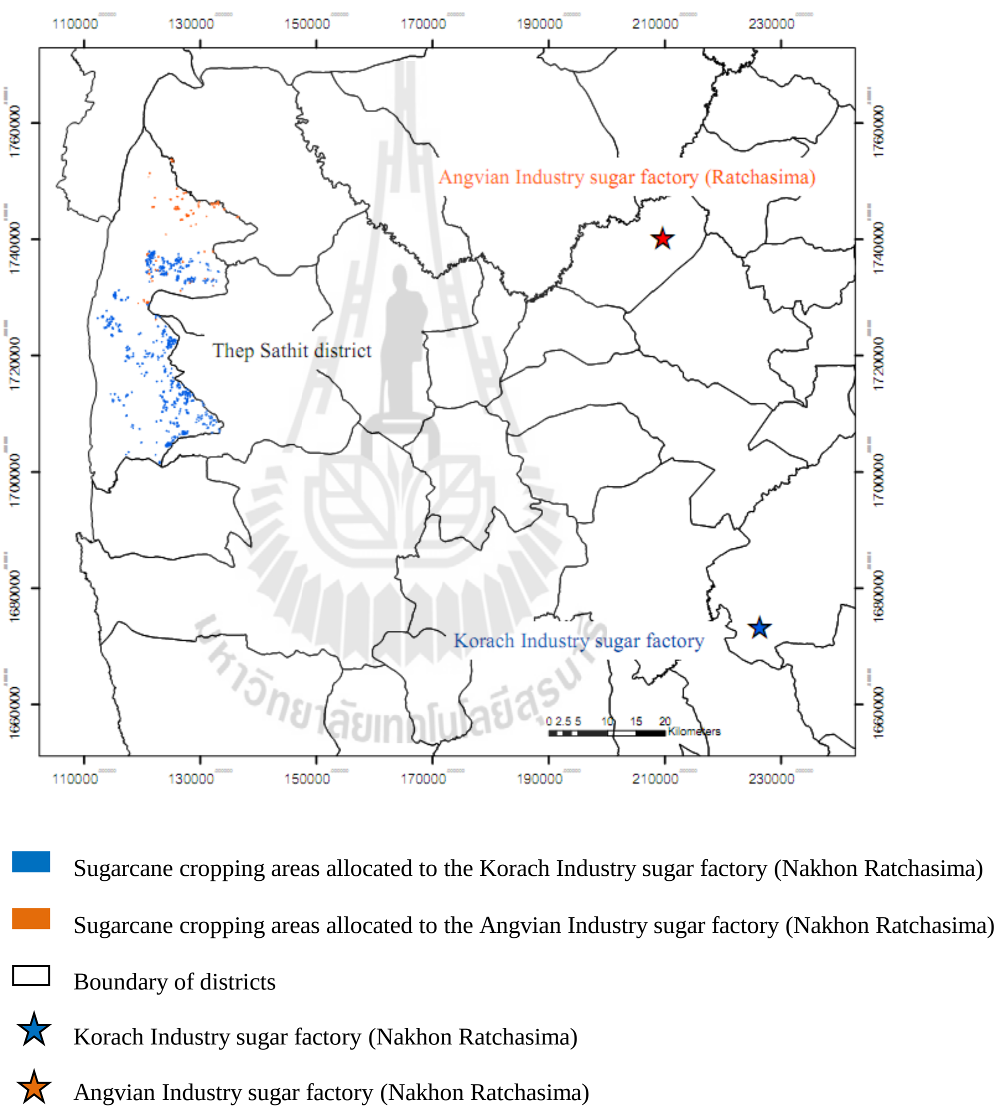


Figure 4.14 Sugarcane allocations from cropping plots in Thep Sathit district in Chaiyaphum province to a set of optimal factories at minimum TC.

(8) Nikhom Kham Soi district in Mukdahan province had the sugarcane product of 190,593.83 tons. They were allotted for 2 factories, Mitr Kalasin (Kalasin) and Saharuang (Mukdahan), as shown in Figure 4.15. The amounts of sugarcane allocated were 46,019.43 and 144,574.40 tons, respectively. The total TC was 10,609,007.54 baht.

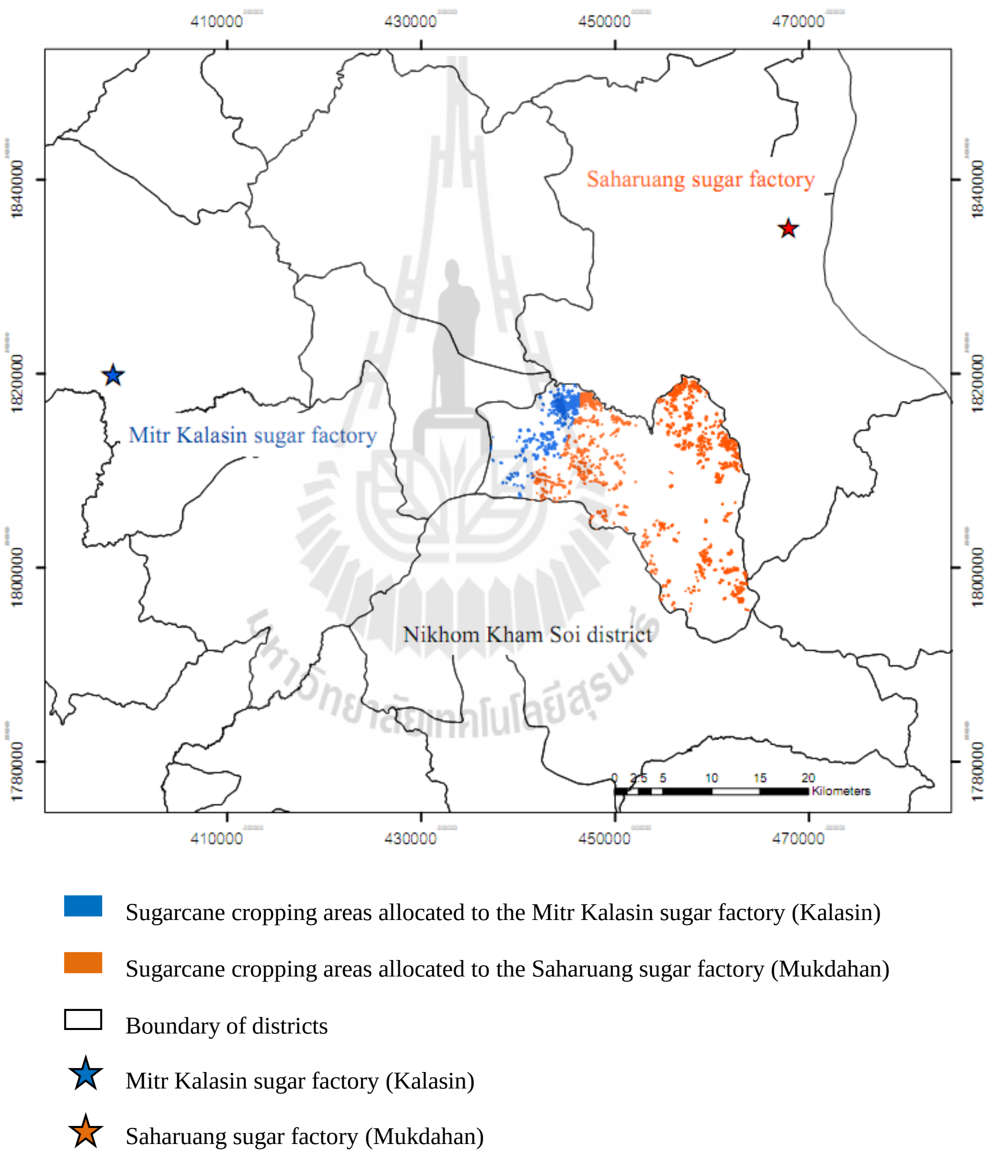


Figure 4.15 Sugarcane allocations from cropping plots in Nikhom Kham Soi district in Mukdahan province to a set of optimal factories at minimum TC.

(9) Non Sa-at district in Udon Thani province had the sugarcane product of 627,682.48 tons. They were allotted for 2 factories, Khon Kaen (Khon Kaen) and Kaset Phol (Udon Thani), as shown in Figure 4.16. The amounts of sugarcane allocated were 361,623.57 and 266,058.91 tons, respectively. The total TC was 21,052,710.57 baht.

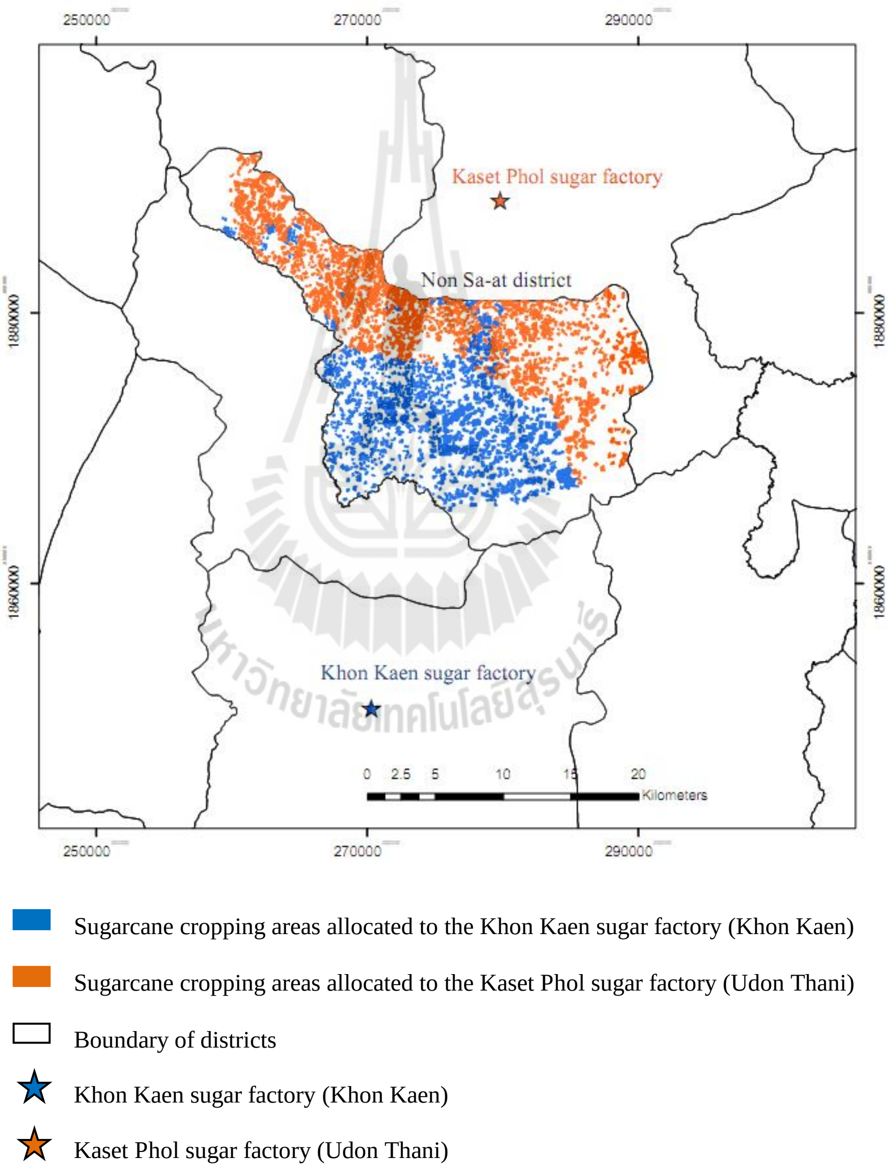


Figure 4.16 Sugarcane allocations from cropping plots in Non Sa-at district in Udon Thani province to a set of optimal factories at minimum TC.

(10) Mueang Amnat Charoen district in Amnat Charoen province had the sugarcane product of 20,101.30 tons. They were allotted for 2 factories, Mitr Kalasin (Kalasin) and Surin (Surin), as shown in Figure 4.17. The amounts of sugarcane allocated were 6,370.and 13,730.79 tons, respectively. The total TC was 4,785,615.42 baht.

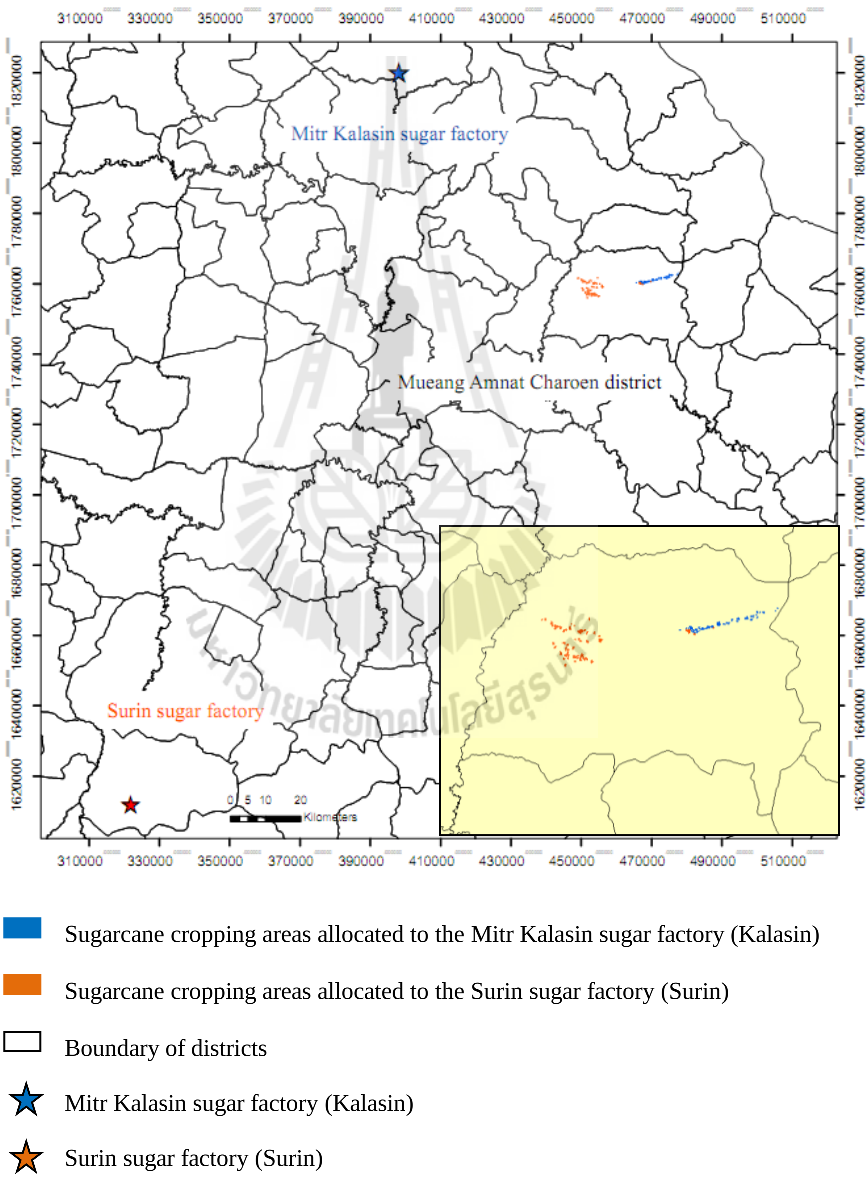
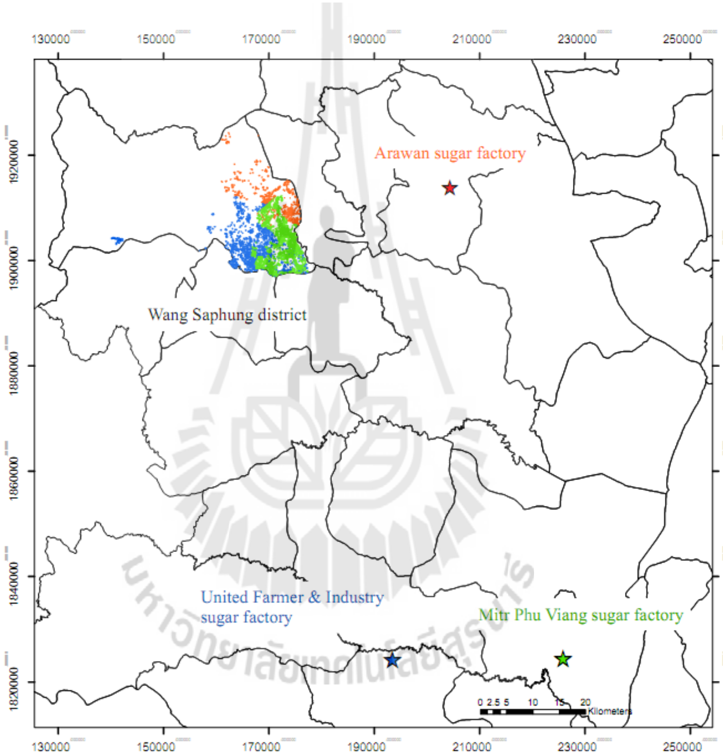


Figure 4.17 Sugarcane allocations from cropping plots in Mueang Amnat Charoen district in Amnat Charoen province to a set of optimal factories at minimum TC.

(11) Wang Saphung district in Loei province had the sugarcane product of 359,520.97 tons. They were allotted for 3 factories, Mitr Phu Viang (Khon Kaen), United Farmer & Industry (Chaiyaphum), and Arawan (Nong Bua Lam Phu), as shown in Figure 4.18. The amounts of sugarcane allocated were 151,739.37, 143,519.16, and 64,262.43 tons, respectively. The total TC was 42,076,945.09 baht.



Sugarcane cropping areas allocated to the Mitr Phu Viang sugar factory (Khon Kaen)

Sugarcane cropping areas allocated to the United Farmer & Industry sugar factory (Chaiyaphum)

Sugarcane cropping areas allocated to the Arawan sugar factory (Nong Bua Lam Phu)

Boundary of districts

Mitr Phu Viang sugar factory (Khon Kaen)

United Farmer & Industry sugar factory (Chaiyaphum)

Arawan sugar factory (Nong Bua Lam Phu)

Figure 4.18 Sugarcane allocations from cropping plots in Wang Saphung district in Loei province to a set of optimal factories at minimum TC.

(12) Wang Sam Mo district in Udon Thani province had the sugarcane product of 913,268.68 tons. They were allotted for 2 factories, Kumpawapi (Udon Thani) and E – Saan Sugar Industry (Kalasin), as shown in Figure 4.19. The amounts of sugarcane allocated were 274,220.57 and 639,048.11 tons, respectively. The total TC was 36,655,621.52 baht.

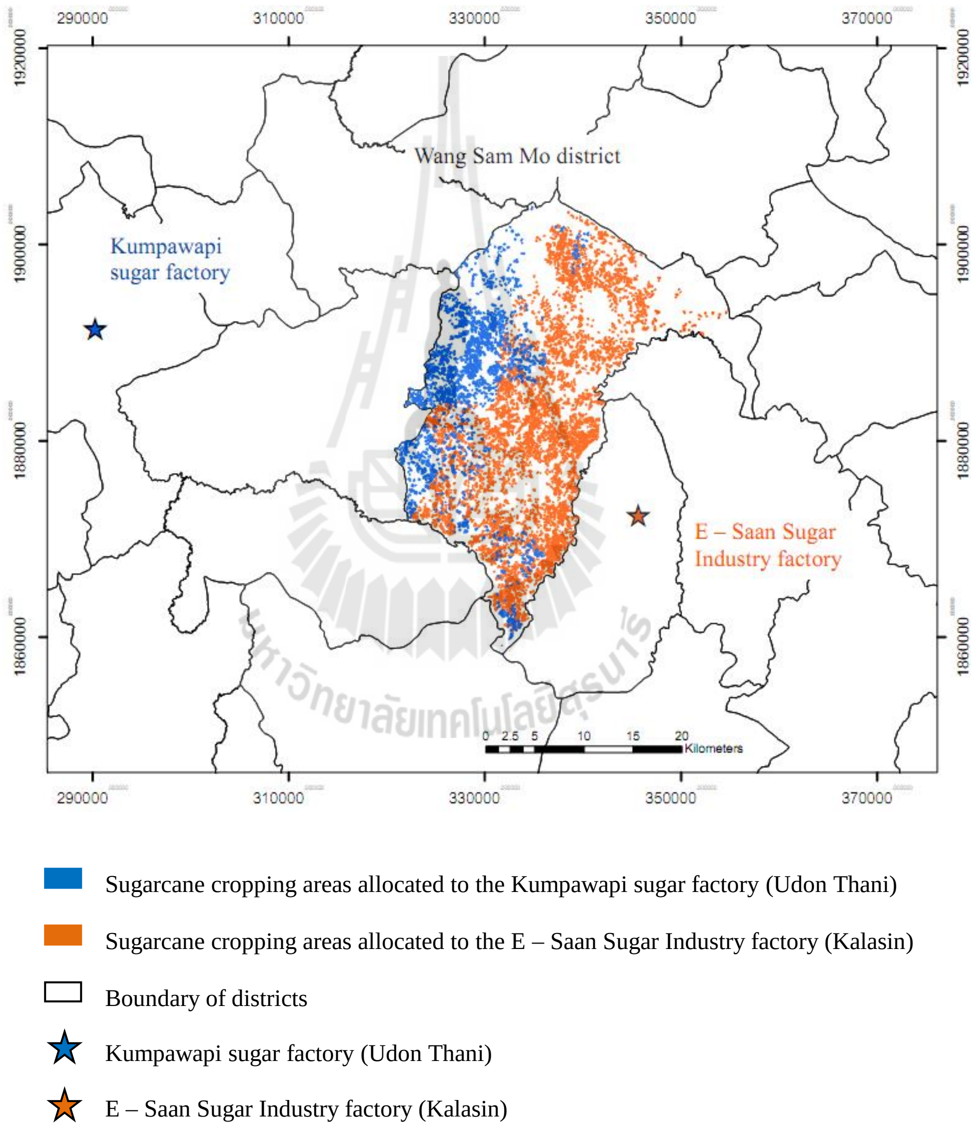


Figure 4.19 Sugarcane allocations from cropping plots in Wang Sam Mo district in Udon Thani province to a set of optimal factories at minimum TC.

(13) Sahatsakhan district in Kalasin province had the sugarcane product of 70,632.96 tons. They were allotted for 2 factories, Mitr Kalasin (Kalasin) and E – Saan Sugar Industry (Kalasin), as shown in Figure 4.20. The amounts of sugarcane allocated were 55,201.09 and 15,431.87 tons, respectively. The total TC was 5,188,476.55 baht.

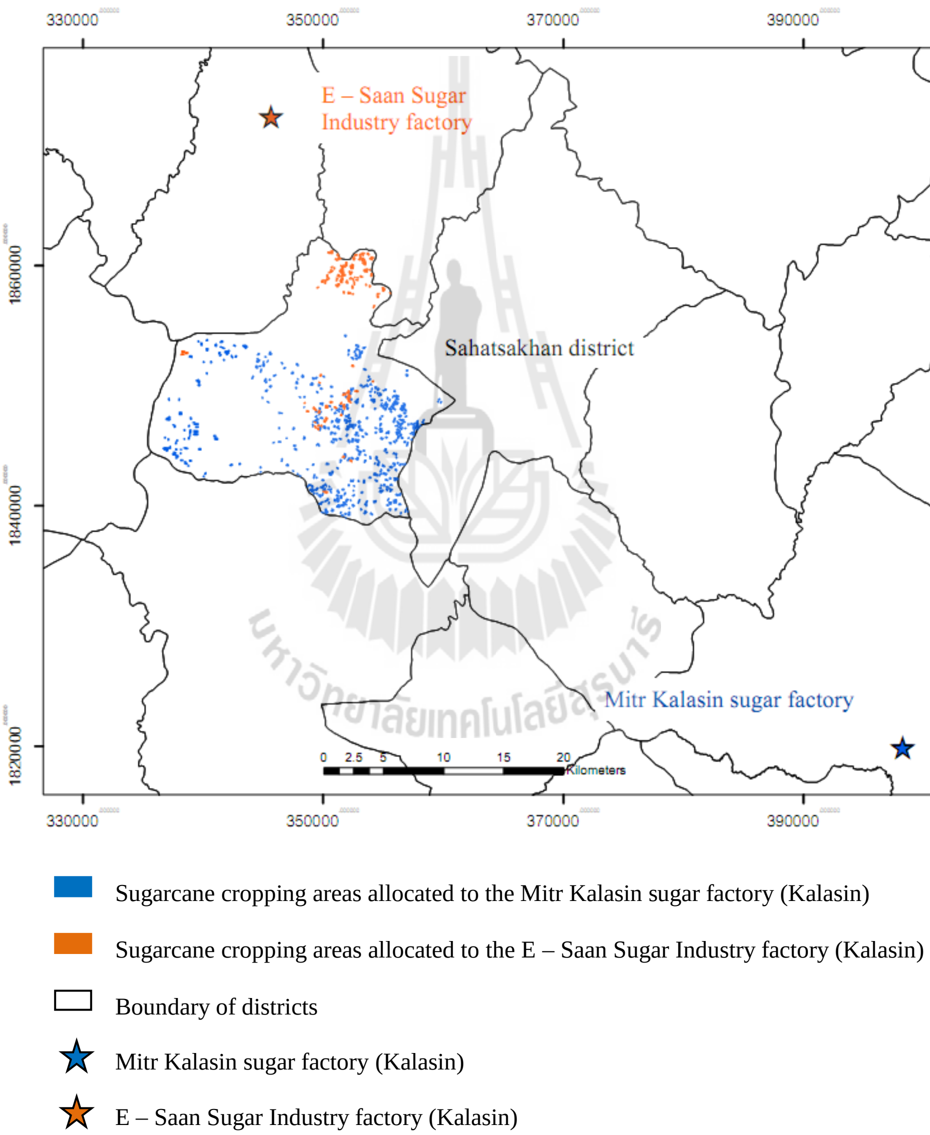


Figure 4.20 Sugarcane allocations from cropping plots in Sahatsakhan district in Kalasin province to a set of optimal factories at minimum TC.

(14) Nong Han district in Udon Thani province had the sugarcane product of 108,145.99 tons. They were allotted for 2 factories, Kumpawapi (Udon Thani) and Rerm Udom (Udon Thani), as shown in Figure 4.21. The amounts of sugarcane allocated were 78,147.35 and 29,998.64 tons, respectively. The total TC was 3,993,778.06 baht.

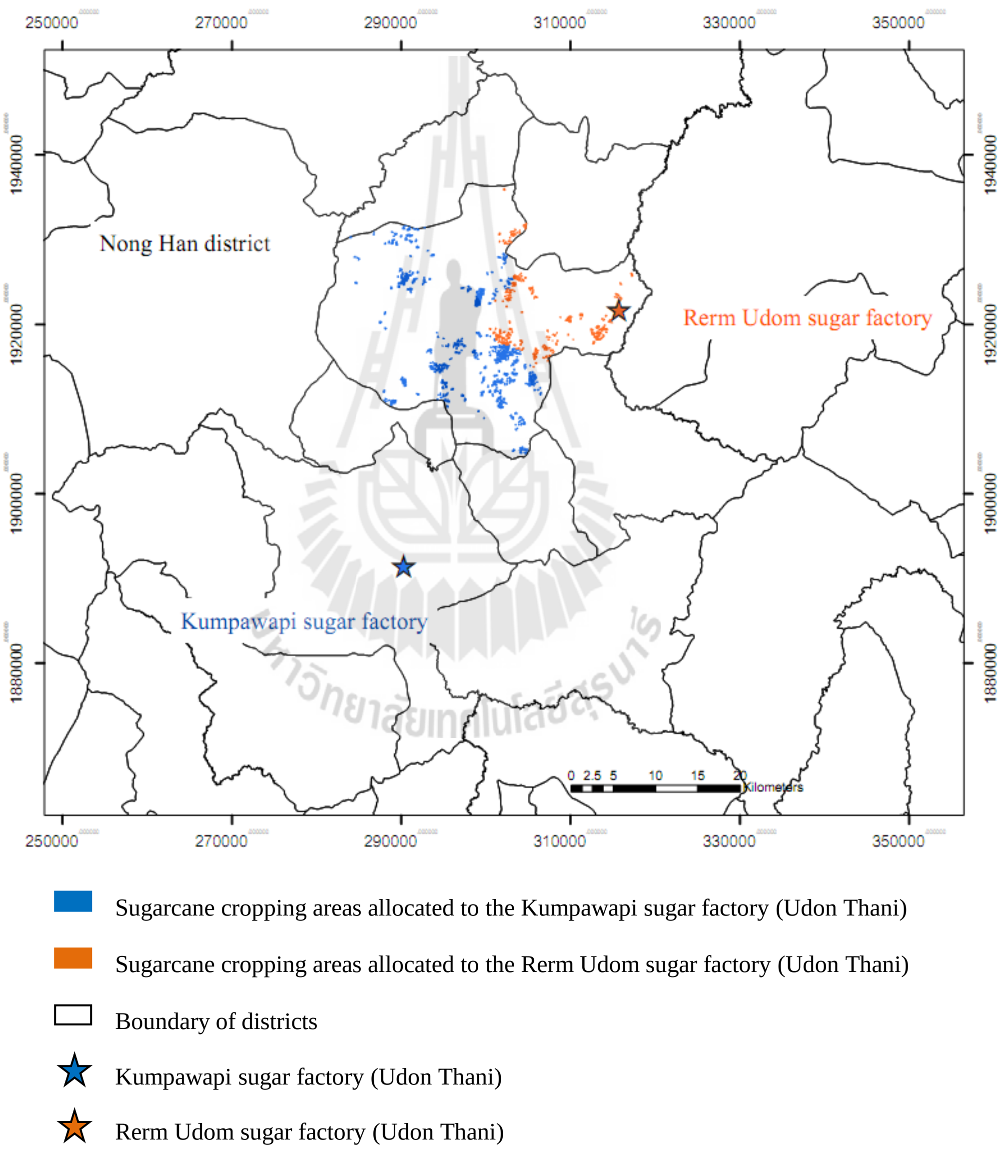
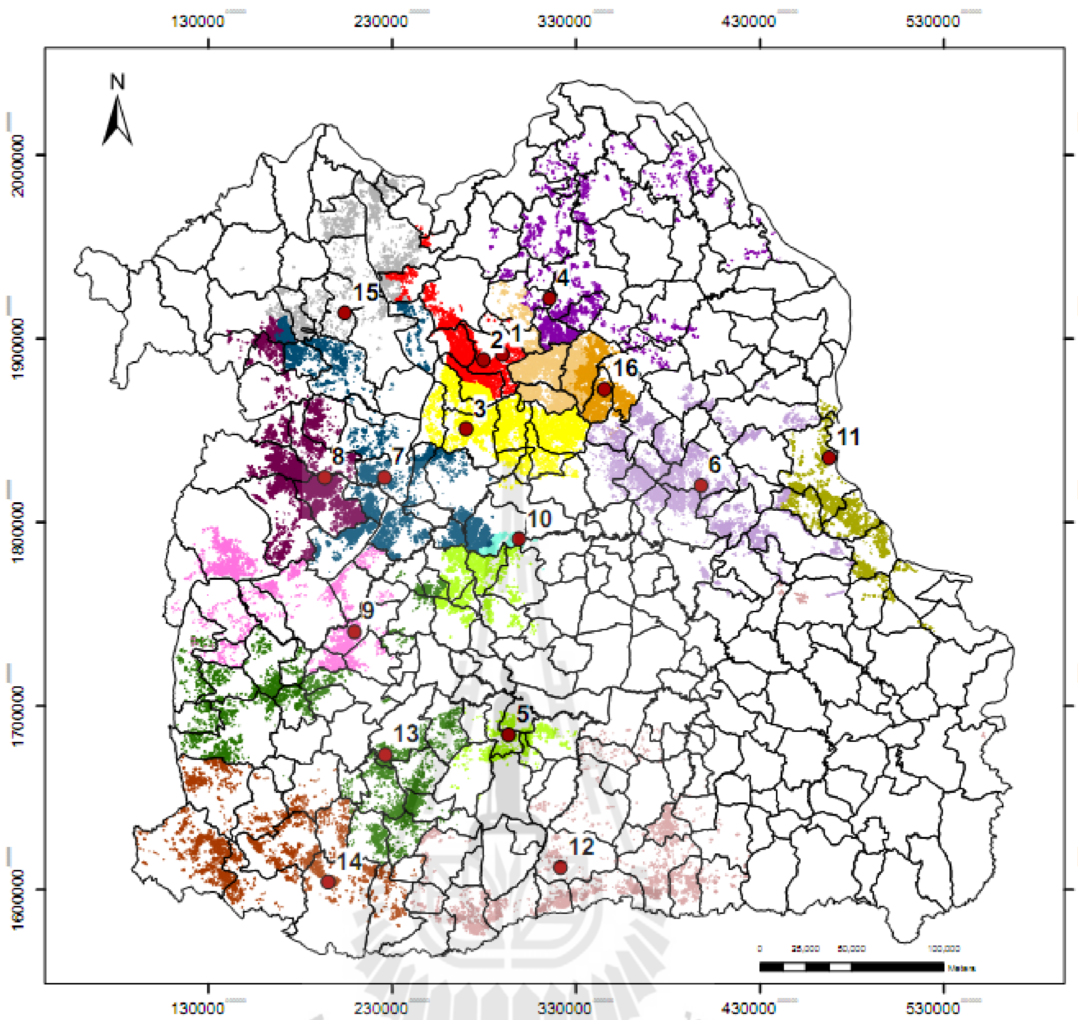


Figure 4.21 Sugarcane allocations from cropping plots in Nong Han district in Udon Thani province to a set of optimal factories at minimum TC.



Sugarcane plots allotted to sugar factory:

: 1. Kumpawapi (Udon Thani)	: 10. Wangkanai (Maha Sarakham)
: 2. Kaset Phol (Udon Thani)	: 11. Saharuang (Mukdahan)
: 3. Khon Kaen (Khon Kaen)	: 12. Surin (Surin)
: 4. Rerm Udom (Udon Thani)	: 13. Korach Industry (Nakhon Ratchasima)
: 5. Burirum (Buri Ram)	: 14. N.Y. (Nakhon Ratchasima)
: 6. Mitr Kalasin (Kalasin)	: 15. Arawan (Nong Bua Lam Phu)
: 7. Mitr Phu Viang (Khon Kaen)	: 16. E – Saan Sugar Industry (Kalasin)
: 8. United Farmer & Industry (Chaiyaphum)	: Boundary of districts
: 9. Angvian Industry (Nakhon Ratchasima)	: Sugar factory

Figure 4.22 Sugarcane allocations from cropping plots in the NE of single objective.

Table 4.7 The total TC of each district at plot level resulted from single objective function.

No.	District Name	TC	No.	District Name	TC
1.	Kranuan	19,950,383.92	41.	Kosum Phisai	38,448,631.11
2.	Krasang	666,026.80	42.	Kham Thale So	73,704.88
3.	Kap Choeng	4,229,481.01	43.	Kham Sakae Saeng	5,917,720.54
4.	Kut Rang	30,044,324.57	44.	Khukhan	737,720.21
5.	Ku Kaeo	4,149,045.25	45.	Khun Han	35,142.86
6.	Khewa Sinarin	29,494.99	46.	Khemarat	1,584,901.60
7.	Khaen Dong	1,957,216.85	47.	Khao Wong	26,197.57
8.	Khok Pho Chai	3,362,609.07	48.	Khao Suan Kwang	7,597,174.09
9.	Chuen Chom	5,900,058.80	49.	Khong	14,447,074.29
10.	Sap Yai	2,705,047.32	50.	Khon Buri	5,338,504.19
11.	Sam Sung	5,705,196.59	51.	Khon Sawan	3,198,422.86
12.	Don Chan	10,042,560.61	52.	Khon San	16,968,403.66
13.	Thepharak	8,353,379.56	53.	Kham Cha-I	5,212,733.89
14.	Na Khu	126,375.17	54.	Kham Ta Kla	88,504.46
15.	Non Narai	13,532.63	55.	Kham Muang	3,141,997.80
16.	Non Sila	12,564,278.35	56.	Khu Mueang	1,409,419.75
17.	Bua Lai	2,437,834.81	57.	Chom Phra	1,219,759.42
18.	Ban Dan	862,272.49	58.	Chakkarat	8,275,152.67
19.	Ban Haet	15,949,209.56	59.	Chatturat	20,252,013.64
20.	Prachak Sinlapakhom	331,891.48	60.	Charoen Sin	1,752,328.82
21.	Fao Rai	3,427,561.46	61.	Chaloem Phrakiat	1,008,302.12
22.	Phanom Dong Rak	3,442,749.32	62.	Chonnabot	5,096,670.19
23.	Phra Thongkham	13,755,174.24	63.	Chanuman	14,266,947.10
24.	Pho Tak	4,290,502.23	64.	Chamni	317,224.24
25.	Lam Thamenchai	76,310.84	65.	Chum Phuang	6,755,561.85
26.	Si Narong	10,474,972.79	66.	Chum Phae	6,722,909.69
27.	Sa Khrai	2,196,723.86	67.	Chiang Yuen	589,529.01
28.	Sam Chai	4,826,427.03	68.	Chok Chai	7,122,735.29
29.	Nong Na Kham	534,567.04	69.	Chaiwan	10,538,157.67
30.	Nong Hin	18,926,633.79	70.	Seka	7,696,051.36
31.	Arawan	6,965,871.16	71.	So Phisai	1,716,297.19
32.	Kuchi Narai	9,467,082.76	72.	Dong Luang	5,868,092.69
33.	Kut Khao Pun	1,661,212.38	73.	Don Tan	13,694,112.81
34.	Kut Chap	15,389,480.37	74.	Dan Khun Thot	42,102,181.72
35.	Kut Chum	1,914,268.53	75.	Trakan Phuet Phon	119233.19
36.	Kut Bak	1,622,179.99	76.	Tao Ngoi	1,500,117.03
37.	Kumphawapi	8,699,219.18	77.	Sai Mun	678,742.76
38.	Kaset Sombun	20,559,085.50	78.	Tha Khantho	16,656,171.74
39.	Kaeng Khro	16,070,512.40	79.	Tha Tum	508,730.89
40.	Kaeng Sanam Nang	3,386,807.86	80.	Tha Bo	642,885.72

Table 4.7 (Continued).

No.	District Name	TC	No.	District Name	TC
81.	Tha Uthen	843,721.55	121.	Bueng Kan	33,434.78
82.	Thung Fon	427,471.33	122.	Bueng Khong Long	5,465,183.90
83.	Thep Sathit	13,244,508.31	123.	Pathum Ratchawongsa	2,806,178.99
84.	Thai Charoen	2,287,825.04	124.	Prakhon Chai	483,435.08
85.	That Phanom	2,287,825.04	125.	Prang Ku	905,871.66
86.	Na Klang	1,206,981.06	126.	Prasat	750,388.15
87.	Na Kae	571,317.00	127.	Pakham	1,909,633.74
88.	Nang Rong	5,957,947.80	128.	Pak Thong Chai	14,764,750.24
89.	Na Chueak	5,180,750.83	129.	Pak Khat	48,058.76
90.	Na Duang	183,500.12	130.	Pak Chong	62,778,923.27
91.	Na Dun	438,827.18	131.	Pa Tio	2,471,565.75
92.	Na Thom	844,086.35	132.	Pueai Noi	7,320,696.15
93.	Na Pho	44,405.76	133.	Pha Khao	27,904,253.35
94.	Na Mon	5,461,928.21	134.	Phon Charoen	1,739,562.76
95.	Na Yung	313,469.57	135.	Phanna Nikhom	3,285,075.73
96.	Na Wang	2,388,347.54	136.	Phra Yuen	467,997.42
97.	Nam Phong	7,903,884.66	137.	Phon	4,372,509.83
98.	Nam Som	10,069,133.09	138.	Phang Khon	168,414.00
99.	Nikhom Kham Soi	10,609,007.54	139.	Phibun Rak	1,303,930.47
100.	Nikhom Nam Un	777,989.66	140.	Phimai	5,208,338.45
101.	Noen Sa-Nga	4,641,645.63	141.	Phen	759,050.49
102.	Non Din Daeng	1,785,080.37	142.	Pho Chai	10,029,468.25
103.	Non Thai	84,921.82	143.	Pho Sai	532,600.21
104.	Non Sa-At	21,052,710.57	144.	Phon Thong	9,109,185.62
105.	Non Sang	142,627.55	145.	Phon Phisai	1,848,891.08
106.	Non Suwan	846,846.53	146.	Phon Sawan	147,241.27
107.	Borabue	9,362,735.26	147.	Phrai Bueng	64,992.66
108.	Bua Chet	13,295,080.88	148.	Phakdi Chumphon	1,466,311.86
109.	Bua Yai	3,634,911.03	149.	Phu Kradueng	2,969,277.94
110.	Ban Kruat	5,841,079.18	150.	Phu Khiao	25,233,192.87
111.	Ban Khwao	2,607,339.11	151.	Phu Pha Man	4,863,088.43
112.	Ban Dung	7,825,940.44	152.	Phu Phan	2,601,612.57
113.	Ban Thaen	5,462,912.00	153.	Phu Wiang	4,331,348.51
114.	Ban Phue	22,078,108.09	154.	Phu Sing	2,914,766.86
115.	Ban Phai	31,054,895.99	155.	Phu Luang	2,699,190.52
116.	Ban Fang	4,855,704.21	156.	Mancha Khiri	18,268,847.76
117.	Ban Phaeng	185,392.96	157.	Moei Wadi	1,162,185.59
118.	Ban Muang	6,806,527.26	158.	Mueang Kalasin	6,667,575.82
119.	Ban Lueam	5,921,972.56	159.	Mueang Khon Kaen	10,901,536.95
120.	Bamnet Narong	12,634,398.58	160.	Mueang Chaiyaphum	7,101,768.06

Table 4.7 (Continued).

No.	District Name	TC	No.	District Name	TC
161.	Mueang Nakhon Ratchasima	4,662,191.78	195.	Sawang Daen Din	4,225,618.55
162.	Mueang Buri Ram	924,867.89	196.	Sahatsakhan	5,188,476.55
163.	Mueang Maha Sarakham	58,393.59	197.	Song Dao	5451757.1
164.	Mueang Mukdahan	15,677,215.23	198.	Sangkha	8,946,997.74
165.	Mueang Yasothon	401,091.91	199.	Sangkhom	656,338.26
166.	Mueang Loei	59,686.05	200.	Samrong Thap	70,251.52
167.	Mueang Sakon Nakhon	1,868,189.82	201.	Sirindhorn	250,218.97
168.	Mueang Surin	894,937.49	202.	Si Khio	24,424,461.13
169.	Mueang Nong Khai	73,475.85	203.	Si Chomphu	14,226,004.10
170.	Mueang Nong Bua Lamphu	2,142,369.42	204.	Suwanna Khuha	1,781,977.78
171.	Mueang Amnat Charoen	4,785,615.42	205.	Sung Noen	6,547,521.25
172.	Mueang Udon Thani	9,366,628.70	206.	Senangkha Nikhom	1,223,978.63
173.	Yang Talat	1,981,905.26	207.	Selaphum	3,215,021.34
174.	Rattana Buri	88,612.03	208.	Soeng Sang	5,139,512.99
175.	Lahan Sai	15,399,687.48	209.	Nong Ki	9,996,763.51
176.	Lamduan	223,259.76	210.	Nong Kung Si	31,911,590.23
177.	Lam Plai Mat	1,958,942.77	211.	Nong Bua Daeng	34,889,487.58
178.	Loeng Nok Tha	14,187,862.80	212.	Nong Bua Rawe	3,899,678.92
179.	Wang Nam Khiao	14,538,349.24	213.	Nong Bunnak	11,862,287.75
180.	Wang Saphung	42,076,945.09	214.	Nong Phok	7,682,736.72
181.	Wang Sam Mo	36,655,621.52	215.	Nong Ruea	2,862,818.67
182.	Waritchaphum	834,679.98	216.	Nong Wua So	18,242,987.68
183.	Waeng Noi	293,745.70	217.	Nong Song Hong	11,509,652.18
184.	Waeng Yai	397,090.25	218.	Nong Sung	1,214,986.96
185.	Si Chiang Mai	3,727,109.63	219.	Nong Saeng	7,980,521.93
186.	Si That	28,544,562.16	220.	Nong Hong	9,195,042.57
187.	Si Bunrueang	26,810,048.97	221.	Nong Han	3,993,778.06
188.	Si Wilai	1,030,189.06	222.	Huai Thalaeng	5,420,740.82
189.	Si Songkhram	2,188,139.93	223.	Huai Thapthan	119,995.86
190.	Si Khoraphum	436,356.74	224.	Huai Phueng	5,206,806.32
191.	Satuek	2,757,745.06	225.	Huai Mek	11,288,048.98
192.	Sanom	606,847.92	226.	Wan Yai	545,473.89
193.	Somdet	7,117,025.83	227.	Akat Amnuai	307,035.93
194.	Sang Khom	141,855.27	228.	Ubonrat	3646447.53
	Total TC at plot level of single objective				**1,551,454,082.19**

4.2.2 Multi objectives function: Minimizing transportation cost and environmental impact

The analytical steps of the multiple objectives function were the same as the single objective function but involved with the EI and made the allotment of sugarcane transportations at minimum total TC and EI. The EI related information included: (1) EI caused by transportation routes, (2) EI based on industrial standard of factories, and (3) EI caused by the productivity of factories. These factors affected the decision making process using LP analysis.

At district level

(1) Network analysis

NA for multi objectives function resulted in 3,648 shortest paths from districts to factories. Each path included length of road passing through the buffer zone for each O-D. Thus, each O-D distance resulted from the process must be subtracted by length of road passing through the buffer zone before using in TC (c_{ij}) calculation. The subtracted distance was the actual distance of each O-D. The TC (c_{ij}) of each path was estimated by multiplying distance from NA with the standard TC (baht/km/ton) and became TC (baht/ton) or c_{ij}. These TCs (c_{ij}) were used in the LP analysis to minimize the total TC and EI of sugarcane transportation from districts to sugar factories.

(2) Linear programming

The LP analysis was used to allocate sugarcane from each district and transport to a set of optimal factories at minimum total TC and EI. Information of TC (c_{ij}) from NA and synthesized EI were used to formulate the LP as expressed in Equation (9). In this step, before input to the LP, EI was normalized using Equations (14) and (15) while c_{ij} and x_{ij}variables were normalized using Equations (14).

The process resulted in the minimum total TC and EI and allotment(s) from each district to a set of optimal factories in service. The normalized results of TC and allotments were multiplied with their maximum actual values to obtain the actual values used for further analysis. Table 4.8 shows the briefly results and the Table C.2 in Appendix C shows the complete results. The minimum total TC of district level in NE region of multi objectives function was 1,478,985,242.38 baht.

From Table C.2 in Appendix C, 214 districts had a single pair of allotment from each district to one sugar factory. Other 14 districts had allotment from each district to a set of sugar factories which were either 2 or 3 factories as shown in Table 4.9.

For these 14 districts, the allotment in plot level was performed from each plot to a certain set of factories using LP analysis. The factory destinations and their allotments of each district from the LP result in district level became constraints of the process. The results was the optimum allotment(s) from each plot to a factory or a set of factories at minimum total TC and EI.

Table 4.8 A part of multi objectives result from LP at district level.

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Kranuan	1	-	-	535,044.40	-	-	-	-	-	-	-	-	-	-	-	-	-	535,044.40	19,721,064.34
Krasang	2	-	-	-	-	-	-	-	-	-	-	-	9,109.84	-	-	-	-	9,109.84	656,055.13
Kap Choeng	3	-	-	-	-	-	-	-	-	-	-	-	101,040.35	-	-	-	-	101,040.35	4,454,411.22
Kut Rang	4	-	-	-	-	225,429.89	-	-	-	-	-	-	-	-	-	-	-	225,429.89	31,002,545.78
Ku Kaeo	5	121,553.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	121,553.20	5,244,222.17
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Nong Wua So	216	-	57,859.59	-	-	-	-	69,334.59	-	-	-	-	-	-	-	-	-	127,194.18	14,860,730.28
Nong Song Hong	217	-	-	-	-	102,733.66	-	-	-	-	-	-	-	-	-	-	-	102,733.66	12,909,209.38
Nong Sung	218	-	-	-	-	-	23,895.50	-	-	-	-	-	-	-	-	-	-	23,895.50	1,342,406.96
Nong Saeng	219	-	331,369.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	331,369.23	6,574,169.22
Nong Hong	220	-	-	-	-	-	-	-	-	-	-	-	-	170,453.64	-	-	-	170,453.64	8,957,581.33
Nong Han	221	-	-	-	108,145.99	-	-	-	-	-	-	-	-	-	-	-	-	108,145.99	2,475,991.38
Huai Thalaeng	222	-	-	-	-	-	-	-	-	-	-	-	-	131,573.13	-	-	-	131,573.13	4,652,276.53
Huai Thapthan	223	-	-	-	-	-	-	-	-	-	-	-	896.89	-	-	-	-	896.89	121,728.89
Huai Phueng	224	-	-	-	-	-	111,312.06	-	-	-	-	-	-	-	-	-	-	111,312.06	4,562,594.56
Huai Mek	225	-	-	191,277.25	-	-	-	-	-	-	-	-	-	-	-	-	-	191,277.25	10,657,389.45
Wan Yai	226	-	-	-	-	-	-	-	-	-	-	19,489.65	-	-	-	-	-	19,489.65	584,633.56
Akat Amnuai	227	-	-	-	2,744.53	-	-	-	-	-	-	-	-	-	-	-	-	2,744.53	298,378.16
Ubonrat	228	-	-	101,907.62	-	-	-	-	-	-	-	-	-	-	-	-	-	101,907.62	2,930,677.36
Factory Allotted Capacity (dj)		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,209,000**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**	**Total Cost**	**1,478,985,242.38**
Allotted Quantity		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,051,843**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**		

Table 4.9 Summary of allotments from 14 districts to a set of factories at district level analysis of multi objectives function.

No.	District	Sets of optimal factory	Allotted amount (Tons)
1	Non Sila (Khon Kaen)	- Burirum (Burirum) - Korach Industry (Nakhon Ratchasima)	12,419.79 79,837.16
2	Kut Chap (Udon Thani)	- Kumpawapi (Udon Thani) - Arawan (Nong Bua Lam Phu)	21,657.81 185,924.58
3	Kosum Phisai (Maha Sarakham)	- Burirum (Burirum) - Mitr Phu Viang (Khon Kaen) - Wangkanai (Maha Sarakham)	5,497.55 370,360.87 160,416.28
4	Chok Chai (Nakhon Ratchasima)	- Korach Industry (Nakhon Ratchasima) - N.Y. (Nakhon Ratchasima)	1,871.22 131,400.59
5	Chaiwan (Udon Thani)	- Kumpawapi (Udon Thani) - Rerm Udom (Udon Thani)	61,536.25 261,138.22
6	Tha Khantho (Kalasin)	- Kumpawapi (Udon Thani) - Khon Kaen (Khon Kaen)	239,444.10 82,520.71
7	Thep Sathit (Chaiyaphum)	- Angvian Industry (Nakhon Ratchasima) - Korach Industry (Nakhon Ratchasima)	8,636.29 65,430.42
8	Nikhom Kham Soi (Mukdahan)	- Mitr Kalasin (Kalasin) - Saharuang (Mukdahan)	46,019.43 144,574.40
9	Non Sa-at (Udon Thani)	- Khon Kaen (Khon Kaen) - Kaset Phol (Udon Thani)	217,705.84 409,976.64
10	Non Suwan (Buriram)	- Surin (Surin) - N.Y. (Nakhon Ratchasima)	2,461.84 10,222.32
11	Wang Saphung (Loei)	- United Farmer & Industry (Chaiyaphum) - Mitr Phu Viang (Khon Kaen)	143,519.16 216,001.81
12	Wang Sam Mo (Udon Thani)	- Kumpawapi (Udon Thani) - E – Saan Sugar Industry (Kalasin)	297,234.52 616,034.17
13	Sahatsakhan (Kalasin)	- Mitr Kalasin (Kalasin) - E – Saan Sugar Industry (Kalasin)	32,187.14 38,445.82
14	Nong Wua So (Udon Thani)	- Mitr Phu Viang (Khon Kaen) - Kaset Phol (Udon Thani)	69,334.59 57,859.59

At plot level

(1) Network analysis

NA in plot level of 14 districts which had either 2 or 3 destinations (sugar factories) was performed. In this level, each path included length of road passing through the buffer zone for each O-D. Thus, each O-D distance resulted from the process must be subtracted by length of road passing through the buffer zone before using in TC calculation. The subtracted distance was the actual distance of each O-D. These paths were then multiplied with the standard TC for further LP analysis to find the optimal path for sugarcane transport from each cropping plot to optimal factories that could obtain the minimum the total TC and EI.

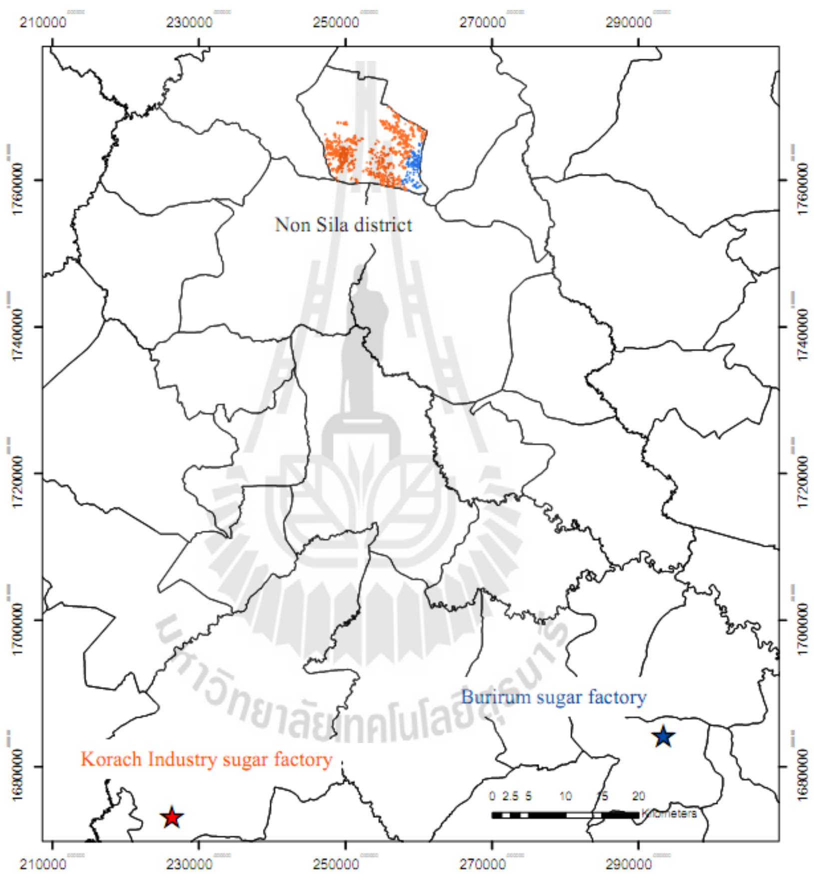
For other districts, 214 districts which sugarcane were allotted to only one optimal factory, each O-D distance resulted from NA must be subtracted by length of road passing through the buffer zone and became the actual distance of each O-D. The TC (c_{ij}) in plot level of districts was estimated by multiplying actual distance from NA with the standard TC (baht/km/ton) and became TC (baht/ton) or c_{ij}. The path for sugarcane allotment from each plot to an optimal factory had only one path, no LP analysis was required. Therefore, each O-D distance from NA in plot level subtracted by length of road passing through the buffer zone was the actual distance of shortest path for each plot to target factory.

(2) Linear programming

The TC (c_{ij}) of each O-D from previous step of 14 districts, which had sugarcane allotments to a set of factories, were used as input to the LP to find an optimal path from each plot to a sugar factory that provided minimum total TC and EI. Information of TC (c_{ij}) from NA and synthesized EI were used to formulate the LP as expressed in Equation (9). In this step, before input to the LP, EI was normalized using Equations (14) and (15) while c_{ij} and x_{ij}variables were normalized using Equations (14). Quantities of sugarcane allotment in Table 4.9 were used as constraints of decision rule for LP in plot level of each district.

To minimize total TC and EI, the results of this step were a set of optimal factories of each plot, the allotments of each plot to factories, and total TC of each district in plot level. The normalized results of TC and allotments were multiplied with their maximum actual values to obtain the actual values. The result of allotment process could be summarized and displayed as maps of 14 districts as shown in Figures 4.23-4.36. The sugarcane allotment to each factory in the NE region was summarized and shown in Figure 4.37. The plot groups allotted to optimal factories were separated by colors. The minimum total TC of plot level in NE region of multi objectives function was 1,570,661,893.63 baht. Table 4.10 shows the total TC of each district at plot level.

(1) Non Sila district in Khon Kaen province had the sugarcane product of 92,256.96 tons. They were allotted for 2 factories, Burirum (Burirum) and Korach Industry (Nakhon Ratchasima), as shown in Figure 4.23. The amounts of sugarcane allocated were 12,419.79 and 79,837.16 tons, respectively. The total TC was 12,718,504.78 baht and EI score was 119.21.



Sugarcane cropping areas allocated to the Burirum sugar factory (Burirum)

Sugarcane cropping areas allocated to the Korach Industry sugar factory (Nakhon Ratchasima)

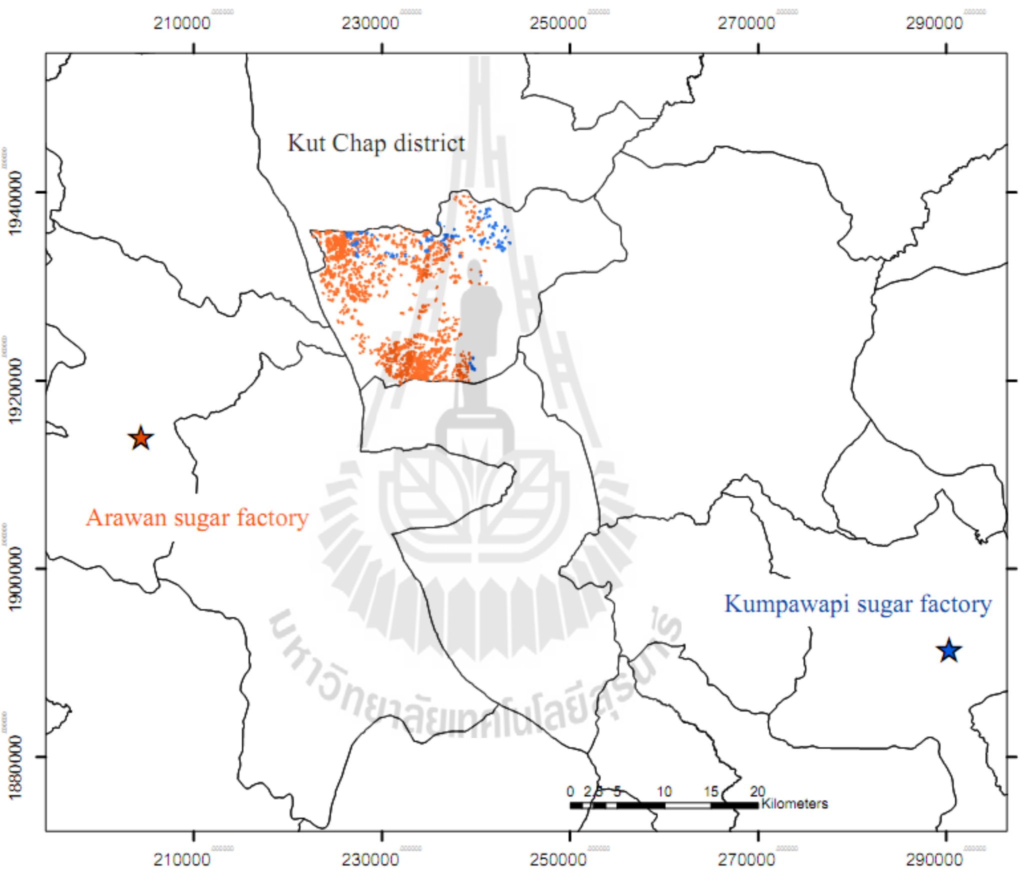
Boundary of districts

Burirum sugar factory (Burirum)

Korach Industry sugar factory (Nakhon Ratchasima)

Figure 4.23 Sugarcane allocations from cropping plots in Non Sila district in Khon Kaen province to a set of optimal factories at minimum TC and EI.

(2) Kut Chap district in Udon Thani province had the sugarcane product of 207,582.40 tons. They were allotted for 2 factories, Kumpawapi (Udon Thani) and Arawan (Nong Bua Lam Phu), as shown in Figure 4.24. The amounts of sugarcane allocated were 21,657.81 and 185,924.58 tons, respectively. The total TC was 14,831,007.44 baht and EI score was 118.05.



Sugarcane cropping areas allocated to the Kumpawapi sugar factory (Udon Thani)

Sugarcane cropping areas allocated to the Arawan sugar factory (Nong Bua Lam Phu)

Boundary of districts

Kumpawapi sugar factory (Udon Thani)

Arawan sugar factory (Nong Bua Lam Phu)

Figure 4.24 Sugarcane allocations from cropping plots in Kut Chap district in Udon Thani province to a set of optimal factories at minimum TC and EI.

(3) Kosum Phisai district in Maha Sarakham province had the sugarcane product of 536,274.70 tons. They were allotted for 3 factories, Burirum (Burirum), Mitr Phu Viang (Khon Kaen), and Wangkanai (Maha Sarakham), as shown in Figure 4.25. The amounts of sugarcane allocated were 5,497.55, 370,360.87, and 160,416.28 tons, respectively. The total TC was 39,382,911.20 baht and EI score was 381.94.

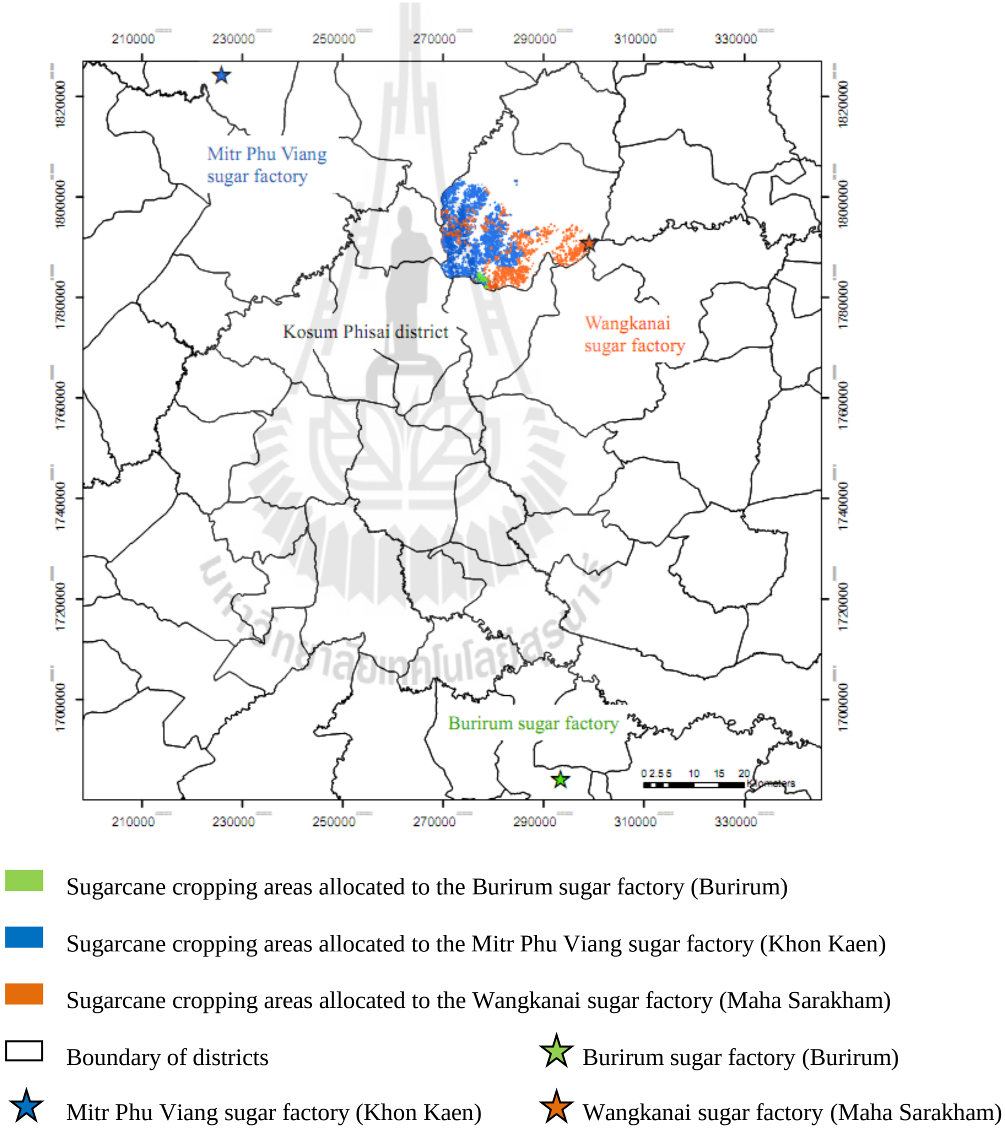


Figure 4.25 Sugarcane allocations from cropping plots in Kosum Phisai district in Maha Sarakham province to a set of optimal factories at minimum TC and EI.

(4) Chok Chai district in Nakhon Ratchasima province had the sugarcane product of 133,271.81 tons. They were allotted for 2 factories, Korach Industry (Nakhon Ratchasima) and N.Y. (Nakhon Ratchasima), as shown in Figure 4.26. The amounts of sugarcane allocated were 1,871.22 and 131,400.59 tons, respectively. The total TC was 7,228,875.66 baht and EI score was 44.92.

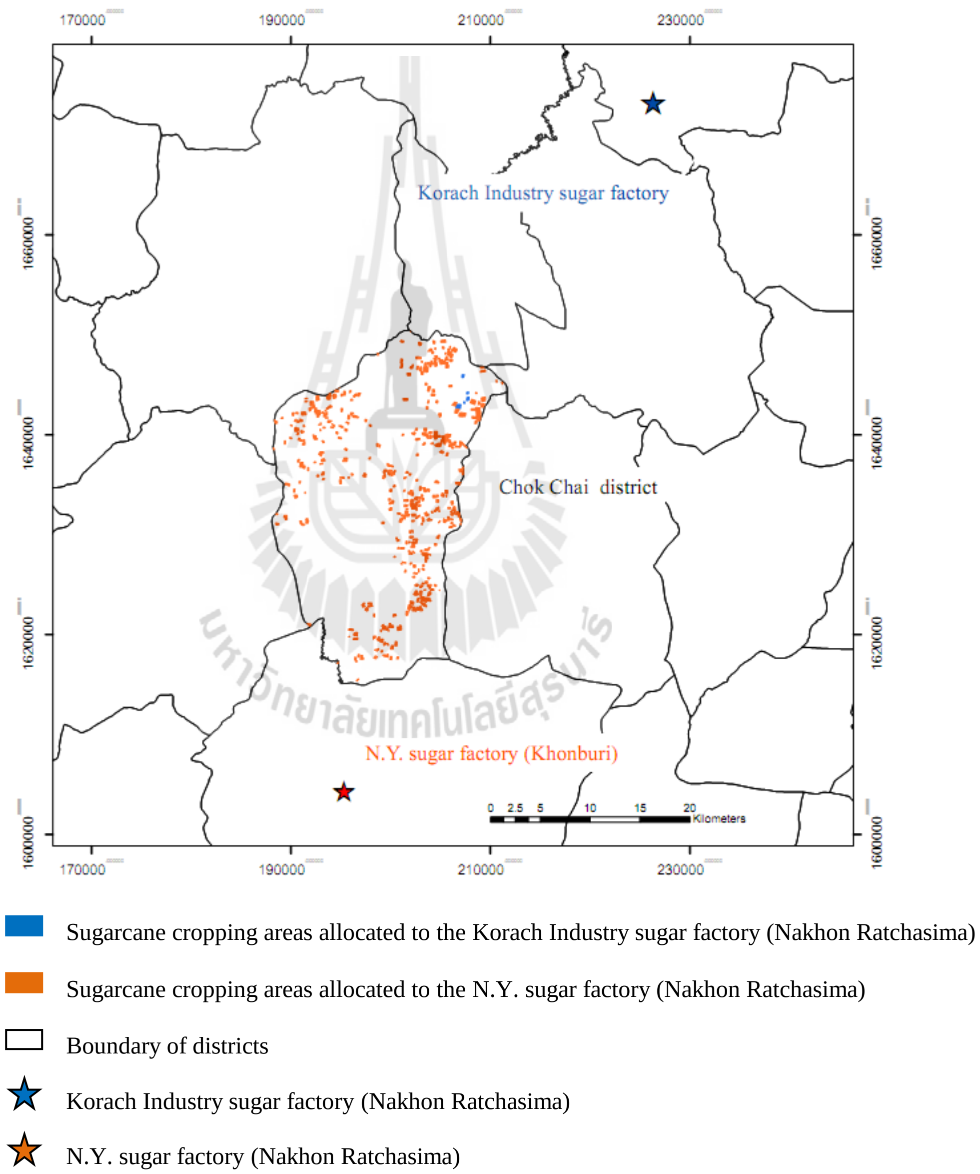


Figure 4.26 Sugarcane allocations from cropping plots in Chok Chai district in Nakhon Ratchasima province to a set of optimal factories at minimum TC and EI.

(5) Chaiwan district in Udon Thani province had the sugarcane product of 322,674.46 tons. They were allotted for 2 factories, Kumpawapi (Udon Thani) and Rerm Udom (Udon Thani), as shown in Figure 4.27. The amounts of sugarcane allocated were 61,536.25 and 261,138.22 tons, respectively. The total TC was 10,607,121.98 baht and EI score was 224.66.

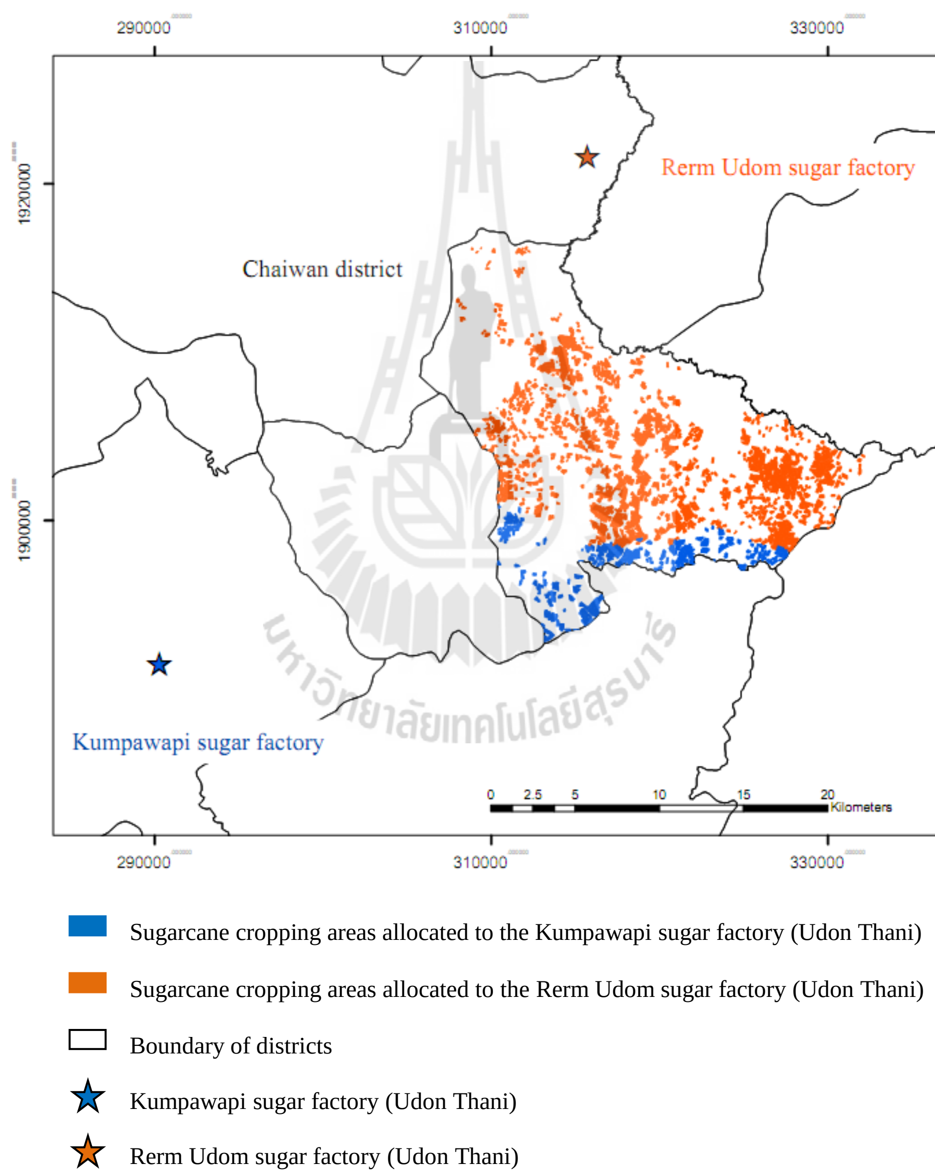


Figure 4.27 Sugarcane allocations from cropping plots in Chaiwan district in Udon Thani province to a set of optimal factories at minimum TC and EI.

(6) Tha Khantho district in Kalasin province had the sugarcane product of 321,964.81 tons. They were allotted for 2 factories, Khon Kaen (Khon Kaen) and Kumpawapi (Udon Thani), as shown in Figure 4.28. The amounts of sugarcane allocated were 82,520.71 and 239,444.10 tons, respectively. The total TC was 17,622,898.84 baht and EI score was 223.62.

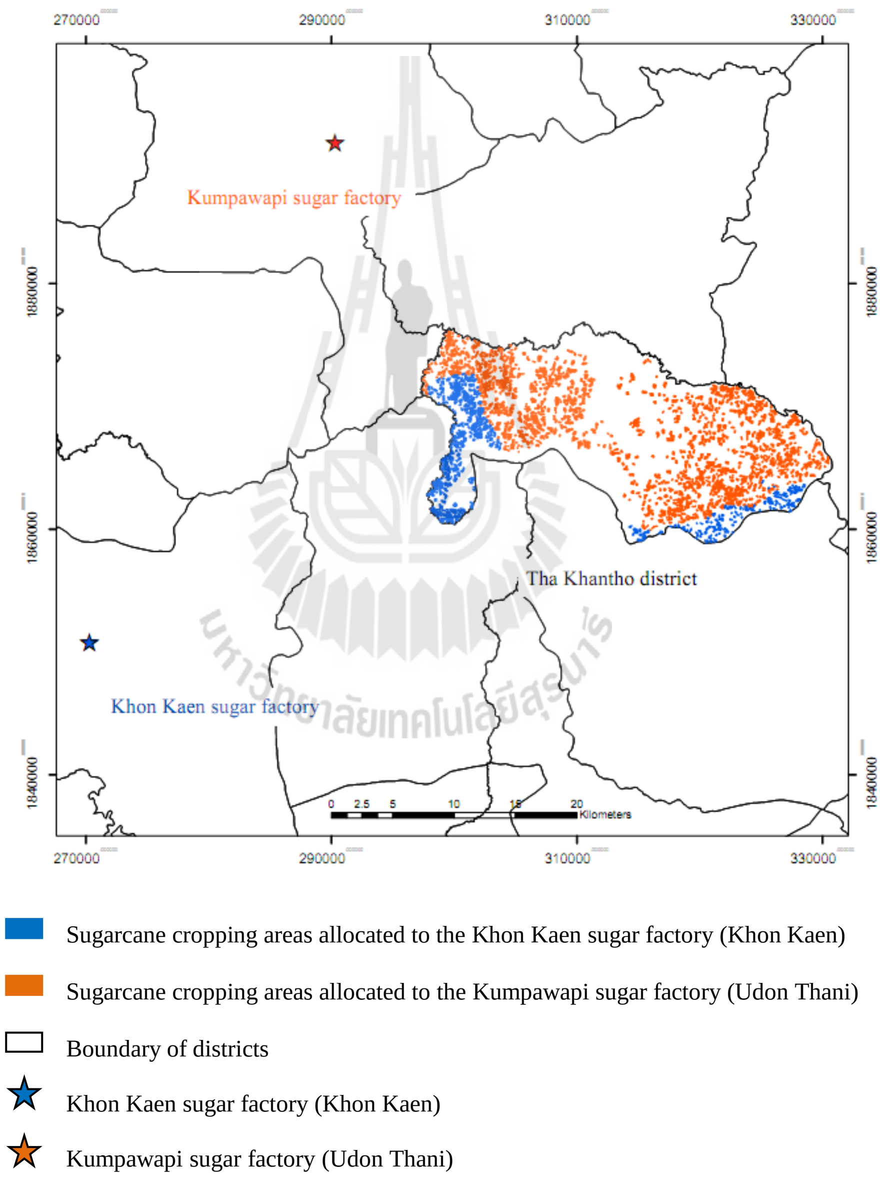


Figure 4.28 Sugarcane allocations from cropping plots in Tha Khantho district in Kalasin province to a set of optimal factories at minimum TC and EI.

(7) Thep Sathit district in Chaiyaphum province had the sugarcane product of 74,066.70 tons. They were allotted for 2 factories, Korach Industry (Nakhon Ratchasima) and Angvian Industry (Nakhon Ratchasima), as shown in Figure 4.29. The amounts of sugarcane allocated were 65,430.42 and 8,636.29 tons, respectively. The total TC was 13,479,130.38 baht and EI score was 96.22.

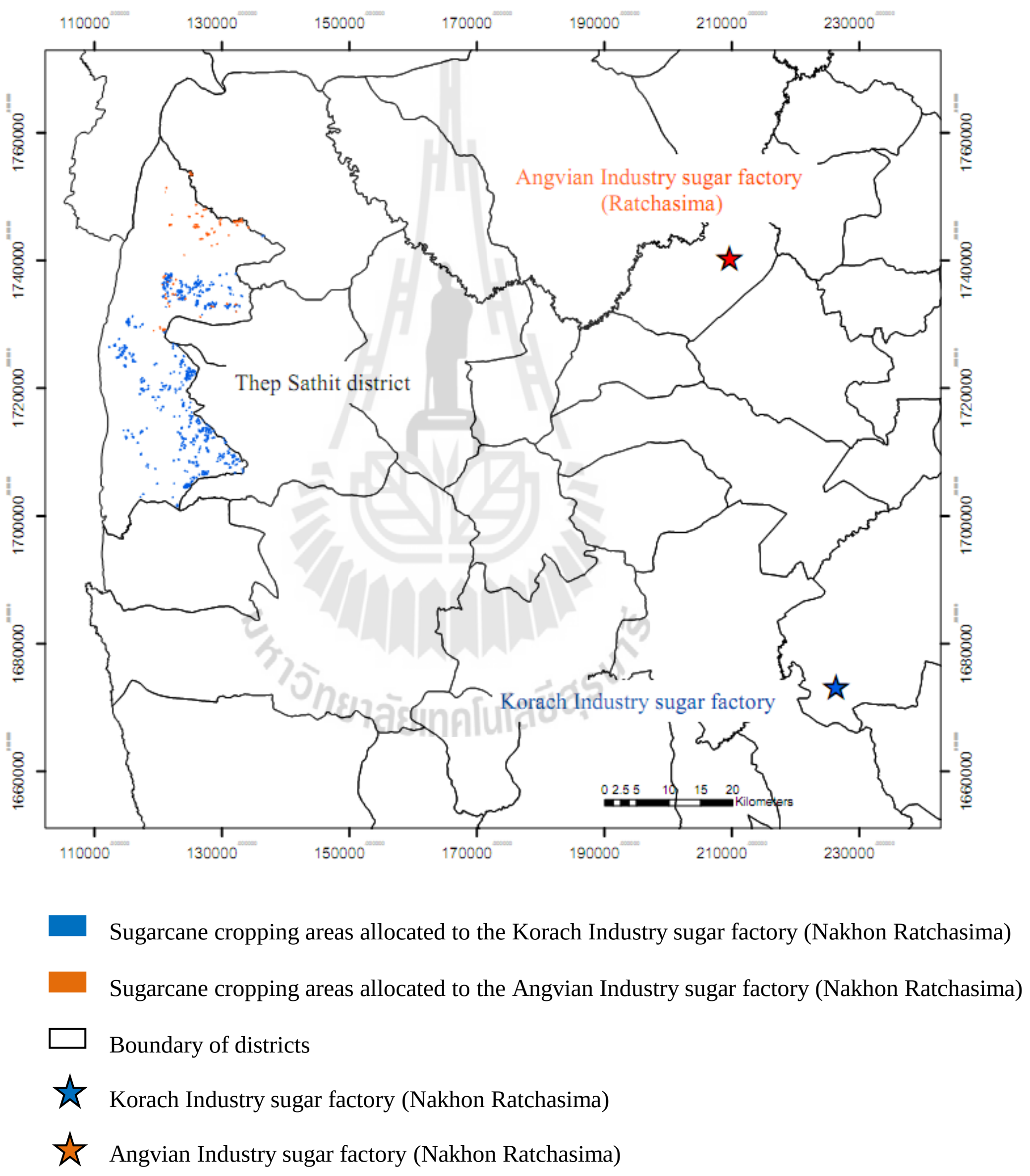


Figure 4.29 Sugarcane allocations from cropping plots in Thep Sathit district in Chaiyaphum province to a set of optimal factories at minimum TC and EI.

(8) Nikhom Kham Soi district in Mukdahan province had the sugarcane product of 190,593.83 tons. They were allotted for 2 factories, Mitr Kalasin (Kalasin) and Saharuang (Mukdahan), as shown in Figure 4.30. The amounts of sugarcane allocated were 46,019.43 and 144,574.40 tons, respectively. The total TC was 10,630,007.12 baht and EI score was 102.94.

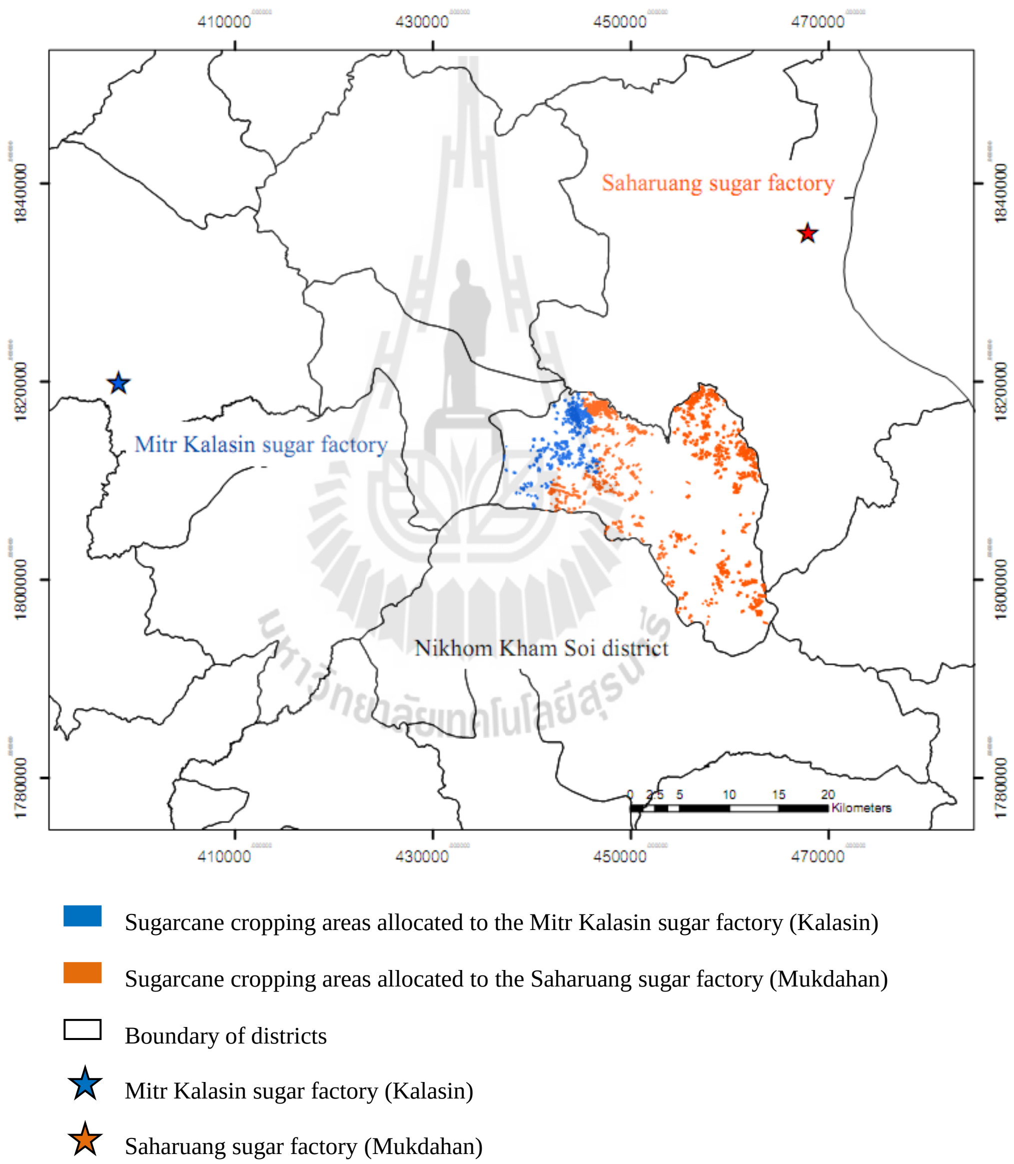


Figure 4.30 Sugarcane allocations from cropping plots in Nikhom Kham Soi district in Mukdahan province to a set of optimal factories at minimum TC and EI.

(9) Non Sa-at district in Udon Thani province had the sugarcane product of 627,682.48 tons. They were allotted for 2 factories, Khon Kaen (Khon Kaen) and Kaset Phol (Udon Thani), as shown in Figure 4.31. The amounts of sugarcane allocated were 217,705.84 and 409,976.64 tons, respectively. The total TC was 20,044,236.80 baht and EI score was 449.65.

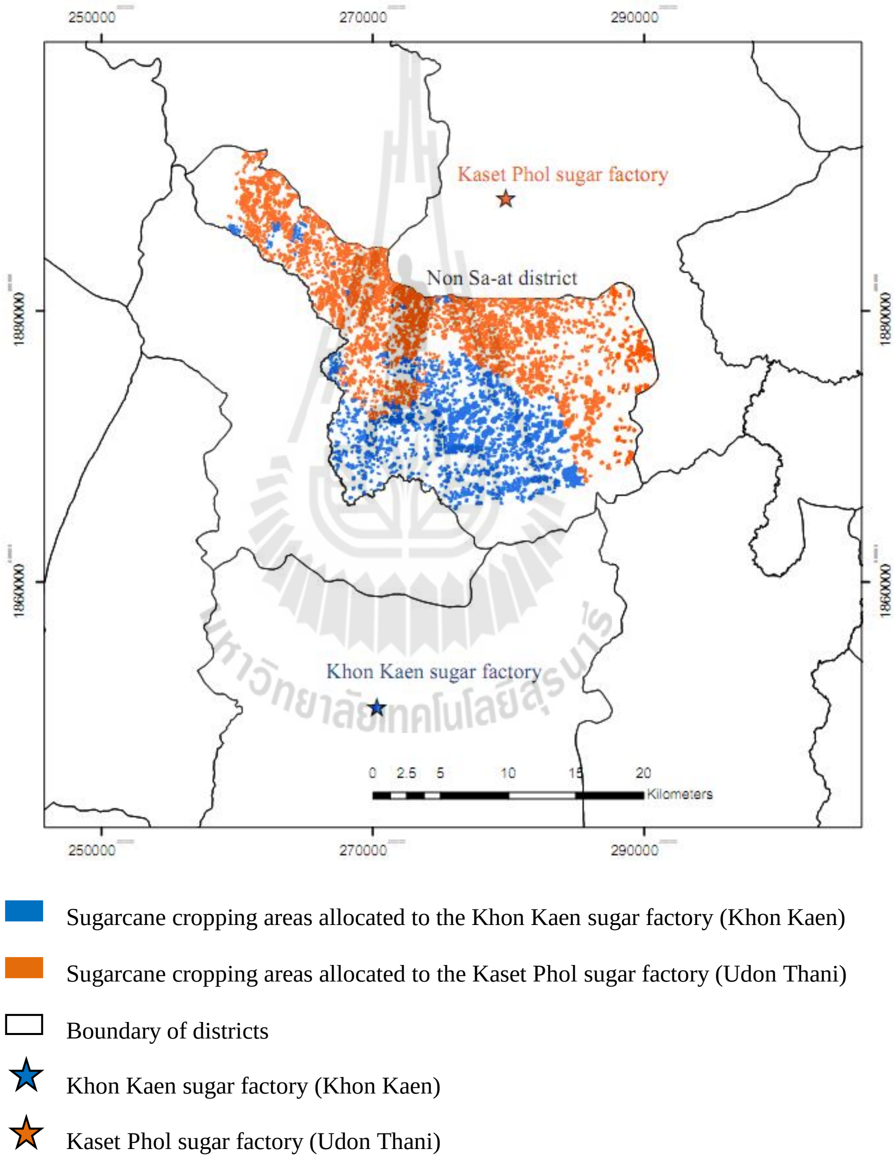


Figure 4.31 Sugarcane allocations from cropping plots in Non Sa-at district in Udon Thani province to a set of optimal factories at minimum TC and EI.

(10) Non Suwan district in Buriram province had the sugarcane product of 12,684.16 tons. They were allotted for 2 factories, Surin (Surin) and N.Y. (Nakhon Ratchasima), as shown in Figure 4.32. The amounts of sugarcane allocated were 2,461.84 and 10,222.32 tons, respectively. The total TC was 896,302.60 baht and EI score was 11.34.

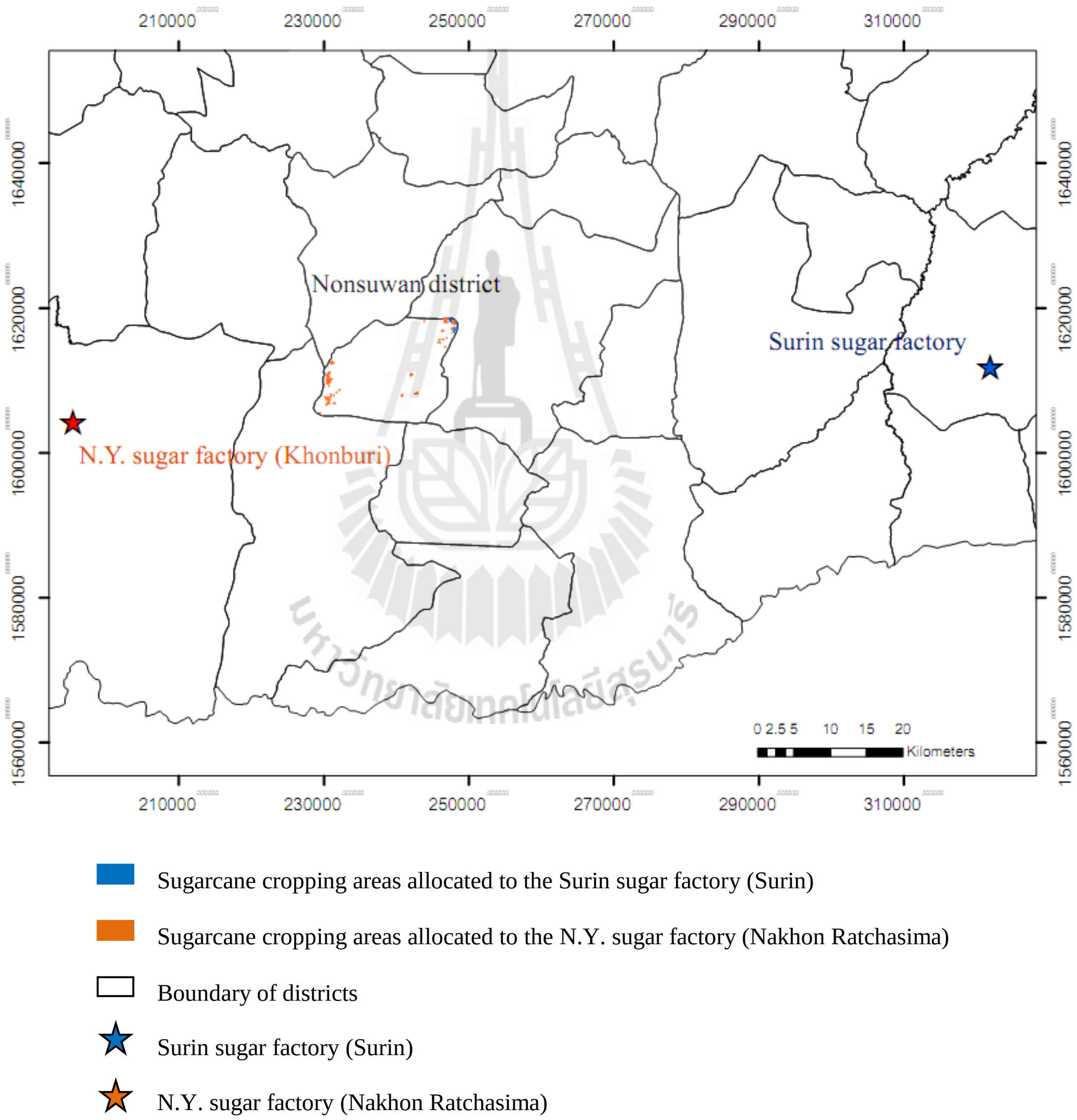


Figure 4.32 Sugarcane allocations from cropping plots in Non Suwan district in Buriram province to a set of optimal factories at minimum TC and EI.

(11) Wang Saphung district in Loei province had the sugarcane product of 359,520.97 tons. They were allotted for 2 factories, United Farmer & Industry (Chaiyaphum) and Mitr Phu Viang (Khon Kaen), as shown in Figure 4.33. The amounts of sugarcane allocated were 143,519.16 and 216,001.81 tons, respectively. The total TC was 49,503,289.02 baht and EI score was 317.44.

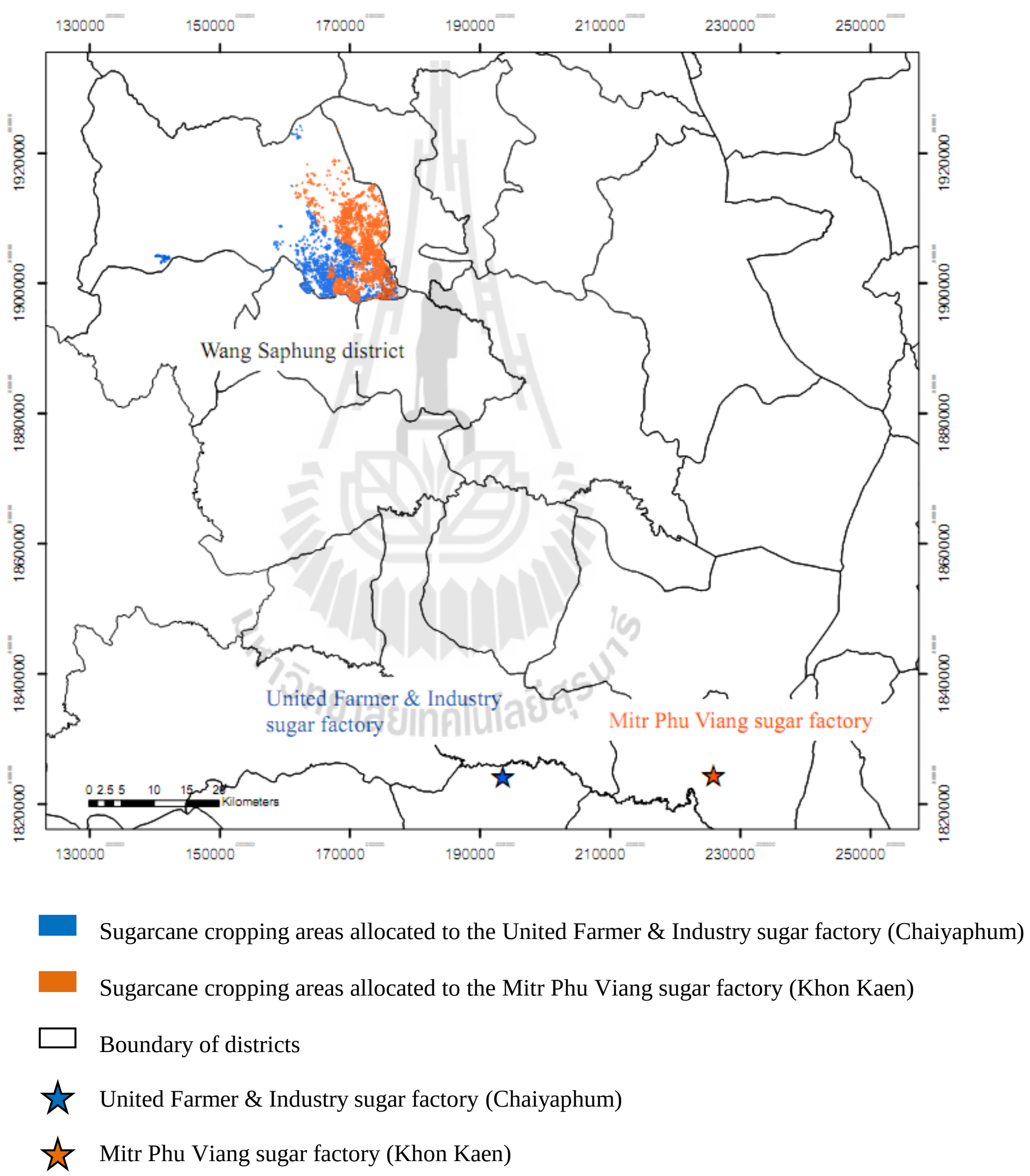


Figure 4.33 Sugarcane allocations from cropping plots in Wang Saphung district in Loei province to a set of optimal factories at minimum TC and EI.

(12) Wang Sam Mo district in Udon Thani province had the sugarcane product of 913,268.68 tons. They were allotted for 2 factories, Kumpawapi (Udon Thani) and E – Saan Sugar Industry (Kalasin), as shown in Figure 4.34. The amounts of sugarcane allocated were 297,234.52 and 616,034.17 tons, respectively. The total TC was 37,437,605.86 baht and EI score was 513.14.

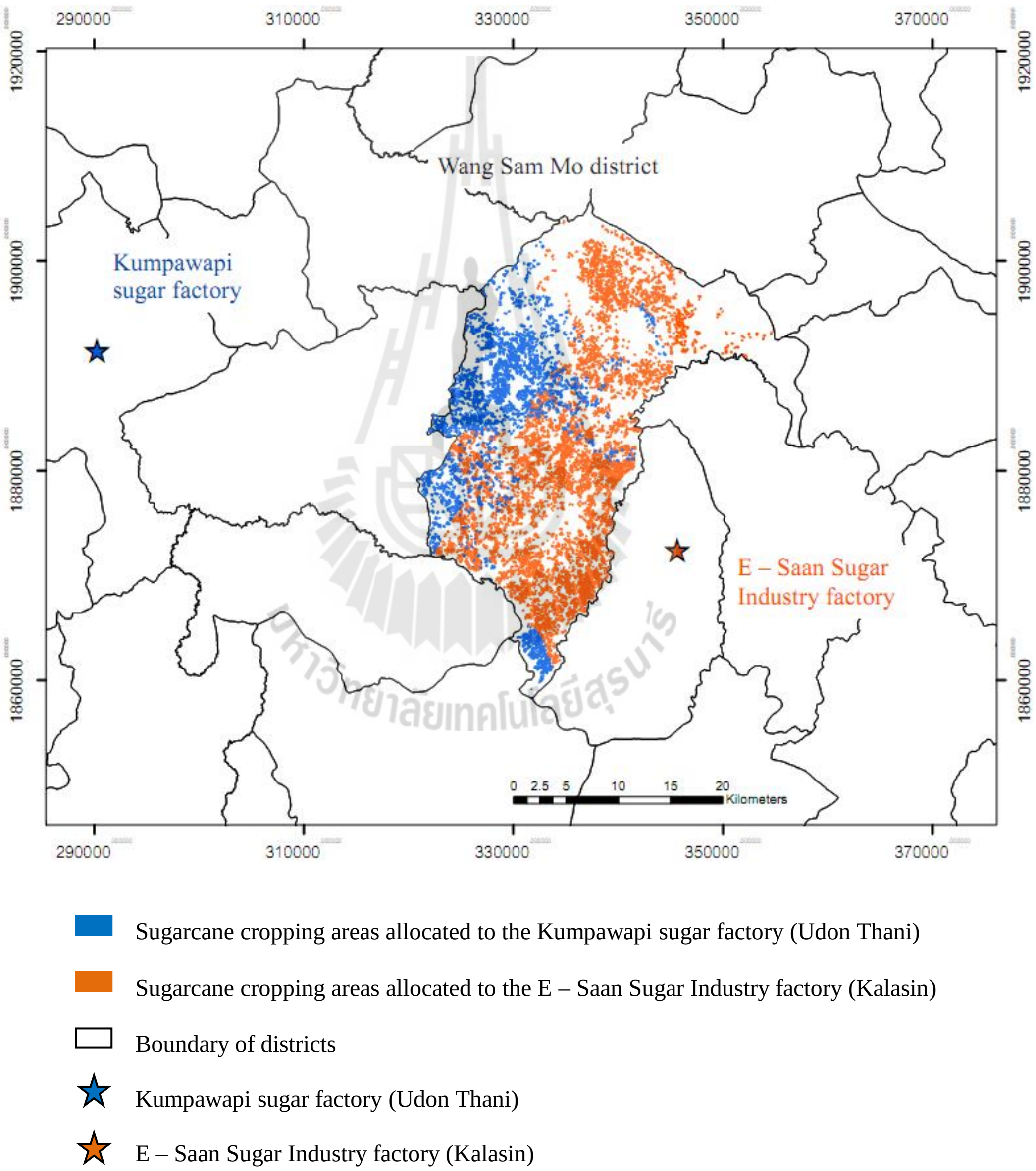


Figure 4.34 Sugarcane allocations from cropping plots in Wang Sam Mo district in Udon Thani province to a set of optimal factories at minimum TC and EI.

(13) Sahatsakhan district in Kalasin province had the sugarcane product of 70,632.96 tons. They were allotted for 2 factories, Mitr Kalasin (Kalasin) and E – Saan Sugar Industry (Kalasin), as shown in Figure 4.35. The amounts of sugarcane allocated were 32,187.14 and 38,445.82 tons, respectively. The total TC was 4,337,437.89 baht and EI score was 68.98.

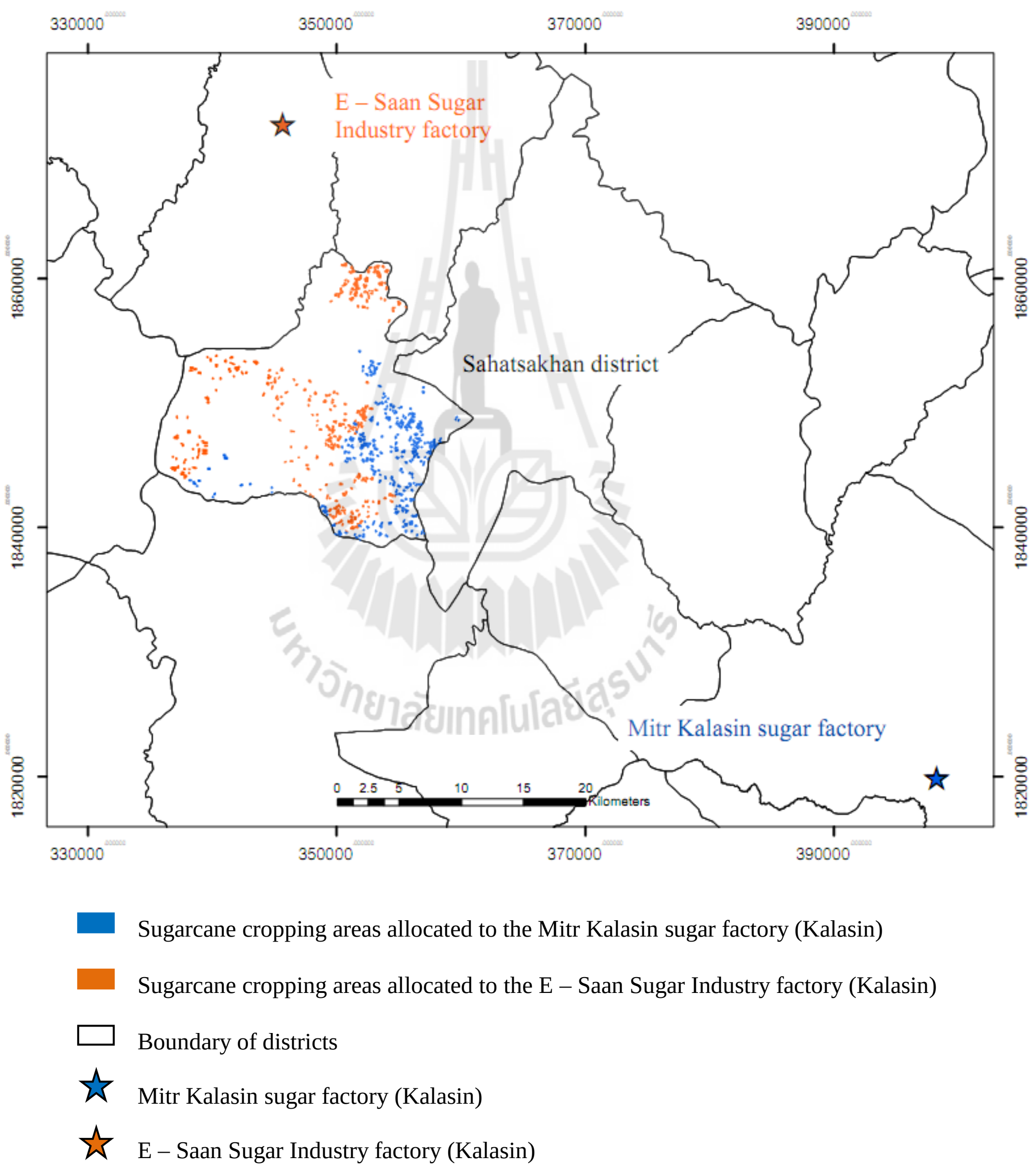


Figure 4.35 Sugarcane allocations from cropping plots in Sahatsakhan district in Kalasin province to a set of optimal factories at minimum TC and EI.

(14) Nong Wua So district in Udon Thani province had the sugarcane product of 127,194.18 tons. They were allotted for 2 factories, Mitr Phu Viang (Khon Kaen) and Kaset Phol (Udon Thani), as shown in Figure 4.36. The amounts of sugarcane allocated were 69,334.59 and 57,859.59 tons, respectively. The total TC was 14,897,926.64 baht and EI score was 74.91.

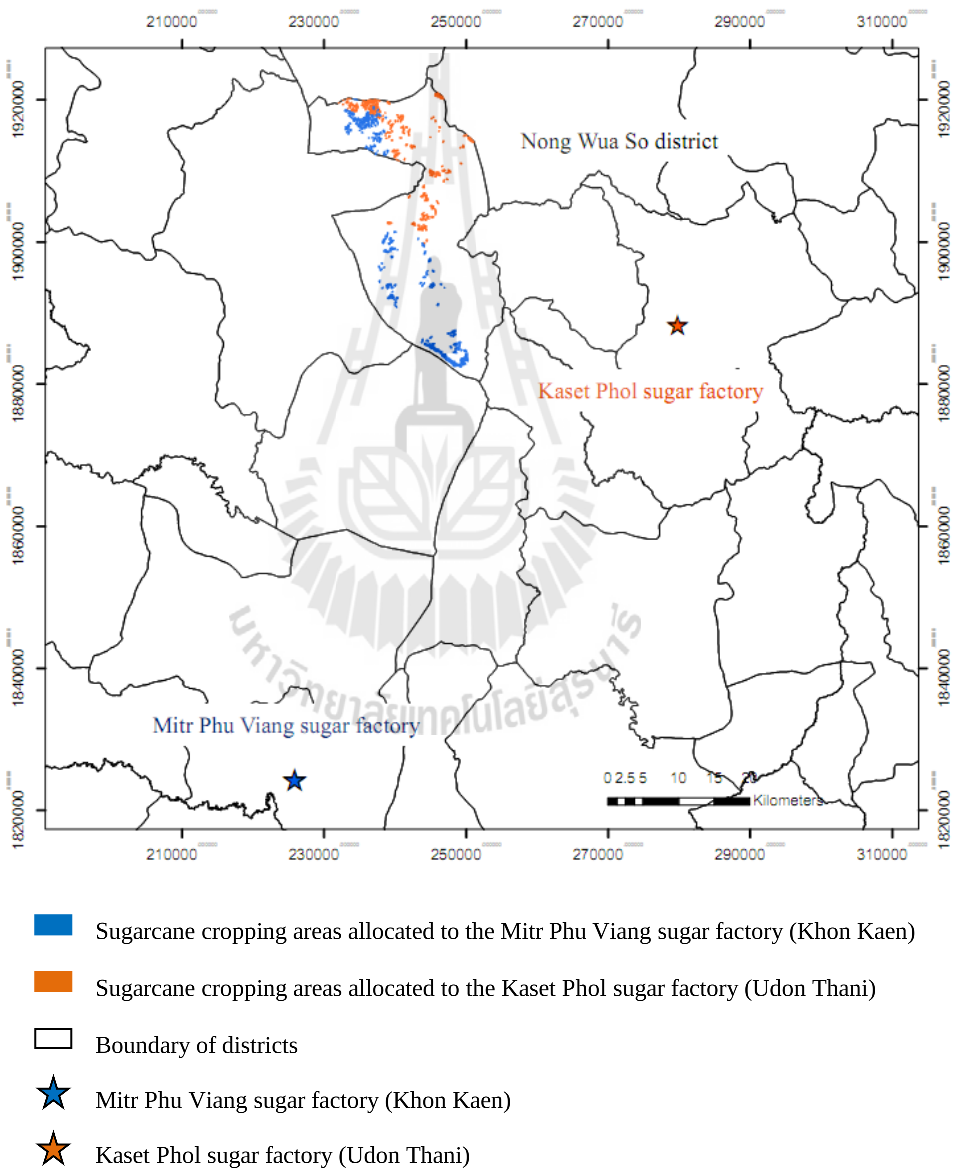
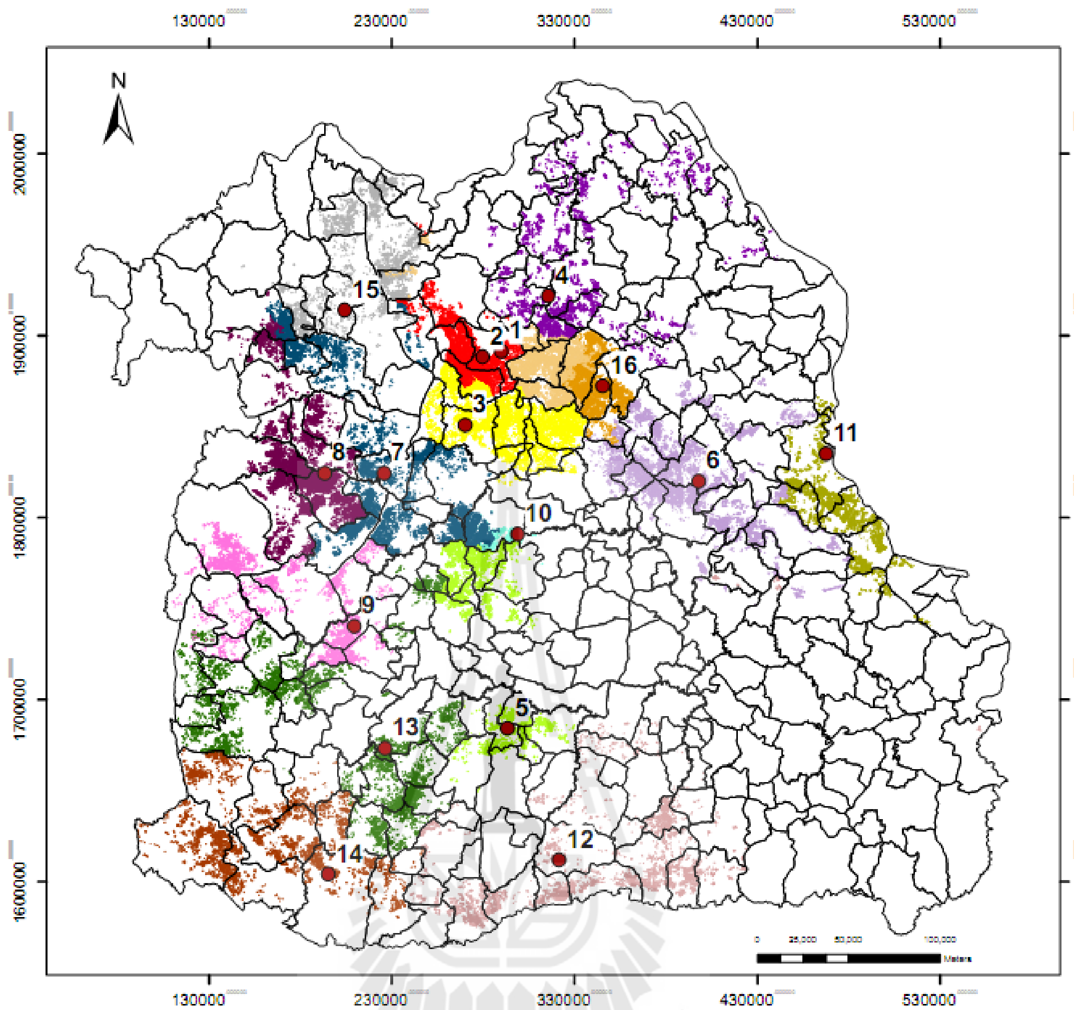


Figure 4.36 Sugarcane allocations from cropping plots in Nong Wua So district in Udon Thani province to a set of optimal factories at minimum TC and EI.



Sugarcane plots allotted to sugar factory:

- : 1. Kumpawapi (Udon Thani)
- : 2. Kaset Phol (Udon Thani)
- : 3. Khon Kaen (Khon Kaen)
- : 4. Rerm Udom (Udon Thani)
- : 5. Burirum (Buri Ram)
- : 6. Mitr Kalasin (Kalasin)
- : 7. Mitr Phu Viang (Khon Kaen)
- : 8. United Farmer & Industry (Chaiyaphum)
- : 9. Angvian Industry (Nakhon Ratchasima)
- : 10. Wangkanai (Maha Sarakham)
- : 11. Saharuang (Mukdahan)
- : 12. Surin (Surin)
- : 13. Korach Industry (Nakhon Ratchasima)
- : 14. N.Y. (Nakhon Ratchasima)
- : 15. Arawan (Nong Bua Lam Phu)
- : 16. E – Saan Sugar Industry (Kalasin)
- : Boundary of districts
- : Sugar factory

Figure 4.37 Sugarcane allocations from cropping plots in the NE of multi-objectives.

Table 4.10 The total TC of each district at plot level of multi objectives.

No.	District Name	TC	No.	District Name	TC
1.	Kranuan	20,367,835.50	41.	Kosum Phisai	39,382,911.20
2.	Krasang	670,840.44	42.	Kham Thale So	73,704.88
3.	Kap Choeng	4,274,004.72	43.	Kham Sakae Saeng	5,917,750.75
4.	Kut Rang	31,247,502.16	44.	Khukhan	737,720.21
5.	Ku Kaeo	4,157,830.10	45.	Khun Han	35,142.86
6.	Khewa Sinarin	29,494.99	46.	Khemarat	1,584,901.60
7.	Khaen Dong	1,957,216.85	47.	Khao Wong	26,197.57
8.	Khok Pho Chai	3,417,596.81	48.	Khao Suan Kwang	7,648,395.51
9.	Chuen Chom	5,990,416.79	49.	Khong	14,502,825.04
10.	Sap Yai	2,711,703.16	50.	Khon Buri	5,351,640.39
11.	Sam Sung	5,757,118.11	51.	Khon Sawan	3,202,390.92
12.	Don Chan	10,046,405.30	52.	Khon San	17,301,468.56
13.	Thepharak	8,353,379.56	53.	Kham Cha-I	5,212,733.89
14.	Na Khu	126,375.17	54.	Kham Ta Kla	88,504.46
15.	Non Narai	15,474.18	55.	Kham Muang	3,183,591.48
16.	Non Sila	12,718,504.78	56.	Khu Mueang	1,413,632.55
17.	Bua Lai	2,438,003.48	57.	Chom Phra	1,222,211.01
18.	Ban Dan	865,389.74	58.	Chakkarat	8,358,939.84
19.	Ban Haet	16,188,238.67	59.	Chatturat	20,256,249.43
20.	Prachak Sinlapakhom	331,891.48	60.	Charoen Sin	1,782,095.76
21.	Fao Rai	3,446,534.23	61.	Chaloem Phrakiat	1,027,993.99
22.	Phanom Dong Rak	3,442,749.32	62.	Chonnabot	5,096,670.86
23.	Phra Thongkham	13,758,781.29	63.	Chanuman	14,267,026.80
24.	Pho Tak	4,293,682.76	64.	Chamni	415,118.01
25.	Lam Thamenchai	79,950.50	65.	Chum Phuang	6,792,665.14
26.	Si Narong	10,550,216.74	66.	Chum Phae	6,994,483.08
27.	Sa Khrai	2,331,698.80	67.	Chiang Yuen	604,141.79
28.	Sam Chai	4,827,416.59	68.	Chok Chai	7,228,875.66
29.	Nong Na Kham	534,567.92	69.	Chaiwan	10,607,121.98
30.	Nong Hin	19,616,744.42	70.	Seka	7,769,987.40
31.	Arawan	6,968,016.45	71.	So Phisai	1,728,035.42
32.	Kuchi Narai	9,470,542.27	72.	Dong Luang	5,886,662.66
33.	Kut Khao Pun	1,663,501.74	73.	Don Tan	13,700,561.37
34.	Kut Chap	14,831,007.44	74.	Dan Khun Thot	42,835,576.05
35.	Kut Chum	1,915,240.84	75.	Trakan Phuet Phon	119,233.19
36.	Kut Bak	1,622,179.99	76.	Tao Ngoi	1,500,117.03
37.	Kumphawapi	8,798,015.20	77.	Sai Mun	1,756,478.60
38.	Kaset Sombun	20,585,217.82	78.	Tha Khantho	17,622,898.84
39.	Kaeng Khro	16,162,116.98	79.	Tha Tum	510,831.16
40.	Kaeng Sanam Nang	3,393,389.43	80.	Tha Bo	642,885.72

Table 4.10 (Continued).

No.	District Name	TC	No.	District Name	TC
81.	Tha Uthen	844,321.66	121.	Bueng Kan	34,366.33
82.	Thung Fon	428,663.70	122.	Bueng Khong Long	5,486,939.08
83.	Thep Sathit	13,479,130.38	123.	Pathum Ratchawongsa	2,815,515.13
84.	Thai Charoen	2,287,825.04	124.	Prakhon Chai	483,435.08
85.	That Phanom	559,988.32	125.	Prang Ku	917,149.89
86.	Na Klang	1,210,988.38	126.	Prasat	750,775.78
87.	Na Kae	571,317.00	127.	Pakham	1,913,171.23
88.	Nang Rong	5,969,062.46	128.	Pak Thong Chai	14,797,040.78
89.	Na Chueak	5,439,463.30	129.	Pak Khat	50,776.79
90.	Na Duang	183,500.12	130.	Pak Chong	62,918,226.74
91.	Na Dun	442,456.52	131.	Pa Tio	2,596,718.90
92.	Na Thom	874,753.68	132.	Pueai Noi	7,665,437.60
93.	Na Pho	47,308.06	133.	Pha Khao	28,275,861.82
94.	Na Mon	5,462,277.54	134.	Phon Charoen	1,827,597.95
95.	Na Yung	313,469.57	135.	Phanna Nikhom	3,325,260.97
96.	Na Wang	2,388,347.54	136.	Phra Yuen	467,997.42
97.	Nam Phong	7,981,038.99	137.	Phon	4,373,291.31
98.	Nam Som	10,072,060.06	138.	Phang Khon	173,206.14
99.	Nikhom Kham Soi	10,630,007.12	139.	Phibun Rak	1,303,930.47
100.	Nikhom Nam Un	777,989.66	140.	Phimai	5,260,948.54
101.	Noen Sa-Nga	4,642,966.36	141.	Phen	769,690.07
102.	Non Din Daeng	1,785,080.37	142.	Pho Chai	10,029,520.54
103.	Non Thai	84,921.84	143.	Pho Sai	533,798.20
104.	Non Sa-At	20,044,236.80	144.	Phon Thong	13,144,909.81
105.	Non Sang	142,627.55	145.	Phon Phisai	1,849,951.84
106.	Non Suwan	896,302.60	146.	Phon Sawan	147,754.38
107.	Borabue	9,736,471.08	147.	Phrai Bueng	64,992.66
108.	Bua Chet	13,384,912.90	148.	Phakdi Chumphon	1,468,483.21
109.	Bua Yai	3,650,940.96	149.	Phu Kradueng	3,123,759.22
110.	Ban Kruat	5,872,986.58	150.	Phu Khiao	25,364,001.47
111.	Ban Khwao	2,614,883.21	151.	Phu Pha Man	5,186,885.92
112.	Ban Dung	7,911,922.66	152.	Phu Phan	2,601,845.76
113.	Ban Thaen	5,472,086.56	153.	Phu Wiang	4,335,705.15
114.	Ban Phue	22,125,607.39	154.	Phu Sing	2,935,607.57
115.	Ban Phai	32,284,802.93	155.	Phu Luang	2,790,096.03
116.	Ban Fang	4,856,010.78	156.	Mancha Khiri	18,301,055.94
117.	Ban Phaeng	191,823.32	157.	Moei Wadi	1,167,850.12
118.	Ban Muang	6,947,337.42	158.	Mueang Kalasin	6,685,786.10
119.	Ban Lueam	5,957,510.68	159.	Mueang Khon Kaen	10,919,715.90
120.	Bamnet Narong	12,648,561.07	160.	Mueang Chaiyaphum	7,208,877.86

Table 4.10 (Continued).

No.	District Name	TC	No.	District Name	TC
161.	Mueang Nakhon Ratchasima	4,681,293.23	195.	Sawang Daen Din	4,302,113.69
162.	Mueang Buri Ram	925,327.15	196.	Sahatsakhan	4,337,437.89
163.	Mueang Maha Sarakham	58,393.59	197.	Song Dao	5,573,194.74
164.	Mueang Mukdahan	15,700,146.40	198.	Sangkha	9,013,814.18
165.	Mueang Yasothon	401,091.91	199.	Sangkhom	656,741.07
166.	Mueang Loei	59,686.05	200.	Samrong Thap	76,261.18
167.	Mueang Sakon Nakhon	2,237,023.55	201.	Sirindhorn	250,218.97
168.	Mueang Surin	902,280.08	202.	Si Khio	24,500,318.79
169.	Mueang Nong Khai	73,475.85	203.	Si Chomphu	14,568,452.94
170.	Mueang Nong Bua Lamphu	2,150,255.16	204.	Suwanna Khuha	1,782,840.17
171.	Mueang Amnat Charoen	3,016,670.06	205.	Sung Noen	6,615,433.44
172.	Mueang Udon Thani	9,742,170.08	206.	Senangkha Nikhom	1,226,197.93
173.	Yang Talat	1,988,348.75	207.	Selaphum	3,233,990.65
174.	Rattana Buri	101,371.51	208.	Soeng Sang	5,181,879.31
175.	Lahan Sai	15,434,021.27	209.	Nong Ki	10,362,581.72
176.	Lamduan	223,259.76	210.	Nong Kung Si	32,044,760.29
177.	Lam Plai Mat	1,959,248.02	211.	Nong Bua Daeng	34,931,016.48
178.	Loeng Nok Tha	14,212,072.75	212.	Nong Bua Rawe	3,900,414.17
179.	Wang Nam Khiao	14,557,592.99	213.	Nong Bunnak	12,231,213.58
180.	Wang Saphung	49,503,289.02	214.	Nong Phok	7,843,937.51
181.	Wang Sam Mo	37,437,605.86	215.	Nong Ruea	2,863,477.85
182.	Waritchaphum	836,355.09	216.	Nong Wua So	14,897,926.64
183.	Waeng Noi	298,056.14	217.	Nong Song Hong	12,037,674.52
184.	Waeng Yai	407,831.18	218.	Nong Sung	1,215,446.74
185.	Si Chiang Mai	3,735,795.42	219.	Nong Saeng	8,230,574.37
186.	Si That	28,575,576.40	220.	Nong Hong	9,210,023.59
187.	Si Bunrueang	26,845,380.30	221.	Nong Han	2,797,124.65
188.	Si Wilai	1,070,572.36	222.	Huai Thalaeng	5,426,066.21
189.	Si Songkhram	2,202,094.55	223.	Huai Thapthan	119,995.86
190.	Si Khoraphum	452,255.21	224.	Huai Phueng	5,214,396.87
191.	Satuek	2,763,885.71	225.	Huai Mek	11,340,646.12
192.	Sanom	630,294.36	226.	Wan Yai	551,694.69
193.	Somdet	7,152,779.23	227.	Akat Amnuai	307,035.93
194.	Sang Khom	141,855.27	228.	Ubonrat	3,708,573.44
	Total TC at plot level of multi objectives				**1,570,661,893.68**

4.3 Comparison of the Results

At district level, the minimum total TCs resulted from both functions, single objective and multi objectives, were 1,466,641,682.33 baht and 1,478,985,242.38 baht, respectively. The minimum total TC of single objective function was less than the one of multi objectives function, which was reasonable, because the decision of the later one had to deal with EI that required more cost.

At plot level, the minimum total TCs of the single objective and multi objectives were 1,551,454,082.19 baht and 1,570,661,893.68 baht, respectively. As same as the result in district level, in this level the minimum total TC of single objective function was also less than the one of multi objectives function because the decision of the later one had to deal with EI that required more cost as well.

The results from both levels of both objectives as shown in Table 4.11 were consistent with the research hypotheses which stated that "there is the difference of allotments based on consideration with and without EI". The difference percentage of transportation costs between decision with and without EI in district level and the plot level were 0.83% and 1.22%, respectively. The minimum total TC of multi objectives decision was higher due to including EI to consider. This caused the change of transport routes and target factories to achieve minimum EI. However, the difference was not so high, it indicates that EI showed less important role in the study. If higher weight of EI was assigned, more difference could be the result.

Due to the limitation of available software that allows only 8,000 combinations for a time of running, this research, dealing with a huge data of cropping plots, was designed to divide analysis into two levels of two objectives as described above. This methodology finally could solve problem on dealing with huge amounts of plots existing in the big region and could provide reasonable results as discussed.

Table 4.11 The total TC from district and plot levels obtained from single and multi-objective functions.

Level	Single objective (without EI)	Multi objectives (with EI)
District level	1,466,641,682.33	1,478,985,242.38
Plot level	1,551,454,082.19	1,570,661,893.68

4.4 Hypotheses Evaluation

Two hypotheses of the study were evaluated to accept as follows.

(1) The first hypothesis. The cost of sugarcane transportation from each plot to factory(s) achieved from the study was the minimum compared to other non-systematic transportation allotments. The evaluated methods for this hypothesis had 3 trials. Each of them selected a district as an example to perform the test and the result was observed to accept or reject the hypothesis.

- *The case of plot allotments in a district to one sugar factory with different transportation route from the study result*.

Dan Khun Thot district in Nakhon Ratchasima province was selected as an example for the case of sugarcane allotment to one sugar factory (Korach Industry sugar factory in Nakhon Ratchasima province). Transportation routes were changed the trial. Figure 4.38(a) shows the transportation routes of the research, and Figure 4.38(b) shows the transportation routes changed for hypothesis evaluation by random matching. TCs of this research and the evaluation case were 42,102,181.72

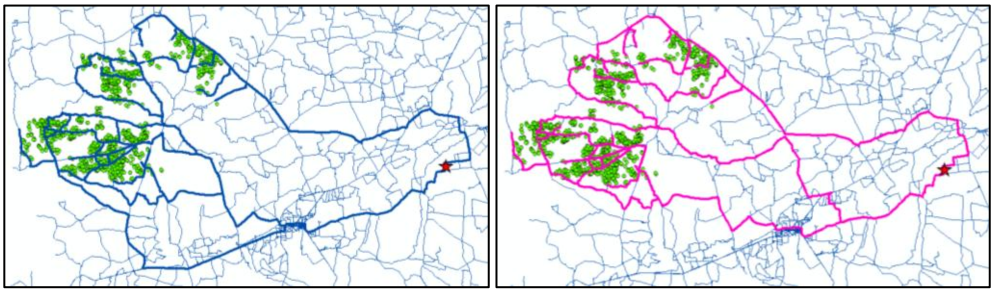
and 42,835,576.05 baht, respectively. The cost of sugarcane transportation according to the changing route was higher than the cost resulted from the research.

- *The case of plot allotments in a district to a set of sugar factories with different transportation routes.*

Non Sila district in Khon Kaen province was selected as an example for the case of allotment to 2 factory, Korach Industry (Nakhon Ratchasima) and Burirum (Buri Ram) sugar factories. The transportation routes were changed by random matching while factory allotments were kept the same. Figure 4.39(a) shows the transportation routes of the research, and Figure 4.39(b) shows the transportation routes changed for evaluation case. TCs of this research and the evaluation case were 12,564,278.35 and 12,645,973.63.05 baht, respectively. The cost of sugarcane transportation according to the changing route was higher than the cost resulted from the research.

- *The plot allotment pattern in a district to a set of sugar factories was changed while factory allotments were kept the same.*

Non Sila district in Khon Kaen province was selected as an example case of allotment to a set of sugar factories, Korach Industry (Nakhon Ratchasima) and Burirum (Buri Ram) sugar factory with changed allotment pattern while factory allotments were kept the same. Figure 4.40(a) shows the allotment pattern of the research, and Figure 4.40(b) shows the changed allotment pattern for evaluation case. TCs of this research and the evaluation case were 12,564,278.35 and 12,783,173.32 baht, respectively. The cost of sugarcane transportation according to the changing allotment pattern was higher than the cost resulted from the research.



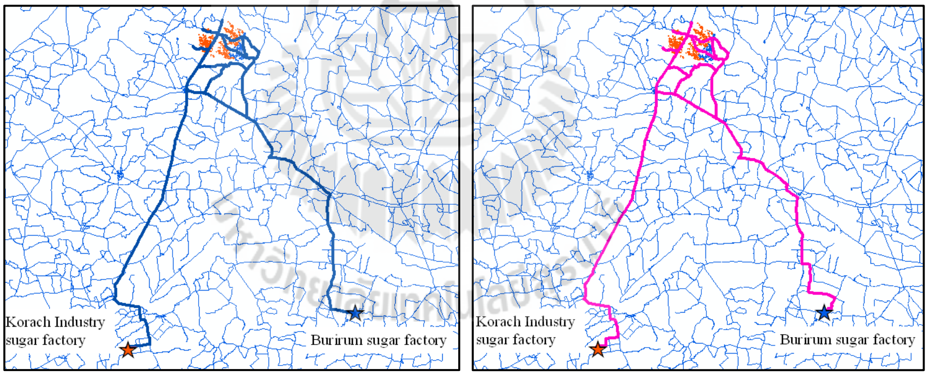
(a) the routes of this research (TC= 42,102,181.72)   (b) the routes for evaluation (TC= 42,102,181.72)

Centroids of cropping plots in Dan Khun Thot district in Nakhon Ratchasima province

Korach Industry sugar factory (Nakhon Ratchasima)   Road data

Transportation route of this research   Transportation route for evaluation case

Figure 4.38 Hypothesis evaluation of plot allotments in a district to one sugar factory with different transportation route: (a) the routes of this research, and (b) the routes changed for evaluation case.



(a) the routes of this research (TC= 12,564,278.35)   (b) the routes for evaluation (TC= 12,645,973.63)

Sugarcane cropping areas allocated to the Burirum sugar factory (Buri Ram)

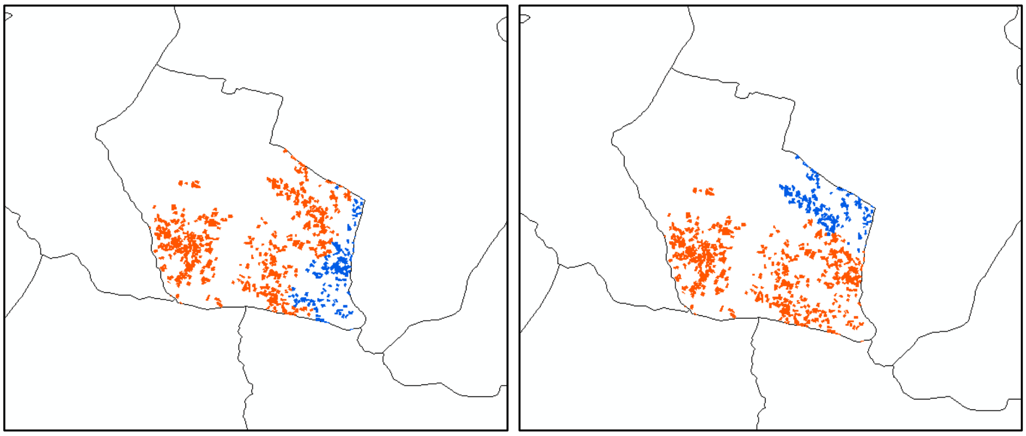
Sugarcane cropping areas allocated to the Korach Industry sugar factory (Nakhon Ratchasima)

Burirum Industry sugar factory (Buri Ram)   Korach Industry sugar factory (Nakhon Ratchasima)

Road data   Transportation route of this research

Transportation route for evaluation case

Figure 4.39 Hypothesis evaluation of plot allotments in a district to a set of sugar factories with different transportation routes: (a) the routes of this research, and (b) the routes changed for evaluation case.



(a) allotment pattern of the research

(TC= 12,564,278.35)

(b) allotment pattern of the evaluation case

(TC= 12,783,173.32)

Sugarcane cropping plots allocated to the Burirum sugar factory (Buri Ram)

Sugarcane cropping plots allocated to the Korach Industry sugar factory (Nakhon Ratchasima)

Boundary of districts

Figure 4.40 Hypothesis evaluation of changed plot allotment in a district to a set of sugar factories while factory allotments were kept the same: (a) allotment pattern of the research, and (b) allotment pattern of the evaluation case.

(2) The second hypothesis. There was the difference of allotments based on consideration with and without EI.

The results of the research revealed that the minimum TCs from both levels of both objectives with and without EI were different. The minimum TCs in district level of both objectives, single objective decision (without EI) and multi objectives decision (with EI), were 1,466,641,682.33 baht and 1,478,985,242.38 baht, respectively. The minimum TCs in plot level of both objectives, single objective decision (without EI) and multi objectives decision (with EI), were 1,551,454,082.19

baht and 1,570,661,893.68 baht, respectively. Therefore, the multi objectives decision with EI provides the higher minimum total TC than the ones without EI.

The results from the evaluation cases of both hypotheses were consistent with the research hypotheses. Therefore, the hypotheses of the research were accepted.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Currently, the sugarcane quota management has been carried out by an agreement between factories and leaders of sugarcane growers. The sugarcane transportation management has relied only on leader unsystematic decisions. The total cropping areas of the NE region have been the biggest compared to other regions. The locations of 16 sugar factories have been also randomly distributed in the region. The goal of the research was therefore to advise the method to optimize allotment pattern of sugarcane transportation from plots to factories. The optimization is to minimize the total TC alone for single objective function and minimize both TC and EI for multi objectives function.

Ideally, the optimized decision in sugarcane transportation management should deal with sugarcanes from all plots as origin points to 16 factories as destination points at once and the best result can be expected. Unfortunately, a number of plots existing in the region has been so tremendous amount that over the limitation of available software performance. To solve this foreseen problem, the analytical process was separated into 2 levels. The first level considered the whole region in district level. This consideration was to allot the sugarcane transportation from each district to all factories in the region. The results provided which factory(s) and how much the sugarcane productivity from the each district should be allotted to so as to meet both objective function requirements. The second level considered the sugarcane allotments and transportation routes from plots in district to a factory or a set of factories. This level used factory allotments from the first level result as input. The results provided which factory(s) and how much the sugarcane productivity from the each plot should be allotted to so as to meet both objectives function requirements.

The NA in the research was for selecting the shortest routes with and without EI considerations from the origins to factories. The LP analysis was for minimizing the total TC alone of single objective and minimizing both TC and EI for multi objectives. In this study, it was able to conclude that the NA and LP worked well for minimization sugarcane TC and TC including EI. For the first objective of the study, the minimum total TCs at district and plot levels were 1,466,641,682.33 baht and 1,551,454,082.19 baht, respectively. For the second objectives, the minimum total TCs at district and plot levels were 1,478,985,242.38 baht and 1,570,661,893.68 baht, respectively. In conclusion on different research objectives, some districts showed different sets of destinations/factories and some different allotments to factories. Being reasonable to the fact, the results from both steps of both objectives were consistent with the research hypotheses. The multi objectives decision with EI consideration required higher total TC than the single objective without EI. Adding EI caused the changes in transport routes and factories allotment that affected the total TC.

Two hypotheses of the study were evaluated and accepted. The first hypothesis, the cost of sugarcane transportation from each plot to factories achieved from the study is the minimum compared to other non-systematic transportation allotments. The second hypothesis, there is the difference of allotments based on consideration with and without EI. Some districts were selected as example cases to perform different transportation routes and allotments as described in chapter 4. The results of evaluation cases of both hypotheses were consistent with the research stated hypotheses. Therefore, the research hypotheses were theoretically and practically accepted.

This study was fruitfully successful in providing proper methods and techniques to optimize pattern of sugarcane transportation management from plots to factories when had to deal with huge amount of plots in the region. The optimization was to minimize the total TCs with and without EI considerations. The technique obtained using NA and LP of district and plot levels could solve problem on dealing with huge amounts of plots existing in the big region. The optimized transportation pattern resulted from using NA and MODA provided better result compared to any non-systematic methods. The transportation pattern achieved from the study could be applied to quota allotment from plots to certain sets of factories with acceptable benefit.

5.2 Recommendations

The recommendations could be made for properly management of sugarcane transportation in the future as the following.

(1) The study found that the data had much effects in this study was the vector-based road network. Invalid road network data layer could absolutely cause wrong shortage paths from the NA. Thus, GIS data checking process in term of topology must be performed carefully and seriously prior using for further analysis.

(2) Another conclusion draw from this study was that the centroids of the districts were obtained from the mean center method with weighting of plot productivity that might represent all sugarcane cropping plots. However, other methods for plot grouping are suggested to try. They might be more appropriate for a larger study area.

(3) If actual information on the sugarcane quota allotment is available, the comparison can provide more realistic result and can lead to benefit policy establishment.

(4) With EI consideration, if other practical EI information such as budget of environmental management and environmental monitoring of the organization, etc. are available, they should be brought to incorporate in the MODA. The more realistic result could be expected.

(5) Related hardware and software that support huge amounts of plot data could provide more precise and realistic results and reduce computing time.

REFERENCES

REFERENCES

ณัฐพร สุวรรณศูนย์. (2543). **ทำเลที่ตั้งและขนาดที่เหมาะสมของโรงงานน้ำตาลทรายในประเทศไทย**. วิทยานิพนธ์ปริญญามหาบัณฑิต คณะเกษตรศาสตร์ สาขาวิชาเศรษฐศาสตร์เกษตร มหาวิทยาลัยเชียงใหม่.

ไทยชูการ์ มิลเลอร์. (2553). รายชื่อโรงงานน้ำตาลและกลุ่มสมาชิก [ออนไลน์]. ได้จาก: http://www.thaisugarmillers.com/tsmc-01-05.html.

พรชัย ท้วมปาน. (2545). **โครงสร้างต้นทุนการขนส่งอ้อย**. วิทยานิพนธ์ปริญญามหาบัณฑิต ภาควิชาวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย.

ภูวนาท แสนนา และวรรธนะ กระภูพันธ์. (2550). **การวางแผนด้านพื้นที่และโครงข่ายการขนส่งเพื่อลดต้นทุน Logistics ของอุตสาหกรรมอ้อยและน้ำตาลทรายในภาคตะวันออกเฉียงเหนือ**. ภาควิชาวิศวกรรมอุตสาหการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยขอนแก่น.

สำนักงานคณะกรรมการอ้อยและน้ำตาลทราย. (2552). รายงานพื้นที่การปลูกอ้อย ปีการผลิต 2551/2552 [ออนไลน์]. ได้จาก: http://ocsb.go.th/uploads/contents/11/attachfiles/AreaCane Western2551-52.pdf.

สำนักวิเคราะห์ผลลกระทบสิ่งแวดล้อม. (ม.ป.ป.). รายงานการวิเคราะห์ผลกระทบสิ่งแวดล้อมโครงการโรงน้ำตาลวังขนาย [ออนไลน์]. ได้จาก: http://onep.go.th/eia/page2/km_HIA/ HIA_ other/wangkanan.doc.

Ayyasamy, P. M., Yasodha, R., Rajakumar, S., Lakshmanaperumalsamy, P., Rahman, P. K. S. M., and Lee, S. (2008). Impact of sugar factory effluent on the growth and biochemical characteristics of terrestrial and aquatic plants. **Bulletin of Environmental Contamination and Toxicology**. 81: 449-454.

Baruah, A. K., Sharma, R. N., and Borah, G. C. (1993). Impact of sugar mill and distillery effluent on water quality of river Galabil, Assam. **Indian Journal of Environmental Health**. 35: 288-293. quoted in Ayyasamy, P. M., *et al*. (2008). Impact of sugar factory effluent on the growth and biochemical characteristics of terrestrial and aquatic plants. **Bulletin of Environmental Contamination and Toxicology**. 81: 449-454.

Baskaran, L., Ganesh, K. S., Chidambaram, A. L. A., and Sundaramoorthy, P. (2009). Amelioration of sugar mill effluent polluted soil and its effect of greengram. **Botany Research International**. 2: 131-135.

Bazaraa, M. S., Jarvis, J. J., and Sherali, H. D. (1990). **Linear programming and network flows**. New York: John Wiley & Sons.

BusinessDictionary. (2010). Environmental impact [On-line]. Available: http:// businessdictionary.com/definition/environmental-impact.html.

Chang, T-K. (2002). **Introduction to geographical information systems**. New Delhi: Tata McGraw-hill.

Chansoontorn, W., Naksrimork, J., and Norasatworachai, P. (2010). Green Logistics contest 2010, case study of Sugar Co.,Ltd [On-line]. Available: http://www. greenlogisticsthai.org/attachments/article/63/Envirgreen.pdf.

Chen, Y-W., Wang, C-H., and Lin, S-J. (2008). A multi-objective geographic information system for route selection of nuclear waste transport. **Omega**. 36: 363-372.

ESRI. (2006). ArcMap 9.2 [Computer software]. New York: ESRI.

Evans, J. R. and Minieka, E. (1992). **Optimization algorithms for networks and graphs**. New York: Marcel dekker.

Herrera, C. M. (1999). Cane, sugar and the environment [On-line]. Available: http://fao.org/docrep/005/x4988e/x4988e01.htm.

Heywood, I., Cornelius, S., and Carver, S. (2002). **An introduction to geographical information systems**. England: Pearson Education.

Keshkamat, S. S., Looijen, J. M., and Zuidgeest, M. H. P. (2009). The formulation and evaluation of transport route planning alternatives: a spatial decision support system for the Via Baltica project, Poland. **Journal of Transport Geography**. 17: 54-64.

Malczewski, J. (1999). **GIS and multi criteria decision analysis**. New York: John Wiley & Sons.

Milan, E. L., Fernandez, S. M., and Aragones, L. M. P. (2006). Sugar cane transportation in Cuba, a case study. **European Journal of Operational Research.** 174: 374-386.

Monprapussorn, S., Thaitakoo, D., Banomyong, R., and Watts, D. J. (2007). The application of geographic information system and multi criteria decision analysis: toward hazardous waste transport sustainability. **International Society for Environmental Information Sciences**. 5: 480-487.

Nagar, A. and Tawfik, H. (2007). A multi-criteria based approach to prototyping urban road networks. **Informing Science and Information Technology**. 4: 749-756.

Ozkan, L., Erguder, T. H., and Demirer, G. N. (2010). Investigation of the effect of culture type on biological hydrogen production from sugar industry wastes. **Waste Management**. 30: 192-198.

Paiva, R. P. O. and Morabito, R. (2009). An optimization model for the aggregate production planning of a Brazilian sugar and ethanol milling company. **Annals of Operations Research.** 169: 117-130.

Ping, W. X., Fang, C. X., Qun, M. C., Yu, Y. X., Ping, R. M., and Ding, M. X. (2004). Comprehensive assessment method for environmental impact of railway based on geographic information system. **Journal of Central South University of Technology**. 11: 340-342.

Pontawepitanun, N. (2004). **Geo-Informatics for sugar cane industry zoning in Eastern Thailand.** M.S. Thesis, Mahidol University, Thailand.

Scarpari, M. S. and Beauclair, E. G. F. (2010) Optimized agricultural planning of sugarcane using linear programming. **Revista Investigacion Operacional.** 31(2): 126-132.

Solomon, K. S. (2005). Environmental pollution and sugar industry in India its management in: an appraisal. **Sugar Technology**. 7: 77-81.

Verbyla, L. D. (2002). **Practical GIS analysis**. London: Taylor & Francis.

Wei, Y-A. and Xu, Y-J. (2004). Eco-friendly management of sugar industry effluents in Guangxi, China. **Sugar Tech**. 6: 285-290.

Zhou, Z. and Ping, W. J. (2009). Evaluation of the current situation and planning of the greenspace system in Huaibei city using GIS based network analysis. **Management and Service Science**. 9: 1-4.

APPENDICES

APPENDIX A

QUESTIONNAIRE

แบบสอบถามงานวิจัย เรื่อง

ความคิดเห็นของผู้เชี่ยวชาญในการจัดลำดับความสำคัญมาตรฐานอุตสาหกรรม ที่มีผลต่อสิ่งแวดล้อม

วัตถุประสงค์ แบบสอบถามงานวิจัยฉบับนี้มีวัตถุประสงค์เพื่อศึกษาความคิดเห็นของผู้เชี่ยวชาญในเรื่องการจัดลำดับความสำคัญมาตรฐานอุตสาหกรรมต่างๆ ที่มีผลต่อสิ่งแวดล้อม เพื่อนำมาประยุกต์ใช้ในการทำวิทยานิพนธ์เรื่อง การจัดการการขนส่งอ้อยโดยใช้การวิเคราะห์โครงข่ายและการตัดสินใจแบบหลายวัตถุประสงค์ จึงใคร่ขอความร่วมมือจากท่าน

<u>ตอนที่ 1</u> ข้อมูลพื้นฐาน เกี่ยวกับผู้ตอบแบบสอบถาม

คำชี้แจง โปรดทำเครื่องหมาย ✓ ลงในช่อง ☐ หน้าข้อความที่ตรงกับสภาพความเป็นจริงของท่าน หรือเติมข้อความลงในช่องว่างที่กำหนด

1. สถานะ

☐ บัณฑิตศึกษา/ดุษฎีบัณฑิต คณะ/สาขา...

☐ พนักงาน

☐ อื่น (โปรดระบุ)..

2. ท่านทำงานในฝ่ายงานใด

☐ วิศวกรรมอุตสาหการ ☐ วิศวกรรมสิ่งแวดล้อม ☐ อนามัยสิ่งแวดล้อม

☐ อาชีวอนามัยและความปลอดภัย ☐ อื่น (โปรดระบุ)...

3. ที่ทำงานของท่านประกอบกิจการด้านใด

☐ การศึกษา ☐ ผลิตอาหาร

☐ อื่น (โปรดระบุ)..

<u>ตอนที่ 2</u> ความคิดเห็นด้านความสำคัญของมาตรฐานอุตสาหกรรมต่างๆ ที่มีผลต่อสิ่งแวดล้อม

คำชี้แจง โปรดทำเครื่องหมาย ✓ ลงในช่องว่างที่ตรงกับความคิดเห็นของท่านมากที่สุด

5 = สำคัญมากที่สุด 4 = สำคัญมาก 3 = สำคัญปานกลาง 2 = สำคัญน้อย 1 = ไม่สำคัญ

ความคิดเห็นด้านความสำคัญของมาตรฐานอุตสาหกรรมต่างๆ ที่มีผลต่อสิ่งแวดล้อม	ความสำคัญ					หมายเหตุ
	มากที่สุด (5)	มาก (4)	ปานกลาง (3)	น้อย (2)	ไม่สำคัญ (1)	
1. ISO 9000						
2. ISO 9000 : 2008						
3. ISO 9001						
4. ISO 9001 : 2000						
5. ISO 9002						
6. ISO 14001						
7. ISO 14001 : 2004						
8. GMP						
9. HACCP						
10. HALAL						
11. Kosher						
12. มอก.						
13. ไทยแลนด์แบรนด์						
14. กรมส่งเสริมการส่งออก						

<u>หมายเหตุ :</u> แต่ละมาตรฐานเป็นระเบียบตรวจสอบที่ต่างกันในแต่ละด้าน ดังนี้

1. ISO 9000 การจัดการทางด้านคุณภาพและการประกันคุณภาพ
2. ISO 9000 : 2008 มาตรฐานโดยทั่วไปสำหรับการจัดการคุณภาพ แต่ก็มีการเปลี่ยนแปลงบางอย่าง การเปลี่ยนแปลงที่เห็นได้ชัดนั้นเกี่ยวกับโครงสร้างใหม่ของระบบ ISO 9000 โดยเฉพาะอย่างยิ่งได้เลิกใช้ ISO 9002 และ ISO 9003 (ทุกองค์กรจะใช้ ISO 9001 แทน)
3. ISO 9001 ถูกพัฒนาขึ้นเป็นระบบมาตรฐานสากลเพื่อที่จะทำให้มั่นใจได้ว่าผู้ผลิตหรือผู้ให้บริการได้จัดตั้งและรักษาระบบการจัดการด้านคุณภาพที่เป็นมาตรฐานเดียวกัน โดยมีจุดประสงค์ที่จะตอบสนองความต้องการของลูกค้าให้ดียิ่งขึ้น โดยมาตรฐานนี้เกี่ยวกับ การออกแบบ การพัฒนา การผลิต และการให้บริการ
4. ISO 9001 : 2000 มาตราฐานสำหรับระบบบริหารคุณภาพซึ่งมุงเนนใหมีโครงสรางการบริหารเพื่อใหลูกคามีความพอใจสูงสุด
5. ISO 9002 เหมือน ISO 9001 แต่ไม่มีข้อกำหนดที่ว่าด้วยการควบคุมการออกแบบ เท่านั้น
6. ISO 14001 มาตรฐานระดับสากลสำหรับระบบการจัดการสิ่งแวดล้อม (EMS)
7. ISO 14001 : 2004 มาตรฐานการจัดการสิ่งแวดล้อม เป็นแนวทางในการจัดการลักษณะปัญหาสิ่งแวดล้อม (Environmental aspects) ขององค์กรได้อย่างมีประสิทธิภาพควบคู่ไปกับการรักษาสิ่งแวดล้อม การป้องกันมลพิษ และความต้องการทางด้านเศรษฐกิจและสังคมข้อมูลพื้นฐาน.
8. GMP (Good Manufacturing Practice) ระบบสุขลักษณะโรงงานอุตสาหกรรมอาหาร
9. HACCP (Hazard Analysis and Critical Control Point) ระบบการจัดการคุณภาพด้านความปลอดภัย ซึ่งใช้ในการควบคุมกระบวนการผลิตให้ได้อาหารที่ปราศจากอันตรายจากเชื้อจุลินทรีย์ สารเคมี และสิ่งแปลกปลอมต่าง ๆ
10. HALAL กระบวนการผลิตตั้งแต่เริ่มต้นถึงสิ้นสุด ตลอด "สายโซ่การผลิต" จะต้อง "ฮาลาล" คือถูกต้องตามบัญญัติศาสนาอิสลาม
11. Kosher อาหารนั้นเป็นไปตามหลักศาสนาและยอมรับตามศาสนายิว
12. มอก. มาตรฐานผลิตภัณฑ์อุตสาหกรรม

APPENDIX B

NORMALIZATION THE DATA LAYERS OF

ENVIRONMENTAL IMPACTS

Table B.1 Normalized of the environmental impacts caused by the routes of transportation (score 0-1).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Kranuan	1	0.10	0.13	0.06	0.17	0.38	0.27	0.18	0.27	0.33	0.16	0.42	0.56	0.44	0.60	0.26	0.14
Krasang	2	0.53	0.53	0.45	0.61	0.11	0.40	0.45	0.48	0.32	0.30	0.51	0.13	0.21	0.30	0.64	0.51
Kap Choeng	3	0.65	0.67	0.59	0.72	0.27	0.48	0.59	0.62	0.48	0.44	0.55	0.08	0.36	0.37	0.78	0.60
Kut Rang	4	0.27	0.26	0.18	0.35	0.20	0.27	0.19	0.24	0.18	0.05	0.41	0.40	0.29	0.45	0.37	0.28
Ku Kaeo	5	0.06	0.09	0.15	0.08	0.47	0.27	0.27	0.36	0.43	0.25	0.40	0.65	0.53	0.70	0.28	0.10
Khewa Sinarin	6	0.51	0.52	0.44	0.58	0.13	0.33	0.45	0.47	0.33	0.29	0.43	0.14	0.30	0.39	0.63	0.46
Khaen Dong	7	0.45	0.43	0.35	0.53	0.01	0.38	0.35	0.38	0.23	0.23	0.50	0.24	0.19	0.32	0.54	0.46
Khok Pho Chai	8	0.30	0.26	0.20	0.38	0.30	0.39	0.10	0.12	0.10	0.19	0.54	0.51	0.28	0.41	0.30	0.37
Chuen Chom	9	0.15	0.18	0.10	0.23	0.32	0.22	0.18	0.27	0.30	0.10	0.37	0.50	0.41	0.57	0.31	0.15
Sap Yai	10	0.51	0.48	0.41	0.59	0.40	0.60	0.30	0.26	0.17	0.40	0.75	0.54	0.28	0.33	0.46	0.58
Sam Sung	11	0.13	0.15	0.07	0.20	0.33	0.25	0.17	0.25	0.29	0.11	0.40	0.51	0.40	0.56	0.28	0.17
Don Chan	12	0.25	0.28	0.24	0.27	0.37	0.09	0.30	0.38	0.40	0.17	0.23	0.49	0.49	0.66	0.45	0.14
Thepharak	13	0.58	0.54	0.48	0.66	0.40	0.66	0.37	0.35	0.24	0.45	0.81	0.51	0.28	0.27	0.55	0.65
Na Khu	14	0.25	0.28	0.32	0.26	0.46	0.09	0.40	0.48	0.50	0.28	0.19	0.56	0.59	0.76	0.48	0.14
Non Narai	15	0.50	0.53	0.45	0.58	0.19	0.33	0.47	0.52	0.37	0.31	0.40	0.23	0.37	0.48	0.65	0.45
Non Sila	16	0.30	0.26	0.20	0.38	0.19	0.34	0.18	0.21	0.11	0.12	0.48	0.40	0.22	0.38	0.37	0.35
Bua Lai	17	0.38	0.34	0.27	0.46	0.20	0.42	0.25	0.26	0.07	0.21	0.57	0.39	0.17	0.33	0.45	0.43
Ban Dan	18	0.47	0.46	0.38	0.54	0.02	0.36	0.37	0.40	0.25	0.24	0.49	0.22	0.19	0.32	0.56	0.46
Ban Haet	19	0.24	0.21	0.14	0.32	0.24	0.32	0.13	0.20	0.16	0.11	0.47	0.45	0.27	0.43	0.31	0.29
Prachak Sinlapakhom	20	0.06	0.06	0.14	0.08	0.50	0.34	0.25	0.33	0.41	0.29	0.47	0.70	0.52	0.69	0.21	0.17
Fao Rai	21	0.23	0.25	0.33	0.15	0.67	0.44	0.44	0.48	0.61	0.45	0.47	0.85	0.71	0.88	0.34	0.29
Phanom Dong Rak	22	0.68	0.67	0.59	0.76	0.25	0.51	0.59	0.62	0.45	0.46	0.60	0.05	0.32	0.31	0.77	0.64
Phra Thongkham	23	0.49	0.45	0.38	0.57	0.29	0.54	0.28	0.28	0.11	0.32	0.68	0.43	0.17	0.26	0.47	0.54
Pho Tak	24	0.27	0.26	0.32	0.26	0.67	0.54	0.34	0.36	0.52	0.47	0.67	0.87	0.69	0.84	0.16	0.37
Lam Thamenchai	25	0.46	0.43	0.36	0.53	0.06	0.38	0.35	0.36	0.18	0.24	0.52	0.27	0.15	0.30	0.54	0.46
Si Narong	26	0.59	0.62	0.54	0.67	0.23	0.42	0.55	0.58	0.43	0.39	0.45	0.15	0.39	0.44	0.73	0.54
Sa Khrai	27	0.20	0.19	0.25	0.19	0.61	0.47	0.28	0.31	0.47	0.41	0.59	0.81	0.64	0.79	0.13	0.30

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Sam Chai	28	0.12	0.15	0.18	0.16	0.46	0.17	0.31	0.39	0.44	0.24	0.30	0.60	0.55	0.72	0.34	0.02
Nong Na Kham	29	0.25	0.21	0.16	0.29	0.45	0.43	0.08	0.13	0.27	0.25	0.58	0.65	0.45	0.59	0.11	0.34
Nong Hin	30	0.36	0.33	0.28	0.38	0.55	0.57	0.22	0.17	0.35	0.39	0.72	0.76	0.53	0.67	0.12	0.45
Erawan	31	0.30	0.28	0.27	0.32	0.58	0.56	0.21	0.20	0.39	0.38	0.71	0.78	0.57	0.70	0.07	0.41
Kuchi Narai	32	0.27	0.29	0.29	0.29	0.40	0.02	0.37	0.45	0.46	0.24	0.17	0.49	0.52	0.70	0.49	0.15
Kut Khao Pun	33	0.54	0.57	0.56	0.57	0.51	0.30	0.62	0.70	0.61	0.47	0.17	0.51	0.64	0.78	0.77	0.43
Kut Chap	34	0.17	0.15	0.22	0.18	0.57	0.44	0.24	0.27	0.43	0.38	0.57	0.78	0.60	0.74	0.09	0.28
Kut Chum	35	0.43	0.46	0.39	0.46	0.37	0.16	0.44	0.53	0.48	0.31	0.18	0.43	0.51	0.67	0.59	0.32
Kut Bak	36	0.22	0.25	0.31	0.15	0.54	0.19	0.43	0.52	0.56	0.33	0.26	0.66	0.66	0.83	0.41	0.16
Kumphawapi	37	0.02	0.01	0.09	0.11	0.45	0.30	0.20	0.28	0.37	0.24	0.43	0.65	0.47	0.64	0.22	0.13
Kaset Sombun	38	0.35	0.32	0.26	0.44	0.40	0.48	0.13	0.06	0.17	0.28	0.63	0.60	0.35	0.48	0.27	0.43
Kaeng Khro	39	0.30	0.27	0.21	0.39	0.32	0.40	0.08	0.08	0.12	0.20	0.55	0.53	0.30	0.43	0.28	0.38
Kaeng Sanam Nang	40	0.40	0.37	0.30	0.49	0.25	0.45	0.21	0.21	0.02	0.24	0.60	0.44	0.18	0.32	0.40	0.45
Kosum Phisai	41	0.25	0.22	0.14	0.33	0.23	0.26	0.15	0.22	0.21	0.04	0.40	0.43	0.31	0.48	0.32	0.26
Kham Thale So	42	0.56	0.53	0.46	0.64	0.31	0.58	0.37	0.37	0.20	0.40	0.72	0.38	0.14	0.16	0.57	0.61
Kham Sakae Saeng	43	0.46	0.43	0.36	0.55	0.27	0.51	0.26	0.26	0.09	0.30	0.66	0.41	0.15	0.26	0.46	0.51
Khukhan	44	0.63	0.66	0.58	0.71	0.31	0.42	0.62	0.65	0.51	0.47	0.45	0.19	0.45	0.48	0.79	0.59
Khun Han	45	0.67	0.70	0.61	0.74	0.34	0.46	0.66	0.68	0.54	0.50	0.49	0.21	0.47	0.50	0.82	0.62
Khemarat	46	0.51	0.53	0.53	0.53	0.51	0.26	0.59	0.67	0.62	0.45	0.13	0.56	0.65	0.81	0.73	0.39
Khao Wong	47	0.27	0.30	0.32	0.30	0.42	0.04	0.39	0.47	0.48	0.26	0.17	0.51	0.54	0.72	0.50	0.16
Khao Suan Kwang	48	0.09	0.06	0.06	0.18	0.42	0.35	0.14	0.23	0.32	0.21	0.48	0.62	0.44	0.61	0.21	0.18
Khong	49	0.44	0.41	0.34	0.53	0.27	0.49	0.24	0.24	0.07	0.28	0.64	0.41	0.15	0.27	0.44	0.49
Khon Buri	50	0.65	0.62	0.55	0.73	0.29	0.65	0.49	0.49	0.32	0.49	0.78	0.29	0.19	0.03	0.69	0.70
Khon Sawan	51	0.35	0.32	0.25	0.44	0.27	0.44	0.14	0.14	0.06	0.24	0.59	0.48	0.24	0.37	0.34	0.42
Khon San	52	0.35	0.32	0.26	0.43	0.43	0.48	0.13	0.07	0.22	0.30	0.63	0.63	0.41	0.54	0.25	0.44
Kham Cha-I	53	0.32	0.35	0.38	0.33	0.49	0.11	0.46	0.54	0.55	0.33	0.12	0.58	0.62	0.79	0.55	0.21
Kham Ta Kla	54	0.24	0.26	0.34	0.14	0.66	0.37	0.45	0.52	0.62	0.44	0.39	0.82	0.73	0.89	0.39	0.24

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Kham Muang	55	0.14	0.17	0.21	0.16	0.46	0.15	0.33	0.42	0.47	0.25	0.28	0.59	0.58	0.74	0.37	0.03
Khu Mueang	56	0.47	0.45	0.37	0.54	0.01	0.39	0.36	0.39	0.23	0.25	0.52	0.22	0.17	0.30	0.55	0.47
Chom Phra	57	0.49	0.51	0.42	0.56	0.11	0.31	0.43	0.46	0.32	0.27	0.41	0.18	0.29	0.40	0.61	0.44
Chakkarat	58	0.53	0.50	0.43	0.62	0.17	0.53	0.40	0.40	0.21	0.37	0.67	0.25	0.05	0.18	0.59	0.58
Chatturat	59	0.50	0.46	0.40	0.58	0.36	0.59	0.29	0.27	0.16	0.39	0.74	0.49	0.24	0.29	0.47	0.57
Charoen Sin	60	0.20	0.22	0.30	0.10	0.63	0.37	0.41	0.47	0.58	0.41	0.41	0.80	0.69	0.85	0.33	0.22
Chaloem Phrakiat	61	0.54	0.50	0.43	0.62	0.22	0.55	0.40	0.40	0.22	0.37	0.69	0.29	0.06	0.14	0.59	0.59
Chonnabot	62	0.30	0.27	0.20	0.39	0.22	0.36	0.19	0.22	0.12	0.14	0.50	0.43	0.23	0.39	0.37	0.35
Chanuman	63	0.50	0.53	0.51	0.52	0.48	0.25	0.56	0.65	0.59	0.43	0.13	0.54	0.62	0.78	0.71	0.39
Chamni	64	0.57	0.54	0.47	0.65	0.15	0.50	0.44	0.45	0.26	0.36	0.63	0.18	0.12	0.19	0.64	0.58
Chum Phuang	65	0.46	0.43	0.36	0.55	0.12	0.43	0.34	0.36	0.18	0.26	0.57	0.28	0.10	0.26	0.53	0.49
Chum Phae	66	0.32	0.29	0.23	0.36	0.43	0.45	0.10	0.05	0.23	0.27	0.60	0.64	0.41	0.55	0.17	0.40
Chiang Yuen	67	0.17	0.18	0.09	0.24	0.29	0.21	0.15	0.23	0.27	0.07	0.36	0.47	0.38	0.54	0.29	0.18
Chok Chai	68	0.58	0.55	0.48	0.67	0.26	0.60	0.42	0.42	0.25	0.42	0.74	0.32	0.11	0.09	0.62	0.63
Chaiwan	69	0.07	0.09	0.16	0.05	0.48	0.28	0.28	0.37	0.44	0.26	0.41	0.66	0.54	0.71	0.27	0.11
Seka	70	0.31	0.33	0.41	0.21	0.73	0.38	0.52	0.59	0.69	0.51	0.40	0.85	0.79	0.96	0.45	0.31
So Phisai	71	0.27	0.29	0.38	0.20	0.71	0.47	0.48	0.51	0.65	0.49	0.50	0.90	0.76	0.92	0.36	0.33
Dong Luang	72	0.34	0.37	0.41	0.33	0.52	0.14	0.49	0.57	0.58	0.35	0.09	0.61	0.64	0.81	0.57	0.23
Don Tan	73	0.43	0.46	0.46	0.46	0.47	0.19	0.51	0.60	0.58	0.38	0.07	0.54	0.61	0.77	0.66	0.32
Dan Khun Thot	74	0.57	0.54	0.47	0.66	0.37	0.63	0.36	0.34	0.20	0.41	0.77	0.48	0.24	0.24	0.55	0.63
Trakan Phuet Phon	75	0.61	0.64	0.63	0.63	0.57	0.36	0.69	0.77	0.68	0.53	0.24	0.56	0.71	0.83	0.84	0.49
Tao Ngoi	76	0.26	0.28	0.32	0.26	0.48	0.10	0.41	0.49	0.51	0.29	0.17	0.57	0.61	0.78	0.48	0.14
Sai Mun	77	0.39	0.41	0.33	0.44	0.32	0.14	0.39	0.47	0.43	0.24	0.21	0.39	0.46	0.62	0.54	0.31
Tha Khantho	78	0.07	0.10	0.11	0.14	0.40	0.25	0.24	0.32	0.38	0.18	0.38	0.57	0.49	0.65	0.30	0.08
Tha Tum	79	0.47	0.50	0.41	0.55	0.12	0.30	0.42	0.45	0.30	0.26	0.39	0.20	0.29	0.41	0.60	0.43
Tha Bo	80	0.21	0.20	0.27	0.20	0.63	0.48	0.30	0.33	0.49	0.42	0.60	0.83	0.65	0.80	0.14	0.32
Tha Uthen	81	0.36	0.39	0.47	0.27	0.70	0.32	0.57	0.65	0.72	0.49	0.28	0.79	0.82	0.99	0.52	0.32

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Thung Fon	82	0.11	0.14	0.22	0.04	0.55	0.33	0.32	0.40	0.49	0.33	0.45	0.73	0.60	0.76	0.26	0.18
Thep Sathit	83	0.57	0.54	0.47	0.66	0.46	0.67	0.36	0.32	0.23	0.46	0.81	0.59	0.34	0.35	0.53	0.64
Thai Charoen	84	0.41	0.44	0.38	0.43	0.37	0.15	0.44	0.52	0.47	0.30	0.14	0.43	0.51	0.66	0.59	0.29
That Phanom	85	0.41	0.44	0.47	0.37	0.55	0.20	0.54	0.62	0.63	0.40	0.05	0.62	0.69	0.85	0.63	0.29
Na Klang	86	0.24	0.22	0.21	0.25	0.55	0.50	0.20	0.21	0.38	0.35	0.64	0.75	0.56	0.70	0.00	0.34
Na Kae	87	0.34	0.37	0.40	0.29	0.56	0.18	0.49	0.57	0.59	0.37	0.13	0.65	0.69	0.86	0.55	0.22
Nang Rong	88	0.61	0.57	0.50	0.69	0.18	0.54	0.48	0.49	0.30	0.39	0.67	0.18	0.16	0.16	0.68	0.62
Na Chueak	89	0.32	0.32	0.24	0.39	0.15	0.29	0.24	0.27	0.17	0.09	0.44	0.34	0.25	0.42	0.42	0.32
Na Duang	90	0.32	0.30	0.29	0.33	0.63	0.58	0.26	0.24	0.42	0.43	0.72	0.83	0.61	0.74	0.08	0.42
Na Dun	91	0.32	0.32	0.24	0.40	0.16	0.25	0.25	0.32	0.22	0.09	0.40	0.32	0.27	0.45	0.43	0.32
Na Thom	92	0.36	0.39	0.47	0.27	0.74	0.36	0.57	0.65	0.73	0.52	0.34	0.83	0.84	1.00	0.51	0.32
Na Pho	93	0.34	0.31	0.24	0.42	0.13	0.32	0.23	0.26	0.13	0.12	0.47	0.34	0.22	0.39	0.42	0.35
Na Mon	94	0.23	0.26	0.25	0.26	0.39	0.07	0.32	0.40	0.42	0.19	0.21	0.51	0.51	0.68	0.46	0.12
Na Yung	95	0.29	0.28	0.33	0.28	0.66	0.56	0.33	0.34	0.52	0.47	0.69	0.87	0.69	0.83	0.14	0.39
Na Wang	96	0.28	0.26	0.26	0.30	0.59	0.55	0.22	0.21	0.40	0.39	0.68	0.79	0.58	0.71	0.04	0.39
Nam Phong	97	0.12	0.09	0.01	0.21	0.37	0.30	0.14	0.23	0.30	0.16	0.45	0.57	0.40	0.57	0.22	0.17
Nam Som	98	0.29	0.27	0.30	0.29	0.63	0.56	0.30	0.32	0.49	0.44	0.69	0.84	0.66	0.80	0.11	0.39
Nikhom Kham Soi	99	0.38	0.41	0.39	0.41	0.44	0.14	0.45	0.53	0.54	0.32	0.07	0.50	0.58	0.73	0.60	0.27
Nikhom Nam Un	100	0.21	0.24	0.29	0.14	0.57	0.22	0.42	0.50	0.55	0.35	0.29	0.70	0.66	0.82	0.39	0.14
Noen Sa-Nga	101	0.46	0.43	0.36	0.55	0.29	0.51	0.25	0.25	0.09	0.30	0.66	0.45	0.19	0.29	0.45	0.51
Non Din Daeng	102	0.69	0.65	0.59	0.77	0.25	0.58	0.56	0.58	0.40	0.47	0.69	0.18	0.26	0.19	0.76	0.68
Non Thai	103	0.49	0.46	0.39	0.58	0.26	0.53	0.29	0.29	0.12	0.33	0.67	0.40	0.14	0.22	0.49	0.54
Non Sa-At	104	0.06	0.03	0.07	0.15	0.43	0.32	0.17	0.26	0.35	0.22	0.45	0.63	0.45	0.62	0.23	0.15
Non Sang	105	0.22	0.18	0.13	0.28	0.47	0.43	0.11	0.15	0.30	0.27	0.58	0.67	0.48	0.61	0.12	0.31
Non Suwan	106	0.63	0.60	0.53	0.72	0.23	0.57	0.50	0.50	0.32	0.44	0.69	0.20	0.16	0.11	0.70	0.66
Borabue	107	0.27	0.27	0.19	0.35	0.20	0.25	0.20	0.26	0.20	0.04	0.40	0.39	0.30	0.47	0.37	0.27
Bua Chet	108	0.66	0.69	0.61	0.73	0.30	0.48	0.62	0.64	0.50	0.46	0.52	0.15	0.41	0.44	0.80	0.61

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Bua Yai	109	0.42	0.38	0.32	0.50	0.22	0.45	0.22	0.22	0.04	0.26	0.59	0.41	0.16	0.31	0.41	0.47
Ban Kruat	110	0.65	0.64	0.56	0.72	0.21	0.54	0.55	0.58	0.41	0.42	0.64	0.12	0.27	0.24	0.74	0.64
Ban Khwao	111	0.46	0.42	0.35	0.54	0.35	0.55	0.24	0.19	0.12	0.34	0.70	0.55	0.29	0.38	0.39	0.52
Ban Dung	112	0.16	0.18	0.27	0.09	0.60	0.38	0.37	0.42	0.54	0.38	0.45	0.78	0.65	0.81	0.27	0.23
Ban Thaen	113	0.26	0.23	0.17	0.35	0.32	0.39	0.04	0.07	0.15	0.18	0.53	0.53	0.33	0.46	0.24	0.35
Ban Phue	114	0.21	0.20	0.27	0.21	0.61	0.49	0.28	0.31	0.47	0.42	0.62	0.81	0.63	0.78	0.10	0.32
Ban Phai	115	0.28	0.25	0.18	0.37	0.20	0.30	0.17	0.20	0.15	0.09	0.45	0.41	0.26	0.42	0.35	0.31
Ban Fang	116	0.18	0.14	0.08	0.26	0.35	0.32	0.05	0.13	0.22	0.15	0.46	0.55	0.37	0.53	0.21	0.26
Ban Phaeng	117	0.35	0.38	0.46	0.26	0.73	0.35	0.57	0.64	0.72	0.52	0.34	0.82	0.83	0.99	0.51	0.32
Ban Muang	118	0.22	0.24	0.33	0.14	0.67	0.40	0.44	0.48	0.60	0.44	0.43	0.84	0.71	0.87	0.34	0.26
Ban Lueam	119	0.42	0.39	0.32	0.50	0.25	0.47	0.22	0.22	0.05	0.26	0.62	0.43	0.17	0.29	0.42	0.47
Bamnet Narong	120	0.53	0.49	0.42	0.61	0.38	0.62	0.32	0.29	0.19	0.41	0.77	0.51	0.25	0.29	0.50	0.59
Bueng Kan	121	0.32	0.35	0.43	0.23	0.75	0.42	0.53	0.60	0.70	0.53	0.43	0.89	0.81	0.97	0.46	0.32
Bueng Khong Long	122	0.32	0.35	0.43	0.23	0.75	0.37	0.54	0.61	0.70	0.53	0.38	0.84	0.81	0.97	0.47	0.33
Pathum Ratchawongsa	123	0.54	0.57	0.53	0.57	0.48	0.30	0.59	0.67	0.58	0.44	0.17	0.52	0.61	0.77	0.74	0.43
Prakhon Chai	124	0.65	0.63	0.55	0.72	0.21	0.54	0.54	0.56	0.38	0.42	0.64	0.14	0.24	0.22	0.74	0.64
Prang Ku	125	0.59	0.62	0.54	0.66	0.24	0.39	0.55	0.58	0.44	0.40	0.42	0.17	0.40	0.46	0.74	0.54
Prasat	126	0.63	0.64	0.56	0.71	0.22	0.46	0.56	0.59	0.42	0.41	0.56	0.01	0.29	0.30	0.74	0.59
Pakham	127	0.67	0.64	0.57	0.75	0.24	0.58	0.54	0.56	0.38	0.45	0.70	0.20	0.23	0.15	0.74	0.67
Pak Thong Chai	128	0.64	0.60	0.53	0.72	0.33	0.66	0.45	0.45	0.28	0.47	0.79	0.37	0.19	0.08	0.65	0.69
Pak Khat	129	0.30	0.32	0.41	0.22	0.75	0.47	0.51	0.54	0.68	0.52	0.49	0.92	0.79	0.95	0.39	0.33
Pak Chong	130	0.72	0.69	0.62	0.80	0.42	0.74	0.51	0.49	0.35	0.56	0.88	0.46	0.28	0.15	0.70	0.77
Pa Tio	131	0.45	0.47	0.42	0.47	0.36	0.19	0.48	0.56	0.47	0.33	0.16	0.42	0.50	0.66	0.63	0.33
Pueai Noi	132	0.32	0.29	0.22	0.41	0.17	0.32	0.21	0.24	0.13	0.12	0.47	0.37	0.24	0.40	0.39	0.34
Pha Khao	133	0.33	0.30	0.25	0.35	0.55	0.54	0.19	0.17	0.35	0.36	0.69	0.76	0.54	0.67	0.10	0.43
Phon Charoen	134	0.30	0.32	0.41	0.21	0.74	0.44	0.52	0.56	0.68	0.51	0.47	0.90	0.79	0.95	0.42	0.31
Phanna Nikhom	135	0.24	0.27	0.33	0.16	0.60	0.25	0.45	0.54	0.59	0.38	0.28	0.72	0.69	0.86	0.41	0.18

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Phra Yuen	136	0.23	0.20	0.13	0.32	0.32	0.33	0.05	0.13	0.17	0.14	0.48	0.52	0.33	0.49	0.24	0.30
Phon	137	0.32	0.29	0.22	0.40	0.19	0.37	0.20	0.22	0.08	0.16	0.52	0.39	0.19	0.36	0.39	0.37
Phang Khon	138	0.22	0.25	0.30	0.14	0.58	0.23	0.43	0.51	0.56	0.36	0.29	0.70	0.67	0.83	0.40	0.16
Phibun Rak	139	0.11	0.12	0.20	0.08	0.56	0.36	0.31	0.35	0.47	0.34	0.49	0.75	0.58	0.75	0.22	0.21
Phimai	140	0.48	0.45	0.38	0.56	0.15	0.47	0.35	0.35	0.16	0.31	0.61	0.29	0.03	0.23	0.54	0.53
Phen	141	0.15	0.15	0.24	0.12	0.59	0.40	0.34	0.37	0.51	0.38	0.50	0.78	0.62	0.78	0.21	0.25
Pho Chai	142	0.29	0.32	0.25	0.31	0.34	0.10	0.31	0.39	0.40	0.17	0.25	0.46	0.47	0.64	0.46	0.18
Pho Sai	143	0.61	0.64	0.63	0.63	0.57	0.36	0.69	0.77	0.68	0.53	0.24	0.56	0.71	0.83	0.84	0.49
Phon Thong	144	0.31	0.34	0.27	0.34	0.36	0.03	0.33	0.41	0.42	0.20	0.20	0.47	0.49	0.66	0.48	0.20
Phon Phisai	145	0.21	0.23	0.31	0.14	0.65	0.42	0.42	0.47	0.59	0.43	0.47	0.83	0.70	0.86	0.32	0.27
Phon Sawan	146	0.37	0.39	0.48	0.28	0.69	0.31	0.58	0.66	0.72	0.49	0.27	0.78	0.82	0.99	0.52	0.33
Phrai Bueng	147	0.64	0.67	0.59	0.72	0.33	0.43	0.65	0.67	0.53	0.48	0.46	0.20	0.46	0.49	0.80	0.59
Phakdi Chumphon	148	0.49	0.46	0.40	0.58	0.44	0.62	0.27	0.21	0.21	0.42	0.77	0.64	0.38	0.47	0.42	0.58
Phu Kradueng	149	0.32	0.29	0.24	0.34	0.50	0.51	0.17	0.11	0.30	0.34	0.66	0.71	0.48	0.61	0.16	0.41
Phu Khiao	150	0.31	0.28	0.22	0.40	0.37	0.44	0.09	0.02	0.17	0.25	0.59	0.58	0.35	0.48	0.22	0.40
Phu Pha Man	151	0.35	0.32	0.26	0.38	0.46	0.48	0.13	0.08	0.26	0.31	0.63	0.67	0.44	0.58	0.20	0.44
Phu Phan	152	0.24	0.27	0.31	0.25	0.48	0.12	0.39	0.47	0.49	0.27	0.18	0.59	0.60	0.76	0.47	0.12
Phu Wiang	153	0.26	0.23	0.17	0.32	0.41	0.39	0.04	0.09	0.23	0.21	0.54	0.61	0.41	0.54	0.16	0.35
Phu Sing	154	0.68	0.71	0.63	0.75	0.34	0.47	0.66	0.69	0.54	0.50	0.50	0.19	0.46	0.48	0.83	0.63
Phu Luang	155	0.36	0.34	0.30	0.38	0.56	0.58	0.23	0.18	0.36	0.40	0.73	0.77	0.54	0.68	0.12	0.47
Mancha Khiri	156	0.26	0.23	0.16	0.35	0.29	0.36	0.08	0.10	0.15	0.15	0.50	0.50	0.30	0.46	0.27	0.33
Moei Wadi	157	0.33	0.36	0.28	0.36	0.37	0.05	0.34	0.42	0.43	0.20	0.16	0.46	0.49	0.66	0.49	0.22
Mueang Kalasin	158	0.23	0.25	0.21	0.25	0.37	0.12	0.28	0.36	0.38	0.16	0.26	0.49	0.48	0.65	0.41	0.11
Mueang Khon Kaen	159	0.18	0.15	0.08	0.27	0.30	0.28	0.08	0.16	0.22	0.11	0.43	0.51	0.33	0.49	0.25	0.25
Mueang Chaiyaphum	160	0.39	0.36	0.29	0.48	0.31	0.49	0.18	0.16	0.08	0.28	0.64	0.51	0.26	0.39	0.37	0.46
Mueang Nakhon Ratchasima	161	0.58	0.55	0.48	0.67	0.30	0.60	0.40	0.40	0.22	0.42	0.74	0.37	0.15	0.11	0.59	0.63
Mueang Buri Ram	162	0.48	0.46	0.39	0.56	0.04	0.41	0.38	0.41	0.25	0.26	0.53	0.20	0.17	0.30	0.57	0.49

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Mueang Maha Sarakham	163	0.24	0.25	0.16	0.32	0.24	0.21	0.18	0.26	0.23	0.01	0.36	0.41	0.33	0.50	0.36	0.24
Mueang Mukdahan	164	0.39	0.42	0.42	0.42	0.47	0.15	0.48	0.56	0.57	0.34	0.04	0.53	0.61	0.76	0.62	0.28
Mueang Yasothon	165	0.38	0.41	0.33	0.44	0.33	0.13	0.38	0.47	0.43	0.23	0.21	0.39	0.47	0.62	0.53	0.30
Mueang Loei	166	0.35	0.32	0.32	0.36	0.63	0.61	0.29	0.24	0.43	0.46	0.75	0.83	0.61	0.74	0.11	0.45
Mueang Sakon Nakhon	167	0.29	0.31	0.37	0.20	0.58	0.21	0.50	0.58	0.60	0.37	0.24	0.69	0.70	0.87	0.45	0.23
Mueang Surin	168	0.53	0.54	0.45	0.61	0.14	0.39	0.46	0.49	0.34	0.30	0.48	0.11	0.28	0.36	0.64	0.50
Mueang Nong Khai	169	0.20	0.19	0.26	0.19	0.62	0.47	0.29	0.32	0.48	0.42	0.59	0.82	0.65	0.79	0.14	0.31
Mueang Nong Bua Lamphu	170	0.21	0.19	0.19	0.23	0.52	0.48	0.19	0.22	0.38	0.33	0.62	0.73	0.55	0.69	0.05	0.32
Mueang Amnat Charoen	171	0.47	0.49	0.45	0.49	0.40	0.22	0.50	0.59	0.51	0.36	0.18	0.46	0.54	0.70	0.65	0.35
Mueang Udon Thani	172	0.11	0.09	0.15	0.14	0.51	0.38	0.24	0.27	0.41	0.31	0.51	0.71	0.54	0.70	0.13	0.21
Yang Talat	173	0.17	0.20	0.12	0.24	0.35	0.19	0.21	0.30	0.33	0.12	0.34	0.50	0.44	0.60	0.33	0.16
Rattana Buri	174	0.50	0.52	0.44	0.57	0.19	0.32	0.47	0.51	0.37	0.30	0.40	0.23	0.37	0.48	0.64	0.45
Lahan Sai	175	0.69	0.66	0.59	0.77	0.25	0.58	0.56	0.58	0.40	0.46	0.69	0.18	0.26	0.21	0.76	0.68
Lamduan	176	0.62	0.64	0.55	0.69	0.24	0.44	0.56	0.59	0.44	0.40	0.51	0.12	0.35	0.41	0.74	0.57
Lam Plai Mat	177	0.49	0.47	0.39	0.56	0.06	0.42	0.37	0.39	0.21	0.27	0.55	0.23	0.12	0.25	0.57	0.49
Loeng Nok Tha	178	0.38	0.41	0.37	0.40	0.41	0.13	0.42	0.51	0.51	0.29	0.12	0.47	0.55	0.70	0.57	0.26
Wang Nam Khiao	179	0.71	0.67	0.61	0.79	0.41	0.73	0.52	0.49	0.34	0.54	0.87	0.43	0.27	0.12	0.70	0.76
Wang Saphung	180	0.34	0.32	0.29	0.35	0.57	0.57	0.23	0.18	0.37	0.40	0.72	0.78	0.55	0.68	0.10	0.44
Wang Sam Mo	181	0.09	0.12	0.17	0.13	0.45	0.20	0.30	0.38	0.43	0.23	0.34	0.62	0.54	0.70	0.32	0.04
Waritchaphum	182	0.18	0.20	0.26	0.10	0.54	0.25	0.38	0.47	0.52	0.31	0.31	0.70	0.63	0.79	0.36	0.11
Waeng Noi	183	0.36	0.32	0.26	0.44	0.22	0.41	0.18	0.18	0.03	0.20	0.56	0.43	0.20	0.34	0.37	0.41
Waeng Yai	184	0.33	0.30	0.23	0.42	0.22	0.39	0.18	0.19	0.08	0.18	0.54	0.42	0.22	0.38	0.37	0.38
Si Chiang Mai	185	0.30	0.29	0.36	0.29	0.70	0.57	0.37	0.40	0.56	0.51	0.69	0.91	0.73	0.87	0.19	0.41
Si That	186	0.05	0.08	0.13	0.08	0.45	0.25	0.26	0.34	0.40	0.23	0.38	0.63	0.51	0.68	0.28	0.08
Si Bunrueang	187	0.28	0.25	0.20	0.30	0.51	0.49	0.15	0.16	0.33	0.32	0.64	0.72	0.52	0.65	0.06	0.37

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Si Wilai	188	0.33	0.36	0.44	0.24	0.76	0.43	0.54	0.59	0.71	0.54	0.45	0.91	0.82	0.98	0.45	0.33
Si Songkhram	189	0.34	0.36	0.44	0.24	0.66	0.29	0.55	0.63	0.68	0.46	0.28	0.76	0.79	0.95	0.49	0.30
Si Khoraphum	190	0.52	0.55	0.47	0.59	0.16	0.34	0.47	0.50	0.36	0.32	0.44	0.18	0.33	0.44	0.66	0.47
Satuek	191	0.44	0.45	0.36	0.52	0.04	0.34	0.37	0.40	0.25	0.21	0.47	0.22	0.21	0.34	0.55	0.43
Sanom	192	0.49	0.52	0.44	0.57	0.16	0.32	0.47	0.51	0.36	0.30	0.41	0.21	0.34	0.45	0.64	0.45
Somdet	193	0.18	0.21	0.24	0.19	0.44	0.12	0.35	0.43	0.45	0.23	0.25	0.56	0.56	0.72	0.41	0.06
Sang Khom	194	0.16	0.16	0.24	0.11	0.60	0.41	0.35	0.39	0.51	0.38	0.49	0.79	0.62	0.79	0.23	0.25
Sawang Daen Din	195	0.12	0.14	0.22	0.02	0.55	0.30	0.33	0.41	0.50	0.33	0.39	0.73	0.61	0.77	0.28	0.15
Sahatsakhan	196	0.18	0.20	0.22	0.20	0.41	0.13	0.31	0.40	0.43	0.20	0.26	0.54	0.53	0.70	0.40	0.06
Song Dao	197	0.15	0.17	0.25	0.06	0.55	0.28	0.36	0.44	0.53	0.33	0.37	0.71	0.63	0.80	0.32	0.13
Sangkha	198	0.64	0.67	0.59	0.72	0.28	0.47	0.60	0.63	0.48	0.44	0.50	0.13	0.40	0.42	0.78	0.59
Sangkhom	199	0.28	0.26	0.33	0.27	0.68	0.55	0.35	0.37	0.53	0.48	0.68	0.88	0.70	0.85	0.17	0.38
Samrong Thap	200	0.55	0.58	0.50	0.62	0.22	0.35	0.53	0.56	0.42	0.38	0.38	0.21	0.39	0.47	0.71	0.50
Sirindhorn	201	0.72	0.75	0.70	0.75	0.57	0.48	0.75	0.84	0.73	0.60	0.37	0.49	0.74	0.78	0.90	0.61
Si Khio	202	0.63	0.60	0.53	0.72	0.40	0.67	0.42	0.40	0.26	0.47	0.81	0.45	0.26	0.19	0.61	0.69
Si Chomphu	203	0.32	0.29	0.24	0.36	0.47	0.48	0.13	0.08	0.26	0.30	0.63	0.67	0.44	0.58	0.17	0.42
Suwanna Khuha	204	0.25	0.23	0.27	0.26	0.60	0.52	0.27	0.29	0.46	0.41	0.65	0.81	0.63	0.77	0.08	0.35
Sung Noen	205	0.63	0.59	0.52	0.71	0.33	0.65	0.44	0.42	0.27	0.46	0.79	0.37	0.19	0.11	0.63	0.68
Senangkha Nikhom	206	0.48	0.51	0.47	0.51	0.45	0.24	0.53	0.61	0.55	0.39	0.16	0.50	0.59	0.74	0.68	0.37
Selaphum	207	0.38	0.40	0.32	0.41	0.34	0.11	0.38	0.46	0.42	0.23	0.20	0.41	0.47	0.64	0.53	0.27
Soeng Sang	208	0.67	0.64	0.57	0.76	0.27	0.62	0.54	0.54	0.35	0.48	0.74	0.25	0.20	0.09	0.74	0.70
Nong Ki	209	0.60	0.56	0.50	0.68	0.19	0.55	0.46	0.46	0.28	0.40	0.68	0.25	0.12	0.13	0.66	0.62
Nong Kung Si	210	0.10	0.13	0.11	0.17	0.37	0.25	0.23	0.32	0.35	0.15	0.39	0.54	0.46	0.62	0.31	0.09
Nong Bua Daeng	211	0.45	0.42	0.36	0.53	0.41	0.58	0.23	0.17	0.17	0.38	0.73	0.60	0.35	0.44	0.37	0.53
Nong Bua Rawe	212	0.48	0.45	0.38	0.56	0.38	0.57	0.27	0.23	0.14	0.37	0.72	0.55	0.29	0.36	0.44	0.55
Nong Bunnak	213	0.59	0.56	0.49	0.68	0.22	0.58	0.46	0.46	0.27	0.43	0.71	0.25	0.12	0.11	0.66	0.64
Nong Phok	214	0.36	0.39	0.32	0.38	0.39	0.09	0.37	0.46	0.46	0.24	0.16	0.46	0.52	0.69	0.52	0.24

Table B.1 (Continued).

District	No.	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry
Nong Ruea	215	0.23	0.20	0.14	0.32	0.38	0.36	0.01	0.08	0.20	0.18	0.51	0.58	0.38	0.51	0.20	0.32
Nong Wua So	216	0.16	0.14	0.21	0.18	0.54	0.44	0.21	0.24	0.40	0.35	0.57	0.75	0.57	0.71	0.10	0.27
Nong Song Hong	217	0.32	0.29	0.22	0.40	0.18	0.33	0.20	0.23	0.13	0.12	0.48	0.39	0.23	0.40	0.39	0.34
Nong Sung	218	0.34	0.36	0.37	0.36	0.44	0.09	0.42	0.51	0.51	0.29	0.10	0.51	0.57	0.74	0.56	0.22
Nong Saeng	219	0.07	0.03	0.11	0.15	0.47	0.34	0.20	0.28	0.37	0.27	0.47	0.67	0.50	0.66	0.18	0.17
Nong Hong	220	0.56	0.52	0.46	0.64	0.16	0.51	0.42	0.42	0.24	0.36	0.65	0.22	0.08	0.16	0.62	0.59
Nong Han	221	0.07	0.09	0.17	0.04	0.52	0.32	0.28	0.36	0.45	0.29	0.45	0.70	0.56	0.72	0.22	0.16
Huai Thalaeng	222	0.52	0.49	0.42	0.61	0.14	0.49	0.39	0.39	0.20	0.33	0.63	0.24	0.06	0.20	0.59	0.55
Huai Thapthan	223	0.57	0.60	0.52	0.64	0.25	0.37	0.56	0.60	0.45	0.40	0.40	0.21	0.42	0.50	0.73	0.52
Huai Phueng	224	0.21	0.24	0.27	0.24	0.42	0.07	0.35	0.43	0.45	0.23	0.20	0.54	0.55	0.72	0.44	0.10
Huai Mek	225	0.14	0.17	0.09	0.21	0.33	0.21	0.20	0.28	0.32	0.11	0.36	0.50	0.42	0.59	0.30	0.13
Wan Yai	226	0.40	0.43	0.47	0.39	0.54	0.20	0.53	0.61	0.62	0.39	0.04	0.61	0.68	0.84	0.63	0.29
Akat Amnuai	227	0.26	0.29	0.37	0.17	0.69	0.34	0.47	0.55	0.64	0.47	0.36	0.81	0.75	0.91	0.41	0.26
Ubonrat	228	0.13	0.10	0.05	0.22	0.39	0.34	0.10	0.19	0.28	0.19	0.49	0.59	0.42	0.58	0.17	0.22

Table B.2 EI-base score for the industrial standard given by expert interviews via questionnaires.

No.	Industrial standard	The importance					Total score	Order of magnitude	Normalize score of Industrial standard (IS_j / IS_{max})
		Very high 5	high 4	Moderate 3	Level low 2	Ignore 1			
1	ISO 9000	//	///	/		/	26	6	0.79
2	ISO 9000 : 2008	/	////		/	/	24	7	0.73
3	ISO 9001	//	///	/		/	26	6	0.79
4	ISO 9001 : 2000	//	////		/		28	4	0.85
5	ISO 9002	//	///	/		/	26	6	0.79
6	ISO 14001	////	///				32	2	0.97
7	ISO 14001 : 2004	/////	//				33	1	1.00
8	GMP	//	////	/			29	3	0.88
9	HACCP	//	//	///			27	5	0.82
10	HALAL	/	/	/	///	/	19	9	0.58
11	Kosher	/	/	/	//	//	18	10	0.55
12	TIS	///	//		/	/	26	6	0.79
13	Thailand Brand	/	//	//	//		23	8	0.70
14	Board of Investment	//	///	//			28	4	0.85
						Max	**33**		
						Min	**18**		

Note: IS is Industrial Standard

Table B.3 Normalized data of the environmental impacts caused by the industrial standard (score 0-1).

No.	Name of factories	ISO 9000	ISO 9001	ISO 9000:2008	ISO 9001:2000	ISO 9001:2008	ISO 9002	ISO 14001	ISO 14001:2004	GMP	HACCP	GMP/HACCP	HALAL	TIS.	TIS. 56-2553	Thailand Brand	Board of Investment	Kosher	**Total score of factory**	**Normalize score of factory**
1	Kumphawapi	-	-	-	0.85	-	-	-	-	0.88	-	-	0.58	0.79	-	0.70	-	-	3.79	0.48
2	Kaset Phol	-	-	-	0.85	-	-	-	-	0.88	-	-	0.58	-	-	-	-	-	2.30	0.69
3	Khon Kaen	0.79	-	-	-	-	-	-	-	0.88	0.82	-	0.58	-	-	-	-	-	3.06	0.58
4	Rermudom	0.79	-	-	-	-	-	-	-	0.88	-	-	0.58	-	0.79	-	-	-	3.03	0.59
5	Burirum	0.79	-	-	-	-	-	-	-	-	-	-	0.58	-	-	-	-	-	1.36	0.81
6	Mitr Kalasin	0.79	-	-	-	-	-	0.97	-	0.88	0.82	-	-	-	-	-	-	-	3.45	0.53
7	Mitr Phuviang	0.79	-	-	-	-	-	0.97	-	0.88	0.82	-	-	-	-	-	-	-	3.45	0.53
8	United Farmer & Industry	0.79	-	-	-	-	-	0.97	-	0.88	0.82	-	-	-	-	-	-	-	3.45	0.53
9	Angvian Industry (Ratchasima)	-	-	-	-	-	0.79	0.97	-	0.88	0.82	-	0.58	-	-	-	-	-	4.03	0.45
10	Wangkanai	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	1.00
11	Saharuang	0.79	-	-	0.85	-	-	-	1	0.88	0.82	0.85	0.58	0.79	0.79	-	-	-	7.33	0.00
12	Surin	-	-	0.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.73	0.90
13	Korach Industry	-	-	-	0.85	-	-	-	1	0.88	0.82	-	0.58	-	-	-	-	-	4.12	0.44
14	N.Y. (Khonburi)	-	0.79	-	-	0.85	-	-	-	0.88	0.82	0.85	0.58	-	0.79	-	0.85	0.55	6.94	0.05
15	Erawan	-	0.79	0.73	-	-	-	-	-	-	-	-	0.58	-	0.79	-	-	-	2.88	0.61
16	E-Saan Industry	0.79	-	-	-	-	-	-	-	0.88	0.82	-	0.58	0.79	-	-	-	-	3.85	0.48
																		Max	7.33	1.00
																		Min	0.00	0.00

APPENDIX C

RESULTS OF THE LINEAR PROGRAMMING

IN DISTRICT LEVEL

Table C.1 Total results from linear programming of single objective function at district level.

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Kranuan	1	-	-	535,044.40	-	-	-	-	-	-	-	-	-	-	-	-	-	535,044.40	19,313,496.80
Krasang	2	-	-	-	-	-	-	-	-	-	-	-	9,109.84	-	-	-	-	9,109.84	656,055.12
Kap Choeng	3	-	-	-	-	-	-	-	-	-	-	-	101,040.35	-	-	-	-	101,040.35	4,454,411.17
Kut Rang	4	-	-	-	-	225,429.89	-	-	-	-	-	-	-	-	-	-	-	225,429.89	29,801,425.52
Ku Kaeo	5	121,553.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	121,553.20	5,244,222.14
Khewa Sinarin	6	-	-	-	-	-	-	-	-	-	-	-	427.29	-	-	-	-	427.29	29,604.31
Khaen Dong	7	-	-	-	-	110,698.53	-	-	-	-	-	-	-	-	-	-	-	110,698.53	1,118,364.88
Khok Pho Chai	8	-	-	-	-	-	-	905.30	-	48,484.87	-	-	-	-	-	-	-	49,390.16	3,289,206.37
Chuen Chom	9	-	-	97,428.81	-	-	-	-	-	-	-	-	-	-	-	-	-	97,428.81	6,001,826.15
Sap Yai	10	-	-	-	-	-	-	-	-	24,750.83	-	-	-	-	-	-	-	24,750.83	2,645,714.21
Sam Sung	11	-	-	135,817.17	-	-	-	-	-	-	-	-	-	-	-	-	-	135,817.17	6,123,343.93
Don Chan	12	-	-	-	-	-	156,056.80	-	-	-	-	-	-	-	-	-	-	156,056.80	8,795,495.73
Thepharak	13	-	-	-	-	-	-	-	-	-	-	-	-	50,356.97	-	-	-	50,356.97	8,261,994.39
Na Khu	14	-	-	-	-	-	2,539.17	-	-	-	-	-	-	-	-	-	-	2,539.17	128,488.39
Non Narai	15	-	-	-	-	-	-	-	-	-	-	-	102.95	-	-	-	-	102.95	13,532.63
Non Sila	16	-	-	-	-	17,917.34	-	-	-	-	-	-	-	74,339.62	-	-	-	92,256.96	12,724,924.38
Bua Lai	17	-	-	-	-	-	-	-	-	-	-	-	-	23,947.24	-	-	-	23,947.24	2,441,255.82
Ban Dan	18	-	-	-	-	45,590.90	-	-	-	-	-	-	-	-	-	-	-	45,590.90	779,790.68
Ban Haet	19	-	-	-	-	-	-	191,734.83	-	-	-	-	-	-	-	-	-	191,734.83	15,614,215.60
Prachak Sinlapakhom	20	-	9,344.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,344.61	291,319.50
Fao Rai	21	-	-	-	31,310.39	-	-	-	-	-	-	-	-	-	-	-	-	31,310.39	3,044,621.96
Phanom Dong Rak	22	-	-	-	-	-	-	-	-	-	-	-	111,219.28	-	-	-	-	111,219.28	3,008,753.58

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Phra Thongkham	23	-	-	-	-	-	-	-	-	-	-	-	-	130,073.93	-	-	-	130,073.93	13,490,333.95
Pho Tak	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,728.21	-	37,728.21	4,146,235.18
Lam Thamenchai	25	-	-	-	-	1,800.25	-	-	-	-	-	-	-	-	-	-	-	1,800.25	76,865.04
Si Narong	26	-	-	-	-	-	-	-	-	-	-	-	107,200.19	-	-	-	-	107,200.19	10,044,315.64
Sa Khrai	27	-	20,292.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,292.42	2,200,203.25
Sam Chai	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	285,577.90	285,577.90	4,169,411.81
Nong Na Kham	29	-	-	-	-	-	-	8,906.83	-	-	-	-	-	-	-	-	-	8,906.83	490,435.92
Nong Hin	30	-	-	-	-	-	-	-	168,686.42	-	-	-	-	-	-	-	-	168,686.42	18,663,671.67
Erawan	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160,425.64	-	160,425.64	6,672,067.00
Kuchi Narai	32	-	-	-	-	-	355,060.71	-	-	-	-	-	-	-	-	-	-	355,060.71	4,576,776.96
Kut Khao Pun	33	-	-	-	-	-	-	-	-	-	-	14,481.67	-	-	-	-	-	14,481.67	1,661,667.55
Kut Chap	34	-	85,920.25	-	-	-	-	-	-	-	-	-	-	-	-	121,662.15	-	207,582.40	15,692,135.53
Kut Chum	35	-	-	-	-	-	22,490.32	-	-	-	-	-	-	-	-	-	-	22,490.32	2,398,356.46
Kut Bak	36	-	-	-	16,271.86	-	-	-	-	-	-	-	-	-	-	-	-	16,271.86	1,562,261.54
Kumphawapi	37	-	458,029.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458,029.58	4,204,889.58
Kaset Sombun	38	-	-	-	-	-	-	-	419,435.79	-	-	-	-	-	-	-	-	419,435.79	17,865,212.16
Kaeng Khro	39	-	-	-	-	-	-	302,413.55	-	-	-	-	-	-	-	-	-	302,413.55	15,610,029.39
Kaeng Sanam Nang	40	-	-	-	-	-	-	-	-	245,650.97	-	-	-	-	-	-	-	245,650.97	3,669,721.19
Kosum Phisai	41	-	-	-	-	-	-	375,858.42	-	-	160,416.28	-	-	-	-	-	-	536,274.70	40,124,665.99
Kham Thale So	42	-	-	-	-	-	-	-	-	-	-	-	-	885.16	-	-	-	885.16	71,270.41
Kham Sakae Saeng	43	-	-	-	-	-	-	-	-	-	-	-	-	65,109.34	-	-	-	65,109.34	5,968,160.89
Khukhan	44	-	-	-	-	-	-	-	-	-	-	-	5,749.83	-	-	-	-	5,749.83	706,696.71

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Khun Han	45	-	-	-	-	-	-	-	-	-	-	-	259.32	-	-	-	-	259.32	35,142.86
Khemarat	46	-	-	-	-	-	-	-	-	-	-	16,711.09	-	-	-	-	-	16,711.09	1,557,356.16
Khao Wong	47	-	-	-	-	-	1,033.68	-	-	-	-	-	-	-	-	-	-	1,033.68	26,539.17
Khao Suan Kwang	48	-	-	179,720.56	-	-	-	-	-	-	-	-	-	-	-	-	-	179,720.56	7,268,820.36
Khong	49	-	-	-	-	-	-	-	-	-	-	-	-	147,464.51	-	-	-	147,464.51	13,797,409.01
Khon Buri	50	-	-	-	-	-	-	-	-	-	-	-	-	-	254,502.81	-	-	254,502.81	4,200,227.82
Khon Sawan	51	-	-	-	-	-	-	-	-	84,097.52	-	-	-	-	-	-	-	84,097.52	3,370,352.46
Khon San	52	-	-	-	-	-	-	-	450,997.62	-	-	-	-	-	-	-	-	450,997.62	18,210,396.63
Kham Cha-I	53	-	-	-	-	-	73,960.12	-	-	-	-	-	-	-	-	-	-	73,960.12	5,267,754.64
Kham Ta Kla	54	-	-	-	953.27	-	-	-	-	-	-	-	-	-	-	-	-	953.27	87,631.04
Kham Muang	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	172,942.11	172,942.11	2,982,837.08
Khu Mueang	56	-	-	-	-	102,517.17	-	-	-	-	-	-	-	-	-	-	-	102,517.17	857,681.11
Chom Phra	57	-	-	-	-	-	-	-	-	-	-	-	13,109.66	-	-	-	-	13,109.66	1,196,380.73
Chakkarat	58	-	-	-	-	-	-	-	-	-	-	-	-	231,936.39	-	-	-	231,936.39	7,345,268.69
Chatturat	59	-	-	-	-	-	-	-	-	-	-	-	-	145,711.95	-	-	-	145,711.95	20,866,968.95
Charoen Sin	60	-	-	-	26,594.29	-	-	-	-	-	-	-	-	-	-	-	-	26,594.29	1,815,688.11
Chaloem Phrakiat	61	-	-	-	-	-	-	-	-	-	-	-	-	26,013.10	-	-	-	26,013.10	1,000,162.57
Chonnabot	62	-	-	-	-	-	-	-	-	-	-	-	-	35,636.13	-	-	-	35,636.13	5,158,894.92
Chanuman	63	-	-	-	-	-	-	-	-	-	-	152,918.71	-	-	-	-	-	152,918.71	13,549,615.20
Chamni	64	-	-	-	-	-	-	-	-	-	-	-	-	3,941.00	-	-	-	3,941.00	299,725.48
Chum Phuang	65	-	-	-	-	-	-	-	-	-	-	-	-	109,307.89	-	-	-	109,307.89	6,052,281.19

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Chum Phae	66	-	-	-	-	-	-	-	199,209.10	-	-	-	-	-	-	-	-	199,209.10	5,229,408.06
Chiang Yuen	67	-	-	9,512.74	-	-	-	-	-	-	-	-	-	-	-	-	-	9,512.74	578,743.17
Chok Chai	68	-	-	-	-	-	-	-	-	-	-	-	-	4,333.06	128,938.75	-	-	133,271.81	7,451,299.53
Chaiwan	69	-	-	-	322,674.46	-	-	-	-	-	-	-	-	-	-	-	-	322,674.46	9,727,459.50
Seka	70	-	-	-	58,211.91	-	-	-	-	-	-	-	-	-	-	-	-	58,211.91	7,829,160.77
So Phisai	71	-	-	-	13,517.87	-	-	-	-	-	-	-	-	-	-	-	-	13,517.87	1,731,748.71
Dong Luang	72	-	-	-	-	-	66,575.86	-	-	-	-	-	-	-	-	-	-	66,575.86	5,957,711.37
Don Tan	73	-	-	-	-	-	-	-	-	-	-	263,458.52	-	-	-	-	-	263,458.52	12,604,079.22
Dan Khun Thot	74	-	-	-	-	-	-	-	-	-	-	-	-	285,255.83	-	-	-	285,255.83	40,684,474.95
Trakan Phuet Phon	75	-	-	-	-	-	-	-	-	-	-	779.58	-	-	-	-	-	779.58	119,233.19
Tao Ngoi	76	-	-	-	-	-	22,915.83	-	-	-	-	-	-	-	-	-	-	22,915.83	1,467,411.38
Sai Mun	77	-	-	-	-	-	7,327.95	-	-	-	-	-	-	-	-	-	-	7,327.95	675,979.56
Tha Khantho	78	287,797.17	-	34,167.63	-	-	-	-	-	-	-	-	-	-	-	-	-	321,964.81	16,800,071.04
Tha Tum	79	-	-	-	-	-	-	-	-	-	-	-	4,755.92	-	-	-	-	4,755.92	521,586.70
Tha Bo	80	-	5,665.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,665.02	651,548.99
Tha Uthen	81	-	-	-	4,581.17	-	-	-	-	-	-	-	-	-	-	-	-	4,581.17	837,288.69
Thung Fon	82	-	-	-	12,335.60	-	-	-	-	-	-	-	-	-	-	-	-	12,335.60	336,343.53
Thep Sathit	83	-	-	-	-	-	-	-	-	9,541.58	-	-	-	64,525.12	-	-	-	74,066.70	14,747,947.17
Thai Charoen	84	-	-	-	-	-	22,029.00	-	-	-	-	-	-	-	-	-	-	22,029.00	2,272,936.20
That Phanom	85	-	-	-	-	-	-	-	-	-	-	15,052.19	-	-	-	-	-	15,052.19	554,949.42
Na Klang	86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57,130.45	-	57,130.45	35,726.29
Na Kae	87	-	-	-	-	-	4,682.29	-	-	-	-	-	-	-	-	-	-	4,682.29	564,443.46

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Nang Rong	88	-	-	-	-	-	-	-	-	-	-	-	58,801.55	-	-	-	-	58,801.55	5,786,605.70
Na Chueak	89	-	-	-	-	48,530.63	-	-	-	-	-	-	-	-	-	-	-	48,530.63	4,974,492.76
Na Duang	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,681.46	-	3,681.46	189,032.09
Na Dun	91	-	-	-	-	4,013.96	-	-	-	-	-	-	-	-	-	-	-	4,013.96	439,935.87
Na Thom	92	-	-	-	5,080.34	-	-	-	-	-	-	-	-	-	-	-	-	5,080.34	897,198.82
Na Pho	93	-	-	-	-	511.10	-	-	-	-	-	-	-	-	-	-	-	511.10	44,312.98
Na Mon	94	-	-	-	-	-	121,972.84	-	-	-	-	-	-	-	-	-	-	121,972.84	5,226,513.87
Na Yung	95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,103.89	-	3,103.89	296,333.67
Na Wang	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77,634.58	-	77,634.58	2,018,360.91
Nam Phong	97	-	-	468,132.09	-	-	-	-	-	-	-	-	-	-	-	-	-	468,132.09	3,227,486.18
Nam Som	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120,743.22	-	120,743.22	9,306,305.46
Nikhom Kham Soi	99	-	-	-	-	-	46,019.43	-	-	-	-	144,574.40	-	-	-	-	-	190,593.83	10,297,269.91
Nikhom Nam Un	100	-	-	-	9,485.09	-	-	-	-	-	-	-	-	-	-	-	-	9,485.09	776,389.26
Noen Sa-Nga	101	-	-	-	-	-	-	-	-	-	-	-	-	38,847.64	-	-	-	38,847.64	4,567,087.14
Non Din Daeng	102	-	-	-	-	-	-	-	-	-	-	-	16,787.56	-	-	-	-	16,787.56	1,855,686.54
Non Thai	103	-	-	-	-	-	-	-	-	-	-	-	-	870.20	-	-	-	870.20	74,202.85
Non Sa-At	104	-	361,623.57	266,058.91	-	-	-	-	-	-	-	-	-	-	-	-	-	627,682.48	18,070,998.04
Non Sang	105	-	-	-	-	-	-	1,716.72	-	-	-	-	-	-	-	-	-	1,716.72	131,958.86
Non Suwan	106	-	-	-	-	-	-	-	-	-	-	-	-	-	12,684.16	-	-	12,684.16	849,370.80
Borabue	107	-	-	-	-	68,791.19	-	-	-	-	-	-	-	-	-	-	-	68,791.19	9,360,195.21
Bua Chet	108	-	-	-	-	-	-	-	-	-	-	-	136,914.80	-	-	-	-	136,914.80	13,018,695.62
Bua Yai	109	-	-	-	-	-	-	-	-	119,812.14	-	-	-	-	-	-	-	119,812.14	4,073,133.41

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Ban Kruat	110	-	-	-	-	-	-	-	-	-	-	-	74,718.53	-	-	-	-	74,718.53	5,286,972.96
Ban Khwao	111	-	-	-	-	-	-	-	-	32,215.82	-	-	-	-	-	-	-	32,215.82	2,431,390.93
Ban Dung	112	-	-	-	132,205.26	-	-	-	-	-	-	-	-	-	-	-	-	132,205.26	7,277,357.96
Ban Thaen	113	-	-	-	-	-	-	196,407.13	-	-	-	-	-	-	-	-	-	196,407.13	4,725,817.84
Ban Phue	114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	257,478.32	-	257,478.32	18,411,396.20
Ban Phai	115	-	-	-	-	227,696.03	-	-	-	-	-	-	-	-	-	-	-	227,696.03	30,978,115.37
Ban Fang	116	-	-	-	-	-	-	137,447.88	-	-	-	-	-	-	-	-	-	137,447.88	4,544,097.18
Ban Phaeng	117	-	-	-	1,076.04	-	-	-	-	-	-	-	-	-	-	-	-	1,076.04	184,927.17
Ban Muang	118	-	-	-	72,218.41	-	-	-	-	-	-	-	-	-	-	-	-	72,218.41	7,032,467.54
Ban Lueam	119	-	-	-	-	-	-	-	-	167,875.74	-	-	-	-	-	-	-	167,875.74	5,727,892.41
Bamnet Narong	120	-	-	-	-	-	-	-	-	-	-	-	-	80,195.88	-	-	-	80,195.88	12,088,592.93
Bueng Kan	121	-	-	-	229.78	-	-	-	-	-	-	-	-	-	-	-	-	229.78	33,575.45
Bueng Khong Long	122	-	-	-	37,336.93	-	-	-	-	-	-	-	-	-	-	-	-	37,336.93	5,347,084.92
Pathum Ratchawongsa	123	-	-	-	-	-	-	-	-	-	-	25,513.99	-	-	-	-	-	25,513.99	2,889,633.73
Prakhon Chai	124	-	-	-	-	-	-	-	-	-	-	-	6,513.22	-	-	-	-	6,513.22	530,637.85
Prang Ku	125	-	-	-	-	-	-	-	-	-	-	-	7,859.54	-	-	-	-	7,859.54	874,387.98
Prasat	126	-	-	-	-	-	-	-	-	-	-	-	39,439.22	-	-	-	-	39,439.22	226,014.76
Pakham	127	-	-	-	-	-	-	-	-	-	-	-	16,195.39	-	-	-	-	16,195.39	1,921,414.67
Pak Thong Chai	128	-	-	-	-	-	-	-	-	-	-	-	-	-	305,522.77	-	-	305,522.77	14,224,985.80
Pak Khat	129	-	-	-	326.92	-	-	-	-	-	-	-	-	-	-	-	-	326.92	48,058.76
Pak Chong	130	-	-	-	-	-	-	-	-	-	-	-	-	-	575,049.39	-	-	575,049.39	56,877,601.51
Pa Tio	131	-	-	-	-	-	-	-	-	-	-	-	9,240.86	-	-	-	-	9,240.86	2,459,824.50

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (C_i) (Baht)
Pueai Noi	132	-	-	-	-	63,395.75	-	-	-	-	-	-	-	-	-	-	-	63,395.75	6,985,101.56
Pha Khao	133	-	-	-	-	-	-	223,185.50	-	-	-	-	-	-	-	-	-	223,185.50	28,116,007.35
Phon Charoen	134	-	-	-	12,366.91	-	-	-	-	-	-	-	-	-	-	-	-	12,366.91	1,718,075.94
Phanna Nikhom	135	-	-	-	32,919.28	-	-	-	-	-	-	-	-	-	-	-	-	32,919.28	3,009,944.01
Phra Yuen	136	-	-	-	-	-	-	11,946.43	-	-	-	-	-	-	-	-	-	11,946.43	389,156.60
Phon	137	-	-	-	-	-	-	-	-	-	-	-	-	35,336.77	-	-	-	35,336.77	4,233,944.77
Phang Khon	138	-	-	-	1,999.26	-	-	-	-	-	-	-	-	-	-	-	-	1,999.26	168,478.69
Phibun Rak	139	-	-	-	27,536.19	-	-	-	-	-	-	-	-	-	-	-	-	27,536.19	1,469,284.44
Phimai	140	-	-	-	-	-	-	-	-	-	-	-	-	246,192.57	-	-	-	246,192.57	4,000,019.86
Phen	141	-	-	-	10,126.10	-	-	-	-	-	-	-	-	-	-	-	-	10,126.10	785,317.98
Pho Chai	142	-	-	-	-	-	149,506.15	-	-	-	-	-	-	-	-	-	-	149,506.15	9,841,692.05
Pho Sai	143	-	-	-	-	-	-	-	-	-	-	3,498.60	-	-	-	-	-	3,498.60	535,096.00
Phon Thong	144	-	-	-	-	-	298,031.24	-	-	-	-	-	-	-	-	-	-	298,031.24	5,669,226.74
Phon Phisai	145	-	-	-	20,696.07	-	-	-	-	-	-	-	-	-	-	-	-	20,696.07	1,830,400.29
Phon Sawan	146	-	-	-	795.55	-	-	-	-	-	-	-	-	-	-	-	-	795.55	148,834.46
Phrai Bueng	147	-	-	-	-	-	-	-	-	-	-	-	506.38	-	-	-	-	506.38	64,996.31
Phakdi Chumphon	148	-	-	-	-	-	-	-	-	10,613.45	-	-	-	-	-	-	-	10,613.45	1,486,689.29
Phu Kradueng	149	-	-	-	-	-	-	-	37,192.68	-	-	-	-	-	-	-	-	37,192.68	2,805,777.48
Phu Khiao	150	-	-	-	-	-	-	-	1,119,186.07	-	-	-	-	-	-	-	-	1,119,186.07	12,929,850.16
Phu Pha Man	151	-	-	-	-	-	-	-	93,144.04	-	-	-	-	-	-	-	-	93,144.04	4,435,443.59
Phu Phan	152	-	-	-	-	-	34,571.93	-	-	-	-	-	-	-	-	-	-	34,571.93	2,723,537.84
Phu Wiang	153	-	-	-	-	-	-	120,395.75	-	-	-	-	-	-	-	-	-	120,395.75	3,342,911.33

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Phu Sing	154	-	-	-	-	-	-	-	-	-	-	-	24,056.87	-	-	-	-	24,056.87	3,014,249.54
Phu Luang	155	-	-	-	-	-	-	-	21,612.60	-	-	-	-	-	-	-	-	21,612.60	2,615,752.79
Mancha Khiri	156	-	-	-	-	-	-	323,978.03	-	-	-	-	-	-	-	-	-	323,978.03	16,726,481.87
Moei Wadi	157	-	-	-	-	-	32,193.53	-	-	-	-	-	-	-	-	-	-	32,193.53	1,182,258.32
Mueang Kalasin	158	-	-	-	-	-	87,766.46	-	-	-	-	-	-	-	-	-	-	87,766.46	6,390,200.41
Mueang Khon Kaen	159	-	-	-	-	-	-	168,791.18	-	-	-	-	-	-	-	-	-	168,791.18	8,235,596.40
Mueang Chaiyaphum	160	-	-	-	-	-	-	-	-	117,511.27	-	-	-	-	-	-	-	117,511.27	6,576,482.51
Mueang Nakhon Ratchasima	161	-	-	-	-	-	-	-	-	-	-	-	-	-	68,119.39	-	-	68,119.39	4,324,620.21
Mueang Buri Ram	162	-	-	-	-	33,653.22	-	-	-	-	-	-	-	-	-	-	-	33,653.22	894,302.28
Mueang Maha Sarakham	163	-	-	-	-	-	-	-	-	-	5,583.72	-	-	-	-	-	-	5,583.72	46,698.45
Mueang Mukdahan	164	-	-	-	-	-	-	-	-	-	-	409,521.60	-	-	-	-	-	409,521.60	10,919,740.38
Mueang Yasothon	165	-	-	-	-	-	4,507.52	-	-	-	-	-	-	-	-	-	-	4,507.52	398,622.47
Mueang Loei	166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	817.01	-	817.01	60,286.09
Mueang Sakon Nakhon	167	-	-	-	16,611.10	-	-	-	-	-	-	-	-	-	-	-	-	16,611.10	1,923,941.56
Mueang Surin	168	-	-	-	-	-	-	-	-	-	-	-	14,512.44	-	-	-	-	14,512.44	799,919.85
Mueang Nong Khai	169	-	676.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	676.15	73,370.94
Mueang Nong Bua Lamphu	170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57,964.04	-	57,964.04	1,771,415.63
Mueang Amnat Charoen	171	-	-	-	-	-	6,370.51	-	-	-	-	-	13,730.79	-	-	-	-	20,101.30	4,844,930.90
Mueang Udon Thani	172	-	169,079.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	169,079.17	9,177,918.17
Yang Talat	173	-	-	25,219.90	-	-	-	-	-	-	-	-	-	-	-	-	-	25,219.90	1,838,253.34

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Rattana Buri	174	-	-	-	-	-	-	-	-	-	-	-	676.54	-	-	-	-	676.54	88,265.07
Lahan Sai	175	-	-	-	-	-	-	-	-	-	-	-	149,660.03	-	-	-	-	149,660.03	16,660,129.57
Lamduan	176	-	-	-	-	-	-	-	-	-	-	-	3,004.55	-	-	-	-	3,004.55	225,059.67
Lam Plai Mat	177	-	-	-	-	52,983.10	-	-	-	-	-	-	-	-	-	-	-	52,983.10	1,976,149.31
Loeng Nok Tha	178	-	-	-	-	-	156,331.87	-	-	-	-	-	-	-	-	-	-	156,331.87	13,054,222.77
Wang Nam Khiao	179	-	-	-	-	-	-	-	-	-	-	-	-	-	178,673.89	-	-	178,673.89	14,036,081.66
Wang Saphung	180	-	-	-	-	-	-	151,739.37	143,519.16	-	-	-	-	-	-	64,262.43	-	359,520.97	44,358,468.53
Wang Sam Mo	181	274,220.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	639,048.11	913,268.68	35,444,877.63
Waritchaphum	182	-	-	-	13,529.09	-	-	-	-	-	-	-	-	-	-	-	-	13,529.09	869,148.74
Waeng Noi	183	-	-	-	-	-	-	-	-	8,883.97	-	-	-	-	-	-	-	8,883.97	218,106.44
Waeng Yai	184	-	-	-	-	-	-	-	-	7,638.55	-	-	-	-	-	-	-	7,638.55	435,618.40
Si Chiang Mai	185	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29,451.30	-	29,451.30	3,915,410.44
Si That	186	747,281.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	747,281.71	29,075,524.58
Si Bunrueang	187	-	-	-	-	-	-	252,700.43	-	-	-	-	-	-	-	-	-	252,700.43	24,519,745.45
Si Wilai	188	-	-	-	7,066.61	-	-	-	-	-	-	-	-	-	-	-	-	7,066.61	1,076,143.44
Si Songkhram	189	-	-	-	13,228.26	-	-	-	-	-	-	-	-	-	-	-	-	13,228.26	2,170,298.34
Si Khoraphum	190	-	-	-	-	-	-	-	-	-	-	-	4,481.55	-	-	-	-	4,481.55	461,847.72
Satuek	191	-	-	-	-	99,737.28	-	-	-	-	-	-	-	-	-	-	-	99,737.28	2,782,997.80
Sanom	192	-	-	-	-	-	-	-	-	-	-	-	5,436.94	-	-	-	-	5,436.94	596,659.35
Somdet	193	-	-	-	-	-	96,359.44	-	-	-	-	-	-	-	-	-	-	96,359.44	7,278,774.56
Sang Khom	194	-	-	-	1,983.68	-	-	-	-	-	-	-	-	-	-	-	-	1,983.68	148,860.76
Sawang Daen Din	195	-	-	-	160,586.09	-	-	-	-	-	-	-	-	-	-	-	-	160,586.09	2,524,469.80

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Sahatsakhan	196	-	-	-	-	-	55,201.09	-	-	-	-	-	-	-	-	-	15,431.87	70,632.96	5,051,700.15
Song Dao	197	-	-	-	149,403.05	-	-	-	-	-	-	-	-	-	-	-	-	149,403.05	5,829,861.67
Sangkha	198	-	-	-	-	-	-	-	-	-	-	-	114,114.22	-	-	-	-	114,114.22	9,729,445.06
Sangkhom	199	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,635.25	-	5,635.25	655,476.54
Samrong Thap	200	-	-	-	-	-	-	-	-	-	-	-	551.27	-	-	-	-	551.27	67,715.21
Sirindhorn	201	-	-	-	-	-	-	-	-	-	-	-	769.60	-	-	-	-	769.60	249,779.59
Si Khio	202	-	-	-	-	-	-	-	-	-	-	-	-	-	193,337.52	-	-	193,337.52	23,874,808.44
Si Chomphu	203	-	-	-	-	-	-	-	278,016.54	-	-	-	-	-	-	-	-	278,016.54	12,858,058.79
Suwanna Khuha	204	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34,282.05	-	34,282.05	1,931,456.29
Sung Noen	205	-	-	-	-	-	-	-	-	-	-	-	-	-	89,817.03	-	-	89,817.03	6,113,181.56
Senangkha Nikhom	206	-	-	-	-	-	8,116.53	-	-	-	-	-	-	-	-	-	-	8,116.53	1,250,773.48
Selaphum	207	-	-	-	-	-	43,797.04	-	-	-	-	-	-	-	-	-	-	43,797.04	3,027,429.74
Soeng Sang	208	-	-	-	-	-	-	-	-	-	-	-	-	-	93,354.29	-	-	93,354.29	4,712,753.37
Nong Ki	209	-	-	-	-	-	-	-	-	-	-	-	-	141,004.45	-	-	-	141,004.45	11,007,155.16
Nong Kung Si	210	-	-	443,712.92	-	-	-	-	-	-	-	-	-	-	-	-	-	443,712.92	30,414,690.52
Nong Bua Daeng	211	-	-	-	-	-	-	-	-	296,914.26	-	-	-	-	-	-	-	296,914.26	35,334,977.58
Nong Bua Rawe	212	-	-	-	-	-	-	-	-	43,009.02	-	-	-	-	-	-	-	43,009.02	3,744,851.91
Nong Bunnak	213	-	-	-	-	-	-	-	-	-	-	-	-	174,688.47	-	-	-	174,688.47	11,819,548.30
Nong Phok	214	-	-	-	-	-	138,375.13	-	-	-	-	-	-	-	-	-	-	138,375.13	7,950,723.11
Nong Ruea	215	-	-	-	-	-	-	202,678.46	-	-	-	-	-	-	-	-	-	202,678.46	1,827,271.49
Nong Wua So	216	-	-	-	-	-	-	127,194.18	-	-	-	-	-	-	-	-	-	127,194.18	18,076,967.95

Table C.1 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai3	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s$_i$)	Transportation cost in district level (Ci) (Baht)
Nong Song Hong	217	-	-	-	-	102,733.66	-	-	-	-	-	-	-	-	-	-	-	102,733.66	12,307,932.98
Nong Sung	218	-	-	-	-	-	23,895.50	-	-	-	-	-	-	-	-	-	-	23,895.50	1,342,406.96
Nong Saeng	219	-	331,369.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	331,369.23	6,574,169.19
Nong Hong	220	-	-	-	-	-	-	-	-	-	-	-	-	170,453.64	-	-	-	170,453.64	8,957,581.39
Nong Han	221	78,147.35	-	-	29,998.64	-	-	-	-	-	-	-	-	-	-	-	-	108,145.99	3,923,651.83
Huai Thalaeng	222	-	-	-	-	-	-	-	-	-	-	-	-	131,573.13	-	-	-	131,573.13	4,652,276.59
Huai Thapthan	223	-	-	-	-	-	-	-	-	-	-	-	896.89	-	-	-	-	896.89	121,728.89
Huai Phueng	224	-	-	-	-	-	111,312.06	-	-	-	-	-	-	-	-	-	-	111,312.06	4,562,594.51
Huai Mek	225	-	-	191,277.25	-	-	-	-	-	-	-	-	-	-	-	-	-	191,277.25	10,657,389.56
Wan Yai	226	-	-	-	-	-	-	-	-	-	-	19,489.65	-	-	-	-	-	19,489.65	584,633.57
Akat Amnuai	227	-	-	-	2,744.53	-	-	-	-	-	-	-	-	-	-	-	-	2,744.53	298,378.16
Ubonrat	228	-	-	101,907.62	-	-	-	-	-	-	-	-	-	-	-	-	-	101,907.62	2,930,677.39
Factory Allotted Capacity (dj)		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,209,000**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**	**Total TC**	**1,466,641,682.33**
Allotted Quantity		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,051,843**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**		

Table C.2 Total results from linear programming of multi objectives function at district level.

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Kranuan	1	-	-	535,044.40	-	-	-	-	-	-	-	-	-	-	-	-	-	535,044.40	19,721,064.34
Krasang	2	-	-	-	-	-	-	-	-	-	-	-	9,109.84	-	-	-	-	9,109.84	656,055.13
Kap Choeng	3	-	-	-	-	-	-	-	-	-	-	-	101,040.35	-	-	-	-	101,040.35	4,454,411.22
Kut Rang	4	-	-	-	-	225,429.89	-	-	-	-	-	-	-	-	-	-	-	225,429.89	31,002,545.78
Ku Kaeo	5	121,553.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	121,553.20	5,244,222.17
Khewa Sinarin	6	-	-	-	-	-	-	-	-	-	-	-	427.29	-	-	-	-	427.29	29,604.31
Khaen Dong	7	-	-	-	-	110,698.53	-	-	-	-	-	-	-	-	-	-	-	110,698.53	1,118,364.85
Khok Pho Chai	8	-	-	-	-	-	-	-	-	49,390.16	-	-	-	-	-	-	-	49,390.16	3,321,604.20
Chuen Chom	9	-	-	97,428.81	-	-	-	-	-	-	-	-	-	-	-	-	-	97,428.81	6,001,826.15
Sap Yai	10	-	-	-	-	-	-	-	-	24,750.83	-	-	-	-	-	-	-	24,750.83	2,645,714.21
Sam Sung	11	-	-	135,817.17	-	-	-	-	-	-	-	-	-	-	-	-	-	135,817.17	6,123,343.99
Don Chan	12	-	-	-	-	-	156,056.80	-	-	-	-	-	-	-	-	-	-	156,056.80	8,795,495.79
Thepharak	13	-	-	-	-	-	-	-	-	-	-	-	-	50,356.97	-	-	-	50,356.97	8,473,107.23
Na Khu	14	-	-	-	-	-	2,539.17	-	-	-	-	-	-	-	-	-	-	2,539.17	128,488.39
Non Narai	15	-	-	-	-	-	-	-	-	-	-	-	102.95	-	-	-	-	102.95	15,474.18
Non Sila	16	-	-	-	-	12,419.79	-	-	-	-	-	-	-	79,837.16	-	-	-	92,256.96	12,831,161.73
Bua Lai	17	-	-	-	-	-	-	-	-	-	-	-	-	23,947.24	-	-	-	23,947.24	2,441,256.26
Ban Dan	18	-	-	-	-	45,590.90	-	-	-	-	-	-	-	-	-	-	-	45,590.90	779,790.70
Ban Haet	19	-	-	-	-	-	-	191,734.83	-	-	-	-	-	-	-	-	-	191,734.83	15,919,430.16
Prachak Sinlapakhom	20	-	9,344.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,344.61	291,319.50

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Fao Rai	21	-	-	-	31,310.39	-	-	-	-	-	-	-	-	-	-	-	-	31,310.39	3,044,621.95
Phanom Dong Rak	22	-	-	-	-	-	-	-	-	-	-	-	111,219.28	-	-	-	-	111,219.28	3,008,753.64
Phra Thongkham	23	-	-	-	-	-	-	-	-	-	-	-	-	130,073.93	-	-	-	130,073.93	13,490,336.45
Pho Tak	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,728.21	-	37,728.21	4,148,981.39
Lam Thamenchai	25	-	-	-	-	1,800.25	-	-	-	-	-	-	-	-	-	-	-	1,800.25	76,865.04
Si Narong	26	-	-	-	-	-	-	-	-	-	-	-	107,200.19	-	-	-	-	107,200.19	10,044,315.65
Sa Khrai	27	20,292.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,292.42	2,361,973.77
Sam Chai	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	285,577.90	285,577.90	4,169,411.72
Nong Na Kham	29	-	-	-	-	-	-	8,906.83	-	-	-	-	-	-	-	-	-	8,906.83	490,435.92
Nong Hin	30	-	-	-	-	-	-	-	168,686.42	-	-	-	-	-	-	-	-	168,686.42	19,352,267.09
Erawan	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160,425.64	-	160,425.64	6,672,067.08
Kuchi Narai	32	-	-	-	-	-	355,060.71	-	-	-	-	-	-	-	-	-	-	355,060.71	4,576,777.06
Kut Khao Pun	33	-	-	-	-	-	-	-	-	-	-	14,481.67	-	-	-	-	-	14,481.67	1,661,667.56
Kut Chap	34	21,657.81	-	-	-	-	-	-	-	-	-	-	-	-	-	185,924.58	-	207,582.40	14,101,436.44
Kut Chum	35	-	-	-	-	-	22,490.32	-	-	-	-	-	-	-	-	-	-	22,490.32	2,398,356.47
Kut Bak	36	-	-	-	16,271.86	-	-	-	-	-	-	-	-	-	-	-	-	16,271.86	1,562,261.53
Kumphawapi	37	-	458,029.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458,029.58	4,204,889.41
Kaset Sombun	38	-	-	-	-	-	-	-	419,435.79	-	-	-	-	-	-	-	-	419,435.79	17,865,212.10
Kaeng Khro	39	-	-	-	-	-	-	302,413.55	-	-	-	-	-	-	-	-	-	302,413.55	15,610,029.31
Kaeng Sanam Nang	40	-	-	-	-	-	-	-	-	245,650.97	-	-	-	-	-	-	-	245,650.97	3,669,721.18

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Kosum Phisai	41	-	-	-	-	5,497.55	-	370,360.87	-	-	160,416.28	-	-	-	-	-	-	536,274.70	40,474,968.71
Kham Thale So	42	-	-	-	-	-	-	-	-	-	-	-	-	885.16	-	-	-	885.16	71,270.41
Kham Sakae Saeng	43	-	-	-	-	-	-	-	-	-	-	-	-	65,109.34	-	-	-	65,109.34	5,968,162.13
Khukhan	44	-	-	-	-	-	-	-	-	-	-	-	5,749.83	-	-	-	-	5,749.83	706,696.71
Khun Han	45	-	-	-	-	-	-	-	-	-	-	-	259.32	-	-	-	-	259.32	35,142.86
Khemarat	46	-	-	-	-	-	-	-	-	-	-	16,711.09	-	-	-	-	-	16,711.09	1,557,356.16
Khao Wong	47	-	-	-	-	-	1,033.68	-	-	-	-	-	-	-	-	-	-	1,033.68	26,539.17
Khao Suan Kwang	48	-	-	179,720.56	-	-	-	-	-	-	-	-	-	-	-	-	-	179,720.56	7,268,820.46
Khong	49	-	-	-	-	-	-	-	-	-	-	-	-	147,464.51	-	-	-	147,464.51	13,797,411.75
Khon Buri	50	-	-	-	-	-	-	-	-	-	-	-	-	-	254,502.81	-	-	254,502.81	4,200,227.92
Khon Sawan	51	-	-	-	-	-	-	-	-	84,097.52	-	-	-	-	-	-	-	84,097.52	3,370,352.43
Khon San	52	-	-	-	-	-	-	-	450,997.62	-	-	-	-	-	-	-	-	450,997.62	18,210,396.75
Kham Cha-I	53	-	-	-	-	-	73,960.12	-	-	-	-	-	-	-	-	-	-	73,960.12	5,267,754.63
Kham Ta Kla	54	-	-	-	953.27	-	-	-	-	-	-	-	-	-	-	-	-	953.27	87,631.04
Kham Muang	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	172,942.11	172,942.11	3,400,278.06
Khu Mueang	56	-	-	-	-	102,517.17	-	-	-	-	-	-	-	-	-	-	-	102,517.17	857,681.12
Chom Phra	57	-	-	-	-	-	-	-	-	-	-	-	13,109.66	-	-	-	-	13,109.66	1,196,380.73
Chakkarat	58	-	-	-	-	-	-	-	-	-	-	-	-	231,936.39	-	-	-	231,936.39	7,345,268.78
Chatturat	59	-	-	-	-	-	-	-	-	-	-	-	-	145,711.95	-	-	-	145,711.95	20,866,971.67
Charoen Sin	60	-	-	-	26,594.29	-	-	-	-	-	-	-	-	-	-	-	-	26,594.29	1,845,154.99

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (C_i) (Baht)
Chaloem Phrakiat	61	-	-	-	-	-	-	-	-	-	-	-	-	26,013.10	-	-	-	26,013.10	1,000,162.56
Chonnabot	62	-	-	-	-	-	-	-	-	-	-	-	-	35,636.13	-	-	-	35,636.13	5,158,895.57
Chanuman	63	-	-	-	-	-	-	-	-	-	-	152,918.71	-	-	-	-	-	152,918.71	13,549,615.20
Chamni	64	-	-	-	-	-	-	-	-	-	-	-	3,941.00	-	-	-	-	3,941.00	412,927.21
Chum Phuang	65	-	-	-	-	-	-	-	-	-	-	-	-	109,307.89	-	-	-	109,307.89	6,052,283.20
Chum Phae	66	-	-	-	-	-	-	-	199,209.10	-	-	-	-	-	-	-	-	199,209.10	5,352,470.90
Chiang Yuen	67	-	-	9,512.74	-	-	-	-	-	-	-	-	-	-	-	-	-	9,512.74	587,388.30
Chok Chai	68	-	-	-	-	-	-	-	-	-	-	-	-	1,871.22	131,400.59	-	-	133,271.81	7,445,204.41
Chaiwan	69	61,536.25	-	-	261,138.22	-	-	-	-	-	-	-	-	-	-	-	-	322,674.46	10,977,063.26
Seka	70	-	-	-	58,211.91	-	-	-	-	-	-	-	-	-	-	-	-	58,211.91	7,829,160.77
So Phisai	71	-	-	-	13,517.87	-	-	-	-	-	-	-	-	-	-	-	-	13,517.87	1,731,748.72
Dong Luang	72	-	-	-	-	-	66,575.86	-	-	-	-	-	-	-	-	-	-	66,575.86	5,957,711.37
Don Tan	73	-	-	-	-	-	-	-	-	-	-	263,458.52	-	-	-	-	-	263,458.52	12,604,079.15
Dan Khun Thot	74	-	-	-	-	-	-	-	-	-	-	-	-	285,255.83	-	-	-	285,255.83	41,880,360.48
Trakan Phuet Phon	75	-	-	-	-	-	-	-	-	-	-	779.58	-	-	-	-	-	779.58	119,233.19
Tao Ngoi	76	-	-	-	-	-	22,915.83	-	-	-	-	-	-	-	-	-	-	22,915.83	1,467,411.38
Sai Mun	77	-	-	-	-	-	-	-	-	-	-	-	7,327.95	-	-	-	-	7,327.95	1,756,057.38
Tha Khantho	78	239,444.10	-	82,520.71	-	-	-	-	-	-	-	-	-	-	-	-	-	321,964.81	18,799,704.31
Tha Tum	79	-	-	-	-	-	-	-	-	-	-	-	4,755.92	-	-	-	-	4,755.92	522,502.28
Tha Bo	80	-	5,665.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,665.02	651,548.99

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Tha Uthen	81	-	-	-	4,581.17	-	-	-	-	-	-	-	-	-	-	-	-	4,581.17	837,288.69
Thung Fon	82	-	-	-	12,335.60	-	-	-	-	-	-	-	-	-	-	-	-	12,335.60	336,343.53
Thep Sathit	83	-	-	-	-	-	-	-	-	8,636.29	-	-	-	65,430.42	-	-	-	74,066.70	14,805,903.99
Thai Charoen	84	-	-	-	-	-	22,029.00	-	-	-	-	-	-	-	-	-	-	22,029.00	2,272,936.20
That Phanom	85	-	-	-	-	-	-	-	-	-	-	15,052.19	-	-	-	-	-	15,052.19	554,949.42
Na Klang	86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57,130.45	-	57,130.45	35,726.31
Na Kae	87	-	-	-	-	-	4,682.29	-	-	-	-	-	-	-	-	-	-	4,682.29	564,443.46
Nang Rong	88	-	-	-	-	-	-	-	-	-	-	-	58,801.55	-	-	-	-	58,801.55	5,786,605.72
Na Chueak	89	-	-	-	-	48,530.63	-	-	-	-	-	-	-	-	-	-	-	48,530.63	5,233,070.36
Na Duang	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,681.46	-	3,681.46	189,032.09
Na Dun	91	-	-	-	-	4,013.96	-	-	-	-	-	-	-	-	-	-	-	4,013.96	439,935.87
Na Thom	92	-	-	-	5,080.34	-	-	-	-	-	-	-	-	-	-	-	-	5,080.34	927,558.77
Na Pho	93	-	-	-	-	511.10	-	-	-	-	-	-	-	-	-	-	-	511.10	47,215.29
Na Mon	94	-	-	-	-	-	121,972.84	-	-	-	-	-	-	-	-	-	-	121,972.84	5,226,513.94
Na Yung	95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,103.89	-	3,103.89	296,333.67
Na Wang	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77,634.58	-	77,634.58	2,018,360.95
Nam Phong	97	-	-	468,132.09	-	-	-	-	-	-	-	-	-	-	-	-	-	468,132.09	3,227,486.28
Nam Som	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120,743.22	-	120,743.22	9,306,305.50
Nikhom Kham Soi	99	-	-	-	-	-	46,019.43	-	-	-	-	144,574.40	-	-	-	-	-	190,593.83	10,297,269.96
Nikhom Nam Un	100	-	-	-	9,485.09	-	-	-	-	-	-	-	-	-	-	-	-	9,485.09	776,389.26

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Noen Sa-Nga	101	-	-	-	-	-	-	-	-	-	-	-	-	38,847.64	-	-	-	38,847.64	4,567,087.85
on Din Daeng	102	-	-	-	-	-	-	-	-	-	-	-	16,787.56	-	-	-	-	16,787.56	1,855,686.55
Non Thai	103	-	-	-	-	-	-	-	-	-	-	-	-	870.20	-	-	-	870.20	74,202.86
Non Sa-At	104	-	409,976.64	217,705.84	-	-	-	-	-	-	-	-	-	-	-	-	-	627,682.48	16,590,855.40
Non Sang	105	-	-	-	-	-	-	1,716.72	-	-	-	-	-	-	-	-	-	1,716.72	131,958.86
Non Suwan	106	-	-	-	-	-	-	-	-	-	-	-	2,461.84	-	10,222.32	-	-	12,684.16	962,690.93
Borabue	107	-	-	-	-	68,791.19	-	-	-	-	-	-	-	-	-	-	-	68,791.19	9,804,707.20
Bua Chet	108	-	-	-	-	-	-	-	-	-	-	-	136,914.80	-	-	-	-	136,914.80	13,183,784.86
Bua Yai	109	-	-	-	-	-	-	-	-	119,812.14	-	-	-	-	-	-	-	119,812.14	4,073,133.48
Ban Kruat	110	-	-	-	-	-	-	-	-	-	-	-	74,718.53	-	-	-	-	74,718.53	5,340,076.84
Ban Khwao	111	-	-	-	-	-	-	-	-	32,215.82	-	-	-	-	-	-	-	32,215.82	2,445,158.96
Ban Dung	112	-	-	-	132,205.26	-	-	-	-	-	-	-	-	-	-	-	-	132,205.26	7,277,357.90
Ban Thaen	113	-	-	-	-	-	-	196,407.13	-	-	-	-	-	-	-	-	-	196,407.13	4,725,817.85
Ban Phue	114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	257,478.32	-	257,478.32	18,411,396.08
Ban Phai	115	-	-	-	-	227,696.03	-	-	-	-	-	-	-	-	-	-	-	227,696.03	32,191,310.06
Ban Fang	116	-	-	-	-	-	-	137,447.88	-	-	-	-	-	-	-	-	-	137,447.88	4,544,097.13
Ban Phaeng	117	-	-	-	1,076.04	-	-	-	-	-	-	-	-	-	-	-	-	1,076.04	191,357.53
Ban Muang	118	-	-	-	72,218.41	-	-	-	-	-	-	-	-	-	-	-	-	72,218.41	7,112,486.70
Ban Lueam	119	-	-	-	-	-	-	-	-	167,875.74	-	-	-	-	-	-	-	167,875.74	5,727,892.43
Bamnet Narong	120	-	-	-	-	-	-	-	-	-	-	-	-	80,195.88	-	-	-	80,195.88	12,088,594.38

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Bueng Kan	121	-	-	-	229.78	-	-	-	-	-	-	-	-	-	-	-	-	229.78	34,507.00
Bueng Khong Long	122	-	-	-	37,336.93	-	-	-	-	-	-	-	-	-	-	-	-	37,336.93	5,351,964.57
Pathum Ratchawongsa	123	-	-	-	-	-	-	-	-	-	-	25,513.99	-	-	-	-	-	25,513.99	2,889,633.73
Prakhon Chai	124	-	-	-	-	-	-	-	-	-	-	-	6,513.22	-	-	-	-	6,513.22	530,637.85
Prang Ku	125	-	-	-	-	-	-	-	-	-	-	-	7,859.54	-	-	-	-	7,859.54	874,387.98
Prasat	126	-	-	-	-	-	-	-	-	-	-	-	39,439.22	-	-	-	-	39,439.22	226,014.74
Pakham	127	-	-	-	-	-	-	-	-	-	-	-	16,195.39	-	-	-	-	16,195.39	1,921,414.67
Pak Thong Chai	128	-	-	-	-	-	-	-	-	-	-	-	-	-	305,522.77	-	-	305,522.77	14,224,985.82
Pak Khat	129	-	-	-	326.92	-	-	-	-	-	-	-	-	-	-	-	-	326.92	50,776.79
Pak Chong	130	-	-	-	-	-	-	-	-	-	-	-	-	-	575,049.39	-	-	575,049.39	56,877,601.20
Pa Tio	131	-	-	-	-	-	-	-	-	-	-	-	9,240.86	-	-	-	-	9,240.86	2,622,615.29
Pueai Noi	132	-	-	-	-	63,395.75	-	-	-	-	-	-	-	-	-	-	-	63,395.75	7,322,882.52
Pha Khao	133	-	-	-	-	-	-	223,185.50	-	-	-	-	-	-	-	-	-	223,185.50	28,116,007.34
Phon Charoen	134	-	-	-	12,366.91	-	-	-	-	-	-	-	-	-	-	-	-	12,366.91	1,806,045.13
Phanna Nikhom	135	-	-	-	32,919.28	-	-	-	-	-	-	-	-	-	-	-	-	32,919.28	3,010,238.93
Phra Yuen	136	-	-	-	-	-	-	11,946.43	-	-	-	-	-	-	-	-	-	11,946.43	389,156.60
Phon	137	-	-	-	-	-	-	-	-	-	-	-	-	35,336.77	-	-	-	35,336.77	4,233,945.43
Phang Khon	138	-	-	-	1,999.26	-	-	-	-	-	-	-	-	-	-	-	-	1,999.26	173,037.84
Phibun Rak	139	-	-	-	27,536.19	-	-	-	-	-	-	-	-	-	-	-	-	27,536.19	1,469,284.45
Phimai	140	-	-	-	-	-	-	-	-	-	-	-	-	246,192.57	-	-	-	246,192.57	4,000,024.52

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Phen	141	-	-	-	10,126.10	-	-	-	-	-	-	-	-	-	-	-	-	10,126.10	795,846.17
Pho Chai	142	-	-	-	-	-	149,506.15	-	-	-	-	-	-	-	-	-	-	149,506.15	9,841,692.13
Pho Sai	143	-	-	-	-	-	-	-	-	-	-	3,498.60	-	-	-	-	-	3,498.60	535,096.00
Phon Thong	144	-	-	-	-	-	298,031.24	-	-	-	-	-	-	-	-	-	-	298,031.24	5,669,226.84
Phon Phisai	145	-	-	-	20,696.07	-	-	-	-	-	-	-	-	-	-	-	-	20,696.07	1,830,400.29
Phon Sawan	146	-	-	-	795.55	-	-	-	-	-	-	-	-	-	-	-	-	795.55	149,347.57
Phrai Bueng	147	-	-	-	-	-	-	-	-	-	-	-	506.38	-	-	-	-	506.38	64,996.31
Phakdi Chumphon	148	-	-	-	-	-	-	-	-	10,613.45	-	-	-	-	-	-	-	10,613.45	1,489,212.73
Phu Kradueng	149	-	-	-	-	-	-	-	37,192.68	-	-	-	-	-	-	-	-	37,192.68	2,957,601.84
Phu Khiao	150	-	-	-	-	-	-	-	1,119,186.07	-	-	-	-	-	-	-	-	1,119,186.07	12,929,849.61
Phu Pha Man	151	-	-	-	-	-	-	-	93,144.04	-	-	-	-	-	-	-	-	93,144.04	4,815,667.16
Phu Phan	152	-	-	-	-	-	34,571.93	-	-	-	-	-	-	-	-	-	-	34,571.93	2,723,537.84
Phu Wiang	153	-	-	-	-	-	-	120,395.75	-	-	-	-	-	-	-	-	-	120,395.75	3,342,911.32
Phu Sing	154	-	-	-	-	-	-	-	-	-	-	-	24,056.87	-	-	-	-	24,056.87	3,061,165.39
Phu Luang	155	-	-	-	-	-	-	-	21,612.60	-	-	-	-	-	-	-	-	21,612.60	2,703,977.64
Mancha Khiri	156	-	-	-	-	-	-	323,978.03	-	-	-	-	-	-	-	-	-	323,978.03	16,726,481.71
Moei Wadi	157	-	-	-	-	-	32,193.53	-	-	-	-	-	-	-	-	-	-	32,193.53	1,182,258.31
Mueang Kalasin	158	-	-	-	-	-	87,766.46	-	-	-	-	-	-	-	-	-	-	87,766.46	6,390,200.45
Mueang Khon Kaen	159	-	-	-	-	-	-	168,791.18	-	-	-	-	-	-	-	-	-	168,791.18	8,235,596.39
Mueang Chaiyaphum	160	-	-	-	-	-	-	-	-	117,511.27	-	-	-	-	-	-	-	117,511.27	6,899,314.23

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Mueang Nakhon Ratchasima	161	-	-	-	-	-	-	-	-	-	-	-	-	-	68,119.39	-	-	68,119.39	4,324,620.19
Mueang Buri Ram	162	-	-	-	-	33,653.22	-	-	-	-	-	-	-	-	-	-	-	33,653.22	894,302.28
Mueang Maha Sarakham	163	-	-	-	-	-	-	-	-	-	5,583.72	-	-	-	-	-	-	5,583.72	46,698.45
Mueang Mukdahan	164	-	-	-	-	-	-	-	-	-	-	409,521.60	-	-	-	-	-	409,521.60	10,919,740.35
Mueang Yasothon	165	-	-	-	-	-	4,507.52	-	-	-	-	-	-	-	-	-	-	4,507.52	398,622.46
Mueang Loei	166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	817.01	-	817.01	60,931.84
Mueang Sakon Nakhon	167	-	-	-	-	-	16,611.10	-	-	-	-	-	-	-	-	-	-	16,611.10	2,216,261.43
Mueang Surin	168	-	-	-	-	-	-	-	-	-	-	-	14,512.44	-	-	-	-	14,512.44	799,919.85
Mueang Nong Khai	169	-	676.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	676.15	73,370.94
Mueang Nong Bua Lamphu	170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57,964.04	-	57,964.04	1,771,415.66
Mueang Amnat Charoen	171	-	-	-	-	-	20,101.30	-	-	-	-	-	-	-	-	-	-	20,101.30	2,845,159.22
Mueang Udon Thani	172	-	169,079.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	169,079.17	9,177,918.26
Yang Talat	173	-	-	25,219.90	-	-	-	-	-	-	-	-	-	-	-	-	-	25,219.90	1,838,253.33
Rattana Buri	174	-	-	-	-	-	-	-	-	-	-	-	676.54	-	-	-	-	676.54	101,024.56
Lahan Sai	175	-	-	-	-	-	-	-	-	-	-	-	149,660.03	-	-	-	-	149,660.03	16,660,129.50
Lamduan	176	-	-	-	-	-	-	-	-	-	-	-	3,004.55	-	-	-	-	3,004.55	225,059.67
Lam Plai Mat	177	-	-	-	-	52,983.10	-	-	-	-	-	-	-	-	-	-	-	52,983.10	1,994,496.01
Loeng Nok Tha	178	-	-	-	-	-	156,331.87	-	-	-	-	-	-	-	-	-	-	156,331.87	13,054,222.85
Wang Nam Khiao	179	-	-	-	-	-	-	-	-	-	-	-	-	-	178,673.89	-	-	178,673.89	14,036,081.66

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (C_i) (Baht)
Wang Saphung	180	-	-	-	-	-	-	216,001.81	143,519.16	-	-	-	-	-	-	-	-	359,520.97	50,610,784.64
Wang Sam Mo	181	297,234.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	616,034.17	913,268.68	36,473,096.31
Waritchaphum	182	-	-	-	13,529.09	-	-	-	-	-	-	-	-	-	-	-	-	13,529.09	869,148.75
Waeng Noi	183	-	-	-	-	-	-	-	-	8,883.97	-	-	-	-	-	-	-	8,883.97	223,409.38
Waeng Yai	184	-	-	-	-	-	-	-	-	7,638.55	-	-	-	-	-	-	-	7,638.55	453,782.92
Si Chiang Mai	185	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29,451.30	-	29,451.30	3,917,554.17
Si That	186	747,281.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	747,281.71	29,075,524.44
Si Bunrueang	187	-	-	-	-	-	-	252,700.43	-	-	-	-	-	-	-	-	-	252,700.43	24,519,745.35
Si Wilai	188	-	-	-	7,066.61	-	-	-	-	-	-	-	-	-	-	-	-	7,066.61	1,104,792.60
Si Songkhram	189	-	-	-	13,228.26	-	-	-	-	-	-	-	-	-	-	-	-	13,228.26	2,182,921.48
Si Khoraphum	190	-	-	-	-	-	-	-	-	-	-	-	4,481.55	-	-	-	-	4,481.55	511,457.80
Satuek	191	-	-	-	-	99,737.28	-	-	-	-	-	-	-	-	-	-	-	99,737.28	2,782,997.84
Sanom	192	-	-	-	-	-	-	-	-	-	-	-	5,436.94	-	-	-	-	5,436.94	596,659.35
Somdet	193	-	-	-	-	-	96,359.44	-	-	-	-	-	-	-	-	-	-	96,359.44	7,326,415.21
Sang Khom	194	-	-	-	1,983.68	-	-	-	-	-	-	-	-	-	-	-	-	1,983.68	155,996.13
Sawang Daen Din	195	-	-	-	160,586.09	-	-	-	-	-	-	-	-	-	-	-	-	160,586.09	2,524,469.88
Sahatsakhan	196	-	-	-	-	-	32,187.14	-	-	-	-	-	-	-	-	-	38,445.82	70,632.96	4,197,023.41
Song Dao	197	-	-	-	149,403.05	-	-	-	-	-	-	-	-	-	-	-	-	149,403.05	5,829,861.69
Sangkha	198	-	-	-	-	-	-	-	-	-	-	-	114,114.22	-	-	-	-	114,114.22	9,729,445.02
Sangkhom	199	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,635.25	-	5,635.25	655,886.73

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (C_i) (Baht)
Samrong Thap	200	-	-	-	-	-	-	-	-	-	-	-	551.27	-	-	-	-	551.27	73,817.65
Sirindhorn	201	-	-	-	-	-	-	-	-	-	-	-	769.60	-	-	-	-	769.60	249,779.59
Si Khio	202	-	-	-	-	-	-	-	-	-	-	-	-	-	193,337.52	-	-	193,337.52	24,000,668.69
Si Chomphu	203	-	-	-	-	-	-	-	278,016.54	-	-	-	-	-	-	-	-	278,016.54	12,858,058.77
Suwanna Khuha	204	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34,282.05	-	34,282.05	1,931,456.29
Sung Noen	205	-	-	-	-	-	-	-	-	-	-	-	-	-	89,817.03	-	-	89,817.03	6,113,181.61
Senangkha Nikhom	206	-	-	-	-	-	8,116.53	-	-	-	-	-	-	-	-	-	-	8,116.53	1,252,992.78
Selaphum	207	-	-	-	-	-	43,797.04	-	-	-	-	-	-	-	-	-	-	43,797.04	3,050,703.90
Soeng Sang	208	-	-	-	-	-	-	-	-	-	-	-	-	-	93,354.29	-	-	93,354.29	4,712,753.40
Nong Ki	209	-	-	-	-	-	-	-	-	-	-	-	-	141,004.45	-	-	-	141,004.45	11,007,155.12
Nong Kung Si	210	-	-	443,712.92	-	-	-	-	-	-	-	-	-	-	-	-	-	443,712.92	30,414,690.26
Nong Bua Daeng	211	-	-	-	-	-	-	-	-	296,914.26	-	-	-	-	-	-	-	296,914.26	35,405,571.23
Nong Bua Rawe	212	-	-	-	-	-	-	-	-	43,009.02	-	-	-	-	-	-	-	43,009.02	3,744,851.93
Nong Bunnak	213	-	-	-	-	-	-	-	-	-	-	-	-	174,688.47	-	-	-	174,688.47	11,819,548.20
Nong Phok	214	-	-	-	-	-	138,375.13	-	-	-	-	-	-	-	-	-	-	138,375.13	8,552,251.28
Nong Ruea	215	-	-	-	-	-	-	202,678.46	-	-	-	-	-	-	-	-	-	202,678.46	1,827,271.39
Nong Wua So	216	-	57,859.59	-	-	-	-	69,334.59	-	-	-	-	-	-	-	-	-	127,194.18	14,860,730.28
Nong Song Hong	217	-	-	-	-	102,733.66	-	-	-	-	-	-	-	-	-	-	-	102,733.66	12,909,209.38
Nong Sung	218	-	-	-	-	-	23,895.50	-	-	-	-	-	-	-	-	-	-	23,895.50	1,342,406.96

Table C.2 (Continued).

District	No	Kumpawapi	Kaset Phol	Khon Kaen	Rerm Udom	Burirum	Mitr Kalasin	Mitr Phu Viang	United Farmer & Industry	Angvian Industry (Ratchasima)	Wangkanai	Saharuang	Surin	Korach Industry	N.Y. sugar (Khonburi)	Arawan	E – Saan Sugar Industry	Total Production of District (s_i)	Transportation cost in district level (Ci) (Baht)
Nong Saeng	219	-	331,369.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	331,369.23	6,574,169.22
Nong Hong	220	-	-	-	-	-	-	-	-	-	-	-	-	170,453.64	-	-	-	170,453.64	8,957,581.33
Nong Han	221	-	-	-	108,145.99	-	-	-	-	-	-	-	-	-	-	-	-	108,145.99	2,475,991.38
Huai Thalaeng	222	-	-	-	-	-	-	-	-	-	-	-	-	131,573.13	-	-	-	131,573.13	4,652,276.53
Huai Thapthan	223	-	-	-	-	-	-	-	-	-	-	-	896.89	-	-	-	-	896.89	121,728.89
Huai Phueng	224	-	-	-	-	-	111,312.06	-	-	-	-	-	-	-	-	-	-	111,312.06	4,562,594.56
Huai Mek	225	-	-	191,277.25	-	-	-	-	-	-	-	-	-	-	-	-	-	191,277.25	10,657,389.45
Wan Yai	226	-	-	-	-	-	-	-	-	-	-	19,489.65	-	-	-	-	-	19,489.65	584,633.56
Akat Amnuai	227	-	-	-	2,744.53	-	-	-	-	-	-	-	-	-	-	-	-	2,744.53	298,378.16
Ubonrat	228	-	-	101,907.62	-	-	-	-	-	-	-	-	-	-	-	-	-	101,907.62	2,930,677.36
Factory Allotted Capacity (dj)		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,209,000**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**	**Total Cost**	**1,478,985,242.38**
Allotted Quantity		**1,509,000**	**1,442,000**	**2,488,000**	**1,246,000**	**1,206,000**	**2,149,000**	**2,798,000**	**2,931,000**	**1,217,000**	**166,000**	**1,066,000**	**1,051,843**	**2,418,000**	**1,900,000**	**1,032,000**	**1,113,000**		

CURRICULUM VITAE

Name Miss Warunee Unphoklang

Date of Birth January 14, 1986

Place of Birth Nakhon Ratchasima

Education 2003 - 2007 Bachelor of Information Science (Management Information Systems), Suranaree University of Technology, Nakhon Ratchasima, Thailand.

Publication

Warunee Aunphoklang, Sunya Sarapirome, and Patiwat Littidej. 2011. Comparison on different clustering of origins for sugarcane transportation using Network Analysis and Linear Programming. **Proceedings of the 32nd Asian Conference on Remote Sensing 2011**, Oct 03–07. Taipei, Taiwan.

Sunya Sarapirome, Warunee Aunphoklang, and Patiwat Littidej. 2013. Sugarcane transportation management using Network Analysis and Linear Programming. **Proceedings of the 1st Conference on Geoinformatics for Graduate Students and Young Researcher**s **2013**, June 19-21. Nakhon Ratchasima, Thailand, PI18-216, 14 p.

Grants and Fellowships Potential scholarship, Suranaree University of Technology