COMPARISON ON DIFFERENT CLUSTERING OF ORIGINS FOR SUGARCANE TRANSPORTATION USING NETWORK ANALYSIS AND LINEAR PROGRAMMING

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ABSRACT: 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 transportation cost unnecessary. The purpose of the study is to apply Network Analysis (NA) and Linear Programming (LP) to perform transportation management of sugarcane produced in the Khon Kaen province of Thailand. The NA is for selecting the shortest routes from the origins to factories. The single objective decision analysis is optimization function through the LP in order that total transportation cost of sugarcane product from origins to sets of factories is minimized. Analyses cannot be performed by plots due to their huge amount which are over the limitation of any software. To avoid this limitation, the conventional method always used centers of provinces or districts as the origins. Instead, this study sets up clustering by representative points of districts, sub-districts, and sugarcane plots in sub-districts as the origins. Results from the different clustering of origins for transportation were compared in terms of sugarcane allotment to factories. The study revealed that, with different clustering of origins, the performance by lower clustering level showed more number of factories as destinations and more details of allotments.

1. INTRODUCTION

Sugar industry is one among important industries in Thailand which can make high income for both agricultural and industry sectors. The sugar production cost depends more on the cost of sugarcane transportation from cropping areas to factories. Currently, the sugarcane transportation management relies only on leader decisions. The decision can be unsystematic and low efficiency. This can lead to great loss in transportation cost unnecessary. According to information surveyed by the Office of the Cane and Sugar Board (OCSB) in the production year 2009/2010, Khon Kaen province in the Northeast region of Thailand has been one among provinces having the biggest sugarcane cropping area in this region. There are 11 sugar factories around this province. This province supplies 3,902,000 tons of sugarcane to factories. The number of plots distributing in this province is so tremendous amount that analyses cannot be performed by plots. Their huge amount is over the limitation of any software. To avoid this limitation, the conventional method always used centers of provinces or districts as the origins of transportation. In this study, sets of clustering represented by points of districts, sub-districts, and sugarcane plots in sub-districts were varied to be the origins of transportation. The purpose of the study is to apply Network Analysis (NA) and Linear Programming (LP) to performing minimized transportation cost of sugarcane produced in the Khon Kaen province from different kinds of mentioned origins to factories. The allotments of sugarcane from different origins to certain sets of factory were observed and reported.

The Study Area

The study area is Khon Kaen province in the Northeastern region of Thailand. It covers approximately 10,600 km^2 and consists of 25 districts and 199 sub-districts, but sugarcane cropping area available in only 157 sub-districts. According to information surveyed by the Office of the Cane and Sugar Board (OCSB) of the year 2009/2010, the sugarcane produced from this province was approximately 3,902,000 tons. The study area, locations of sugar factories, and sugarcane cropping areas are displayed in Figure 1.

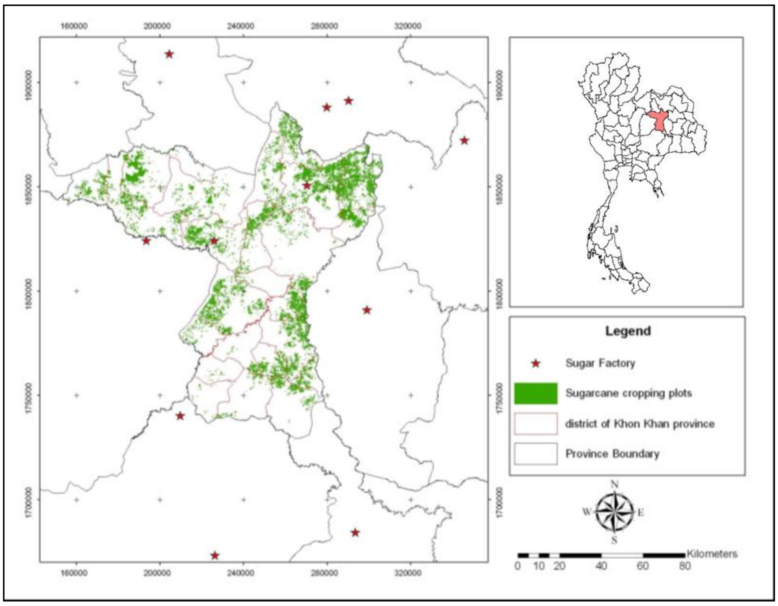

Figure 1 Districts, locations of sugar factories, and sugarcane cropping areas in the study area.

2. PROCEDURES OF THE STUDY

The procedure framework in this study is illustrated in Figure 2. It includes data collection and 3 clustering of origins of sugarcane transportation which are district, sub-district, and plots of sub-districts. Only plots from 4 sub-districts were taken as a sample set of plots to analysis. The analytical procedure of each clustering is the same. Their centroid as point data and road network were input for the NA which resulted in O-D matrix of distance from each origin in the clustering to the each destination which is a set of surrounding factories. Sugarcane amount and distance from the O-D matrix were input to the LP to match a certain allotment from each origin to a certain set of destinations or factories. The matching was performed to achieve the minimum total cost of transportation of all sugarcane products in each origin. Results were compared to confirm that allotments for factories should be different and lower clustering level provided more detail routes from origins and allotments.

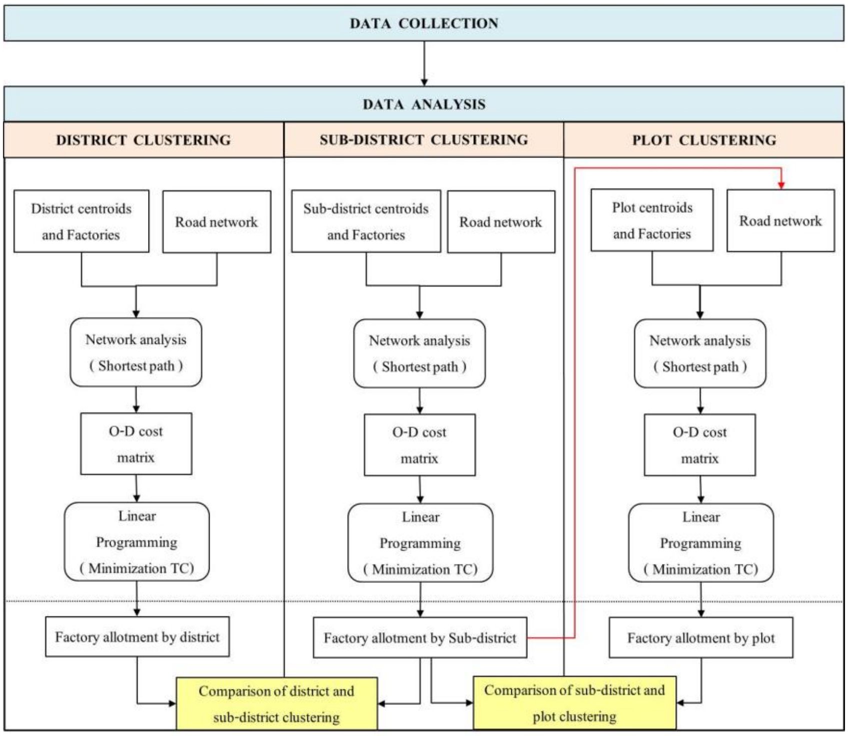

Figure 2 Procedure framework of the study.

2.1 Data Collection

Data used for the analyses include GIS layers of cropping plots, administrative boundary of districts and sub-districts in the province, locations of sugarcane factories, and road network. Data of official allotment to factories and basic transportation cost of sugarcane in the region were also needed as input of objective function and constraints for the LP. The sources and dates of data collected are listed in Table 1.

Table 1 Types, sources, and dates of data used as input for the NA and the LP

Type of data	Source	Year
1) Sugarcane cropping plots	OCSB	2009/2010
2) Sugar factory locations	OCSB	2009
3) Official factory allotment	OCSB	2009/2010
4) Road network	Ministry of Transport	2010
5) Transportation cost (baht/km/tons)	Thai transportation and Logistics Association	2010

The input of each clustering for the NA includes road network, a number of origins (centroids of districts, sub-districts, and a sample set of plots from 4 sub-districts), and destinations (factories). The input of the LP of each clustering include the O-D cost matrix resulted from the NA, sugarcane production of each centroid in the clustering, official factory allotment as constraints. The whole factories were used in the LP for the district and sub-district clustering whereas plot clustering used certain sets of factories from the sub-district clustering which were results of the LP analysis.

2.2 Network Analysis (NA)

In this study, the network analysis was performed under the shortest path solution. The Closest Facility analysis which is the function of ArcGIS 9.x was used to solve the shortest path problem through Dijkstra's algorithm (Evans and Minieka, 1992). 25 points and 157 points were the centroids of districts and sub-districts while 11 points were for factory locations. Output from the NA was the shortest route (distance) of each origin to each destination and expressed in form of O-D cost matrix when multiplied by transportation cost (baht /ton). There are 275 and 1,727 routes in districts and sub-district clustering.

2.3 Linear Programming (LP)

This single objective analysis is to minimize the total transportation cost from origins to destinations. The transportation cost from NA (O-D cost matrix) was input to the LP model to calculate minimized cost of sugarcane transportation to factories. c_{ij} is the transportation costs of the sugarcane from the origin *i* to the sugar factory or destination *j*. The LP model working as the transportation optimization function can be expressed as the following equations (Bazaraa et al., 1990).

Minimize $$TC = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \quad (1)$$

Subject to constraints:

$$\sum_{j=1}^{n} x_{ij} = s_i \quad \text{for } \forall_i \quad (2)$$

$$\sum_{i=1}^{m} x_{ij} \leq d_j \quad \text{for } \forall_j \quad (3)$$

$$x_{ij} \geq 0 \quad \text{for } \forall_{i,j} \quad (4)$$

When:

TC - total cost of sugarcane transportation (Baht).

c_{ij} - the cost of sugarcane transportation from origin i to sugar factory j (Baht/tons).

x_{ij} - the quantity of sugarcane at origin i to sugar factory j (Tons).

s_i - the quantity of sugarcane production at origin i (Tons).

d_j - the factory allotment for factory j , that receive from the OCSB (Tons).

i - origin, get i = 1,2,3,..,m

j - sugar factory, get j = 1,2,3,..,n

3. Result of the Analyses

The results of the LP analyses in each clustering include minimized cost of sugarcane transportation, certain set of factories and proper sugarcane allotment from each origin to certain set of factories. Allotments of plots within origins to factories can be displayed as maps. The comparisons were performed between results district and sub-district origins and between sub-district and plot origin as discussed below.

Comparison between results from district and sub-district origins

The maps of plots in districts and sub-districts to certain factories are displayed in Figurer 3. Allotments of plots to factories are separated by different colors. Plots from the origin and a factory or factories in service are displayed in the same color. A set of factories in service of sub-district clustering has one factory more than of district clustering. Allotments of plots to factories in two types of clustering are different.

In district clustering, 6 factories from 11 factories are in service with different allotments, including Kaset Phol Factory (185,020 tons), Khon Kaen Factory (1,282,904 tons), Mitr Phu Viang Factory (1,194,467 tons), United Farmer & Industry Factory (587,604 tons), Angvian Factory (479,823 tons) and Wangkanai Factory (172 ,019 tons).

In sub-district clustering, 7 factories from 11 factories are in service with different allotments, including Kumpawapi Factory (35,313 tons), Kaset Phol Factory (53,665 tons), Khon Kaen Factory (1,588,947 tons), Mitr Phu Viang Factory (1,080,943 tons), United Farmer & Industry Factory (566,577 tons), Angvian Factory (410,393 tons) and Wangkanai Factory (166,000 tons).

Comparison between results from sub-district and plot origins

The centroid data of plots from only 4 sub-districts were taken for analysis in plot clustering as examples due to great time required for data preparation. Herein, result of Na Ngiew sub-district which covered 2 factories in service in plot clustering was brought to discuss as an example. 307 centroids of plots in this sub-districts were operated with 7 factories as same as the ones in service for sub-district clustering. In plot clustering, sugarcane products were allotted to Kaset Phol Factory (49,765 tons) and Khon Kaen Factory (3,900 tons) while in sub-district clustering the whole product (53,665 tons) was allotted to Kaset Phol Factory.

It is important to note that the comparison of total costs from different clustering cannot be performed because of the difference in a number of origins. The bigger number of origin leads to more variety of optimum routes, for example, 275 and 1727 routes for district and sub-district clustering. Transportation costs estimated from these routes were used in the LP analysis. Therefore, the lower clustering level tends to have the higher total transportation cost.

4. CONCLUSION

The single objective decision analysis using the NA and the LP can be an efficient tool to allot sugarcane products to factories with minimized total transportation cost performed under the requirement on constraints and the shortest path. Three different clustering of origins were set for the analyses. The results can provide minimized cost of sugarcane transportation, certain set of factories and proper sugarcane allotment from each origin to certain set of factories. The comparisons of results from all clustering revealed that the lower clustering level was able to provide more detail in optimum routes from the origins to destinations, more detail of allotments and factories in service.

In the study, the clustering levels were designed because of the limitation of software capability and capacity in dealing with huge amount of records of sugarcane plots. Therefore, if all plots can be operated in the analysis at once with all available factories, the best result can be expected.

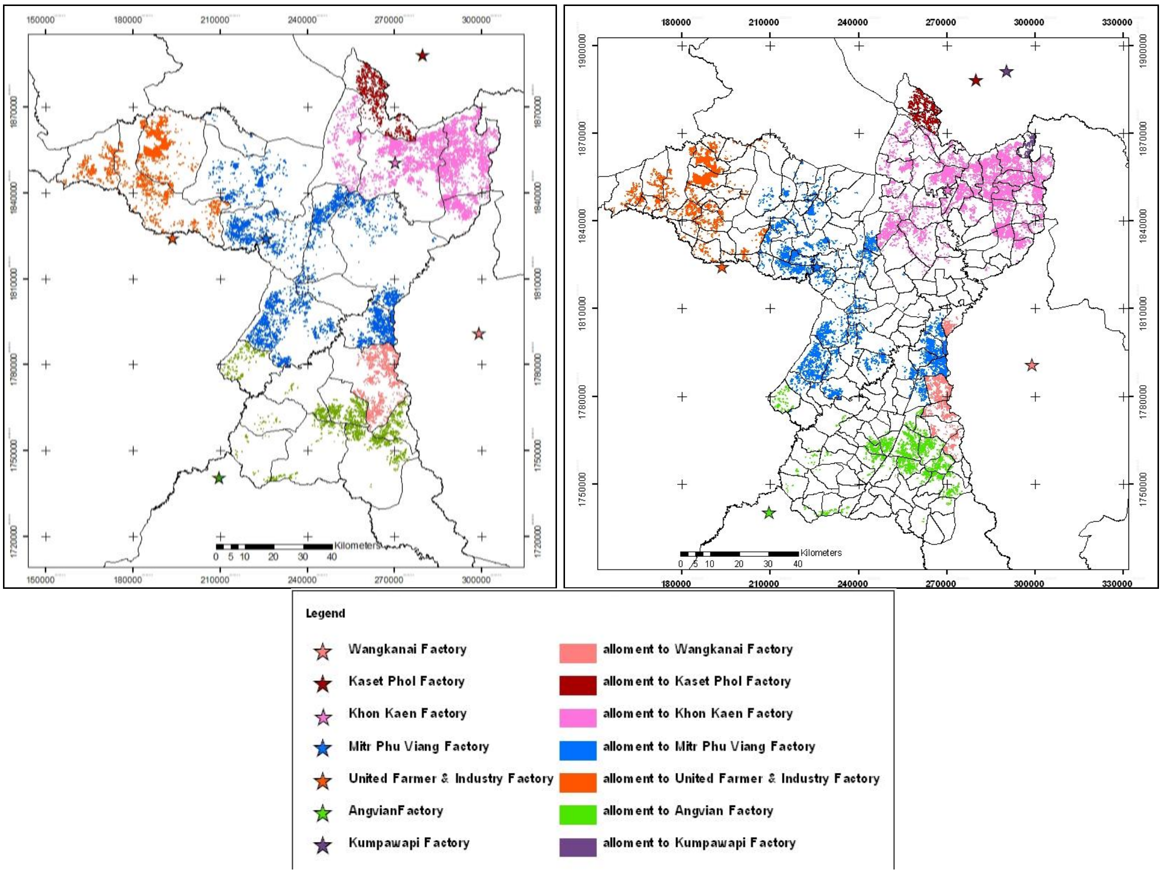

Figure 3 Comparison of allotments of sugarcane products to factories based on district and sub-district clustering.

5. REFERENCES

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