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Supply Chain Network Design of Ethanol in Thailand

Rojanee Homchalee[1,a] and Weerapat Sessomboon[2,b*]

[1,2]Department of Industrial Engineering, Khon Kaen University, Khon Kaen, Thailand

[a]rojaneeh@hotmail.com, [b]weerapatkku@hotmail.com

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Abstract. The proposed model is location-allocation model developed to design and manage the plants-to-customers ethanol supply chain in Thailand with the objective to minimize the total cost. The results showed that Thailand should have only one ethanol export depot and central depot located along wharfs in Samut Prakan province and along the highway in Non Sung district, Nakhon Ratchasima province, respectively. This model also provided solutions on opening and expanding of production capacity of ethanol plants over time and appropriate ethanol allocation both of direct distribution and through the central depot for long term (2012-2021).

Introduction

Ethanol is listed in alternative energy plan of Thailand called "The Renewable and Alternative Energy Development Plan for 25% in 10 Years (AEDP 2012-2021)". Major feedstocks for ethanol production in Thailand are molasses and cassava. Although there is expansion both supply and demand, logistic systems of Thai ethanol supply chain is quite low efficient. Since ethanol is transported from plants to gasohol blending depots by trailer trucks only. And all of ethanol plants are located in the Northeast, East, West and Central region, but most gasohol depots are in Bangkok and its vicinity [1, 2]. So these result in higher costs of supply chain. Therefore, this study aims to design and manage the plants-to-customers ethanol supply chain in Thailand.

Supply chain management has been used to improve the organizations with three parts of key components: 1) supply chain drivers such as customer service initiative, monetary value 2) supply chain constraints such as capacity, demand 3) supply chain decision variables such as location, allocation, inventory level, etc. [3]. Supply chain modeling approaches can be divided into four groups: deterministic models, stochastic models, economic models, and simulation models [4]. There are models used for decision support makings in strategic supply chain planning, especially the integration of location and supply chain network design [5]. Location-allocation model was applied for facility location and resource allocation in biofuel supply chain [6]. For example, there was a mathematical model for design the supply chain and manage the logistics of a biorefinery. The proposed model can be used to make a decision for supply chain design in long-term and logistics management in medium to short-term [7]. From these literatures, we have taken as guidelines to develop a mathematical model for supply chain network design of ethanol in Thailand.

Methodology

Initially, alternative central depots were determined by K-means clustering and analyzed by SPSS statistics 17.0 consisting of 1) Nong Sarai, Don Chedi district, Suphan Buri 2) Kabin, Kabin Buri district, Prachin Buri 3) Nai Mueang, Ban Phai district, Khon Kaen 4) Nong Sam Si, Senangkhanikhom district, Amnat Charoen. We also set alternative depots by considering the transportation infrastructure for both road and railway. It provided two alternative depots, 1) Don Wai, Non Sung district, Nakhon Ratchasima and 2) Chong Khae, Takhli district, Nakhon Sawan.

Subsequently, location-allocation model was developed for plants-to-customers ethanol supply chain with minimizes the total cost. Parameters of model were derived from our past research [2]. Moreover, they were forecasted by time series analysis and ANN [8]. This proposed model was solved by optimization modelling software, LINGO 11.0.

Mathematical Model

We formulated the location-allocation model consisting of indices sets are: I is set of existing ethanol plants; M is set of new ethanol plants; J is set of ethanol export depot; K is set of gasohol blending depots; N is set of new gasohol blending depots; L is set of ethanol central depots; T is set of periods. The parameters used in this model are: ω_{it} is operating cost per unit of plant i in period t; δ_{jt}^{E} and δ_{lt}^{D} are annual operating cost of export depot j and central depot l in period t; α_t and β_t are transportation cost by truck and by rail in period t; d_{il}^{PD}, d_{ij}^{PE}, d_{ik}^{PC}, d_{lk}^{DC}, d_{lj}^{DE} are distance among plant i, central depot l, export depot j, and gasohol depot k; Cap_i is production capacity of plant i; Dm_{kt}^{C} and Dm_{t}^{E} are demand of gasohol depot k and demand from abroad in period t; M is positive large number. The decision variables used in this model are: P_{it} is binary variable that equals to 1 if the new plant i is opened in period t, and 0 o/w; E_{jt} is binary variable that equals to 1 if the export depot j is located in period t, and 0 o/w; D_{lt} is binary variable that equals to 1 if the central depot l is located in period t, and 0 o/w; C_{kt} is binary variable that equals to 1 if the new gasohol depot k is opened in period t, and 0 o/w; π_{it} is expanded production capacity of plant i in period t; Pr_{it} is amount of ethanol produced at plant i in period t; $Tr_{ilt}^{PD}, Tr_{ijt}^{PE}, Tr_{ikt}^{PC}$ are amount of ethanol shipped from plant i to central depot l, to export depot j, and to gasohol depot k in period t; Tr_{lkt}^{DC} and Tr_{ljt}^{DE} are amount of ethanol shipped from central depot l to gasohol depot k and to export depot j in period t.

Objective function:

$$\begin{aligned} Minimize \Bigg\{ & \sum_{i\in(I\cup M)}\sum_{t\in T}\omega_{it}Pr_{it} + \sum_{j\in J}\sum_{t,t^*\in T}\sum_{t^*\geq t}\delta_{jt^*}^{E}E_{jt} + \sum_{l\in L}\sum_{t,t^*\in T}\sum_{t^*\geq t}\delta_{lt^*}^{D}D_{lt} + \sum_{i\in(I\cup M)}\sum_{l\in L}\sum_{t\in T}\alpha_t d_{il}^{PD}Tr_{ilt}^{PD} \\ & + \sum_{i\in(I\cup M)}\sum_{j\in J}\sum_{t\in T}\alpha_t d_{ij}^{PE}Tr_{ijt}^{PE} + \sum_{i\in(I\cup M)}\sum_{k\in(K\cup N)}\sum_{t\in T}\alpha_t d_{ik}^{PC}Tr_{ikt}^{PC} \\ & + \sum_{l\in L}\sum_{k\in(K\cup N)}\sum_{t\in T}\beta_t d_{lk}^{DC}Tr_{lkt}^{DC} + \sum_{l\in L}\sum_{j\in J}\sum_{t\in T}\beta_t d_{lj}^{DE}Tr_{ljt}^{DE} \Bigg\} \end{aligned} \quad (1)$$

Subject to:

$$Pr_{it} = Cap_i + \pi_{it} \quad ; \forall i \in (I \cup M);\ \forall t \in T \quad (2)$$

$$\pi_{it} \leq Cap_i \quad ; \forall i \in (I \cup M);\ \forall t \in T \quad (3)$$

$$\pi_{i,t-1} \leq \pi_{it} \quad ; \forall i \in (I \cup M);\ \forall t \in T \quad (4)$$

$$Pr_{it} \geq \sum_{l\in L}Tr_{ilt}^{PD} + \sum_{j\in J}Tr_{ijt}^{PE} + \sum_{k\in(K\cup N)}Tr_{ikt}^{PC} \quad ; \forall i \in (I \cup M);\ \forall t \in T \quad (5)$$

$$\sum_{i\in(I\cup M)}Tr_{ikt}^{PC} + \sum_{l\in L}Tr_{lkt}^{DC} = Dm_{kt}^{C} \quad ; \forall k \in K;\ \forall t \in T \quad (6)$$

$$\sum_{i\in(I\cup M)}Tr_{ikt^*}^{PC} + \sum_{l\in L}Tr_{lkt^*}^{DC} = Dm_{kt^*}^{C}\left(C_{kt}\right) \quad ; \forall k \in N;\ \forall t,t^* \in T, t^* \geq t \quad (7)$$

$$\sum_{i\in(I\cup M)}\sum_{j\in J}Tr_{ijt}^{PE} + \sum_{l\in L}\sum_{j\in J}Tr_{ljt}^{DE} = Dm_{t}^{E} \quad ; \forall t \in T \quad (8)$$

$$\sum_{i\in(I\cup M)}Tr_{ilt}^{PD} = \sum_{k\in(K\cup N)}Tr_{lkt}^{DC} + \sum_{j\in J}Tr_{ljt}^{DE} \quad ; \forall l \in L;\ \forall t \in T \quad (9)$$

$$\sum_{i\in(I\cup M)}Tr_{ijt^*}^{PE} + \sum_{l\in L}Tr_{ljt^*}^{DE} \leq M\left(E_{jt}\right) \quad ; \forall j \in J;\ \forall t,t^* \in T, t^* \geq t \quad (10)$$

$$\sum_{i\in(I\cup M)} Tr_{ilt^*}^{PD} \le M\left(D_{lt}\right) \quad ; \forall l \in L; \forall t, t^* \in T, t^* \ge t \tag{11}$$

$$\sum_{l\in L} Tr_{ilt^*}^{PD} + \sum_{j\in J} Tr_{ijt^*}^{PE} \le M\left(P_{it}\right) \quad ; \forall i \in M; \forall t, t^* \in T, t^* \ge t \tag{12}$$

$$Pr_{it}, \pi_{it} \ge 0 \quad ; \forall i \in (I \cup M); \forall t \in T \tag{13}$$

$$Tr_{ilt}^{PD}, Tr_{ikt}^{PC}, Tr_{ijt}^{PE}, Tr_{lkt}^{DC}, Tr_{ljt}^{DE} \ge 0 \quad ; \forall i \in I; \forall j \in J; \forall l \in L; \forall k \in K; \forall t \in T \tag{14}$$

$$P_{it}, E_{jt}, D_{lt}, C_{kt} \in \{0,1\} \quad ; \forall i \in I; \forall j \in J; \forall l \in L; \forall k \in K; \forall t \in T \tag{15}$$

The condition of the model as (2) indicates that amount of ethanol produced at each ethanol plant that is equivalent of total production capacity. Expansion of production capacity in each year must not exceed the production capacity of each plant, and must not less than the year before as (3) and (4), respectively. Equation (5) ensures that amount of ethanol have sufficient production for distribution. Moreover, the amount of ethanol shipped to customer must meet both domestic and export demands, as indicated by (6)-(8). Equation (9) indicates the balance of ethanol shipped to and from central depots. Equation (10) and (11) indicates that amount of ethanol shipped to export depots and central depots are equal to the positive large number. Amount of ethanol shipped from plants is also equal to the positive large number, as (12).

Results

The results showed that total production capacity of ethanol plants should expand in the year 2016 and increase every year to 2021. For locating the depots, Thailand should have only one ethanol central depots located along the highway at Don Wai, Non Sung district, Nakhon Ratchasima province and only one export depot located along wharfs in Samut Prakan province. Moreover, amount of ethanol allocated from plants to export depot and central depot will change each year, but ethanol allocated to the gasohol blending depots will increase continuously as Table 1. For distribution network as Table 2, ethanol is produced in the Northeast should be allocated to a central depot and should not be allocated directly to export depot. Ethanol produced in the East should be allocated to gasohol blending depots in Bangkok and its vicinity, and should not be allocated directly to export depot likewise. For ethanol produced in the West and Central region should be allocated to gasohol blending depots in Bangkok and its vicinity, and also should be allocated to export depot.

Table 1 Amount of ethanol allocated from ethanol plants (2012-2021)

Million liters

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Plant-to-Export depot	321.07	327.08	214.21	96.81	39.98	113.76	220.17	190.92	166.75	151.26
Plant-to-Central depot	760.70	672.41	670.96	669.51	667.16	672.54	695.16	851.00	853.87	873.82
Plant-to-Gasohol depots	496.23	578.51	692.84	811.68	896.42	1,028.63	1,110.90	1,195.63	1,428.25	1,635.11
Total	**1,578.00**	**1,578.00**	**1,578.00**	**1,578.00**	**1,603.56**	**1,814.93**	**2,026.23**	**2,237.55**	**2,448.88**	**2,660.18**

Table 2 Yearly average amount of ethanol allocated from ethanol plants (2012-2021)

Million liters/Year

Ethanol plants	Export depot in Samut Prakan	Central depot in Nakhon Ratchasima	**Gasohol blending depots**				**Total**
			Northeast region	East region	Bangkok and its vicinity	South region	
Northeast region	-	730.00	10.69	-	2.96	-	**743.65**
East region	-	2.71	-	69.61	306.97	-	**379.29**
West and Central region	184.20	6.00	-	0.17	595.86	1.16	**787.39**
Total	**184.20**	**738.71**	**10.69**	**69.78**	**905.79**	**1.16**	**1,910.33**

For allocation of ethanol from the central depot located in Nakhon Ratchasima province, ethanol should be distributed to export depot since the year 2014, and increased steadily each year. Furthermore, ethanol should be distributed to gasohol depots in the East region, South region, and Bangkok and its vicinity. In contrast, ethanol should not be distributed from central depot to gasohol depots in the Northeast because the ethanol plants in this region can be shipped directly.

Conclusion and Discussion

The results of this study according to the country's renewable energy plan, "AEDP 2012-2021" showed that Thailand should have only one export depot and a central depot located along wharfs in Samut Prakan and along the highway in Non Sung district, Nakhon Ratchasima, respectively. Furthermore, opening and expanding of production capacity of ethanol plants over time were suggested, and appropriate ethanol allocation was obtained for horizontal plan until 2021. Ethanol was allocated both through the central depot and direct to customers and export depot. These results were derived from the model minimizing the total cost of plants-to-customers ethanol supply chain, especially overall transportation costs, inventory cost of ethanol plants, and collecting cost of ethanol central and export depots. Consequently, an efficient logistic system of Thai ethanol supply chain can be obtained. It still accommodates the demand increase and expansion of ethanol industry in the future. In addition, if the transport infrastructure for both highway and rail systems in Thailand improved, this will support the enhancement of logistics system for ethanol supply chain network with central depot for distribution. Additionally, the collection and transportation of ethanol in massive volume by rail system will reduce the total transportation costs significantly, and storing ethanol in the central depot will be an energy reserve for the security of the country, as well.

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Reference

[1] R. Homchalee and W. Sessomboon, Modelling of Ethanol Supply Chain in Thailand, in The 2014 International Computer Science and Engineering Conference (ICSEC2014), Khon Kaen, Thailand, ©2014 IEEE, doi: 10.1109/ICSEC.2014.6978128.

[2] R. Homchalee, S. Arunyanart and W. Sessomboon, An Analysis of Ethanol Supply Chain in Thailand, Advanced Materials Research, 931-932 (2014) 1676-1682.

[3] H. Min and G. Zhou, Supply chain modeling: past, present and future, Computers & Industrial Engineering, 43 (2002) 231-249.

[4] B. M. Beamon, Supply chain design and analysis: Models and methods, International Journal of Production Economics, 55 (1998) 281-294.

[5] M. T. Melo, S. Nickel and F. Saldanha-da-Gama, Facility location and supply chain management – A review, European Journal of Operational Research, 196 (2009) 401-412.

[6] J. Mula, D. Peidro, M. Díaz-Madroñero and E. Vicens, Mathematical programming models for supply chain production and transport planning, European Journal of Operational Research, 204 (2010) 377-390.

[7] S. D. Ekşioğlu, A. Acharya, L. E. Leightley and S. Arora, Analyzing the design and management of biomass-to-biorefinery supply chain, Computers & Industrial Engineering, 57 (2009)1342-1352.

[8] R. Homchalee and W. Sessomboon, A Comparison of Forecasting Models using Multiple Regression and Artificial Neural Networks for the Supply and Demand of Thai Ethanol, in The IEEE International Conference on Industrial Engineering and Engineering Management (IEEM2013), Bangkok, Thailand, ©2013 IEEE, doi: 10.1109/IEEM.2013.6962554.