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ORIGINAL ARTICLE

An Evaluation Method of Supply Chain Efficiency Considering Customers' Satisfaction

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Abstract: Evaluating supply chain management is important because it helps to find out supply chain's weakness. Customers' satisfactions is one of important topics because a propose of supply chain management is to satisfy customers requirements. If an organization lacks satisfaction of customer needs, it will lose an opportunity in business. Usually, agricultural supply chain consists of a manufacture and several suppliers. In this case, the manufacture has to evaluate performances of chains with possible suppliers. The manufacture may replace some suppliers to improve their customers' satisfactions. However, the current evaluate methods cannot be used such usage because the methods cannot consider a situation in which some suppliers are replaced. Therefore, a new evaluation model is proposed. The proposed model allows the users to inspect a chain's efficiency with considering to replace some of supply chain suppliers. In order to show the ability of the method, a case study of Thai frozen shrimp industry is shown and the results is discussed.
Keywords: *Data envelopment analysis, Customer satisfactions, Customer complaints*

1. INTRODUCTION

Supply chain management (SCM) is a principle of management of activities that happen between every member in a chain. A main concept of SCM consists principles of corporation as a foundation of strategy [1-3]. An intention of introducing SCM is to satisfy customers requirements and achieve sustainable competitive advantages. In the context of rapid change of business scene, performance measurement plays an important role in developments of SCM because it helps to indicate current efficiency, and find out its weakness [4]. In this paper, the concept of efficiency is defined that how economically a firm's resources are utilized while remaining a level of customer satisfaction [5].

Considering customers' satisfactions is one of important topics because an aim of SCM is to satisfy customers requirements. Besides, it is also one of key factors to determine how successful the organization will be in customer relationships [6]. Customer satisfaction is defined as "the number of customers, or percentage of total customers, whose reported experience with a firm, its products, or its services exceeds specified satisfaction goals [7]." Satisfying customers would bring profit to a company which also brings employee satisfaction; hence, organizations need to understand what extend their customers number who are satisfied [6].

It is also a person's feelings of pleasure or disappointment resulting from comparing a product's perceived performance in relation to his or her expectations [8]. Customer satisfaction or dissatisfaction is considered as a measurement of a gap between customer's expectations and performance outcomes of organizations [9-11]. One of important response from a customer is 'customer complaints' hence they report problems or failures in processes which need to recover quickly in order to avoid migration of profitable customers [12]. Branes [13] mentioned that "a typical business only hears from 4% of its dissatisfied customers, the other 96% leave." That is obvious that complaints which are received from customers are needed to be care instantly.

Usually agricultural supply chains consist of a manufacture and several suppliers. In these chains, a manufacturer is connected with suppliers by inter product flow and suppliers' contracts. A suppliers' contract system is introduced to make stable production. It means contracted supplier has to deliver products to the manufacturers stable under the contract. On the other hand, non-contracted suppliers need to improve their efficiency, or they could be replaced by the manufacturers [3].

Data envelopment analysis (DEA) is one of famous techniques for measuring efficiency [14]. It is an approach based on linear programming that assesses a relative performance of a set of production processes called decision-making units (DMUs) [15]. Although a traditional DEA has been implemented variously but it fails to deal with a complex structure, i.e. supply chain structure. Thus a multilevel DEA model has been developed [16]. There are many researches that focus on internal structure [17]. But there have been not any researches which concern suppliers' properties yet. Therefore, a new evaluate model

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is proposed in this paper to analyze an efficiency in the case that a manufacture replaces its suppliers to improve their customers' satisfactions. A network DEA which considers suppliers' performances is extended to consider replaceable suppliers. The proposed model allows a manufacturer to inspect supply chain efficiency with suppliers' efficiency. In order to show the ability of the model, a case study of Thai frozen shrimp industry is shown and the results is discussed.

2. BACKGROUND

2.1 Customer satisfactions

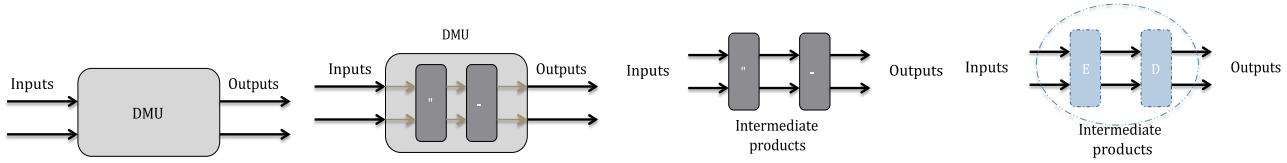
Customer satisfaction has been a major goal for business organizations for many years because loyal customers contribute to the company's profitability by spending more on the company's products and services [18]. Kotler [8] defined customer satisfaction as "the level of a persons feeling state resulting from comparing a product's perceived performance or outcome with his/her own expectation." Customer satisfaction is also defined as a comparative behavior between inputs beforehand and post obtainment [19]. From those definitions, customer satisfaction could be considered as customer requirements are met on their expectations. Of cause, the criterion reflects not only degree of customer satisfaction, but also reflects how companies providing products or services to meet customer demand [20].

Dissatisfaction is the opposite word of satisfaction, and it means feelings of discomfort and related actions, such as complaining behavior [10, 21]. Oliver [10] explained dissatisfaction as "the consumers' fulfillment response and judgment that a product or service feature, or the product or service itself, provides (or is providing) a discomfort level of consumption-related fulfillment, including levels of under-fulfillment." Thus, 'Customer complaints' is one of important responses which describes customer dissatisfaction. Indeed complaints provide managers with useful information to enhance service quality [22]. When dissatisfied customers fail to complain, companies are likely to miss the opportunity of redressing the type of the problems and then to learn about mistakes, through feedbacks from dissatisfied customers [22]. As above mentions, the customers' complaints could be indication of organizations hence they report problems or failures in processes which need quick recovery in order to avoid migration of profitable customers [12]. Therefore, customer complaints should be considered in performance measurement process as one of parameters.

2.2 DEA model considers internal structure

In this section, network DEA models are discussed. The traditional DEA considers all processes as 'black block' as shown in Fig. 1(a). It is obvious that it fails to deal with internal and complex structure. Hence Fare and Grosskopf [16] introduced the network DEA in 1996, by considering components' structure within a black box of DMU as show in Fig. 1(b). In this model, there is just one efficiency score which represents a supply chain efficiency. In 2003, Zhu [23] proposed a model to evaluate an efficiency of supply chain as shown in Fig. 1(c). This model provides to assess efficiency of a chain which is constructed by its efficient members. This concept stands for the fact that an efficiency of a supply chain depends on its members' efficiency [24]. This is beginning of multi-stage DEA model which considers an internal structure.

In 2011, Chen and Yan [25] constructed alternative network DEA models that are unified internal structures, centralized, decentralized and mixed organization. The difference of three concepts is an existing of decision maker which is introduced to manage amount of intermediate products. In the centralized organization, the decision maker can manage all of member together. Meanwhile the decentralized organization, there are not the decision maker. In the mixed organization, there are the decision makers but they can manager only some members. Even two above mentioned models have been proposed under concept of internal structure, but none of them are considered relationship of each member in a chain. In their models, an efficiency score is measured from existence supply chain. In 2009, Yang et. al. [26] introduced the supply chain DEA model in which every members in a chain can be replaced by introducing



(a) Traditional DEA [14] (b) Network DEA [16] (c) DEA for supply chain [23], [25] (d) Yan's model [26]

Figure 1: DEA models for supply chain

separate production possibility set as in shown Fig. 1(d). In this figure, there are two blue rectangles with dashed line which stand for replaceable member. In this model, an efficiency of each member influences to overall supply chain efficiency. With this model, we can take account with some virtual supply chains which is constructed by replacing all member with other. The efficiency of chain is calculated under considering all efficient members together as one chain as shown by dashed circle in Fig. 1(d).

To analyze customer complaints with considering inefficient suppliers, the previous models cannot be used because efficiency of chain cannot be calculated from each member's efficiency, not same as Zhu's model. There are not decision maker in a chain, not same as Chen and Yan's model, and all members cannot be separated to improve their efficiencies and considers them as one member not same as Yang's model. Thus, an alternative efficiency evaluation model which can analyze effects of inefficient suppliers in a chain with considering customer complaints is required. In the next section, the traditional network DEA model is extended and modified to respond the requirement.

3. METHODOLOGY

The framework proposed in this section aims to introduce efficiency of suppliers to evaluate efficiency of supply chain with considering customer complaints. It also aims to provide a network DEA framework for the evaluation system. The framework is based on the supply chain model of Chen and Yan [25] and separating members concept model of Yan [26].

The outline of this research is illustrated in Fig. 2. The followings show the procedure;

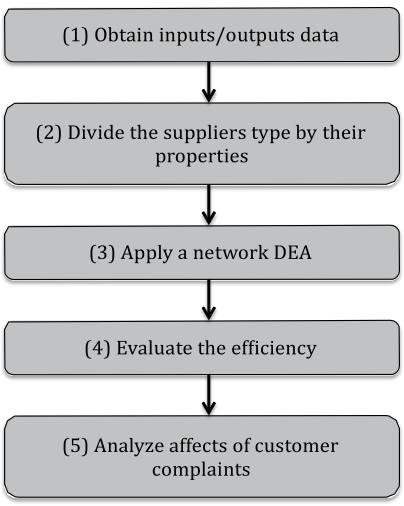


Figure 2: Outline of research methodology

1) To apply the proposed framework, data for inputs and outputs, which represent the efficiency of each stage, are obtained.
2) All suppliers in chain are separated into two types, replaceable and irreplaceable supplier.
3) The network DEA model with supply chain concept and separating members concept will be applied.
4) The efficiency is measured by using the model generated from previous step.
5) The effect of suppliers and customer complaints on efficiency of chain is analyzed.

3.1 Supply chain structure

Generally, agricultural supply chain consists of a manufacture and several suppliers. Some suppliers are connected with a manufacturer by products flow and theirs contract while the others are connected with a manufacturer by just products flow. Thus, in order to improve customers' satisfactions, a manufacturer would consider to replace non-contracted suppliers with better ones. To simplify this kind of chain, a situation in which there are three members, two suppliers and one manufacturer is assumed. Fig. 3 illustrates a structure of the above mentioned situation. The upper part of Fig. 3 shows an actual situation, the right part of this figure stands for supply chain and the left part of this figure stands for customers. In the supply chain part, S1, S2 and M represent the irreplaceable supplier, the replaceable supplier and the manufacturer, respectively. X^1 and X^2 stand for inputs of supplier 1 (S1) and supplier 2 (S2) respectively. Intermediate products of S1 and S2 are Y^1 and Y^2. And final output is Z. After customers got their products, they would send theirs complaints in a case that they did not satisfy the products or services. Since that, their complaints can be considered as undesirable output for a supply chain which represent as the bottom part of Fig. 3.

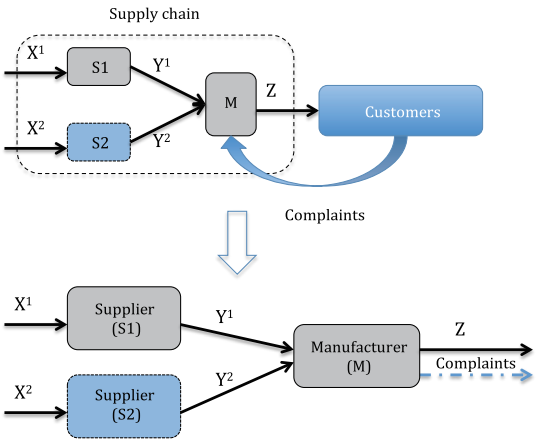


Figure 3: Framework structure

3.2 The DEA model

The DEA model which has been used in this study is represented with following formula;

$$
(R)\quad
\begin{array}{ll}
\text{minimize} & \theta_R \\
\text{subject to} & \theta_R X^1_{io} - \sum_{j=1}^{n} \lambda^1_j X^1_{ij} \geq 0 \\
& \sum_{j=1}^{n} \lambda^1_j Y^1_{lj} \geq Y^1_{lo} \\
& \theta_R X^2_{io} - \sum_{j=1}^{n} \lambda^2_j \theta_{s2} X^2_{ij} \geq 0 \\
& \sum_{j=1}^{n} \lambda^2_j Y^2_{lj} \geq Y^2_{lo} \\
& \sum_{j=1}^{n} \lambda^3_j Y^1_{lj} \leq Y^1_{lo} \\
& \sum_{j=1}^{n} \lambda^3_j Y^2_{lj} \leq Y^2_{lo} \\
& \sum_{j=1}^{n} \lambda^3_j Z_{kj} \geq Z_{ko} \\
& \lambda^1_j, \lambda^2_j, \lambda^3_j \geq 0
\end{array}
$$

Where

θ_R : Efficiency score of chain.
θ_{S2} : Efficiency score of changeable supplier.
X^1_{ij} : Vector of *i-th* supplier 1's inputs for *j-th* chain.
Y^1_{ij} : Vector of *l-th* intermediate products of supplier 1 in *j-th* chain.
X^2_{ij} : Vector of *i-th* supplier 2's inputs for *j-th* chain.
Y^2_{ij} : Vector of *l-th* intermediate products of supplier 2 in *j-th* chain.
Z_{kj} : Vector of *k-th* final outputs for manufacturer of *j-th* chain.
n : The number of chains.

This model allows us to analyze effects of each suppliers and complaints of customers on the efficiency of the chain.

3.3 The advantage of the model

As the above mentioned situation, the traditional network DEA is not allowed a manufacturer to examine an efficiency of replaceable suppliers. By using the proposed model, it leads us to inspect that which chain has an inefficient replaceable supplier. After find a chain which has a supplier that need to improve, the efficiency score of the chain could be analyzed how the chain efficiency could be enhanced by replacing the supplier. If an inefficient chain improves its suppliers which means it consumes less inputs to produce same amount of outputs, we can get the chain with has higher efficiency score.

4. EXPERIMENT

In the previous section, the model which allows the user to investigate a chain consists of a replaceable supplier is proposed. In this section, some numerical examples are shown to demonstrate efficacies and applicabilities of the proposed model. The model has been applied to frozen shrimp supply chains in Thailand. The data of export factories, which are located in the southern and eastern of Thailand and comprise the members of the Thailand Institute of Scientific and Technological Research (TISTR), Food Technology Department is used. The criteria and datasets that have been used are shown in Table 1 and 2.

Table 3 reports the efficiency scores of non-contracted suppliers and supply chain obtained from the proposed model. First, the efficiency score is analyzed then inefficient supply chains are focused on with 'customer complaints' criterion.

From the second column of Table 3, we can find that replaceable suppliers of chain 1, 2, 5, 6, and 8 are inefficient, it means only 3 suppliers are efficient among 8 suppliers. On the other hand, in the third column, there are 5 inefficient chains among 8 chains. From those inefficient chains, there are 4 chains have inefficient suppliers.

Here, let's discuss about inefficiency chains under 'customer complaints' criterion. We assume that an efficient supply chain should cause less number of customer complaints. As the above result, there are five inefficient chains in the examples. These five inefficient chains have high number of customer complaints. This fact supports the above assumption. This result can be explained that 'customer complaints' criterion is also one of important factors that affects to efficiency of chain. For instance, the most inefficient chain, which is the fifth chain, is used for the discussion. The manufacturer of this chain got 23 complaints from customers, and it is the highest number of the 8 chains. Besides, replaceable supplier of the fifth chain is the most inefficient of all replaceable suppliers as well.

Table 1: Measurement Criteria

Construct	Criteria
Inputs (X)	X_1 : Fixed Assess (10^6 Baht)
	X_2 : Production Capacity (10kg per 3.95 Acres)
	X_3 : Inventory and Transportation Cost (%)
Intermediate Products (Y)	Y_1 : Damage Rate (%)
	Y_2 : Supplier On-time Rate (%)
Output (Z)	Z_1 : Return on Assess
	Z_2 : Rate of Accepted Products (%)
	Z_3 : Customer complaints (Number of registered per year)

Table 2: Data sets of the samples

DMUs		X_1	X_2	X_3	Y_1	Y_2	Z_1	Z_2	Z_3
1	s1	7.49	306.90	42.50	96.63	93.23	0.36	98.53	17.00
	s2	8.21	271.30	42.50	97.14	96.20			
2	s1	4.46	271.30	42.50	96.49	92.23	0.66	96.92	15.00
	s2	12.05	306.90	42.50	96.93	95.30			
3	s1	6.58	306.90	40.00	95.00	91.88	1.23	98.62	13.00
	s2	12.06	282.80	40.00	97.12	96.00			
4	s1	7.67	271.30	43.00	96.00	91.09	2.33	97.65	9.00
	s2	13.40	271.30	45.00	97.62	94.20			
5	s1	4.97	373.80	47.00	96.56	91.83	2.72	97.08	1.00
	s2	14.11	373.80	45.00	96.97	95.20			
6	s1	5.20	282.80	42.50	96.40	91.68	3.41	97.18	18.00
	s2	16.51	306.90	47.00	98.22	95.60			
7	s1	6.00	373.80	45.00	96.62	91.59	3.46	97.74	8.00
	s2	20.37	271.30	42.50	97.69	94.00			
8	s1	5.24	282.80	42.50	96.04	91.79	3.97	97.31	16.00
	s2	21.03	373.80	42.50	97.39	94.90			

Table 3: Efficiency results vs. customer complaints

DMUs	θ_{S2}	θ_R	customer complaints
1	0.999	0.973	17.00
2	0.949	1.000	15.00
3	1.000	1.000	13.00
4	1.000	1.000	9.00
5	0.888	0.904	23.00
6	0.902	0.989	18.00
7	1.000	0.936	8.00
8	0.944	0.995	16.00

The θ_R shows an efficiency score of each chain in case that its replaceable supplier is inefficient. In the same way as the above example, the fifth chain is focused on. We assume that only the fifth chain replaces its replaceable supplier with better one, a result that only the fifth chain improves is shown the third column of Table 4.

In this table, efficiency score of the fifth chain are highlight. In third column, the fifth chain becomes efficient. Besides, in the last column, in which the results of all chains are improved are shown, the fifth chain is also efficient. From the result, we can find that the fifth chain can be efficient by replacing its inefficient supplier in the both cases, the fifth chain is an only one chain that replaced it supplier or all of chains replace their suppliers. As the above result, the proposed model is enable to investigate replaceable suppliers efficiency with chain efficiency and customer complaints while the tradition DEA models do not.

Table 4: Efficiency results under improvement

DMUs	No Improvement θ_R	Improve only fifth chain	All chains improve
1	0.973	0.987	0.998
2	1.000	1.000	1.000
3	1.000	1.000	1.000
4	1.000	1.000	1.000
5	0.904	1.000	1.000
6	0.989	0.989	1.000
7	0.936	0.983	0.989
8	0.995	0.985	1.000

5. CONCLUSION

In this paper, the authors have proposed an extended network DEA model to investigate an efficiency of supply chain which focus on suppliers' side together with customer complaints. To consider efficiency of a chain with complaints of customers, an efficient supply chain should consist efficient supplier and it provides less customer complaints. An extended network DEA model for supply chain under considering replaceable and irreplaceable suppliers concept has been used and the Thai frozen shrimp industry is brought as an example. From the results, we can conclude that the proposed model is effective for measuring an efficiency of a supply chain which consists replaceable and irreplaceable suppliers. Forthermore, to improve a chain efficiency, an efficiency score of chains under considering replacing inefficient suppliers with better one can be calculated with the proposed model while the tradition DEA models do not.

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