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# Finding Weak links in Supply chain Case Study: Thai Frozen Shrimp Industry

Patchanee Patitad [1)] Hidetsugu Suto[1*)] Woramol Chaowarat Watanabe[2)]
[1)]Graduate school of Engineering, Muroran Institute of Technology
27 Mizumoto-cho, Muroran-shi, Hokkaido, 050-8585 Japan
[2)]School of Logistics and Supply Chain, Naresuan University
99, Moo 9, T. Tha Pho, Muang District, Phitsanulok, 65000 Thailand
[*]Corresponding author: info@sdlabo.net

## ABSTRACT

Usually, a manufacture receives materials from one or more suppliers in a supply chain. Performance of each supplier in a chain affects on the chain's performance. Thus, evaluating suppliers in a supply chain is important for achieving efficient supply chain. Many methods have already been developed for evaluating performance of suppliers. Most of the existing methods show us suppliers' performance, but they do not indicate directions for improving supply chains. With the proposed method, we can find that which factors of which suppliers should be improved to achieve efficient condition. Thus, manufacturers can make decision for improving or changing suppliers more easily. A case study of Thai frozen shrimp industry is represented to show the applicability of the proposed scheme.

## KEYWORDS

Data envelopment analysis (DEA), performance measurement, multiple suppliers

## 1 INTRODUCTION

Due to the existing severe competition in business environment, organizations have to improve their performance and develop competitiveness [1]. To achieve improved competitiveness, many manufacturers have utilized Supply Chain Management (SCM) for increasing their performance [2]. SCM is a principle to manage total flow of distribution channel from supplier to ultimate customer, in order to minimize total cost while satisfying customer requirements [3]. Efficient supply chain managements lead to improve customer value, better utilization of resources, and increased profitability [4].

Suppliers are considered as important elements of supply chain network because their performances influences in the overall chain performance [5]. To obtain efficient supply chain, manufacturers have to choose better suppliers to consist their supply chain [6]. However, choosing appropriate suppliers is difficult because the criteria are multiple and complex. In addition, many qualitative and quantitative performance indicators should be considered such as quality of raw material, price, on time delivery rate, etc [7].

Data Envelopment Analysis (DEA) is one of the well known techniques that is used for evaluating relative efficiency of suppliers [8]. DEA has been applied in many types of organizations, and some modified DEA models have been proposed [9]. Most of them are designed for evaluating current performance of suppliers, and showing improvement way is beyond the area of these studies. In other words, with the traditional DEA models, we can know the efficiency score of a supplier, but we cannot know the strategies to achieve efficient situation when it is inefficient [10]. Usually, inefficient chains consist of inefficient suppliers. To increase efficiency of overall performance of chains, such inefficient suppliers should be improved. However, it is difficult that all of the inefficient suppliers become efficient because of constrains of each supplier. Thus, a new method to find hopeless suppliers which cannot be efficient is proposed. With the proposed method, which factors of which suppliers should be improved is clarified. The proposed method can support manufacturers' decision making about managing the supply chains.

In section 2, previous works about supplier performance measurement in supply chain are shown. Next, the outline of the proposed scheme is described in section 3. In order to show the usefulness of the proposed method, Thai frozen shrimp industry cases are discussed as a case study in section 4. Finally, results of the proposed scheme are discussed and concluded in section 5.

## 2 EVALUATING SUPPLIERS' PERFORMANCE

DEA is an applicable tool for evaluating supplier performance. It is an approach based on linear programming that assesses relative performances of a set of production processes called decision-making units (DMUs) [11]. For apply DEA with realistic situation, many researchers have been trying to integrate DEA with other useful approach. For example, fuzzy theory was combined with DEA in order to deal with a vague data [12]. Stochastic DEA is proposed to deal with a dynamic environment [13]. However, most of previous researches focus on the way to judge suppliers on the current condition, only few studies provide improvement plan for the future.

Shabanpour et al. [10] proposed a method of benchmarking suppliers by considering on the future condition. This method consists of two steps, evaluating step and benchmarking step. In the first step, expected performance of each supplier is decided by the manufacturer. Then, the feasibilities of the expected performances are investigated. In the second step, benchmark scores of suppliers which can achieve the expected performance are calculated. The benchmark stands for an order of suppliers which can satisfy the manufacturers' requests. Thus they can try to improve their performance by referring the benchmarks.

Chaowarat et al. [14] have proposed a model by extending network DEA model in order to investigate efficiency of chains and suppliers on the post-improvement condition. This model is created under the assumption that all inefficient suppliers have the potentials to become efficient suppliers. First, the efficiencies of suppliers and chains are evaluated by using network DEA model [15]. Then, all inefficient suppliers are supposed to be efficient and the virtual chains are constructed. Finally, the virtual chains' performance are evaluated. With this model, manufacturers could explore the weaknesses and strengths of each alternative in supplier selection. However, this model does not consider feasibility of the virtual chains. Thus, this paper proposes a method to determine feasibility of each inefficient suppliers for becoming efficient suppliers.

## 3 A NEW METHOD FOR FINDING WEAK LINKS IN SUPPLY CHAINS

Supply chain structure can be considered as multistage operational processes. In the context, less efficient stages are called "weak links" of the supply chain [16]. Such weak links can be divided into two types, i.e. stages which have a potential to be efficient and stages which do not have. In this paper, "weak links" of a supply chain is defined as suppliers who lack a potential to achieve efficient condition, because manufacturers have to consider to replace such suppliers in order to achieve efficient situations of the chain.
In this section, a proposed method for finding out such weak links of supply chains is described. The outline of the method is illustrated in Fig 1.

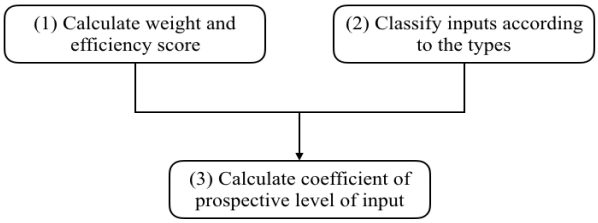


**Figure 1.** Outline of the proposed method.

Based on results of DEA model, there are two main perspectives for performance improvement, i.e. input-oriented and output-oriented. Suppliers minimize the use of input to produce a given level of output under input-oriented strategies. On the other hand, suppliers need to maximize their outputs while the inputs remain unchanged under output-oriented strategies [17]. In this paper, input-oriented perspective is employed because usually cost reducing is easier than increasing productivity.
To become efficient suppliers, inefficient suppliers have to reduce their inputs until reaching prospective level. Consider an example of an inefficient supplier which has input vector $\mathcal{X}$ and efficiency score of $\theta(< 1.0)$. In this case, if the input vector can be changed as $(1-\theta)\mathcal{X}$, the supplier can be efficient. It means the all of input factors are reduced at same ratio of $(1-\theta)$. Here, it is expected that some input factors could be changed by actions of operation, but the others could be difficult. For example, capacity of machine tools is not easy to change. It means the efficient situation must be achieved by improving only realistically changeable input factors.

In order to find enough improvement goal, an equation for calculating coefficient of prospective level of changeable factors is proposed. Manufacturers can make decision for improving or changing suppliers based on values of coefficient of prospective level.
The steps to find out weak links in supply chains are described as follows:

**Step 1: Calculate weight and efficiency score of chains and suppliers**

In the first step, three kinds of factors that used to indicate chains' performance, input, intermediate product and output are determined. The 'input' means input resources of suppliers. Output from a supplier which enter into the manufacturer are called as 'intermediate products.' The 'output' means final products from the manufacturer.
Input $i$ of supplier $x$ in chain $j$ is represented by $X_{ij}^{x}$, intermediate product $l$ of supplier $x$ in chain $j$ is represented by $Y_{lj}^{x}$, and output $k$ of manufacturer in chain $j$ is represented by $Z_{kj}$. Next, data set of such factors of each member is prepared. After that, weights of each factor and efficiency score of each member are calculated by using network DEA model shown in section 2.
Units which get efficiency score below than one are considered as inefficient. These inefficient suppliers should improve their performance.

**Step 2: Classify types of inputs**

In the second step, inputs are classified into two types, i.e. changeable inputs and unchangeable inputs, based on the experiences of the manufacturer. For instance, inputs come from infrastructure could be classified into unchangeable, and inputs come from electric power could be classified into changeable.

**Step 3: Calculate coefficient of prospective level of changeable inputs**

In the third step, coefficient of prospective level of changeable inputs are calculated by using the equation (1).
Coefficient of prospective level indicates ratio between required input and current input. The ratio implies possibility that inefficient supplier can become efficient. If the coefficient of prospective level is lower than zero, it means the supplier cannot become efficient by decreasing the changeable inputs.

$$\alpha_S = \frac{\theta_S(\sum_{i=1}^{n} \lambda_i X_i) - \sum_{i=1}^{m} \lambda_i^u X_i^u}{\sum_{i=1}^{n-m} \lambda_i^c X_i^c} \quad (1)$$

Where

$\alpha_S$ : Coefficient of prospective level of supplier $S$

$\theta_S$ : Efficiency score of supplier $S$

$X_i$ : The $i$-th input

$X_i^u$ : The $i$-th unchangeable input

$X_i^c$ : The $i$-th changeable input

$\lambda_i$ : Weight of the $i$-th input

$\lambda_i^u$ : Weight of the $i$-th unchangeable input

$\lambda_i^c$ : Weight of the $i$-th changeable input

$m$ : Number of input factors

$n$ : Number of changeable input factors

## 4 CASE STUDY: THAI FROZEN SHRIMP INDUSTRY

In this section, an example of Thai frozen shrimp industry is discussed to show the usefulness of the proposed scheme. In this example, fifteen representative chains are investigated. In these chains, a manufacturer receives fresh shrimps from two suppliers. Then, the manufacturer processes raw materials into frozen shrimp. Finally, the finished goods are delivered to the customers. Figure 2 shows the structure of the chains.

### 4.1 Calculate weight and efficiency score of chains and suppliers (Step1)

The factors that used for indicating performance are shown in Table 1. The data of each factor has been collected by interviewings. The data sets of the chains are shown in Table 2.
The weight of each factor and efficiency score of each chain were calculated by using network DEA model. The results are shown in Table 3 and Table 4.

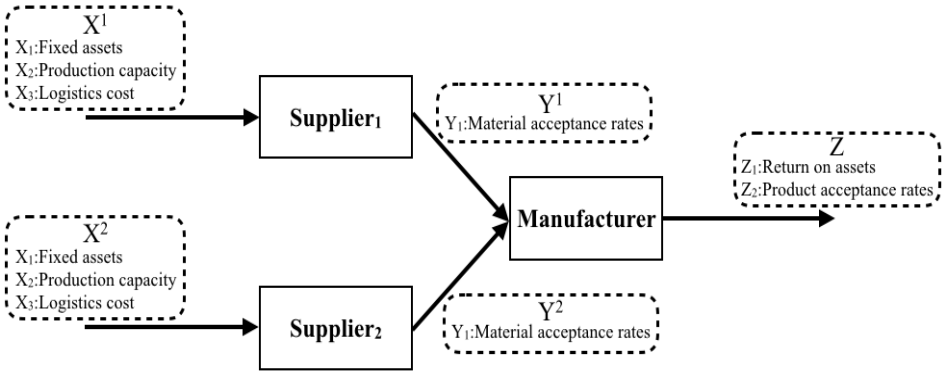


**Figure 2.** Structure of two stage chain with two suppliers and one manufacturer.

**Table 1.** Performance factors

| Construct | Factors | Description |
|---|---|---|
| Inputs ($X$) | $X_1$: Fixed assets ($10^6$ Baht) | A long-term tangible property that a organization owns and uses in the production of its income, e.g. building, machinery,vehicle, etc. |
| | $X_2$: Production capacity (kilogram) | Volume of products that can be generated by a production plant in a given period by using current resources. |
| | $X_3$: Logistics cost (%) | The costs of inventory management and inbound-outbound transportation over a certain period of time. Typically, inventory cost includes carrying cost, ordering cost and shortage cost. |
| Intermediate-product ($Y$) | $Y_1$: Material acceptance rates (%) | Percentage of materials being accepted by a manufacturer. |
| | $Y_2$: Supplier on-time rate (%) | The number of orders that delivered on the requested delivery date compares with the total number of order. |
| Outputs ($Z$) | $Z_1$: Return on assets | Calculated by dividing a company's annual earning by its total assets. |
| | $Z_2$: Product acceptance rates (%) | Percentage of acceptable products by the customers. |

The results indicate that there are seven inefficient chains, i.e. chain 5, 6, 7, 8, 11, 12 and 13. Considering efficiency score of supplier$_1$, there are seven efficient chains, i.e. chain 1, 3, 4, 7, 9, 10 and 15. While only four chains that consist of efficient supplier$_2$, i.e. chain 4, 9,14 and 15. In other words, only chain 4, 9 and 10 consist of efficient suppliers, and it means only these three chain are good enough in the current stage. Thus, to improve the chains' performance these inefficient suppliers should be improved.

### 4.2 Classify types of inputs (Step2)

In this example, each supplier has three input factors, fixed asset, production capacity and logistics costs as shown in Table 1. Due to characteristic of agricultural production, it is quite difficult to improve fixed asset and production capacity. Therefore, we should pay attention to logistics cost. Thus, in this case, logistics costs ($X_3$) are considered as changeable input, while fixed assets ($X_1$) and production capacity ($X_2$) are considered as unchangeable inputs.

### 4.3 Calculate coefficient of prospective level of input (Step3)

Coefficient of prospective level of changeable input is calculated with the equation (1). Under the condition of this case, equation for calculating coefficient of prospective level of changeable inputs is shown as follows:

$$\alpha_S = \frac{\theta_S(\lambda_1 X_1 + \lambda_2 X_2 + \lambda_3 X_3) - (\lambda_1 X_1 + \lambda_2 X_2)}{\lambda_3 X_3} \quad (2)$$

Where

$\alpha_S$ : Coefficient of prospective level of supplier $S$

$\theta_S$ : Efficiency score of supplier $S$

$X_1$ : Fixed assets of supplier $S$ (unchangeable)

$X_2$ : Production capacity of supplier $S$ (unchangeable)

$X_3$ : Logistic costs of supplier $S$ (changeable)

$\lambda_i$ : Weight of the $i$-th input of supplier $S$

**Table 2.** Data sets of the representative chains in the frozen shrimp industry.

| Chain | | $X_1$ | $X_2$ | $X_3$ | $Y_1$ | $Y_2$ | $Z_1$ | $Z_2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | s1 | 8.21 | 271.30 | 42.50 | 97.14 | 96.18 | 0.36 | 98.53 |
| | s2 | 7.49 | 306.90 | 42.50 | 96.63 | 93.23 | | |
| 2 | s1 | 12.05 | 306.90 | 42.50 | 96.93 | 95.27 | 0.66 | 96.92 |
| | s2 | 4.46 | 271.30 | 42.50 | 96.49 | 92.23 | | |
| 3 | s1 | 12.06 | 282.80 | 40.00 | 97.12 | 96.03 | 1.23 | 98.62 |
| | s2 | 6.58 | 306.90 | 40.00 | 95.00 | 91.88 | | |
| 4 | s1 | 13.40 | 271.30 | 45.00 | 97.62 | 94.24 | 2.33 | 97.65 |
| | s2 | 7.67 | 271.30 | 43.00 | 96.00 | 91.09 | | |
| 5 | s1 | 14.11 | 373.80 | 45.00 | 96.97 | 95.20 | 2.72 | 97.08 |
| | s2 | 4.97 | 373.80 | 47.00 | 96.56 | 91.83 | | |
| 6 | s1 | 16.51 | 306.90 | 47.00 | 98.22 | 95.57 | 3.41 | 97.18 |
| | s2 | 5.20 | 282.80 | 42.50 | 96.40 | 91.68 | | |
| 7 | s1 | 20.37 | 271.30 | 42.50 | 97.69 | 93.97 | 3.46 | 97.74 |
| | s2 | 6.00 | 373.80 | 45.00 | 96.62 | 91.59 | | |
| 8 | s1 | 21.03 | 373.80 | 42.50 | 97.39 | 94.90 | 3.97 | 97.31 |
| | s2 | 5.24 | 282.80 | 42.50 | 96.04 | 91.79 | | |
| 9 | s1 | 24.42 | 347.30 | 32.50 | 97.08 | 94.39 | 3.97 | 98.42 |
| | s2 | 4.89 | 271.30 | 35.00 | 96.39 | 92.29 | | |
| 10 | s1 | 27.87 | 306.90 | 35.00 | 98.04 | 95.58 | 4.31 | 97.45 |
| | s2 | 4.68 | 347.30 | 40.00 | 96.91 | 91.85 | | |
| 11 | s1 | 29.04 | 309.50 | 45.00 | 97.14 | 95.96 | 4.71 | 97.68 |
| | s2 | 5.45 | 306.90 | 45.00 | 96.05 | 91.53 | | |
| 12 | s1 | 29.85 | 282.80 | 43.00 | 97.17 | 94.71 | 9.79 | 98.06 |
| | s2 | 4.03 | 282.80 | 47.00 | 95.89 | 92.34 | | |
| 13 | s1 | 36.59 | 373.80 | 42.50 | 96.96 | 95.47 | 10.08 | 97.61 |
| | s2 | 4.00 | 373.80 | 42.50 | 95.57 | 92.44 | | |
| 14 | s1 | 37.41 | 282.80 | 40.00 | 96.77 | 95.55 | 16.86 | 97.35 |
| | s2 | 3.95 | 309.50 | 35.00 | 96.30 | 91.42 | | |
| 15 | s1 | 38.60 | 271.30 | 42.50 | 97.69 | 94.41 | 18.43 | 98.12 |
| | s2 | 3.51 | 271.30 | 40.00 | 96.99 | 92.45 | | |

Coefficient of prospective level of changeable inputs is shown as $\alpha$ in Table 4.

From the table, we can see that chain 12 and chain 13 are expected to achieve efficient condition because the suppliers need to decrease their logistics costs only 20%-6%, and they look realistic goals.

The coefficient value of some suppliers are lower than zero, i.e. $\text{supplier}_2$ of chain 6, $\text{supplier}_2$ of chain 7 and $\text{supplier}_2$ of chain 8. It indicates that these inefficient suppliers cannot become efficient by decreasing only logistics costs. In this case, the manufacturers should decide to change out the suppliers. Alternatively, these inefficient suppliers should turn to pay attention to improve their performance by considering output-oriented perspective or fundamental investment.

## 5 DISCUSSION AND CONCLUSION

A new method for finding weak links in supply chains has been proposed. To show the usefulness of the proposed method, an example of Thai frozen shrimp industry is discussed as a case study.

With the proposed method, manufacturer can decide either requesting inefficient suppliers to improve their performances or replacing them by considering the value of coefficient of prospective level. This method has been proposed based on an input-oriented strategy. Sometimes it is difficult to decrease input until input reaches prospective level. Alternatively, inefficient suppliers should consider to improve their performance by consid-

**Table 3.** Efficiency results of the representative chains in frozen vegetable industry. $\theta_{As-is}$ means efficiency score of chains. $\theta_{S1}$ means efficiency score of supplier$_1$. $\theta_{S2}$ means efficiency score of supplier$_2$

| Chain | $\theta_{As-is}$ | $\theta_{S1}$ | $\theta_{S2}$ |
|---|---|---|---|
| 1 | 1.000 | 1.000 | 0.884 |
| 2 | 1.000 | 0.949 | 0.999 |
| 3 | 1.000 | 1.000 | 0.880 |
| 4 | 1.000 | 1.000 | 1.000 |
| 5 | 0.882 | 0.884 | 0.806 |
| 6 | 0.953 | 0.902 | 0.957 |
| 7 | 0.994 | 1.000 | 0.791 |
| 8 | 0.952 | 0.890 | 0.962 |
| 9 | 1.000 | 1.000 | 1.000 |
| 10 | 1.000 | 1.000 | 0.923 |
| 11 | 0.903 | 0.904 | 0.878 |
| 12 | 0.968 | 0.972 | 0.959 |
| 13 | 0.910 | 0.823 | 0.925 |
| 14 | 1.000 | 0.996 | 1.000 |
| 15 | 1.000 | 1.000 | 1.000 |

ering output-oriented strategy or fundamental investment. Such cases also be dealt by modifying the proposed model as output-oriented strategy.

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**Table 4.** Coefficient of prospective level of logistics costs of frozen shrimp industry when considering input-oriented perspective. $\alpha$ means coefficient of prospective level of suppliers

| Chain | | $\lambda_1$ | $\lambda_2$ | $\lambda_3$ | $\alpha$ |
|---|---|---|---|---|---|
| 5 | s1 | 2.459 | 0 | 6.276 | 0.870 |
| | s2 | 0 | 0.3651 | 2.290 | 0.560 |
| 6 | s1 | 0 | 1.922 | 6.872 | 0.723 |
| | s2 | 0 | 1.557 | 0.134 | -2.368 |
| 7 | s2 | 0 | 0.875 | 0.892 | -0.911 |
| 8 | s1 | 1.726 | 0 | 12.780 | 0.883 |
| | s2 | 0 | 1.131 | 0.076 | -2.810 |
| 11 | s1 | 0.641 | 0 | 18.748 | 0.902 |
| | s2 | 0 | 1.081 | 7.221 | 0.753 |
| 12 | s1 | 0 | 1.586 | 20.964 | 0.958 |
| | s2 | 0.642 | 0 | 0.112 | 0.939 |
| 13 | s1 | 2.751 | 0 | 26.113 | 0.807 |
| | s2 | 1.35 | 0 | 3.476 | 0.922 |

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