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Imprecise Data Envelopment Analysis Approach in Performance Evaluation of Supply Chain

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Abstract. Spurred by intensifying competition in global markets, most companies have been increasingly implementing supply chain management (SCM) and information systems (IS) practices. As well, globalization policies have created a more intensive competition amongst manufacturers; in additional the priority of supply over demand, market competition and importance of some factor such as quality, accountability has encouraged companies to integrate their activities using SCM. Performance measurement of supply chain management reflects the need for improvement in operational areas which are found wanton in performance measures. In addition to the results obtained from the evaluation of supply chain performance based on inner changed data can help the integration of supply chain activities and their inner changed data through improving the chain relations and it satisfies customers. In addition, Supply chain (SC) performance evaluation problems cover a wide range from evaluating the performance of independent organizations among supply chains to evaluating the performance of a whole supply chain system. Therefore, in this paper, as regards, performance evaluation is of great importance for effective supply chain management, it has been tried to evaluate supply chain performance by both exact and interval data. This model is illustrated by a numerical example.

Keywords: Imprecise Data Envelopment Analysis (IDEA), Supply Chain Management (SCM).

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1. Introduction

A supply chain is a network, which consists of all stages (e.g. order processing, purchasing, inventory control, manufacturing, and distribution) involved in producing and delivering a final product or service. The entire chain connects customers, retailers, distributors, manufacturers and/or suppliers, beginning with the creation of

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raw material or component parts by suppliers and ending with consumption of the product by customers. Supply chain management (SCM) is related to the coordination of materials, products and information flows among suppliers, manufacturers, distributors, retailers and customers [12]. Meanwhile, supply chain management (SCM) has been a great importance in competitive strategy to enhance organizational productivity and profitability. Researchers have paid much attention to issues concerning supply chain due to demand of market. It is obvious that increase of company competition between supply chains highlights the importance of using a proper system for evaluating its performance to recognize competition improvement opportunity. Neely et al. [10] defined performance measurement as the process of quantifying the effectiveness and efficiency of action. Performance measurement systems are described as the overall set of metrics used to quantify both the efficiency and effectiveness of action.
Wikner, et al. [14] examined five supply chain improvement strategies, and then implements these strategies on a three-stage reference supply chain model. The five strategies are:

1. Fine-tuning the existing decision rules.
2. Reducing time delays at and within each stage of the supply chain.
3. Eliminating the distribution stage from the supply chain.
4. Improving the decision rules at each stage of the supply chain.
5. Integrating the flow of information, and separating demands into .real.

Orders, which are true market demands, and .cover. Orders, which are orders that bolster safety stocks.

However, study on suitable performance measurement systems are still quite limited. Recent years have seen a great variety of applications of DEA (Data Envelopment Analysis) for use in evaluating the performances of many different kinds of entities engaged in many different activities in many different contexts in many different countries. Therefore, DEA is used as a powerful instrument to measure the overall chain and each subsystem (supply chain member). Also it's possible to convert interval data to exact data and use them to have more effective evaluation. The objectives of this paper are to provide a focused on performance assessment and improving performance of supply chain when information flow is exact and interval data are used as a DEA method to evaluate supply chain.

2. DEA and Supply Chain

Data envelopment analysis (DEA) has been widely utilized for evaluating relative efficiency of organizations with multiple input resources and output products (Figure 1). In these setting, a DMU represents a two-stage process and intermediate measures exist in between the two stages. The first stage uses inputs to generate outputs which become the inputs to the second stage. The second stage then uses these intermediate measures to produce outputs. The standard data envelopment analysis (DEA) method requires that the values for all inputs and outputs be known exactly. When some outputs and inputs are unknown decision variables such as bounded data, ordinal data, and ratio bounded data, the DEA model becomes a non-linear programming problem and is called imprecise DEA (IDEA).

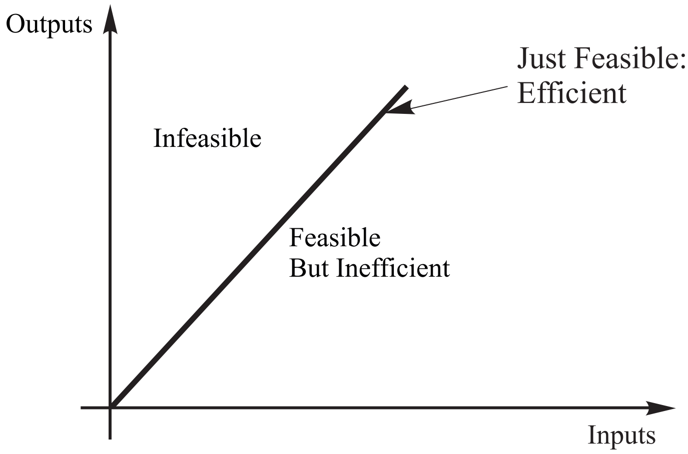

Figure 1. The Concept of a Frontier.

2.1 *Imprecise Data Envelopment Analysis (IDEA)*

In some enterprises we may come across imprecise data such as interval, ordinal and fuzzy data. Considering the importance of these data and how to deal with them, data envelopment analysis has received a great deal of attention from researchers. Cooper et al. [3] introduced the applications of DEA whose data was imprecise. In imprecise data envelopment analysis (IDEA), the data can be ordinal, interval or fuzzy, which results in a non-linear DEA model. Therefore, Imprecise DEA (IDEA), proposed in that work, is the first unified approach for dealing directly with imprecise data in DEA (bounds and/or rankings imposed directly on input/output data). Cooper et al. [4] and Zhu [15, 16] also used ordinal and interval data in DEA.

2.2 *Supply Chain*

A supply chain is an integrated manufacturing process wherein raw materials are converted into final products, then delivered to customers. On the other hand, a supply chain is a logistics network, which consists of all stages (e.g. order processing, purchasing, inventory control, manufacturing, and distribution) involved in producing and delivering a final product or service. At its highest level, a supply chain is comprised of two basic, integrated processes: (1) the Production Planning and Inventory Control Process, and (2) the Distribution and Logistics Process. These Processes, illustrated below in Figure 2, provide the basic framework for the conversion and movement of raw materials into final products.

Considering the importance of imprecise data in SCM, for the convenience of discussion we suppose N two-stage supply chains peer for evaluation, e.g., supplier-manufacturer supply chain (SC) as shown in Figure 3 which produce multiple outputs y_{rj} $(r = 1, 2, \dots, s)$, by utilizing multiple inputs x_{ij} $(= 1, 2, \dots, m)$ in each SC while some of them are interval data. As described in Figure 1, any supplier consumes m inputs to generate z intermediate products. These z_{dj}, intermediate produce, are used to evaluate the impact of all units of each circle such as distributor and supplier on the efficiency of Supply Chain Management (SCM) and the manufacturer consumes those intermediate products to produce y outputs [3].

As mentioned in chen et al. [2], in examining the efficiency of two stage processes, all outputs of the first stage, intermediate measure, become inputs for the second stage, this all happens in one model. The Chen et al. [2] model is better than last two stage DEA model such as Kao and Hwang. Those models mentioned in Chen et al. [2] use exact data to evaluate the efficiency. Due to existence of uncertainty

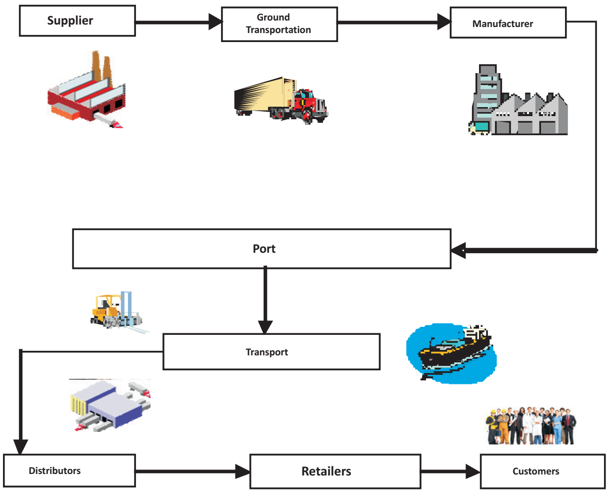

Figure 2. Supply Chain Process.

in the SCM, we face the situation of imprecise data such as interval data which is a problem worth study. As mentioned in Zhu [15], their defined model converts imprecise data into exact data and then uses the standard linear DEA model. So we developed models Chen et al. [2] with interval data in the way of Zhu [15]. Assume $[\underline{x}_{ij}, \bar{x}_{ij}]$ is the ith inputs of subsystem j that $\underline{x}_{ij}$ is the lower bound and $\bar{x}_{ij}$ is the upper bound of the inputs of subsystem s and $[\underline{z}_{dj}, \bar{z}_{dj}]$ is the dth intermediate measure of subsystem j and also $[\underline{y}_{dj}, \bar{y}_{dj}]$ is the rth output of DMU$_j$. So we proposed the following two stage model with interval data.
Input_Oriented model:

$$
\begin{array}{lll}
\min \theta & & \\
\text{s.t.} & \sum\limits_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j \bar{x}_{ij} + \lambda_o \underline{x}_{io} \leqslant \theta \underline{x}_{io} & i \in BI \\
& \sum\limits_{j=1}^{n} \lambda_j x_{ij} \leqslant \theta x_{io} & i \notin BI \\
& \sum\limits_{\substack{j=1 \\ j\neq o}}^{n} \mu_j \underline{y}_{rj} + \mu_o \bar{y}_{ro} \geqslant \bar{y}_{ro} & r \in BO \\
& \sum\limits_{j=1}^{n} \mu_j y_{rj} \geqslant y_{ro} & r \notin BO \\
& \sum\limits_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j \underline{z}_{dj} + \lambda_o \bar{z}_{do} \geqslant \bar{z}_{do} & d \in BN \\
& \sum\limits_{j=1}^{n} \lambda_j z_{dj} \geqslant z_{do} & d \notin BN \\
& \sum\limits_{\substack{j=1 \\ j\neq o}}^{n} \mu_j \bar{z}_{dj} + \mu_o \underline{z}_{do} \leqslant \underline{z}_{do} & d \in BN \\
& \sum\limits_{j=1}^{n} \mu_j z_{dj} \leqslant z_{do} & d \notin BN \\
& \lambda_j, \mu_j \geqslant 0 & j = 1, 2, \ldots, n
\end{array}
\tag{1}
$$

Where BI is bounded input set, BO is bounded output set and BN is bounded intermediate measure set.

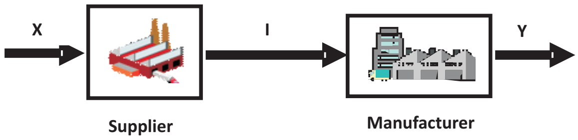

Figure 3. Supply Chain Process.

3. Application

We use the newly developed model (1) with the interval and exact data set used that consist of 5 SCs each having three inputs, two intermediate measure and two outputs. Two inputs of each DMU are interval and the other one is exact data, Table 1. Moreover the intermediate measure and the outputs are interval too. In this manner, we can evaluate the efficiency of SCs which has some exact data with some interval data. For example, Table 1 shows that Supplier 1 consumes 504 units of exact input and 2 type interval inputs,$x_2 = [105, 285]$ and $x_3 = [97, 214]$ to produce 517 units of intermediate products and $z_2 = [105, 285]$. Manufacturer 1 uses these intermediate products to produce 117 units of output and $y_2 = [207, 427]$.

Table 1. Data

NO.	x_1	$\underline{x}_2$	$\underline{x}_3$	$\bar{x}_2$	$\bar{x}_3$	z_1	$\underline{z}_2$	$\bar{z}_2$	y_1	$\underline{y}_2$	$\bar{y}_2$
SC1	504	105	97	285	214	517	205	628	117	207	427
SC2	4406	2004	1511	3800	2024	90	349	544	402	21	25
SC3	815	945	475	1085	913	101	281	725	520	301	335
SC4	412	914	715	1116	820	498	118	416	628	828	930
SC5	1009	191	310	417	818	64	45	76	24	619	921

So the efficiency score of each DMU are reported in Table 2. In this manner, we can evaluate the efficiency of DMUs which has some exact data with some interval data also the frontier points for inefficient DMUs can be defined.

Table 2. Performance evaluation

No.	Efficiency (input-oriented)
SC1	1.0000
SC2	0.3774
SC3	1.0000
SC4	1.0000
SC5	0.5532

4. Conclusions

After proceeding with international management, enterprises have to face the challenge of SCM mainly because of the rapid change in the business environment and severe competition I market and customers' diverse demand. Therefore, how to operate information technology to upgrade the efficiency of a supply chain has currently become one of the most important issues for enterprises. The future stage of this research is focused on analyzing biases in efficiency scores Network supply chain. In addition, this paper also accesses to the effect of supply chain collaboration (VMI).

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