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A New Model for Ranking 3PL Providers

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Abstract: Reverse logistics is an activity within organizations delegated to the customer service function, where customers with warranted or defective products would return them to their suppliers. To rank third-party reverse logistic (3PL) providers with regard to various criteria, including dual-role factors, this paper introduces a new model, which is based on data envelopment analysis. A numerical example demonstrates the application of the proposed model.

Key words: Data envelopment analysis, 3PL provider, Dual-role factors, Super-efficiency analysis

INTRODUCTION

Reverse logistics is the movement of something from its end user to some other activity or location, usually after its intended utility is fully or partly consumed (Haas *et al*. 2003).

Outsourcing logistics functions to third-party reverse logistic (3PL) providers has been a source of competitive advantage for most companies. Most companies cite greater flexibility, operational efficiency, improved customer service levels, and a better focus on their core businesses as part of the advantages of engaging the services of 3PL providers (Göl and Çatay (2007)).

The main benefits of logistics alliances are to allow the outsourcing company to concentrate on the core competence, increase the efficiency, improve the service, reduce the transportation cost, restructure the supply chains, and establish the marketplace legitimacy. Hence, a proper 3PL provider which meets various demands is crucial for the growth and competence of an enterprise.

One of the uses of data envelopment analysis (DEA) can be 3PL provider ranking. DEA serves as a mechanism to evaluate the relative efficiencies of a set of homogeneous decision making units (DMUs). DMUs are evaluated relative to one another using a specified set of input and output factors.

In some situations there is a strong argument for permitting certain factors to simultaneously play the role of both inputs and outputs.

Consider using the number of nurse trainees on staff in a study of hospital efficiency. Such a factor clearly constitutes an output measure for a hospital, but at the same time it is an important component of the hospital's total staff complement, hence it is an input. In a completely different setting, consider the problem of evaluating researchers who receive grants from universities. Such an evaluation might be undertaken as a means of identifying the highest-priority awardees, hence deriving an optimal allocation of research funds. In such a setting, while published research (articles in refereed journals, etc.) is likely the predominant output for evaluating the researcher, the extent to which the research contributes to the training of highly qualified personnel is also an important component in the evaluation. Thus, the total number of graduate students being trained is an output. On the input side one might argue that at least two inputs contribute to the generation of research publications: (i) research dollars available to support publication; and (ii) the number of graduate assistants participating in the awardee's research program. Hence, graduate students can be viewed as serving in a dual-role capacity, simultaneously as both an input and an output (Cook *et al*. (2006)).

In reverse logistics context, the size of the solid waste stream can be considered as both an input and an output. Remembering that the simple definition of efficiency is the ratio of output to input, an output can be defined as anything whose increase will cause an increase in efficiency. Similarly, an input can be defined as anything whose decrease will cause an increase in efficiency. If the size of the solid waste stream collected and disposed of is considered an output, then the increase in the size of the stream without a proportional

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increase in the cost of handling will increase the efficiency of the channel. Likewise, if the solid waste stream is considered as an input, then any decrease in the size of the stream without a proportional decrease in the outputs will increase efficiency. So, depending on how one looks at it, either increasing or decreasing the solid waste stream can increase efficiency.

Beasley (1990, 1995), in a study of the efficiency of university departments, treated research funding on both the input and output sides. However, as Cook *et al*. (2006) addressed, the model proposed by Beasley (1990, 1995) has two limitations. The first limitation is that in the absence of constraints (e.g., assurance region or cone ratio) on the multipliers, each DMU will be 100% efficient. The second limitation is that the dual-role factor is considered as a discretionary factor.

Cook *et al*. (2006) developed a new model that has not the abovementioned limitations. However, their development pertains to a single dual-role factor and does not consider multiple dual-role factors. Meanwhile, their model does not address the ranking of DMUs.

The objective of this paper is to propose a model for ranking 3PL providers in the presence of multiple dual-role factors. This paper depicts the 3PL provider ranking process through a DEA model, while allowing for the incorporation of multiple dual-role factors.

This paper proceeds as follows. In Section 2, literature review is presented. Section 3 discusses the proposed method for 3PL provider ranking. Numerical example is discussed in Sections 4. Section 5 discusses concluding remarks.

2. Literature Review:

There have been some reported research efforts focusing on 3PL provider selection. Aghazadeh (2003) developed a five step method to choose an effective 3PL provider. It was determined that third party logistics are beneficial to many companies. Knemeyer and Murphy (2004) evaluated the performance of 3PL provider in a relationship marketing perspective. Six relationship dimensions of trust, communication, opportunistic behavior, reputation, satisfactory prior interactions, and relationship-specific investments are used to form a model to evaluate 3PL providers. Yan *et al*. (2003) developed a model of decision support system based on case-based reasoning for 3PL provider evaluation.

Meade and Sarkis (2002) established a conceptual model for selecting and evaluating 3PL providers with analytic network process (ANP). Göl and Çatay (2007) used analytic hierarchy process (AHP) for selecting 3PL providers. They highlighted the efforts of a leading Turkish automotive company to restructure its supply chain for export parts. Meanwhile, Qureshi *et al*. (2007), Zhang *et al*. (2004), and Ao *et al*. (2007) applied AHP for 3PL provider selection. To select the best 3PL providers in the presence of vagueness, Efendigil *et al*. (2008) developed a two-phase model based on artificial neural networks and fuzzy AHP.

However, AHP and ANP have two main weaknesses. First subjectivity of AHP and ANP is a weakness. The decision maker provides the values for the pairwise comparisons and, therefore, the model is very dependent on the weightings provided by the decision maker. Second the time necessary for completion of such a model is a weakness. The number of pairwise comparisons required could become cumbersome. Meanwhile, when the number of alternatives and criteria grows, the pairwise comparison process becomes difficult, and the risk of generating inconsistencies grows, hence jeopardizing the practical applicability of AHP and ANP. Bottani and Rizzi (2006) presented a multi-attribute approach for the selection and ranking of the most suitable 3PL provider. Their approach is based on the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and the fuzzy set theory. Liu and Wang (in press) presented a fuzzy approach for selection of 3PL providers. Their method consists of three different techniques: (1) use of fuzzy Delphi method to identify important evaluation criteria; (2) use of fuzzy inference method to eliminate unsuitable 3PL providers; and (3) develop a fuzzy linear assignment approach for the final selection.

Haas *et al*. (2003) applied DEA for selecting reverse logistics channels. Min and Joo (2006) used DEA to measure the operational efficiency of 3PL providers relative to prior periods and their competitors. To evaluate the 3PL providers, Zhang *et al*. (2006) formulated a four-step model based on both AHP and DEA and applied the model to a case study.

However, all of the abovementioned references do not consider dual-role factors. To the best of author's knowledge, there is not any reference that discusses 3PL provider ranking in the presence of multiple dual-role factors. The contributions of presented approach in this paper are as below:

- The proposed model does not demand weights from the decision maker. Since classical techniques always require intuitive judgments that have biases, this paper helps decision makers to rank the 3PL providers without relying on intuitive judgments.
- For the first time, this paper proposes a model which ranks the efficient DMUs in the presence of dual-

role factors.
- The proposed model considers dual-role factors for 3PL providers ranking.

3. Proposed Method for 3PL Provider Selection:

DEA proposed by Charnes *et al*. (1978) (CCR model) and developed by Banker *et al*. (1984) (Banker, Charnes, Cooper (BCC) model) is an approach for evaluating the efficiencies of DMUs.

Consider a situation where members j of a set of n DMUs are to be evaluated in terms of s outputs $Y_j = \left(y_{rj}\right)_{r=1}^{s}$ and m inputs $X_j = \left(x_{ij}\right)_{i=1}^{m}$. In addition, assume that a particular factor is held by each DMU in the amount w_j, and serves as both an input and output factor. The proposed model for considering single dual-role factor is as follows (Cook *et al*., 2006).

$$\max \quad \frac{\left(\sum_{r=1}^{s}\mu_r y_{ro} + \gamma w_o - \beta w_o\right)}{\sum_{i=1}^{m} v_i x_{io}},$$

$$st$$

$$\begin{aligned} & \sum_{r=1}^{s}\mu_r y_{rj} + \gamma w_j - \beta w_j - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,\ldots,n \\ & \mu_r, v_i, \gamma, \beta \ge 0. \end{aligned} \tag{1}$$

where μ_r is the weight given to output r and v_i is the weight given to input i. DMU$_o$ is the DMU under consideration. DMU$_o$ consumes x_{io} (i=1, …, m), the amount of input i, to produce y_{ro} (r=1, …, s), the amount of output r.

Now, to demonstrate how to consider multiple dual-role factors in the model, the following model is presented. Assume that some factors are held by each DMU in the amount w_{fj} ($f=1,\ldots,F$), and serve as both an input and output factors. The proposed model for considering multiple dual-role factors is as follows:

$$\max \quad \frac{\left(\sum_{r=1}^{s}\mu_r y_{ro} + \sum_{f=1}^{F}\gamma_f w_{fo} - \sum_{f=1}^{F}\beta_f w_{fo}\right)}{\sum_{i=1}^{m} v_i x_{io}},$$

$$st$$

$$\begin{aligned} & \sum_{r=1}^{s}\mu_r y_{rj} + \sum_{f=1}^{F}\gamma_f w_{fj} - \sum_{f=1}^{F}\beta_f w_{fj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,\ldots,n \\ & \mu_r, v_i, \gamma_f, \beta_f \ge 0. \end{aligned} \tag{2}$$

The linear programming form of model (2) is as follows:

$$\max \quad \sum_{r=1}^{s} \mu_r y_{ro} + \sum_{f=1}^{F} \gamma_f w_{fo} - \sum_{f=1}^{F} \beta_f w_{fo},$$

$$\max \quad \sum_{r=1}^{s} \mu_r y_{ro} + \sum_{f=1}^{F} \gamma_f w_{fo} - \sum_{f=1}^{F} \beta_f w_{fo},$$

st

$$\begin{aligned} & \sum_{i=1}^{m} v_i x_{io} = 1, && (3) \\ & \sum_{r=1}^{s} \mu_r y_{rj} + \sum_{f=1}^{F} \gamma_f w_{fj} - \sum_{f=1}^{F} \beta_f w_{fj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \qquad j = 1,\dots,n \\ & \mu_r, v_i, \gamma_f, \beta_f \ge 0. \end{aligned}$$

Dual problem of model (3) is as below.

$$\min \qquad \theta_o$$

st

$$\begin{aligned} & x_{io}\theta_o - \sum_{j=1}^{n} x_{ij}\lambda_j \ge \mathbf{0} && i = 1,\dots,m \\ & \sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{ro} && r = 1,\dots,s \\ & \sum_{j=1}^{n} w_{fj}\lambda_j = w_{fo} && f = 1,\dots,F \\ & \lambda_j \ge 0 && j = 1,\dots,n \qquad (4) \\ & \theta_o \quad \text{unrestricted in sign} \end{aligned}$$

where θ_o and λ_j are the dual variables. θ_o is radial input shrinkage factor (eventually to become efficiency measure).

On the other hand, an important problem in the DEA literature is that of ranking those DMUs deemed efficient by the DEA model, all of which have a score of unity. One approach to the ranking problem is that provided by the super-efficiency model of Andersen and Petersen (1993). The super-efficiency model involves executing the standard DEA models, but under the assumption that the DMU being evaluated is excluded from the reference set.

Notice that efficient DMUs have super-efficiency score greater than or equal to 1, while inefficient DMUs have super-efficiency score less than 1.

At this stage, the new model which ranks the efficient DMUs in the presence of dual-role factors is introduced. Omitting the column corresponding to DMU_o, the ranking model is obtained as follows

$$
\begin{aligned}
&\min \quad \theta_o \\
&st \\
&\qquad x_{io}\theta_o - \sum_{\substack{j=1 \\ j\neq o}}^{n} x_{ij}\lambda_j \geq \mathbf{0} \qquad i=1,\dots,m \\
&\qquad \sum_{\substack{j=1 \\ j\neq o}}^{n} y_{rj}\lambda_j \geq y_{ro} \qquad r=1,\dots,s \\
&\qquad \sum_{\substack{j=1 \\ j\neq o}}^{n} w_{fj}\lambda_j = w_{fo} \qquad f=1,\dots,F \\
&\qquad \lambda_j \geq 0 \qquad j=1,\dots,n \\
&\qquad \theta_o \quad \text{unrestricted in sign}
\end{aligned}
\tag{5}
$$

Model (5) ranks efficient DMUs in the presence of dual-role factors. If the optimal objective value of model (5) is greater than 1, DMU_o is super-efficient. Otherwise, DMU_o is not super-efficient. The super-efficiency scores of the DMUs obtained by the model (5) can be ranked in descending order.
In the next section, a numerical example is presented.

4. Numerical Example:

The data set for this example is partially taken from Talluri and Baker (2002) and contains specifications on eighteen 3PL providers (DMUs). The 3PL provider input considered is unit operation cost (UOP). UOP is the cost spent for one unit operation of transportation. Size of the solid waste stream (SS) constitutes both an output and an input. The outputs utilized in the study are recycling capacity (RC), and revenue from the sale of recyclables (R). Table 1 depicts the 3PL provider's attributes.

Table 1: Related attributes for eighteen 3PL providers

3PL provider	Input	Dual-role factor	Outputs	
No. (DMU)	UOP ($)	(SS)	RC (10000 kg)	R (1000 $)
	x_{1j}	w_j	y_{1k}	y_{2k}
1	253	24900	187	2
2	268	64300	194	13
3	259	71400	220	3
4	180	180900	160	3
5	257	23800	100	24
6	248	24100	192	28
7	272	140400	194	1
8	330	98400	195	24
9	327	64100	200	11
10	330	58800	171	53
11	321	24100	174	10
12	329	56700	209	7
13	281	56700	165	19
14	309	96700	199	12
15	291	63500	188	33
16	334	79500	168	2
17	249	68900	177	34
18	216	91300	167	9

Applying model (5), the efficiency scores of 3PL providers (DMUs) have been presented in Table 2.

As addressed in Table 2, DMU 6 has infeasible solution. To resolve this problem, Xue and Harker (2002) introduced the implications of the infeasibility in super-efficiency DEA models with respect to the efficiency ranking of the DMUs. They showed that it is still possible to obtain the full ranking of the entire DMUs when infeasibility arises in super-efficiency DEA models.

Notice that the efficiency score reflects the radial distance from the DMU_o to the efficiency frontier estimated with all the DMUs in the observation set in the basic DEA models (CCR and BCC models), and all the DMUs except the DMU_o in the super-efficiency DEA models. That is, in the input-oriented super-efficiency DEA model, for an inefficient DMU, the efficiency score indicates the possible proportional decrease in its input vector that is required for the inefficient DMU to become efficient. The higher the efficiency score, the smaller the required decrease. For an efficient DMU, the efficiency score indicates the possible proportional increase in its input vector that is allowed for the efficient DMU to preserve being efficient. The higher the efficiency score, the larger the allowed increase. Therefore, in general, in an input-oriented super-efficiency DEA model, a higher efficiency score means that a DMU is more efficient. A DMU with an infeasible solution, is a DMU that can proportionately increase its input to positive infinity while remaining efficient, which results in its efficiency score going to positive infinity. Therefore, the efficiency scores for such DMUs are higher than the other DMUs, and consequently they should have the highest efficiency ranking.

Table 2: Super-efficiency scores

3PL provider No. (DMU)	Super-efficiency scores
1	.951
2	.881
3	1.069
4	1.98
5	.698
6	*Infeasible*
7	.821
8	.756
9	.721
10	1.37
11	.696
12	.767
13	.736
14	.774
15	.885
16	.587
17	1.086
18	.922

Now, with respect to the above discussions, the super-efficiency scores of the 3PL providers depicted in Table 2 can be ranked in descending order. Table 3 represents the ranking results. As Table 3 shows, 3PL provider 6 is the most efficient DMU and is the first candidate for selection.

Table 3: Ranking results

3PL provider No. (DMU)	Rank
6	1
4	2
10	3
17	4
3	5
1	6
18	7
15	8
2	9
7	10
14	11
12	12
8	13
13	14
9	15
5	16
11	17
16	18

5. Concluding Remarks:

In order to increase their competitive advantages, many companies consider logistics outsourcing as very important. A successful 3PL provider ranking plays a critical role in building the long term relationships between the outsourcing company and a provider. For this reason, this paper has provided a new model for the problem of 3PL provider ranking. The proposed model integrates two different techniques (the DEA technique which takes into account dual-role factors, and super-efficiency analysis technique) in order to take advantage of the reasoning powers of each one.

The problem considered in this study is at initial stage of investigation and much further researches can be done based on the results of this paper. Some of them are as follows:

- Similar research can be repeated for dealing with fuzzy data in the conditions that dual-role factors exist.
- A potential extension to the methodology includes the case that some of the 3PL providers are slightly non-homogeneous. One of the assumptions of all the classical models of DEA is based on complete homogeneity of DMUs (3PL providers), whereas this assumption in many real applications cannot be generalized. In other words, some inputs and/or outputs are not common for all the DMUs occasionally. Therefore, there is a need to a model that deals with these conditions.
- This study used the proposed model for 3PL provider ranking. It seems that more fields (e.g. technology ranking, personnel ranking, *etc*) can be applied.

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