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A new chance-constrained data envelopment analysis for selecting third-party reverse logistics providers in the existence of dual-role factors

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ABSTRACT

Outsourcing in logistics is a very significant theme and third-party reverse logistics (3PL) provider evaluation and selection has to be realized in a careful manner in order to provide the expected benefits. In this paper a new chance-constrained data envelopment analysis (CCDEA) approach is proposed to assist the decision makers to determine the most appropriate third-party reverse logistics (3PL) providers in the presence of both dual-role factors and stochastic data. A numerical example demonstrates the application of the proposed model.

1. Introduction

Reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of raw equipments, in-process stock, finished merchandise, and related information from the point of expenditure to the point of origin for the aim of recapturing value or of appropriate disposal.

Recycling is a sub-procedure within reverse logistics to decrease the solid waste volume generated by the disposition of consumer cargos normally at the end of product's life-span or due to fault. A reverse canal is the physical distribution process of all these recyclables within which recycled materials are processed into diverse forms in order to eliminate either perilous materials before the final disposition into landfills or to extract valuable substances for reselling back to the market. The capabilities and interactions of the agents in the recycling canal have a momentous impact on the efficiency of processing recycled materials. Different agents within the canals may have dissimilar operations objectives and constraints. They have diverse competition and/or cooperation behaviors with other agents in the same or diverse tiers.

A key logic for outsourcing of logistics functions is the intensified globalization of businesses. During the last two decades, globalization has been appeared as a main force of shaping business strategies, leading firms to develop goods designed for a global marketplace and to source components globally. This has led to more knotty supply chains requiring better participation of managers in logistics functions. Lack of precise awareness of customs, tax regulations and infrastructure of destination countries has forced firms to get hold of expertise of third-party logistics service providers. Consequently, firms are concentrating their energies on core activities and leaving the rest to expert firms.

Outsourcing logistics functions to third-party reverse logistics (3PL) providers have been a resource of competitive benefit for most companies. Most companies quote greater flexibility, operational efficiency, enhanced customer service levels, and a better center on their core businesses as part of the advantages of appealing the services of 3PL providers. The main profits of logistics alliances are to allow the outsourcing company to focus on the core competence, escalate the efficiency, enhance the service, lessen the transportation cost, restructure the supply chains, and create the marketplace legality. Hence, a proper 3PL provider which meets diverse demands is critical for the augmentation and competence of an enterprise. Numerous manufacturers have understood that their core competences are not in the logistics field and have, hence, gradually sought to purchase logistics services and functions from 3PL providers.

The importance of studying reverse logistics has been increased in recent years for several reasons (Farzipoor Saen, 2009; Prahinski & Kocabasoglu, 2006).

- The amount of product returns can be very high, with some industries experiencing returns at over 50% of sales.
- Sales opportunities in secondary and global markets have increased revenue generation from previously discarded products.
- End-of-life take-back laws have proliferated over the past decade in developed countries, requiring businesses to effectively manage the entire life of the product.

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Table 1
A summary of methods for 3PL providers selection.

Technique name	References
Analytic hierarchy process (AHP)	Zhang, Li, Liu, Li, and Zhang (2004), Göl and Çatay (2007), Zhang, Li, Liu, Li, and Zhang (2006)
Fuzzy theory	Kumar et al. (2004), Xu and Wang (2007), Liu and Wang (2009), Zhang and Feng (2007), Mi et al. (2009)
Analytic network process (ANP)	Meade and Sarkis (2002), Jharkharia and Shankar (2007)
Artificial intelligence	Efendigil, Önüt, and Kongar (2008)
Technique for order preference by similarity to ideal solution (TOPSIS)	Bottani and Rizzi (2006), Qureshi et al. (2007), Kannan et al. (2009)
Social welfare function	Cao, Wang, and Cao (2007)
Case-based reasoning (CBR)	Yan, Chaudhry, and Chaudhry (2003)
Data envelopment analysis (DEA)	Haas et al. (2003), Min and Joo (2006), Farzipoor Saen (2009), Farzipoor Saen (2010)
Principal component analysis	Zhang, Zhang, and Zhou (2008)
Multiple criteria decision making (MCDM)	Aguezzoul, Rabenasolo, and Desodt (2006), Işiklar, Alptekin, and Büyüközkan (2007)

- Consumers have successfully pressured businesses to take responsibility for the disposal of their products that contain hazardous waste.
- Landfill capacity has become limited and expensive; alternatives such as repackaging, remanufacturing and recycling have become more prevalent and viable.

Some mathematical programming approaches have been used for 3PL provider selection in the past. Table 1 categorizes the reviewed papers based on applied techniques. Nevertheless, because of the intricacy of the decision making process involved in 3PL provider, all the aforementioned references in Table 1, except for DEA models, rely on some form of procedures that assigns weights to various performance measures. The primary problem associated with arbitrary weights is that they are subjective, and it is often a complex task for the decision maker to precisely assign numbers to preferences. It is an intimidating task for the decision maker to assess weighting information as the number of performance criteria is increased. In the meantime, they do not consider stochastic data.

In some situations there is a strong dispute for permitting certain factors to concurrently play the role of both inputs and outputs. Remembering that the simple meaning of efficiency is the ratio of output to input, an output can be defined as everything whose raise will cause a raise in efficiency. Likewise, an input can be defined as everything that its reduction will cause an increase in efficiency. As Farzipoor Saen (2010) discuss, some factors such as ratings for service-quality experience (EXP) and service-quality credence (CRE) are dual-role factors.

Chance-constrained programming (CCP) is a kind of stochastic optimization approach. It is suitable for solving optimization problems with random variables included in constraints and sometimes in the objective function as well. Stochastic programming deals with optimization problems whose parameters take values from given discrete or continuous probability distributions. One type of the solution method is the CCP method pioneered by Charnes and Cooper. They assume that stochastic objective functions and stochastic constraints will hold with at least a number of probability levels, and the chances are represented by the probabilities that the objectives and constraints are satisfied. The CCP has been used in many areas. Cao, Gu, and Xin (2009) proposed CCP for refinery short-term crude oil scheduling problem. Yang and Wen (2005) applied CCP approach to transmission system expansion planning. Talluri, Narasimhan, and Nair (2006) proposed a chance-constrained data envelopment analysis (CCDEA) approach for vendor selection by incorporating stochastic considerations in vendor evaluation decisions. Olesen and Petersen (1995) applied CCDEA approach for evaluation of the research activities in economic departments at Danish Universities. Li, Huang, Nie, and Qin (2007) applied an inexact two-stage chance-constrained linear programming (ITCLP) method for planning waste management systems. Huang (2007) proposed CCP for capital budgeting problem. Yang, Yu, Wen, and Chung (2007) applied a CCP model for reactive power planning under a competitive electricity market environment. Chen (2002) applied CCDEA and stochastic frontier analysis approaches to compare the technical efficiency of 39 banks in Taiwan. Waller and Ziliaskopoulos (2006) proposed a CCP for system optimum-dynamic traffic assignment (SO-DTA) problem. Land, Lovell, and Thore (1993) applied CCDEA model to measure productive efficiency to the case of stochastic inputs and outputs in 49 school sites.

To the best of knowledge of authors, there is not any reference that deals with 3PL provider selection in the presence of both dual-role factors and stochastic data. The objective of this paper is to propose a method that allows 3PL providers to be evaluated in terms of both stochastic and dual-role factors. In summary, the approach presented in this paper has some distinctive contributions.

- Stochastic data and dual-role factors are considered simultaneously.
- The proposed model does not demand exact weights from the decision maker.
- For the first time, the proposed model is used for the problem of 3PL provider selection.
- The proposed model deals with stochastic data in a direct manner.

This paper proceeds as follows. In Section 2, the proposed model for selecting 3PL providers is introduced. Numerical example and managerial implications are discussed in Sections 3 and 4, respectively. Concluding remarks are illustrated in Section 5.

2. Proposed method

DEA is a decision technique that has been widely used for performance analysis in public and private sectors. DEA developed by Charnes, Cooper, and Rhodes (1978), is a non-parametric estimation method, in the sense that no choice of a parametric functional form is needed in the estimation of the frontier. DEA can be practical to any organization/industry where a rationally homogeneous set of decision making units (DMUs) use the identical set of inputs, maybe in different combinations, to produce an identifiable range of outputs, once more possibly in dissimilar combinations.

Consider a situation where members k of a set of K DMUs are to be evaluated in terms of R outputs $Y_k = (y_{rk})_{r=1}^{R}$ and I inputs $X_k = (x_{ik})_{i=1}^{I}$. In addition, assume that a particular factor is held by each DMU in the amount w_k, and serves as both an input and output factor. Table 2 depicts the used nomenclatures in current paper.

The proposed model for considering dual-role factors is as follows (Cook, Green, & Zhu, 2006).