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A credibility-based fuzzy location model with Hurwicz criteria for the design of distribution systems in B2C e-commerce ☆

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ABSTRACT

Facility location problem is one of the most critical elements in the design of distribution systems, and numerous studies have focused on this issue. However, facility location theory and guidelines for B2C firms are sparse. In this paper, with regard to the customer characteristics peculiar to B2C e-commerce and the turbulence of the competitive market, a new fuzzy location model is proposed to optimize the distribution system design in B2C e-commerce. The model adopts a hierarchical agglomerative clustering method to classify customers and estimate the fuzzy delivery cost. At the same time, due to the turbulence of competitive market, both market supply and customer demand are treated as fuzzy variables in the model. Afterward, the credibility measure and Hurwicz criterion are introduced to convert the model into a crisp one which has NP-hard complexity. In order to solve the crisp model, an improved genetic algorithm with particle swarm optimization is developed. Finally, the computational results of some numerical examples are used to illustrate the application and performance of the proposed model and algorithm.

1. Introduction

Business-to-consumer (B2C) e-commerce has become a global phenomenon with steady increase in online sales across the globe. According to the latest Research Report issued by IDC (http://www.idc.com/), the number of global Internet users had reached 1.4 billion in 2008. This is one quarter of the whole world's gross population. It is estimated that three year later in 2012, this number will grow to 1.9 billion, which is about 30% of the whole world's gross population. Among all Internet users, around 50% have some experience in using the Internet to purchase books and magazines, audio/video publications, computers and electronics, clothes, mobile phones, etc.

The growth in B2C e-commerce has been motivated by several reasons—convenience, ease, pricing, comparative analysis, wider selection of products and services, and so forth. Although B2C e-commerce is on the rise, the challenges have also increased, such as the problems with the payment method (Bin, Chen, & Sun, 2003), the protection of privacy (Tan & Wu, 2004), logistics (Wang, Yao, & Huang, 2007), etc. In this paper, we mainly focus on logistics issues, that is, how to optimize the design of distribution systems in B2C e-commerce. Compared with traditional commerce, B2C e-commerce has advantages in reducing investment cost and selling cost by using Internet and Web technologies. However, since B2C firms must deliver commodities to customers and orders have the characteristics of numerous multi-variety small batch demands and decentralized locations, the new logistical delivery cost is increasing. Therefore, it is very necessary to reduce the delivery cost in order to improve B2C firms' profits.

B2C e-commerce allows transactions to be conducted directly between B2C firms (sellers) and customers (buyers). So the customers of B2C firms are no longer a few retailers or wholesales with mass and centralized demands but lots of terminal customers whose demands are small and decentralized. Therefore, in order to save the delivery cost, a B2C firm has to operate its own vehicle fleet and serve several customers on one route. In this case, the delivery cost per unit can not be expressed as a function of the radial distance between the distribution center and the customer because customers are not served on a straight-there-and-back-again route. Moreover, it is very difficult to precisely estimate the delivery cost per unit. On the other hand, in today's highly competitive market, shorter and shorter product life cycles make customer demands extremely variable (Xu & Zhai, 2008). In addition, the decision maker also faces the uncertainty of market supply (Liu & Sahinidis, 1997). Therefore, it is not easy to forecast the deterministic customer demand and market supply.

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Motivated by the special customer characteristics of B2C e-commerce and taking into consideration the turbulence of today's competitive market, in this paper, a new fuzzy location model is proposed to optimize the distribution system design in B2C e-commerce. We will first review the related literature before describing our model.

The research on optimization of distribution system design is a hot topic since it can dramatically affect the profitability of the firm with savings in the 5–10% range, which can be achieved by using strategic and tactical logistics models (Goetschalckx, Vidal, & Dogan, 2002). In designing a distribution system, the problem of locating the distribution centers, also called the facility location problem (Klose & Drexl, 2005), is one of the most critical elements in strategic logistics planning and in the control of logistic distribution networks (Manzini & Gebennini, 2008). Many researches have studied this facility location problem since Cooper (1963) proposed it for the first time in 1963.

In recent years, the problem of facility location in an uncertain environment has received considerable attention since decision makers may often meet with uncertain parameters due to the unpredictability of the real logistics distribution system. There are two types of uncertain environment, that is, a stochastic environment and a fuzzy environment. With respect to stochastic environment, researchers try to estimate the uncertain parameters in facility location from historical data. Although stochastic models can cater for a variety of cases, they are not sufficient to describe many other situations, where the probability distribution of parameters in models may be unknown or only partially known due to the lack of historical data (Wen & Iwamura, 2008). So, subjective experience, the preferences and judgment of decision makers are used to provide their estimates. For example, the demands of some new customers which can neither be given precisely nor from historical data, can be described by using ambiguous language, e.g. 'the demand of customer A is *about* 20 units per day, customer B is *around* 18–22 units per day'. In these cases, fuzzy set theory may do better in dealing with such ambiguous information (Wang & Shu, 2005; Peidroa, Mula, Poler, & Verdegay, 2009).

Fuzzy set theory was initiated by Zadeh (1965) and has been widely applied in many real problems. It has been proved to be a useful tool to solve problems which contain an element of uncertainty. In the last few decades many researchers have introduced fuzzy theory into the facility location problem. Bhattacharya, Rao, and Tiwari (1992, 1993) proposed a fuzzy goal programming approach to deal with the location problem using multiple fuzzy criteria. Chen and Wei (1998), Darzentas (1987), Rao and Saraswati (1988) have discussed various facility location problems by employing fuzzy logic methods. Canós, Ivorra, and Liern (1999) introduced a fuzzy set of constraints into the classical *p*-median problem, and the decision is made which provides significantly lower costs by leaving a part of the demand uncovered. Chen (2001) proposed a new fuzzy multiple criteria group decision-making method to solve the distribution center (DC) location selection problem. Ishii, Lee, and Yeh (2007) investigated fuzzy facility location problems with preference of candidate sites. However, all the parameters in these problems are certain, and fuzzy theory is only used to solve the classical mathematical programming problems effectively.

More recently, some researchers have been paying more attention to facility location problem by using fuzzy parameters. Pérez, Vega, and Verdegay (2004) considered some location problems on fuzzy graphs and proposed suitable methodologies for solving them. Yang, Ji, Gao, and Li (2007) investigated facility location problems in a fuzzy environment. And a chance constrained programming model for the problem is designed then a tabu search algorithm, a genetic algorithm and a fuzzy simulation algorithm are integrated to seek the approximate best solution for the model. Yang et al. (2007) discussed the capacitated location–allocation problem with fuzzy demands. Three types of fuzzy programming models, i.e., fuzzy expected cost minimization model, fuzzy α-cost minimization model, and credibility maximization model, are proposed according to different decision criteria. For solving these models, some hybrid intelligent algorithms have been designed. Wen and Iwamura (2008) presented a new α-cost model with fuzzy demands under the Hurwicz criterion. In order to solve this model, the paper proposed a hybrid intelligent algorithm integrated by the simplex algorithm, fuzzy simulations and a genetic algorithm.

It is worth pointing out that all of the above literature about facility location problems under a fuzzy environment can not be directly applied to optimize the location of distribution centers in B2C e-commerce. There are three reasons for this: (1) the existing literature does not consider the customer characteristics of B2C e-commerce, such as numerous multi-variety small batch demands and decentralized locations; (2) the existing literature usually takes into account the uncertainty of customer demand but does not consider the uncertainty of market supply; (3) the existing literature focuses almost exclusively on how to optimize the site and the number of distribution centers, neglecting their capacity (size). That is to say, researchers always assume that the setup cost and capacity of a distribution center are fixed once it is selected.

On the basis of the above reasons, we discussed a fuzzy chance-constrained programming model based on the possibility measure in Jiang, Wang, and Ip (2007). However, a possibility measure does not have the property of self-duality, which is absolutely essential in both theory and practice (Liu, 2006, 2008; Huang, 2009). For example, in fuzzy facility location problem, whenever the possibility value of a customer demand greater than a target value is lower than 1, the possibility value of the opposite event (i.e., the customer demand less than or equal to the target value) is the maximum value of 1; or whenever the possibility value of a customer demand less than or equal to a target value is lower than 1, the possibility value of the opposite event (i.e., the customer demand greater than the target value) is the maximum value of 1. These results are quite awkward and will confuse the decision maker. Hence, this paper is an attempt to propose a new fuzzy location model based on the self-duality credibility measure and Hurwicz criterion. Then an improved genetic algorithm with particle swarm optimization is developed in order to solve the model.

The remainder of this paper is organized as follows: Section 2 contains some preliminaries about credibility measures, fuzzy chance-constrained programming and the Hurwicz criterion. In Section 3 the problem is described and the fuzzy programming model, which includes how to define the function of setup cost, and how to calculate the fuzzy delivery cost, is proposed. In Section 4 the conversion of the fuzzy programming model into a fuzzy chance-constrained programming model with its crisp equivalent, by using the credibility measure and Hurwicz criterion, is shown. And then a corresponding crisp model is obtained. In Section 5 the development of an improved genetic algorithm with particle swarm optimization to solve the crisp model is described. Section 6 provides the computational results of some numerical examples to illustrate the application and performance of the proposed model and algorithm. Finally, the conclusion and future research are summarized in Section 7.

2. Preliminaries

2.1. Credibility measure and fuzzy variable

The concept of a fuzzy set, via a membership function, was initiated by Zadeh (1965). In order to measure a fuzzy event,