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Fuzzy facility location-allocation problem under the Hurwicz criterion

Meilin Wen [a], Kakuzo Iwamura [b,*]

[a] Department of Mathematical Sciences, Tsinghua University, Beijing 100084, China
[b] Department of Mathematics, Josai University, Sakado, Saitama 350-0248, Japan

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Abstract

Facility location-allocation (FLA) problem has been widely studied by operational researchers due to its many practical applications. Many researchers have studied the FLA problem in a deterministic environment. However, the models they proposed cannot accommodate satisfactorily various customer demands in the real world. Thus, we consider the FLA problem with uncertainties. In this paper, a new model named α-cost model under the Hurwicz criterion is presented with fuzzy demands. In order to solve this model, the simplex algorithm, fuzzy simulations and a genetic algorithm are integrated to produce a hybrid intelligent algorithm. Finally, some numerical examples are presented to illustrate the effectiveness of the proposed algorithm.

Keywords: Location-allocation problem; Fuzzy programming; Genetic algorithm; Fuzzy simulation

1. Introduction

The facility location-allocation (FLA) problem is widely used in practical life, such as building an emergency service systems and constructing a telecommunication net works, etc. In recent years, people pay significant attention to it especially in supply chain management because of its effect on key operational performance measures, e.g., lead time, inventory, responsiveness, etc.

FLA problem was initially studied by Cooper [5] in 1963, and then Hakimi [12,13] applied it in network design as a powerful tool. In 1982, Murtagh and Niwattisyawong [34] proposed the capacitated FLA problem, which is considered as one of the most important researches in this field, specially focusing on facilities which have capacity constraints. Meanwhile, considerable research has been carried out in the field of FLA theory [1,14]. It is proved that the FLA problem is strongly NP-hard [36], and thus a large amount of solution approaches for different models have been proposed in the past decades [18,33]. A series of heuristic algorithms, including hybrid algorithms, have also been developed to solve complicated FLA problems. For instance, Ernst and Krishnamoorthy [10] combined the simulated annealing and random descent method, and Gong et al. [11] utilized the Lagrange

* Corresponding author. Tel./fax: +81 28 649 6691.
E-mail addresses: wml03@mails.tsinghua.edu.cn (M. Wen), kiwamura@math.josai.ac.jp (K. Iwamura).

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relaxation method and genetic algorithm to approximate the optimal solutions.

In the real world, it is usually very hard to present the precise demands of customers and thus they are estimated from historical data. Furthermore, researchers tried to describe FLA problem under stochastic environment. Logendran and Terrell [19] considered the uncapacitated FLA problem in the presence of price sensitive stochastic demands to maximize the expected net profits. Then Zhou [38] proposed the expected cost model, α-cost model and probability maximum model for uncapacitated FLA problem with stochastic demands. However, in many cases, facilities have a constraining upper limit on the amount of demand. For example, in telecommunications and power transmission networks, there are hard constraints on the capacities of concentrators, switches, and transformers. Thus the expected cost model, α-cost model and probability maximum model were given for capacitated FLA problem with stochastic demands [39].

Although stochastic models can cater for a variety of cases, they are not sufficient to describe many other situations, where the probability distribution of customers demands may be unknown or partially known. For example, we want to build some new water companies in new regions to service some new customers whose demands can neither be given precisely nor from history data. But those demands can be described by the natural language such as large, little or general, etc. In these cases, fuzzy set theory may do better in dealing with ambiguous information. Fuzzy set theory was initialized by Zadeh [42] and has been widely applied in many real problems. It has been proved to be a useful tool to solve problems with uncertainty. In the past decades many researchers have introduced fuzzy theory into FLA problem. Various facility location problems by fuzzy logic methods were discussed [2,4,8]. Apart from the above-mentioned papers, the capacitated FLA problem with fuzzy demands of customers were formulated by Zhou and Liu [40,41].

The most familiar criteria to us is the optimistic criterion and pessimistic criterion which are widely used in uncertain environment. Several other criteria are proposed, and a list of properties of rationality and consistency were set forth as a set of axioms to be obeyed by a rational criterion [32,6]. The most well-known criteria is the Hurwicz criterion, suggested by Hurwicz [15,16] in 1951, which attempts to find a middle ground between the extremes posed by the optimistic and pessimistic criteria. Instead of assuming total optimism or pessimism, the Hurwicz criterion incorporates a measure of both by assigning a certain percentage weight λ to optimism and $1-\lambda$ to pessimism, $\lambda \in [0,1]$. Many researchers use the optimistic criterion or pessimistic criterion to model the FLA problem, which are both extreme cases. In order to give a balance between these two models, we employ the Hurwicz criterion to model the FLA problem.

This paper is organized as follows. In Section 2, we give some basic concepts and conclusions on the fuzzy variables. In Section 3, the problem and symbols are introduced. A new model named α-cost model under the Hurwicz criterion is proposed in Section 4. In order to solve this fuzzy model, we integrate the simplex algorithm, fuzzy simulations and genetic algorithm to design a powerful hybrid intelligent algorithm in Section 5. Finally, Section 6 provides some numerical examples to illustrate the performance and the effectiveness of the proposed algorithm.

2. Fuzzy variable

In this section, we will state some basic concepts and results on fuzzy variables. These results are crucial for the remainder of this paper. An interested reader may consult Liu [25,27] where important properties of fuzzy variables are recorded.

Let Θ be a nonempty set, and $\mathscr{P}(\Theta)$ the power set of Θ. For any $A \in \mathscr{P}(\Theta)$, Liu and Liu [31] presented a credibility measure $\mathrm{Cr}\{A\}$ to express the chance that fuzzy event A occurs. Li and Liu [20] proved that a set function $\mathrm{Cr}\{\cdot\}$ is a credibility measure if and only if

(i) $\mathrm{Cr}\{\Theta\} = 1$;
(ii) $\mathrm{Cr}\{A\} \leqslant \mathrm{Cr}\{B\}$, whenever $A \subset B$;
(iii) Cr is self-dual, i.e., $\mathrm{Cr}\{A\} + \mathrm{Cr}\{A^c\} = 1$, for any $A \in \mathscr{P}(\Theta)$;
(iv) $\mathrm{Cr}\{\cup_i A_i\} \wedge 0.5 = \sup_i \mathrm{Cr}\{A_i\}$ for any collection $\{A_i\}$ in $\mathscr{P}(\Theta)$ with $\mathrm{Cr}\{A_i\} \leqslant 0.5$, in which $\wedge$ is the minimum operator.

The triplet $(\Theta, \mathscr{P}(\Theta), \mathrm{Cr})$ is called a credibility space and a fuzzy variable is defined as a function from this space to the set of real numbers [26]. Furthermore, the credibility theory was developed by Liu [25] as a branch of mathematics for studying the behavior of fuzzy phenomena.

Suppose that ξ is a fuzzy variable defined on the credibility space $(\Theta, \mathscr{P}(\Theta), \mathrm{Cr})$. Then its member-