Applied Mathematical Modelling 39 (2015) 7442–7451

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Mathematical modeling of optimal multi fuzzy locations of facilities based on the assumed step distance among them in a convex set

Hamid Tohidi

Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran

ARTICLE INFO

Article history:
Received 22 January 2011
Received in revised form 18 December 2014
Accepted 22 December 2014
Available online 11 February 2015

Keywords:
Convex set
Linear fuzzy programming
Location
Multiple facilities

ABSTRACT

In current global industries, production units aim to transport goods among suitably located facilities to reduce their production costs. However, rapid changes increase the uncertainty and ambiguity in the environment. Therefore, the use of mathematical optimization models based on fuzzy approaches to locate facilities is particularly important. In this study, we employ fuzzy linear programming to propose a model for locating new facilities among an existing set of facilities. We also give a convex solution and formulate a model for fuzzy data using integer linear programming. We then solve the model using an example where we minimize the total cost related to the placement of facilities based on the assumed step distance among them.

1. Introduction

Layout problems are found in several types of manufacturing systems. Typically, layout problems are related to the locations of facilities (e.g., machines and departments) in a plant and they are known to have great impacts on the system performance [1].

Facility layout design (FLD) has a very important effect on the performance of a manufacturing system. The concept of FLD is usually treated as a multi-objective problem. Thus, the generation of a layout and its evaluation are often challenging and time consuming due to the multiple objectives considered and the data collection process involved. In addition, an effective facility layout evaluation procedure necessitates the consideration of qualitative criteria in the decision-making process, e.g., flexibility in the volume, variety, and quality of a product and production, as well as quantitative criteria such as the material handling cost, adjacency score, shape ratio, and the utilization of material handling vehicles [2]. Finding optimal facility layouts is a classic problem in process system engineering as well as operations research. The initial models were unsuitable for cases with unequal facility sizes or unknown potential positions, so continuous facility layout models were introduced to address these limitations by modeling facilities as geometric entities and searching for an optimal two-dimensional packing. However, solving these new models is much harder and finding the optimal layouts for these models is beyond the capacity of current optimization techniques, except for very small problem cases [3].

Problems related to the configurations and locations of facilities have been discussed and analyzed for centuries. These configuration and location problems have been considered for many years, but they have been addressed more frequently since the advent of operations research.

E-mail address: H_Tohidi@azad.ac.ir

http://dx.doi.org/10.1016/j.apm.2014.12.048
0307-904X/

The configurations and locations of facilities must be represented in a manner that allows their main position configurations to be determined, before selecting the most desirable location for establishing the optimal facilities based on quantitative and qualitative factors.

The location models employed include mathematical models and qualitative models. In general, mathematical models are divided into descriptive and prescriptive models. In descriptive models, the model describes the system's behavior, such as queuing models. However, the application of these models might lead to the recommendation of prescriptive actions that may be optimal in some cases; thus, mathematical programming models are known as prescriptive models.

Mathematical programming models consider the selection of a suitable criterion and a standard. The criterion that determines the best solution among the possible solutions is based on minimizing the distance traveled. This solution assumes that if we minimize the distance traveled, the transportation costs are also minimized. We can classify facility location problems based on the number of new facilities. We can also consider the locations of new facilities as regional or point problems. In some facility location problems, the number of new facilities is known as a decision variable. In addition, the locations of the new facilities may be dependent or independent of the remaining new facilities. If we consider that the locations of the new and existing facilities comprise a regional problem, the facility location problem can be classified based on the size and the form of the facilities, where the location is known as the decision variable.

The locations of facilities may be static or dynamic, or they can be definite. In addition, depending on the size of facilities, their locations may be treated as points or areas. If there is a quantitative and qualitative relationship, we need to identify the facilities that have this relationship. In some cases, the degree of this relationship to facilities is independent of their locations. Experience suggests that when making a final decision about the locations and configurations of facilities, we should consider the qualitative factors and quantitative results. In some cases, there will be impractical solutions among the solutions obtained by solving mathematical models. These solutions should be explained based on criteria that compare the accepted practical solutions with them. Thus, we should consider other models as design tools.

In this study, we emphasize quantitative results but the qualification values of the locations and configuration problems associated with facilities are not neglected. Therefore, by formulating multiple mathematical models of the locations of facilities using fuzzy data, we can increase the decision-making power when determining locations based on different components. In brief, we suggest that determining multiple optimized locations of the facilities can yield the most desirable and optimized position for the configuration of the new facilities in the set.

In this study, we provide a model for determining the optimal locations of multiple facilities in a convex set using fuzzy data based on the assumed step distance among them. The remainder of this paper is organized as follows. In Section 2, we provide a brief review of the concept of fuzzy set theory. Section 3 presents a short review of facility location and layout problems. In Section 4, we describe a general approach for obtaining a mathematical model of multiple optimized facility locations, where we assume the step distance among facilities. In Section 5, we define a mathematical model for determining multiple optimized locations of facilities in the convex set. In Section 6, we extend the mathematical model of multiple optimized locations of facilities in the convex set for fuzzy data. In Section 7, we solve this model using the linear fuzzy programming method based on a numerical example. In Section 8, we give our conclusions.

2. Fuzzy set theory

The successful application of fuzzy set theory to control systems has grown rapidly and it has influenced other fields, such as simulation, artificial intelligence, management, operations research, and many other branches of engineering. Linear programming is one of these areas. Many industrial and management issues involve linear programming problems, but the decision maker cannot determine the exact values of the coefficients. In fact, in traditional linear programming, the coefficients are generally decided using exact values provided by experts. However, in a fuzzy environment, the assumption of precise information provided by experts is unrealistic. Thus, the development and application of fuzzy modeling to real decision problems with imprecise data may be appropriate. In this section, we give a brief review of fuzzy set theory.

Fuzzy set theory was first introduced to deal with the vagueness of human thoughts [4]. A fuzzy set is a class of objects with a continuum of grades of membership. This set is characterized by a membership function that assigns each object with a grade of membership, which ranges between zero and one [4]. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or non-membership, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a fuzzy set [5]. Since sufficient data are not always available for predicting uncertain parameters, fuzzy logic was introduced as a powerful tool for expressing this uncertainty based on an expert's knowledge. The FLD problem, which is a real life problem, can be investigated in a fuzzy environment due to its fuzzy design parameters [6].

Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling uncertain systems in industry, nature, and humanity, where they facilitate common sense reasoning during decision making in the absence of complete and precise information. Their role is significant when applied to complex phenomena that are not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution [7]. Fuzzy set theory provides a broader frame than classic sets theory and it has contributed to the capacity to reflect real world problems [8].

To develop an integrated approach to simulation, the fuzzy analytic hierarchy process and the quality function deployment and multiple criteria decision making method have been employed for FLD improvement and optimization. Computer simulation has also been used to determine quantitative measures [9].