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A new model for robust facility layout problem

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ABSTRACT

The Facility Layout Problem (FLP) is the problem of locating each department in a long plant floor without any overlap between departments in order to minimize the material handling cost. The main purpose of this study is to show the effectiveness of a robust approach to solve FLP.

In this study, it is assumed that the departments' length and width are not predetermined. For modeling this kind of uncertainty, the size of each department is considered as a bounded variable and two new parameters are also introduced to implement a robust approach. Moreover, a new adaptive algorithm is designed to determine the robust layout with respect to the decision makers' requirements. Furthermore, the lower and upper bounds of objective function are obtained in this model. Due to the complexity of the problem, a set of problems is generated and tested by the proposed algorithm. The results show the efficiency of our model.

1. Introduction

Facility Layout Problem (FLP) is one of the classical problems in which the planning for the placement of different types of facilities such as machines, employee workstations, utilities, customer service areas, restrooms, material storage areas, lunchrooms, drinking fountains, offices, and internal walls is discussed [6]. For manufacturing facilities, material handling cost is the most significant measure to determine the efficiency of a layout and is frequently employed since it represents 20–50% of the total operating cost and 15–70% of the total cost of manufacturing of a product [18]. Due to the fact that FLP is an NP-hard problem, various mathematical models and algorithms have been developed in the past three decades to discuss it.

FLP can be categorized into Single Row Facility Layout Problem (SRFLP) and Multi Row Facility Layout Problem (MRFLP). SRFLP consists of a number of rectangular facilities to be sorted on a straight line [15]. MRFLP is defined as locating departments in a plant floor in a way that the sum of the material handling costs is minimized. In general, MRFLP comprises n rectangular departments in which the distances between each pair of departments are assumed to be calculated based on a rectilinear form. This problem has four major inputs: $C = [c_{ij}]$, which represents the cost per unit distance travelled between facilities, $L = [l_i]$ and $W = [w_i]$, which are the length and width of departments respectively and $F = [f_{ij}]$, which is the matrix of flow rates.

Most previous studies focused on deterministic environment in which the size of departments is assumed to be constant. Conversely, in real world environment, the precise dimensions of departments are usually very hard to estimate, and it would be more practical to consider a flexible area for departments. This assumption seems more invaluable when the size of departments can be affected by different factors such as labor, machines, and other equipment that are common between

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two departments. In this study, we assume that there is no deterministic size available for a department. However, we suppose that the area of each department depends on its adjacent departments. Therefore, these two bounded parameters are used to represent the dimensions of departments. In general, the major goal of this study is to solve MRFLP in an area of uncertainty using robust optimization approach.

2. Literature review

The beauty of facility layout problem lies in its tremendous theoretical and practical applications. However, it is proved that the facility layout problem is an NP-complete problem, which cannot be solved in a limited time when the number of facilities is big [17]. Therefore, a large number of articles have been published in this area during the last decades. However, a mixed integer programming model was developed to solve MRFLP [11]. Another mixed integer programming was presented in [7], which is known as ABSMODEL. In this model, four constraints were considered for each pair of departments to prevent them from overlapping, and then a rectilinear method was applied to calculate distances.

In practice, the flexibility and robustness of FLP are two major issues that are centers of attention in recent studies. In the literature, the consistency of layout with uncertainty is defined as flexibility, but different definitions have been given. As a matter of fact, the authors of [16] were pioneers in the field of flexibility in FLP. They developed a model to find a flexible layout under uncertain circumstances with a penalty function criterion. Then, [10] defined the flexible FLP as the ability to manufacture different products. They used a hybrid approach which has to do with a combination of simulation and Tabu-research to solve this problem.

Robustness of layout was presented by [14]. In their study, there were stochastic product demands for a single period and the problem was modeled as Quadratic Assignment Problem (QAP). A new method to find a robust layout under demand uncertainty in multiple period layout problem presented itself in [8]. They also used QAP model and a branch and bound method were used to solve this problem.

A fuzzy approach for FLP was developed by Aiello and Enea [1]. In this study, a ranking method, which considers the different levels of decision makers' pessimism, was used to find a robust layout. The uncertainty inflow of fuzzy numbers between departments was discussed in [4] and the problem was solved by a modified GA. A few years later, uncertainty in a block layout design was developed in [10]. The authors used a simulation technique to solve the problem and called the solution a "robust layout" since it appeared as the optimum solution in the most number of iterations. A stochastic approach in a flexible plant layout in which departments were allowed to be duplicated presented in [3]. A new method to solve FLP was developed in [2]. The authors implemented stochastic characteristics such as intertribal time and diverse part routs in the problem. Moreover, in a study in 2006, a decision-making methodology based on Data Envelopment Analysis (DEA) was presented in which both quantitative and qualitative criteria were considered for the evaluation of FLD [5]. In this paper, inputs were the criteria that are supposed to be minimized whereas outputs were the criteria that are supposed to be maximized. In 2007, the perspectives of using uncertainties in facility layout problems were presented by [9]. Recently, a robust approach was presented to solve Dynamic Facility Layout Problem [13]. This approach assumed that the machines in a layout can be easily relocated; therefore, the corresponding layout will accommodate changes from time to time with low rearrangement and production interruption costs. The use of Evolutionary Algorithm problems in uncertain environments is an efficient and applicable method which has been used recently in [19]. A review paper [12] published recently covered different problems such as the dynamic and robust layout problems and discussed the advantages and disadvantages of various solution methods especially intelligent approaches for solving them.

3. Definition of robustness in MRFLP

In this study, as mentioned earlier, a new model used in finding a robust layout has been developed. For robustness approach, we consider flexible dimensions where $l_i \in [l'_i, l''_i]$ and $w_i \in [w'_i, w''_i]$ for each department. In this definition, l'_i and w'_i show lower bounds for length and width, respectively, while l''_i and w''_i are upper bounds for length and width, respectively. Moreover, we assumed that there is no adequate information about the actual statistical distribution of departments' dimensions. According to these definitions, $\frac{1}{2}\left(l'_i + l'_j\right)$ and $\frac{1}{2}\left(l''_i + l''_j\right)$ state the minimum and maximum distances between central coordinates of two adjacent facilities i and j in the X-axis, respectively, and the same inference can be applied for $\frac{1}{2}\left(w'_i + w'_j\right)$ and $\frac{1}{2}\left(w''_i + w''_j\right)$ in the Y-axis.

To model a robust layout, α_{ij} and θ_{ij} are defined as input parameters. In this definition, α_{ij} and θ_{ij} are called length and width coefficient deviations respectively.

We know that a robust layout can be defined by different models and approaches. In the proposed model, a new definition is presented for a robust layout problem and then a mathematical model and a heuristic algorithm are developed to solve it.

In practice, it is not possible to consider the borderlines of departments independently. In other words, the boundaries of each department are related to the other departments in a layout. If we can calculate the possible changes allowed in the width or length of a department so that no overlap of departments occurs in the general structure of a layout, then we will be able to have a model in which a decision maker can effectively participate in designing the final layout.