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Effects of different fuzzy operators on fuzzy bi-objective cell loading problem in labor-intensive manufacturing cells

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Abstract

In this study, a fuzzy bi-objective cell loading problem in labor-intensive cellular environments is presented and the effects of different fuzzy operators on the model are investigated. The objective functions of the proposed mathematical model for the problem are minimizing the number of the tardy jobs and the minimizing the total manpower needed. The mathematical model determines the number of cells to open and the cell size for each opened cell and assigns products to cells (cell loading) and also determines the sequence of products in each cell simultaneously. Fuzziness stems from the fuzzy aspiration levels attained to both objective functions. To solve the model, fuzzy mathematical programming approach is used and fuzzy achievement function of the model is defined by six different fuzzy operators which are *min*, *fuzzy and*, *fuzzy or*, *minimum bounded sum*, *add*, and *product*. An example problem is solved to represent the performance of the operators. Experimentation shows that the fuzzy and-operator and product-operator are suitable to reach efficient solutions for the problem on hand.

Keywords: Cell loading; Manpower allocation; Fuzzy aspiration levels; Fuzzy operators; Mathematical programming

1. Introduction

Cellular manufacturing continues to be popular both in literature and practice by using the new strategies such as adding the informational vagueness due to the inexactness in parameter estimates to deal with the real life problems.

Manufacturing cells can be machine-intensive or labor intensive. In machine-intensive cells, the number of machines directly determines the output of a cell. Usually, the operator involvement is limited. Even though the number of operators may affect the results, their work may be limited to loading/unloading the machines. An operator might be assigned to run multiple machines. On the other hand, in labor-intensive manufacturing cells operator assignment and involvement plays a central role in the performance of the cell and most of the operations require light and inexpensive machines and equipment.

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This study focuses on the fuzzy bi-objective cell loading problem in labor-intensive manufacturing cells. This problem has been observed in jewelry manufacturing, medical device assembly and apparel manufacturing. The number of operators assigned to a cell can vary from one period to the next to adjust to varying demand. As a result, alternative cell sizes are generated by allocating different number of operators to each cell. However, the total number of operators in the cellular system cannot be exceeded even though the allocation from one cell to the next cell and from one period to the next period can vary. Operators may be assigned to different operations in the same cell and/or different cells in different periods based on requirements.

Informational vagueness in the problem stems from the fuzzy aspiration levels attained to objective functions. Two objectives included in this study are: (1) minimization of the number of tardy jobs (maximizing the number of early jobs) and (2) minimization of the total number of operators with fuzzy aspiration levels. A job is called tardy when it is completed beyond its due date ($c_i > d_i$) where c_i is the completion time and d_i is the due date of job i. The former is a crucial performance measure for the acceptable schedule and the customer satisfaction. The latter is also critical to reduce labor costs and to be competitive in the market place. Compromising between two objectives is important to reach effective and implementable results since both are conflicting in nature. So, fuzzy mathematical programming is chosen as the solution approach which enables us to both express vagueness mathematically and optimize the two objectives simultaneously.

The remainder of the paper is organized as follows. In Section 2, literature is reviewed. In Section 3, the proposed fuzzy bi-objective mathematical model is explained in detail. In Section 4, after preliminary definitions of fuzzy mathematical programming and mathematical representations of the fuzzy operators, fuzzy models generated by using different operators are presented. In Section 5, the effects of the fuzzy operators are investigated on a sample problem. The final section constitutes the conclusions and the future directions.

2. Literature review

In literature, several works have addressed cell loading issues. The early works can be found in Süer and Saiz (1993), Süer, Saiz, Dagli, and Gonzalez (1995), Süer (1996, 1997), Süer and Bera (1997, 1998a, 1998b). Aktürk and Wilson (1998) proposed a hierarchical cell loading approach. Their objective is to minimize the variable production cost. They considered the inventory balance constraints for families and items, and capacity feasibility constraints for group technology cells and resources over the planning horizon. In the Lozano et al.'s study (1999) cell loading problem is modeled as a multi-period LP formulation that determines the quantity of each part type that will follow each alternative route in each period of the planning horizon in order to minimize total transportation and holding costs while keeping both machine and cell utilizations approximately balanced. Süer, Saiz, and Gonzalez (1999) introduced new cell loading rules and presented several possible combinations of these rules and developed two algorithms for cell loading. The performance measures considered are number of tardy jobs, total tardiness, maximum tardiness and the average cell utilization. Babayiğit and Süer (2003) developed four different mathematical models to solve the cell loading problem in labor-intensive cellular environments. The objective is to minimize the number of tardy jobs subject to manpower restriction. Recently, Süer and Dağlı (2005) discussed various approaches for cell loading and manpower allocation in labor-intensive cells. First, a product sequencing problem with the objective of minimizing the total intra-cell manpower transfers is introduced and an optimal solution methodology is proposed. In the second part of the study, a machine-level-based similarity coefficient is discussed and used during the cell loading process to minimize makespan and also machine and space requirements.

None of the studies mentioned above consider the informational vagueness in the problem parameters. To model informational vagueness, Fuzzy Set Theory (Zadeh, 1965) has been applied in many areas for the last two decades. Mathematical programming is one of the areas in which the theory is widely applied. In fuzzy mathematical programming, fuzzy decision is defined by fuzzy operators which are used to define the relationship between goals and constraints. In the literature, widely known operator is the min (intersection) operator which was proposed by Bellman and Zadeh (1970). They define the fuzzy decision as the fuzzy set of alternatives resulting from the set theoretic intersection of the goals and constraints. Min-operator is also known as the non-compensatory operator.