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A heuristic solution for fuzzy mixed-model line balancing problem

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Abstract

This paper addresses the mixed-model line balancing problem with fuzzy processing time. A fuzzy binary linear programming model is formulated for the problem. This fuzzy model is then transformed to a mixed zero–one program. Due to the complexity nature in handling fuzzy computation, new approximated fuzzy arithmetic operation is presented. A fuzzy heuristic is developed to solve this problem based on the aggregating fuzzy numbers and combined precedence constraints. The general idea of our approach is to arrange the jobs in a sequence by a varying-section exchange procedure. Then jobs are allocated into workstations based on these aggregated fuzzy times with the considerations of technological constraint and cycle time limit. Promising results are obtained by experiments.

Keywords: Fuzzy numbers; Mixed-model; Line balancing

1. Introduction

Line balancing problem deals with the assignment of tasks to workstations. The assembly line includes a series of workstations, where product items are processed. To produce a product, it is required to process a set of tasks (jobs). These tasks must follow a given processing order called precedence relationship. The assembly line could be dedicated to produce for a single product model or multiple product models. In the second configuration, many items of a product model could be processed at a time in batches or all product models are handled simultaneously on the same assembly line with the lot sizes of one item for each product model. These configurations of assembly line represent for classes of line balancing problems:

- Single-model assembly line balancing problem with deterministic/stochastic/fuzzy processing time (SMALB).

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- Batch-model assembly line balancing problem with deterministic/stochastic/fuzzy processing time (BMALB).
- Mixed-model assembly line balancing problem with deterministic/stochastic/fuzzy processing time (MALB).

In these line balancing problems, the requirement is often to distribute the tasks to workstations such that a certain objective (number of workstations, total cost, production rate, etc.) is optimized and precedence relationship is not violated. The workstation time, which is the sum of times of all tasks assigned to that workstation, must not exceed the given cycle time. The processing time of tasks are also given. In general, the line balancing problem has several variances. The variety could come from the requirement, objective, or the form of processing time or the structure of the lines. The requirement of the problem is not only to allocate tasks to workstations but also to sequence product models to be assembled in the designing batch/mixed-model lines or determine optimal batch sizes for batch-model configuration. The objective could be other criteria different than number of workstations such as minimization of cycle time for a given number of workstations, minimization of balance delay time, etc. A difference between the cycle time and workstation time is called idle time. The sum of idle time for all workstations is called balance delay time. These objectives could also be taken into account simultaneously in the form of multi-criteria optimization problem. The processing time could be given in deterministic terms or from the stochastic processes or in the form of vagueness of fuzzy sets.

In mathematical complexity, the line balancing problem is NP-complete in strong sense because the NP-complete bin-packing problem can be transformed easily to the line balancing problem in polynomial time. Therefore, several heuristic procedures have been proposed to solve different versions of the line balancing problem. Some comprehensive analyses and reviews of the line balancing problems could be found in the papers of Baybars (1986), Ghosh and Gagnon (1989), Amen (2000) and the book of Scholl (1999). According to Fokkert and de Kok (1997), most of works on assembly line balancing problem are dated back to before 1980s. Most of approaches focus on solving single-model line balancing problem with deterministic processing time (Helgeson and Birnie, 1961; Gutjahr and Nemhauser, 1964; Mansoor, 1967; Hackman et al., 1989; Peterson, 1993; Leu et al., 1994, etc.). Some few efforts have been made for the batch-model and mixed-model line balancing problem. Recently, attention on the batch/mixed-model assembly line balancing is paid back due to the requirement of mass assembly with the support of advanced technologies, which help the assembly lines higher flexibility and faster processing speed. Kabir and Tabucanon (1995) studied the batch-model assembly line balancing problem using a multi-attribute decision making approach. They generate a set of feasible number of workstations, which are balanced for each product model. Then, they select the best configuration (number of workstations) considering multiple criteria such as production rate, variety, minimum distance moved, quality, etc. The survey of Fokkert and de Kok (1997) also shows that there are two approaches in the literature transforming the mixed-model line balancing problem into a single-model line balancing problem. These approaches use combined precedence diagrams and adjusted task processing times. The experiment results also indicate that the position of common tasks in the precedence diagram of the different models has a significant effect on both the computation time and the unequal distribution of the total work content of single models among workstations. The extension the approaches of single-model for mixed-model have been utilized by Gokcen and Erel in their different formulations (Gokcen and Erel, 1997; Gokcen and Erel, 1998; Erel and Gokcen, 1999). The binary goal programming model of Gokcen and Erel (1997) is the first multiple criteria decision making (MCDM) approach to the mixed-model version based on the model of Deckro and Rangachari (1990) for single model assembly line balancing problem. In the next version, Gokcen and Erel (1998) formulate a binary integer programming for the mixed-model assembly line balancing problem. The size of the model has been reduced significantly to an applicable problem with up to 40 tasks by using