Study on a new stochastic multi-product disassembly line balancing problem

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1 Introduction

Remanufacturing, as an important branch of sustainable development, aims to create new economic, social, and environmental values by appropriately managing end-of-life (EOL) products. Disassembly line balancing problem (DLBP) for EOL products is one of the key issues in the remanufacturing industry. With the increasing demand for customized products, the scale of EOL products and their variants is rapidly expanding in the recycling market [1]. However, approximately 96% of related studies in the literature concentrate on the single-product DLBP according to [2]. Moreover, task processing times are often uncertain due to the varying damage degrees of EOL products [3]. In this study, we investigate a multi-product DLBP with stochastic task times. For the studied problem, a joint chance-constrained programming model is formulated. Then, the proposed model is transformed into a distribution-free one. Effective valid inequalities based on problem properties are devised. An enhanced cut-and-solve (CS) algorithm is proposed to solve the large-scale instances with up to 20 products and 400 tasks. Numerical experiments show that the approach obtains favorable results.

2 Problem description

Consider that a set of similar EOL products with identical parts have to be disassembled. The disassembly of identical parts can be accomplished by identical tasks that can be assigned to several workstations. Assume that each EOL product can have several different ways (disassembly schemes) to accomplish the disassembly, and only one is selected. The disassembly scheme consists of several disassembly tasks with precedence relationships caused by geometrical or physical restrictions [4]. During the disassembly, the given task precedence relationships must be respected. We assume that task processing times are mutually independent and stochastic with partial information known, i.e., the mean, standard deviation and upper bound. A predetermined cycle time C must be respected with a given risk level α, i.e., the probability that the task processing times of all workstations exceed the cycle time is less than α. Furthermore, the hazardous parts that will incurs additional costs are considered.

The studied multi-product DLBP aims to select a disassembly scheme for each EOL product, determine the workstations to be opened, and assign the tasks in the selected disassembly schemes to workstations. The objective of the problem is to minimize the total cost consisting of opening workstations and handling hazardous parts. The problem is formulated as a stochastic joint chance-constrained programming model ($P1$).

3 Solution method

First, $P1$ is approximately transformed into a distribution-free model ($P2$) because it cannot be solved directly. To tighten the solution space of $P2$, two valid inequalities are proposed. The first one attempts to pre-calculate the maximal required number of workstations, and the second one aims to reduce the ranges of workstations that tasks can be assigned to. By adding these two valid inequalities, an improved model ($P3$) is obtained.

Next, an enhanced CS algorithm is proposed to solve the studied problem, especially for the large-scale instances. Three improvements are proposed to improve the performance of the algorithm, including 1) a constructive heuristic is proposed to obtain an initial upper bound. 2) double piercing cuts based on partially linear relaxation are devised at each iteration to obtain a better lower bound. 3) sparse problem is further divided into two sub-problems for better resolution at each iteration.

4 Experiment results

The approximated distribution-free model $P2$ is evaluated by comparing with the deterministic model (DM) and sampling average approximation (SAA) model [5]. Experimental results demonstrate that $P2$ outperforms SAA in terms of the computation time, and the solution qualities of $P2$ and SAA are nearly identical. Moreover, numerical experiments show that the average computation time of $P3$ is only 25.17% of the time needed by $P2$, which demonstrates the validity of the proposed inequalities. The proposed enhanced CS algorithm is tested on randomly generated instances where the largest one contains 20 products and 400 tasks, and the proposed algorithm needs only 17.53% and 40.65% of the computation times required by CPLEX and the classic CS algorithm, respectively.

5 Conclusions

This work examines a multi-product DLBP by considering the identical parts of multiple products and the stochastic task processing time. To efficiently solve the problem, a joint chance-constrained model, a distribution-free model, efficient valid inequalities, and an enhanced CS algorithm are devised. Numerical experiments demonstrate the high performance of the proposed approaches.

References

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