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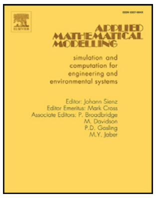

Two-sided assembly line balancing problem with parallel performance capacity

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ABSTRACT

Two-sided assembly line balancing (two-ALB) problems usually occur in plants that produce large high-volume products, such as buses, trucks, locomotives, and home products. In this study, we consider a two-ALB using a new approach that allows the parallel performance of tasks in a real-world locomotive production plant. The problem is formulated as a mixed-integer program and a new heuristic algorithm is proposed, which produces robust results as well as obtaining better quality solutions to some basic two-ALB benchmarks. In fact, the proposed algorithm can obtain optimal solutions for some small-scale problems and near-optimal solutions for some medium-scale problems.

1. Introduction and literature review

Assembly lines can be categorized into several types such as traditional straight lines, U-shaped one-sided lines [1], multi-level lines, and two-sided lines. Two-sided assembly lines, which are the main focus of the present study, are designed for plants that produce large products such as buses, trucks, and locomotives. These lines comprise a set of sequential workstations and tasks, which are performed on both sides of the line (Fig. 1).

Two-sided assembly line balancing (two-ALB) differs from traditional one-sided line balancing (one-ALB) because tasks can be performed in different operation directions. It may be preferable to perform some assembly operations on one of the two sides, whereas others can be performed on either side of the line; therefore, tasks are classified according to three types: left, right, or either tasks.

Two-sided assembly lines have been discussed in previous studies in terms of the solution methods and problem definitions, but to the best of our knowledge, there has been no previous comparison of two-ALB and traditional one-ALB problems. In 1993, Bartholdi [2] was the first to address two-ALB problems in a real case study, where he suggested a simple assignment rule based on the first fit rule (FFR), and focused on the development and use of an interactive program to support the rapid and incremental construction of solutions, where the FFR heuristic aims to minimize the number of workstations as the objective function. Kim et al. [3] developed a genetic algorithm (GA) for solving two-ALB problems. Lee et al. [4] described an assignment procedure for two-ALB problems in order to maximize work relatedness and slackness. Lapierre and Ruiz [5] presented an enhanced priority-based heuristic for solving a specific two-ALB problem. Kim et al. [6] addressed this issue using GA with the objective of minimizing the number of stations within a given cycle time under positional constraints, where this model was applied to a variety of two-ALB problems [7]. Özcan and Toklu [8–10] used this basic model but changed the objective function to minimize the number of mated stations. In addition, Özcan and Toklu [11]

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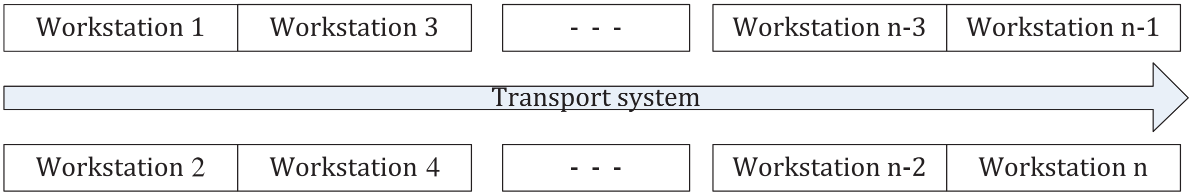

Fig. 1. Two-sided assembly line.

categorized these two-ALB problems as TALBP-I and TALBP-II based on the objectives to minimizing the number of stations and the cycle time, respectively.

In terms of the problem definition, several constraints are considered in most two-ALB problems, including zoning constraints, synchronism constraints, and positioning constraints. Zoning constraints are related to whether tasks can be assigned to the same workstation (Özcan and Toklu [9]), synchronism constraints determine whether paired tasks in a mated station can be started simultaneously on opposite lines (Simaria and Vilarinho [12]), and positioning constraints determine whether tasks are assigned to specific stations (Kim et al. [3]).

Wu et al. [13] proposed a branch-and-bound algorithm for TALBP-I, which minimizes the length of the line and solves the TALBP-I in an optimal manner for 148 tasks described by Bartholdi [2]. Baykasoglu and Dereli [14] applied an ant colony-based heuristic algorithm to solve two-ALB problems, where zoning constraints were introduced into two-ALBP for the first time. Xiaofeng et al. [15] proposed a heuristic algorithm for solving the TALBP-I, where a station-oriented procedure based on the start time is used to assign tasks starting from the left station and moving to the station right of this position. Unsuitable position assignments are finally removed by checking the precedence constraints among the assigned tasks. Özcan and Toklu [16] presented a mathematical model, a pre-emptive goal programming model for precise goals, and a fuzzy goal programming model for imprecise goals for TALBP with zoning constraints, where the number of mated stations, cycle time, and the number of tasks assigned per station are considered as goals. Simaria and Vilarinho [12] proposed a multi-objective ant colony optimization algorithm where two ants 'work' simultaneously, one at each side of the line, to build a balancing solution that satisfies the precedence, zoning, capacity, side, and synchronism constraints of the assembly process. The main goal is to minimize the number of workstations of the line, but workload balancing between stations is also considered as an additional objective. Özcan and Toklu [11] proposed a new mathematical model and a simulated annealing algorithm, which minimizes the number of mated stations (i.e., the line length) as the primary objective and minimizes the number of stations (i.e., the number of operators) as a secondary objective for a certain cycle time. In the proposed algorithm, two performance criteria are considered simultaneously: maximizing the weighted line efficiency and minimizing the weighted smoothness index. Their approach was used to solve a set of standard problems with up to 148 tasks. Özcan and Toklu [9] also presented a tabu search algorithm for this problem and solved it by minimizing the number of stations. Rubiano-Ovalle and Arroyo-Almanza [17] conducted a case study of a local motor cycle production plant and proposed mimetic algorithms to solve the problem. Kim et al. [6] developed a GA to use with the aforementioned basic mathematical model with specific features for two-ALBP. Yegul et al. [18], and subsequently Agpak et al. [19] with additional assumptions, introduced a new hybrid U-shaped, two-sided assembly line and developed a multi-pass random assignment algorithm, where the results were compared to the results obtained for standard straight two-sided line problems. Xiaofeng et al. [20] designed a branch-and-bound algorithm to solve the type 1 two-ALB problem (minimizing the number of stations). Özcan [8] considered the Two-sided assembly line balancing problem (two-ALBP) under stochastic conditions, where he applied the chance-constraint method to the stochastic constraints on the model and proposed a simulated annealing algorithm for solving the problem. Özcan and Toklu [10] considered the setup times in two-sided lines and developed a heuristic based on the computer method of sequencing operations for assembly lines (COMSOL) algorithm, which minimizes the line length and the number of stations. Özcan [8] considered two-sided lines with additional lines parallel to the existing lines to improve and increase the efficiency of the production line. Yin et al. [21] also considered this problem with parallel separate stations. Özbakir and Tapkan [22], and Taha et al. [23] proposed a bee colony algorithm and GA, respectively, to solve two-ALB problems. Tapkan et al. [24] presented a fuzzy environment in addition to a bee algorithm. Rabbani et al. [25] proposed a new multiple U-shaped assembly lines to deal with mixed-model two-ALB problems and to compensate for the decreased effectiveness of simple U-shaped two-sided lines. Chutima and Chimklai [26] presented a particle swarm optimization algorithm to solve a multi-objective, two-sided, mixed-model two-ALB problem, where Pareto optimality was employed to allow the simultaneous optimization of the conflicting objectives.

Purnomo et al. [7] proposed a mathematical model with the aim of simultaneously minimizing the cycle time for a given number of mated workstations and balancing the workstation, where they used FFR and GA. They showed that FFR can exploit the advantage of finding the best position over many workstations and that GA allows more flexible task assignment as well as being significantly faster than the iterative FFR. Hamta et al. [27] formulated a one-ALB by considering flexible operation times, where they developed a bi-criteria nonlinear integer programming model with two opposite objective functions: minimizing the cycle time and minimizing the machine total costs. They used various techniques for different