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Balancing Parallel Two-Sided Assembly Lines with Ant Colony Optimisation Algorithm

Ibrahim Kucukkoc[a,b], David Z. Zhang[a], Edward C. Keedwell[a]

[a]College of Engineering, Mathematics and Physical Sciences, University of Exeter, Harrison Building, EX4 4QF, Exeter, UK
[b]Department of Industrial Engineering, Balikesir University, Cagis Campus, 10145, Balikesir, Turkey
I.Kucukkoc@exeter.ac.uk, D.Z.Zhang@exeter.ac.uk, E.C.Keedwell@exeter.ac.uk

Abstract. Assembly lines are one of the most frequently used flow oriented production systems in industry. Although only a few researchers have studied them, two-sided assembly lines are usually utilised to produce high-volume large-sized products such as trucks and buses. In this study, more than one two-sided assembly line constructed in parallel are balanced simultaneously using a newly developed ant colony optimisation algorithm. To the best knowledge of the authors, the proposed method is the first attempt to solve the parallel two-sided assembly line balancing problem using an ant colony optimisation based algorithm. The proposed approach is also illustrated with examples from the literature to show the procedures of the algorithm.

Keywords: assembly line balancing; parallel two-sided assembly lines; ant colony optimisation; meta-heuristics; artificial intelligence.

1 INTRODUCTION

An assembly line is a sequence of workstations through which a set of tasks is processed. Assembly lines are used to assemble components into a final product and generally workstations are linked by a transportation system like a conveyor or moving belt [1].

Assembly line balancing (ALB) problem is one of the most common problems in industry and a classical Industrial Engineering problem. The main objective of balancing assembly lines is to increase the efficiency of the line by minimising required number of workstations (type I problem) or cycle time (type II problem) [2]. A task can be defined as the smallest work element which cannot be divided between two or more stations [3]. A set of tasks is performed at each workstation and each task has its own *processing time*. Due to technological and organisational conditions, *precedence constraints* must be satisfied in the assignment process [4, 5].

The sum of the completion times of tasks assigned to a work station is called as *workload* of this station. Usually, the cycle time is defined as a value which equals to the largest workload in an assembly line [6]. Hence, the production rate of the system is determined by cycle time [5, 7].

Assembly lines can be classified into two general groups: (i) one sided assembly lines, and (ii) two-sided assembly lines. While stations are utilised on only one side for one sided assembly lines, left and right sides are used to utilise stations for two-sided assembly lines. Two-sided assembly lines are chiefly used to produce large sized products like trucks and buses.

Although a large number of studies have been carried out in the literature on one sided assembly line balancing problem, the studies on two-sided assembly line balancing problem (TALBP) are very limited.

Two-sided assembly line balancing problem was defined by Bartholdi [8]. Bartholdi [8] discussed some theoretical properties of two-sided lines; and developed a first fit heuristic based computer program which embodies a balancing algorithm that emphasizes speed over accuracy for the interactive rapid refinement of solutions. Afterwards, meta-heuristics have been used to solve TALBP. Kim et al. [9, 10], Taha et al. [11], Purnomo et al. [12], and Rabbani et al. [13] developed different genetic algorithms while Baykasoglu and Dereli [14], and Simaria and Vilarinho [15] developed ant colony optimisation (ACO) based algorithms. The study belongs to Baykasoglu and Dereli [14] is one of the first attempts to solve TALBPs using ant colony based heuristic. As different from some other studies, Simaria and Vilarinho [15] employed two ants that work concurrently - one at each side of the line - to build a balancing solution. Ozcan and Toklu [16], and Ozcan [17] implemented simulated annealing algorithms; Ozcan and Toklu [18] proposed tabu search algorithm; Chutima and Chimklai [19] proposed particle swarm optimisation algorithm while Ozbakir and Tapkan [20, 21] developed bees algorithms to solve TALBP. Some exact solution approaches have also been applied to TALBP by Hu et al. [22, 23], and Wu et al. [24]. However, none of these studies considered more than one line. Furthermore, this is the unique study in the literature which applies ACO on any kind of parallel two-sided assembly line balancing problem.

In this study, more than one two-sided assembly line is balanced simultaneously. This problem is known as the *parallel two-sided assembly line balancing problem (PTALBP)* and first (and only) studied by Ozcan et al. [25]. They described the problem and proposed a tabu search algorithm to solve PTALBP.

Simple assembly line balancing problem (SALBP), which is the simplest version of assembly line balancing problems, is an NP-hard class of combinatorial problem [26]. Since PTALBP is a much more complex version of SALBP, it is also NP-Hard, which means that it is difficult to obtain an optimal solution when the problem size increases. Because, the solution space