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# A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem

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**Abstract**

In this paper a new heuristic for solving the assembly line re-balancing problem is presented. The method is based on the integration of a multi-attribute decision-making procedure, named "Technique for Order Preference by Similarity to Ideal Solution" (TOPSIS), and the well-known Kottas and Lau heuristic approach. The proposed methodology does not focus on the balancing of a new line, rather it takes into account the more interesting current industrial aspect of re-balancing an existing line, when some changes in the input parameters (i.e. product characteristics and cycle time) occur. Hence, the algorithm deals with the assembly line balancing problem by considering the minimization of two performance criteria: (i) the unit labour and expected unit incompletion costs, and (ii) tasks re-assignment. Particularly, the latter objective addresses the problem of keeping a high degree of similarity between previous and new balancing, in order to avoid costs related to tasks movements: operators training, product quality assurance, equipment installation and moving. To assess the performance of the presented approach a comparison with the original Kottas and Lau methodology is carried out. The results demonstrate the capability of the proposed algorithm of dealing with the multi-objective nature of the re-balancing problem. Solutions with advantages both in workload re-assignment, implying beneficial effects on the costs factors affected by tasks movements, and in completion costs are obtained in almost half of all problems solved. In the other cases, trade-off balancings with low increases in completion costs are presented.


*Keywords:* Assembly; ALBP; Re-balancing; TOPSIS; Heuristic; Multi-objective

## 1. Introduction

The Assembly Line Balancing Problem (ALBP) consists in the assignment of tasks to operators engaged on the line in such a way that the final item is produced with respect to a pre-specified

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production rate. In literature, a wide variety of algorithms proposing to solve ALBP are found, however almost all of them consider this problem from a static standpoint, that is, before the line deployment.

Nevertheless, continuous changes in market requirements, regarding product design, restyling and quantity needed, combined with high product customization and reduced time-to-market tendency, highlight the need for managing dynamic versions of ALBP solution procedures. This need further increases when the paradigm of agile manufacturing, aiming at developing the capability to promptly respond to variations often unpredictable, is adopted. Particularly, in actual applications, the necessity of a re-balancing oriented design is great due to the occurrence of a wide variety of modifications in the input parameters, such as:

- changes in product features, including tasks adding and removing, and variations in technological precedence relationships;
- increase and decrease in performance tasks time, as a consequence of adopting new equipment;
- modifications to the cycle time, due to changes in market demand.

Those modifications imply variations in tasks assigned to each station. When we deal with manual assembly lines, operators can learn how to perform the new requested tasks, but the learning process needs time and in the first phases involves errors. As a consequence, quality assurance and operators training, along with equipment switching costs, arise. Moreover, such costs are directly affected by the amount of changes in tasks re-assignment. To this extent, agility means capability to promptly face the modifications in the assembly process by minimizing tasks re-assignment, in such a way as to reduce the impact of the change. Hence, in this paper, an innovative heuristic algorithm for solving the assembly line re-balancing problem is presented, with the aim of minimizing both assembly cost and tasks re-assignment.

## 2. Literature review

The ALBP consists of assigning tasks to stations in such a way that (Salveson, 1955):

- each task is assigned to one and only one station;
- the sum of performance task times assigned to each station does not exceed the cycle time;
- the precedence relationships among the tasks are satisfied;
- some performance measures are optimized. Most procedures consider the so-called types I and II ALBP, characterized by minimization of the number of stations, given a desired cycle time or minimization of the cycle time, given a desired number of stations, respectively (Baybars, 1986).

While the first published work concerning ALBP was presented by Salveson (1955), comprehensive reviews of the approaches developed to solve the problem were proposed by Baybars (1986), Ghosh and Gagnon (1989), Erel and Sarin (1998), Scholl (1995), Amen (2000, 2001), and Pierreval et al. (2003).

Following Ghosh and Gagnon (1989) taxonomy, ALBP solution procedures can be mainly classified with respect to two key aspects, that is, the number of items produced on a single line and the nature of performance task times. As a consequence, we can distinguish single model lines assembling only one product from multi/mixed model lines manufacturing more than one item in batches or simultaneously, and deterministic ALBPs, in which performance task times are known constant, from stochastic ALBPs, in which performance task times are distributed according to a specific distribution function.

In this paper, the single-model stochastic version of ALBP is considered. Due to the flexible nature of operators, the assembly line re-balancing problem is particularly felt in manual assembly lines. Hence, the stochastic aspect of performance task times is taken into account. Moreover, the single-model version of the problem is considered, since, nowadays, it still attracts research interests