An Entropy-based Mathematical Formulation for Straight Assembly Line Balancing Problem

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ABSTRACT

This paper focuses on formulating a typical simple assembly line balancing problem. A new objective function based on a nonlinear entropy function is considered for the simple assembly line balancing problem for the first time. This objective function force the stations to have more similar total task processing time, so that the workers of the stations will have similar work load. Using a bounded variable approach, the nonlinear objective function is converted to an approximated linear objective function. Finally, efficiency of the linearized formulation of the entropy-based assembly line balancing problem is tested by a numerical example.

KEYWORDS

Assembly Line Balancing Problem, Bounded Variable Method, Entropy, Linearization, Mathematical Modelling

1. INTRODUCTION

Assembly lines play a critical role in productions systems. Automobile manufacturing industries, electronic devices assembly lines, home appliances production systems, etc. are some instances of the production systems which are based on assembly lines (Kumar et al., 2015). An assembly line contains a series of stations which each one includes one or several assembly activities (tasks). The initial parts of products of the line are given to the beginning of the line and go over the line’s stations to be converted to the final product after passing the last station. In order to complete a product on the assembly line, some related tasks must be performed according to their precedence relationships, therefore, the precedence graph of the tasks would be of the most important limitations that is considered to assign the tasks to the stations. In other words, a task must not be assigned to a station that is placed earlier than the station of its predecessors. The assembly line also should be run by an acceptable speed to be able to produce an amount of product which responds the annual demand of the product. Therefore, all the stations of the line should perform their jobs in a given time which is called “cycle time” of the line. The cycle time of the line is an upper bound for total task time of each of the stations. The problem of assigning the tasks to the stations is named assembly line balancing problem (ALBP) which is a crucial stage in designing an effective production assembly line. Baybars (1986), categorized ALBPs into two main types as simple assembly line balancing problem (SALBP) and generalized assembly line balancing problem (GALBP). In the SALBP (see Scholl and Becker, 2006), the task times are deterministic and certain and also the total task time of each station should not exceed the cycle time of the line. It is supposed that all stations use the
same tools and the same number of workers (manning level), therefore, it is possible to do a task in any station. The tasks should not be assigned to more than one station and a task cannot be divided over the stations. The constraints to be respected are only the precedence relationships of the tasks and the cycle time of the line. On the other hand, GALBPs (see Becker and Scholl, 2006), consider more limitations on the balancing problem e.g. physical shape of the line, physical limitations of the floor, variable cycle time, using parallel stations, etc. In ALBPs, the common objective functions are minimization of the number of stations, minimization of idle time of the stations, minimization of the cycle time, etc. Of course, these objectives may be combined and even in some studies the number of stations assumed to be predetermined.

As there can be many conditions in ALBPs, a variety of studies have been done on ALBPs with different assumptions. In the case of cycle time minimization problem, the studies of Chica et al. (2011) and Hamta et al. (2013) may be of interest. On the other hand, Ponnambalam et al. (2000) and Chica et al. (2011) minimize the number of stations of in ALBPs. Also, minimization of smoothness index was considered in the study of Nourmohammadi and Zandieh (2011). The study which has been done by Cakir et al. (2011), minimizes design cost of assembly lines. As an important objective function, Ögan and Azizoglu (2015) introduced a formulation to minimize equipment cost (Ghasemi, 2015) of the tasks which are assigned to the stations of U-shaped assembly lines. Also system utilization is maximized by the study of Mcmullen and Tarasewich (2006) and Moradi and Zandieh (2013) minimizes variations of production rate. In many ALBPs, there may be more than one objective to be focused. Two or more of the above-mentioned objectives may be considered simultaneously to be optimized in a multi-objective ALBP. In such cases, a tradeoff between the objectives may happen. The studies of Malakooti and Kumar (1996), Merengo et al. (1999), Chen et al. (2002), Kovács et al. (2002), Bukchin and Rubinovitz (2003), Mansouri (2005), Gamberini et al. (2006), Nearchou (2008), Nourmohammadi and Zandieh (2011), Sakiani et al. (2012), Nourmohammadi et al. (2013), etc. can be mentioned as examples of multi-objective ALBPs and other multi-objective studies. On the other hand, ALBPs have been focused in uncertain environment as one or some of the parameters e.g. task time, cycle time, equipment cost, etc. are assumed to be uncertain. For this aim the previous studies mainly used stochastic and robust optimization models (see Guerriero and Miltenburg, 2003; Chiang and Urban, 2006; Urban and Chiang, 2006; Vizvári et al., 2011; Gurevsky et al., 2012; Dolgui and Kovalov, 2012; Hazir and Dolgui, 2013; Nazarian and Ko, 2013; Hazir and Dolgui, 2015; Das and Maiti, 2015).

The literature of ALBPs has a great diversity of solution approaches. In the case of exact and heuristic solutions, different approaches such as nonlinear programming, branch and bound algorithm and decomposition schemes were applied to ALBPs (see Askin and Zhou, 1997; Bukchin and Rubinovitz, 2003; Ogan and Azizoglu, 2015). As ALBPs tend to be NP-hard, meta-heuristics are also widely applied as their solution approaches. Some instances are reported here. Aydemir-Karadag and Turkbey (2013), applied a typical genetic algorithm to a multi-objective stochastic disassembly line. Genetic algorithm was also applied to ALBPs by Ponnambalam et al. (2000) and Zhang and Gen (2011). Simulated annealing and particle swarm optimization algorithm has also been applied to ALBPs by Baykasoglu (2006) and Hamta et al. (2013), respectively.

In this paper a new simple ALBP is modeled. A new objective function based on a nonlinear entropy function is considered for the simple assembly line balancing problem for the first time. This objective function force the stations to have more similar total task processing time, so that the workers of the stations will have similar work load. Using a bounded variable approach, the nonlinear objective function is converted to an approximated linear objective function.

The paper is organized by the following sections. Section 2 formulates the entropy-based assembly line balancing problem. A numerical example presented and solved in Section 3. The paper ends with conclusion in Section 4.
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