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A REVIEW ON MULTI-OBJECTIVE OPTIMIZATION USING EVOLUTIONARY ALGORITHMS FOR TWO-SIDED ASSEMBLY LINE BALANCING PROBLEMS

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ABSTRACT

The review was carried out thoroughly on the field of two-sided assembly line balancing problems. Some researchers have highlighted the multi-objective optimization and found this topic is generally very interesting and should be addressed accordingly. Multi-objective optimization is the problems involves than one objective functions. The task are generally in finding one or more optimum solution. In two-sided assembly line balancing problems, usually the two conflicting objectives often used as the main target is to maximize/minimize as follows; i) number of workstation, ii)number of cycle time, iii) work relatedness, iv)work slackness, v) smoothness index, vi) line length, vii) workload balanced. The survey shows that the two evolutionary algorithms that frequently used to solve two-sided assembly line balancing in the past 5 years are Simulated Annealing algorithms and Genetic Algorithms.

Keywords: two-sided assembly line balancing, multi-objective optimization, cycle time.

INTRODUCTION

Multi-objective optimization is an area of multiple criteria decision making that is concerned with mathematical optimization problems involving more than one objective function to be optimized simultaneously.

There is a copious of study in multi-objective optimization in various fields.

Multi-objective optimization has been applied in many fields of science, including engineering, economics and logistics where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives. In practical problems, there can be more than three objectives.

Among the studies that have been conducted involving multi-objective are from the author (Yapo *et al*. 1998) which presents MOCOM-UA algorithm, an effective and efficient methodology for solving the multiple-objective global optimization problem. (Deb 2001) applies SPEA-2 (another MOOP problem) to a real world problem to find optimal waveforms for a single platform radar system performing multiple radar tasks concurrently.

For a nontrivial multi-objective optimization problem, there does not exist a single solution that simultaneously optimizes each objective. In that case, the objective functions are said to be conflicting, and there exists a (possibly infinite) number of Pareto optimal solutions. A solution is called nondominated, Pareto optimal, Pareto efficient or noninferior, if none of the objective functions can be improved in value without degrading some of the other objective values. Without additional subjective preference information, all Pareto optimal solutions are considered equally good (as vectors cannot be ordered completely). Researchers study multi-objective optimization problems from different viewpoints and, thus, there exist different solution philosophies and goals when setting and solving them. The goal may be to find a representative set of Pareto optimal solutions, and/or quantify the trade-offs in satisfying the different objectives, and/or finding a single solution that satisfies the subjective preferences of a human decision maker.

ASSEMBLY LINE BALANCING PROBLEMS

Introduction to assembly line balancing problems

The idea of manufacturing assembly line was first introduced at Ford factory in Detroit in the early 1900's by the Henry Ford. Basically, each station connected by MHS (Material Handling System) which usually serves two function; storage and transport. So, a good system of MHS should be able to deliver the right amount, material, place, time and condition. If any material handling delay or damage, the line performance will degrade and may become costly.

A set of workstation are arranged in linear and if assembly line has two or more workstations, products must be move from one workstation to another workstation. The material will move through an assembly line with a part being fed into the first station at a predetermined feed rate. A station can be defined as a task is performed on the part at any point on the assembly line. Usually, these tasks can be performed by operators like human, robots and machinery. The part is fed to next operation after the task is performed on the part.

At each operation when a task is performed, the time taken is known as the process time (Sury, 1971). The variation of process time may cause workstation utilization or in-process inventory problems. By comparing their balancing efficiency and try different cycle, the best cycle time can be found in a simplest way. However, from an investment point of view the desired amount of end product to be produced within a certain period is important factor. So, the production rate must be set in order to meet the requirement (Baybars, 1986). The processing time is a function of job complexity, so the sum of the processing times at each station must not exceed the stations cycle time in order to maintain a production rate (Fonseca *et al*, 2005). The idle time according to (Erel *et al*, 1998) occurred when the sum of processing times within a station is less than the cycle time.

The first study on assembly line balancing problems was proposed by (Helgeson *et al*, 1961) and the first publication by (Salveson, 1955) proposed in mathematical form. Many of researchers proposed only trial-and-error methods to balance the lines (Erel *et al*, 1998). However, recently a numerous methods were developed in different ways to solve this problem and heuristic methods have become most popular techniques with a copious publication.

Assembly line balancing is important from four perspectives aiming goals. First, in minimizing number of workstation for a given cycle time (TYPE 1 of ALBP). Another is in minimizing the cycle time for a given number of workstation (TYPE 2 of ALBP). Majority of studies only aiming on minimizing the number of workstations or minimizing the cycle time as an ultimate goal. Recently, researchers begin to solve in multi-objective problem for this two types of assembly line balancing problems simultaneously. However, the study addressing multi-objective on Type E only belongs to (Kucokkoc, 2013) and (Kara *et al*, 2010).

The optimization problem in assembly line balancing is an important issue in order to develop an adequate model. Multi-objective optimization problem also called multi-criteria, multi performance or vector optimization, are defined by (Coello *et al*, 2007) in his paper as finding feasible solution for all the objective functions simultaneously.

Two-sided assembly line balancing problems

Two-sided assembly line is a set of sequential workstations where task operations can be performed in two sides of the line and (Bartholdi 1993) was the first to address two-sided assembly line balancing problem and use of a computer program to balance two-sided assembly lines. The line is important for large-sized products, such as trucks, buses and cars.

In two-sided assembly line balancing problems, some issues need to be addressed and one of them have been proposed by (Kim *et al*. 2000) which are associated with positional constraint and balancing at operational time. Besides that, (Lee *et al*. 2001) introduced a special emphasis on maximizing work relatedness and maximizing work slackness as an important objective, which are of practical significance especially in two-sided lines.

A heuristics become more popular methods and the author (Qin and Jin 2005) tried to propose a heuristic method for solving two-sided assembly line balancing. The important things in finding the optimal solution is how to predict the results and (Grzechca 2008) discussed some measures of solution quality for estimation the balance solution quality.

A copious of researchers try to solve by using evolutionary algorithms and (Baykasoglu and Dereli 2008) proposed the first attempts to show how an ant colony heuristic (ACH) can be applied to solve two-sided assembly line balancing problems. (Kim *et al*. 2009) also presents a mathematical model and a genetic algorithm (GA) for two-sided assembly line balancing (two-ALB) and the results show that the proposed GA outperforms the heuristic and the compared Genetic Algorithms. The selection of single model/multi-model also needs to be addressed by researchers and (Simaria and Vilarinho 2009) considers mixed-model assembly line balancing problem. In the proposed by using ant colony algorithm, the two ants 'work' simultaneously, one at each side of the line, to build a balancing solution which verifies the precedence, zoning, capacity, side and synchronism constraints of the assembly process.

(Özcan and Toklu 2009a) presents a new mathematical model 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 given cycle time and simulated annealing for the mixed-model two-sided assembly line balancing problem. (Ozcan and Toklu 2009) also proposed a tabu search algorithm illustrated with two numerical example problem. (Özcan and Toklu 2009b)presents a mathematical model, a pre-emptive goal programming model for precise goals and a fuzzy goal programming model for imprecise goals for two-sided assembly line balancing.(Özcan *et al.* 2010) consider two or more assembly lines located in parallel to each other and developed a tabu search algorithm.

There are some assignment algorithms highlighted by researcher and (Yegul *et al.* 2010) introduces a new hybrid design for a specific case-of assembly lines, and proposes a multi-pass random assignment algorithm to find the minimum number of stations required. The new design is a combination of two-sided lines and U-shaped lines, which benefits from the advantages of both designs at the same time.

Multi-objective optimization also have been developed by (Cakir *et al*. 2011) who proposed a hybrid simulated annealing for multi-objective optimization of a stochastic assembly line balancing. (Chutima and Chimklai 2012) also presents a Particle Swarm Optimization algorithm with negative knowledge (PSONK) to solve multi-objective two-sided mixed-model assembly line balancing problems. (Kucukkoc and Yaman 2013) also proposed a new hybrid genetic algorithm to solve more realistic mixed-model assembly line balancing problem.

The another constraint which exist in this field is zoning constraint and (Özbakir and Tapkan 2011) proposed Bees Algorithm which is adopted to solve two-sided assembly line balancing problem with zoning constraint with the objective to minimize the number of stations for a given cycle time.

In general, to improve the existing methods some consideration needs to be consider is how to modified initial population and (Taha *et al.* 2011) developed

Genetic Algorithm specifies with a new method for generating the initial population. It applies a hybrid crossover and a modified scramble mutation operators.

U-shaped and parallel line is one of the attention in designing the line and (Yin *et al.* 2011) considers two-sided with multi-parallel stations assembly line balancing based on heuristic algorithm. (Rabbani *et al.* 2012) also implemented U-shaped layouts in two-sided assembly lineswith the mixed-model. (Tapkan *et al.* 2012) presents a mathematical programming model in order to describe the problem formally. Bees algorithm and artificial bee colony algorithm have been applied to the fully constrained two-sided assembly line balancing problem so as to minimize the number of workstations and to obtain a balanced line.
(Jayaswal and Agarwal 2014) proposed a simulated annealing approach by considering U-shaped assembly lines with resource dependent task times. Last but not least, (Kucukkoc *et al*. 2013) also proposed an ant colony optimisation based algorithm method which is the first attempt to solve the parallel two-sided assembly line balancing problem.

The another strategy that have been proposed is Just In Time strategy which (Grzechca 2013) come out in balancing two-sided assembly line structure. (Khorasanian *et al*. 2013) considering the three performance criteria of number of stations, number of mated-stations, and assembly line tasks consistency and proposed a simulated annealing algorithm for solving the two-sided assembly line balancing problem.

(Purnomo *et al.* 2013) used Genetic algorithm and iterative first-fit rule with assignment restrictions for solving two-sided assembly line balancing.(Zhang and Kucukkoc 2013) investigates model variations for parallel two-sided assembly lines to balance the lines.

Recently, an active researcher in the past two years (Kucukkoc and Zhang 2014a) developed Mathematical model and agent based ant colony for the simultaneous balancing by considering the sequencing of mixed-model parallel two-sided assembly line. Futhermore, (Kucukkoc and Zhang 2014b)also introduced mixed-model parallel two-sided assembly line system is based on the parallel two-sided assembly line system previously proposed in the literature.(Kucukkoc and Zhang 2015) introduced type-E parallel two-sided assembly line balancing problem for the first time in the literature and proposed a new ant colony optimisation based approach for solving the problem.

Classical method for multi-objective optimization

For a classical multi-objective optimization algorithm, most algorithm convert the problem from multi-objective into a single objective optimization by using some user-defined procedures. For example, by using weighted sum of objectives, the weighted approach converts multiple objectives into a single objective and the weight vector is user-defined. (Marler and Arora 2010) identified the fundamental deficiencies in terms of a priori articulation of preferences, and guidelines are provided to help avoid blind use of the method.

All conversion that has been made is results in a single objectives optimization problem. So, it must to be solved by using single-objective optimization algorithms. The result in single-objective optimization is expected to be Pareto-optimal solution. (Kim and De Weck 2005) presents a new method that effectively determines a Pareto front for bi-objective optimization with potential application to multiple objectives. The resulting new single-objective optimization problem has to be solved again with the changes parameters in order to find different Pareto-Optimal solution.

Application of assembly line balancing problems by using evolutionary algorithms

Recently, a lot of problems on two-sided assembly line balancing are solving by using evolutionary algorithms and heuristic methods. Genetic algorithm and Simulated Anealling becomes the most interesting methods since there are 4 different researchers involves in this field. (Kucukkoc and Yaman 2013), (Purnomo *et al*. 2013), (Rabbani *et al*. 2012), (Taha *et al.* 2011) proposed Genetic Algorithm which it belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

Simulated annealing (SA) is a generic probabilistic metaheuristic for the global optimization problem of locating a good approximation to the global optimum of a given function in a large search space and this methods have been proposed by(Jayaswal and Agarwal 2014), (Khorasanian *et al*. 2013), (Cakir *et al*. 2011), (Özcan 2010) for solving two-sided assembly line balancing problems.

Besides that, bees algorithms which mimics the food foraging behaviour of honey bee colonies have been proposed by (Tapkan *et al.* 2012), (Özbakir and Tapkan 2011), (Özbakir and Tapkan 2010) for solving two-sided assembly line balancing problems. In its basic version the algorithm performs a kind of neighbourhood search combined with global search, and can be used for both combinatorial optimization and continuous optimization.
Last but not least,and the other methods with only one publication is from (Chutima and Chimklai 2012) which used the method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality called Particle Swarm Optimization.

Futhermore, (Xiaofeng *et al*. 2010) come out with a new Branch and Boundthat formerly known as algorithm that design paradigm for discrete and combinatorial optimization problems, as well as general real valued problems. (Özcan *et al*. 2010) tried to propose a Tabu Search Algorithm in the past 5 years.

Recently, (Kucukkoc *et al.* 2013) (Kucukkoc and Zhang 2015), (Kucukkoc and Zhang 2014b) proposed a new approach by using ant colony optimization in solving two-sided assembly line balancing problems. The ant colony optimization algorithm (ACO) is a probabilistic

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technique for solving computational problems which can be reduced to finding good paths through graphs

The literature covers in the past 5 years are summarized in Figure-1 which gives a new direction in this field and may help the researchers to analyzed the methods used.

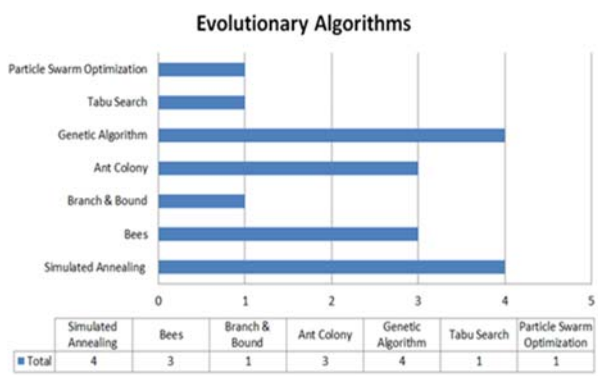

Figure-1. Number of publications.

Multi-objective on two-sided ALBP

There are less than 10 papers from different author have been reported in solving multi-objective on two-sided assembly line balancing problems in the past 10 years. Some of researcher try to deals with primary and secondary objectives. Among of these are (Lee *et al*. 2001) who developed assignment procedure for two-sided assembly line balancing problems. A special emphasis primarily is placed on maximizing work relatedness and the secondary is maximizing work slackness, which are of practical significance especially in two-sided lines. (Baykasoglu and Dereli 2008) proposed ant-colony-based heuristic algorithm for solving two-sided assembly line balancing with the primary objective to minimise the number of workstation and to maximise the work-relatedness.

(Xiaofeng *et al.* 2010) presented a branch and bound algorithms with the main goals to minimize the number of workstation and maximize the work-relatedness. (Simaria and Vilarinho 2009) also used ant colony algorithm which addressed mixed-model to be solve with the objective to minimise number of workstation and to minimise workload balance. (Özcan and Toklu 2009a) proposed mathematical model 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 given cycle time. In the proposed simulated annealing algorithm, two performance criteria are considered simultaneously: maximizing the weighted line efficiency and minimizing the weighted smoothness index.

(Chutima and Chimklai 2012)presents a Particle Swarm Optimization algorithm with negative knowledge (PSONK) to solve multi-objective two-sided mixed-model assembly line balancing problems. The aims of this studies is to minimise number of mated-station and to minimise number of workstation. Recently, (Kucukkoc and Zhang 2015) introduce type-E parallel two-sided assembly line balancing problem to minimize the numbers of workstation and cycle time by using ant colony optimization. The summarization of all the two conflicting objectives as shown in Table-1.

Table-1. Literature review on multi-objective optimization.

Researcher	Minimise two conflicting Objective Simultaneously
Lee et al. (2001)	i.Maximise the indexes of work-relatedness ii.Maximise the indexes of work-slackness
Baykasoglu & Dereli (2008)	i.Minimise the number of workstation. ii.Maximise the work-relatedness
Hu et al. (2008)	i.Minimise total line length ii.Minimise total number of opened station
Simaria & Vilarinho (2009)	i.Minimise number of workstation ii.Minimise workload balance
Ozkan & Toklu (2009a)	i.Minimise number of workstation ii.Minimise number of smoothness index
Parames Chutima &Palida Chimklai (2012)	i.Minimise number of mated-station ii.Minimise number of workstation
Ibrahim Kucukkoc & David Z. Zhang (2015) (Parallel)	i.Minimise number of workstation ii.Minimise cycle time

Novelty of the research

Normally, the area of this research are trying to propose a new heuristic algorithms directly to solve optimization assembly line balancing problems. Besides that, a new mathematical model also one of the considerations can be done. The selection of model and constrains can be properly arrange to represent the scheme and creating a new model. Basically, there are some objective on assembly line balancing problems as follow: i) number of workstation, ii) number of cycle time, iii) work relatedness, iv)work slackness, v)smoothness index, vi) line length, vii) workload balanced and it can simultaneously solved by using multi-objective optimization. The type of assembly line balancing problems also give the direction of the complexity of this area. The research investigation on two sided assembly line balancing are rarely conducted because of it complexity. There are a copious of studies are conducted on heuristic algorithm and mathematical modeling based on one sided assembly line balancing problems. So, by considering all of this options a new novelty on this area of research can be well organized.

DISCUSSIONS

Researchers in this field have contributed in various problems and applications. However, there are still a few unfulfilled potential and gaps and needs to explore accordingly. Two-sided assembly line balancing problems basically are different from simple assembly line balancing based on their complexity. Actually, simple line balancing problems started with basic precedence constraint. This field has progressed to a complex problem with other assembly constraints and become more complex on two-sided problems. In computational experiment research like assembly line balancing, the computational model is nearer to actual situation when less assumption is utilized. However, the problem will become more complicated and requires higher computational cost. The number of publication on multi-objective optimization for two-sided assembly line balancing still less and need more exploration to deals with the actual. The methods used still can be considers for future improvement.

CONCLUSIONS

This paper surveyed the multi-objective optimization for two-sided assembly line balancing problems. The current research trend shows that this research are progressing to a more complicated problem by increment in the number of papers that works on multi-objective optimization for two-sided assembly line balancing problems. Besides that, growth in usage of relatively new algorithm shows that the researchers tend to explore and develop more algorithm which manage to handle more complex problems for two-sided assembly line balancing problems.

In the future, one of the main challenges in two-sided assembly line balancing research is how to simplify and shorten assembly optimisation processes throughout in a different ways. This is an important issue especially for manufacturers to be able to compete in the global market with shorter product life cycle. Another challenge in this field is how to make the problems model closer to the actual situation in industry. This challenge is important to acquire accurate results from simulation computational results. The challenge is to minimize the cost is another future research direction, since the two-sided assembly line balancing problems are getting more complicated. Therefore, it can be concluded that, although many works had been published in this field, research inmulti-objective for two-sided assembly line balancing problems still have a long way to explore.

REFERENCES

Bartholdi, J. J. 1993. Balancing 2-Sided Assembly Lines - a Case-Study. International Journal of Production Research, 31, 2447-2461.

Battaïa, O. and Dolgui, A. 2013. A taxonomy of line balancing problems and their solution approaches. International Journal of Production Economics, 142, 259-277.

Baykasoglu, A. and Dereli, T. 2008. Two-sided assembly line balancing using an ant-colony-based heuristic. International Journal of Advanced Manufacturing Technology, 36, 582-588.

Chutima, P. and Chimklai, P. 2012. Multi-objective two-sided mixed-model assembly line balancing using particle swarm optimisation with negative knowledge. Computers and Industrial Engineering, 62, 39-55.

Grzechca, W. 2013. Just in Time Strategy in Balancing of Two-Sided Assembly Line Structure. International Journal of Materials, Mechanics and Manufacturing, 1, 65-70.

Gutjahr, A. L. and Nemhauser, G. L. 1964. An Algorithm for the Line Balancing Problem. Management Science, 11, 308-315.

Jayaswal, S. and Agarwal, P. 2014. Balancing U-shaped assembly lines with resource dependent task times: A Simulated Annealing approach. Journal of Manufacturing Systems, 33, 522-534.

Khorasanian, D., Hejazi, S. R. and Moslehi, G. 2013. Two-sided assembly line balancing considering the relationships between tasks. Computers and Industrial Engineering, 66, 1096-1105.

Kim, Y. K., Kim, Y. and Kim, Y. J. 2000. Two-sided assembly line balancing: A genetic algorithm approach. Production Planning and Control, 11, 44-53.

Kim, Y. K., Song, W. S. and Kim, J. H. 2009. A mathematical model and a genetic algorithm for two-sided assembly line balancing. Computers and Operations Research.

Kucukkoc, I. and Yaman, R. 2013. A new hybrid genetic algorithm to solve more realistic mixed-model assembly line balancing problem. International Journal of Logistics Systems and Management, 14, 405.

Kucukkoc, I. and Zhang, D. Z. 2015. Type-E parallel two-sided assembly line balancing problem: Mathematical model and ant colony optimisation based approach with optimised parameters. Computers and Industrial Engineering. doi:10.1016/j.cie.2014.12.037

Kucukkoc, I., Zhang, D. Z. and Keedwell, E. C. 2013. Balancing parallel two-sided assembly lines with ant colony optimisation algorithm. In 2nd Symposium on Nature-Inspired Computing and Applications, NICA 2013 - AISB Convention 2013 (pp. 21-28).

Lee, T. O., Kim, Y. and Kim, Y. K. 2001. Two-sided assembly line balancing to maximize work relatedness and slackness. Computers and Industrial Engineering, 40, 273-292.

Nearchou, A. C. 2007. Balancing large assembly lines by a new heuristic based on differential evolution method. International Journal of Advanced Manufacturing Technology, 34, 1016-1029.

Özbakir, L. and Tapkan, P. 2010. Balancing fuzzy multi-objective two-sided assembly lines via Bees Algorithm. In Journal of Intelligent and Fuzzy Systems (Vol. 21, pp. 317-329).

Özbakir, L. and Tapkan, P. 2011a. Bee colony intelligence in zone constrained two-sided assembly line balancing problem. Expert Systems with Applications, 38, 11947-11957.

Özbakir, L. and Tapkan, P. 2011b. Bee colony intelligence in zone constrained two-sided assembly line balancing problem. Expert Systems with Applications, 38, 11947-11957.

Özcan, U. 2010a. Balancing stochastic two-sided assembly lines: A chance-constrained, piecewise-linear, mixed integer program and a simulated annealing algorithm. European Journal of Operational Research, 205, 81-97.

Özcan, U. 2010b. Balancing stochastic two-sided assembly lines: A chance-constrained, piecewise-linear, mixed integer program and a simulated annealing algorithm. European Journal of Operational Research, 205, 81-97.

Ozcan, U. and Toklu, B. 2009. A tabu search algorithm for two-sided assembly line balancing. International Journal of Advanced Manufacturing Technology, 43, 822-829.

Özcan, U., & Toklu, B. 2009a. Balancing of mixed-model two-sided assembly lines. Computers and Industrial Engineering, 57, 217-227.

Özcan, U. and Toklu, B. 2009b. Multiple-criteria decision-making in two-sided assembly line balancing: A goal programming and a fuzzy goal programming models. Computers and Operations Research, 36, 1955-1965.

Özcan, U. and Toklu, B. 2010. Balancing two-sided assembly lines with sequence-dependent setup times. International Journal of Production Research.

Purnomo, H. D., Wee, H. M. and Rau, H. 2013. Two-sided assembly lines balancing with assignment restrictions. Mathematical and Computer Modelling, 57, 189-199.

Rabbani, M., Moghaddam, M. and Manavizadeh, N. 2012a. Balancing of mixed-Model two-Sided assembly lines with multiple u-Shaped layout. International Journal of Advanced Manufacturing Technology, 59, 1191-1210.

Rabbani, M., Moghaddam, M. and Manavizadeh, N. 2012b. Balancing of mixed-Model two-Sided assembly lines with multiple u-Shaped layout. International Journal of Advanced Manufacturing Technology, 59, 1191-1210.

Salveson, M. E. 1955. The assembly line balancing problem. Journal of Industrial Engineering, 6, 18-25.

Scholl, A. and Becker, C. 2006. State-of-the-art exact and heuristic solution procedures for simple assembly line balancing. In European Journal of Operational Research (Vol. 168, pp. 666-693).

Simaria, A. S. and Vilarinho, P. M. 2009. 2-ANTBAL: An ant colony optimisation algorithm for balancing two-sided assembly lines. Computers and Industrial Engineering, 56, 489-506.

Taha, R. B., El-Kharbotly, A. K., Sadek, Y. M., & Afia, N. H. 2011. A Genetic Algorithm for solving two-sided assembly line balancing problems. Ain Shams Engineering Journal, 2, 227-240.

Tapkan, P., Ozbakir, L. and Baykasoglu, A. 2012. Modeling and solving constrained two-sided assembly line balancing problem via bee algorithms. Applied Soft Computing Journal, 12, 3343–3355.

Tuncel, G. and Aydin, D. 2014. Two-sided assembly line balancing using teaching-learning based optimization algorithm. Computers and Industrial Engineering, 74, 291-299.

Xiaofeng, H., Erfei, W., Jinsong, B. and Ye, J. 2010. A branch-and-bound algorithm to minimize the line length of a two-sided assembly line. European Journal of Operational Research, 206, 703-707.

Yegul, M. F., Agpak, K. and Yavuz, M. 2010. A new algorithm for U-shaped two-sided assembly line balancing. Transactions of the Canadian Society for Mechanical Engineering, 34, 225-241.

Zhang, D. Z. and Kucukkoc, I. 2013. Balancing mixed-model parallel two-sided assembly lines. In Proceedings of 2013 International Conference on Industrial Engineering and Systems Management.