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Development and Trends in Assembly Line Balancing–A Review

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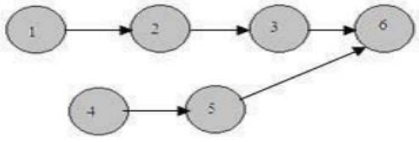
Abstract: *Assembly line balancing is defined as how the tasks are to be assigned to workstations so that the required goal is achieved. Minimization of the production rate, minimization of the cycle time, minimization of labor quantity and maximization of overall productivity are the required goals to be achieved. This paper presents the reviews of various works in the area of assembly line balancing and tries to find out latest development and trends available in industries in order to minimize total equipment.*

1. INTRODUCTION"

The fundamental of line balancing problems is to assign the tasks to an ordered sequence of stationssuch that the precedence relations are satisfied and some measurements of effectiveness are optimized.Assembly Line Balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.



2. OBJECTIVES OF THE WORK"

- To increase productivity and to reduce cost of production
- To identify the location of bottleneck and eliminate them
- To distribute equally the workloads among workmen
- To optimize the production function through construction of mix form of automatic assembly
- To reduce the idle time

3. LITERATURE REVIEW"

S. G Ponnambalam,P. Aravindan and G. Mogileeswar Naidu (1999) [01] represents a comparative evaluation of six popular assembly line balancing heuristics, namely, ranked positional weight ,Kilbridge and Wester, Moodie and Young, Hoffman precedence matrix, immediate update first fit, and rank and assign heuristic. All these methods are tested on 100 problems found in the published literature, and also on randomly generated problems. The evaluation criteria used are the number of excess stations given, line efficiency, smoothness index and CPU time. The trade and transfer phase of the Moodie and Young method is applied to all heuristics, and then the results are compared based on the evaluation criteria. Twenty problems each with 5 different cycle times are used for the comparative evaluation of heuristics. All six heuristics are coded in C++ language. Among the six considered heuristics the Hoffmann enumeration procedure performs the best; but, the execution time for the Hoffmann procedure is longer because this procedure enumerates all the feasible alternative sets of tasks for the stations. A comparison of results is presented in the form of tables and charts. Among the six considered heuristics the Hoffmann enumeration procedure performs best; but the execution time for the Hoffmann procedure is greatest because this procedureenumerates all the feasible alternative sets of tasks at the stations.Amen (2000) [02] presented work for costoriented assembly line balancing .According to him the two station rule had to be used .Backtracking method was introduced for generating optimal solution. Result of experimental investigation showed that the new method finds optimal solution for small and medium sized problem in acceptable time.A survey on heuristic methods for cost-oriented assembly line balancing was presented by Amen (2000)[03]. In this work main focus was on cost-oriented assembly line balancing. This problem mainly occurs where production is still very labor-intensive, and where the wage rates depend on the requirements and qualifications to fulfill the work. A new priority rule called best change of idle cost was proposed

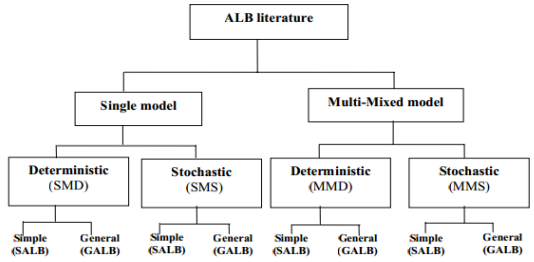
because there is a problem with classification of existent and new heuristic methods for solving this problem. This priority rule differs from the existent priority rules because it was the only one that considers that Production cost were the result of both production time and cost rates. A work on new heuristic method for mixed model assembly line balancing problem was published by Jina and Wub (2002) [04]. S. B. Liu, H.L. Ong, H. C. Huang (2002) [05] The author in his research work proposed a two heuristic algorithms for solving the assembly line balancing type II problem. The proposed algorithms first generate an initial solution by a bi-directional assignment procedure, and then they obtained initial solution is further improved by swapping tasks among workstations. In order to test the performance of the two algorithms, a comparison is carried out on a set of 302 instances that found in the literature and a set of 1440 randomly generated instances..AlexandreDolgui, Nikolai Guschinsky (2003) [06] presented a balancing problem for paced production lines with workstations in series and blocks of parallel operations at the workstations is considered The problem is to choose blocks from a given set and allocate them to workstations in such a way that all the operations are assigned, the precedence and compatibility constrains are satisfied and the line cost is minimal.. A survey on problems and methods in generalized assembly line balancing was presented by Becker and Scholl (2006) [07]. A goal chasing method was presented which is a popular algorithm in JIT system for the mixed model assembly line balancing problem. In his work, definition of best parts and best remaining sequence were provided and analyze their relationship with the optimal solutions objective function value. A new heuristic algorithm was also developed called 'variance algorithm'. The new algorithm can yield better solution shown by experimental study with little computation overhead. Er-Fei,Wu Ye Jin & Jin-Song Bao & Xiao-Feng Hu (2007) [08] have observed that two-sided (left- and right-side) assembly lines are often used in assembly of large-sized products, such as buses and trucks. The large numbers of exact algorithms and heuristics have been proposed to balance the well-known classicalone-sided assembly lines. However, little attention has been paid to balancing the two-sided lines. The author proposed a branch-and-bound algorithm to solve the balancing problem optimally.. Ugur Özcan (2007) [09] in his paper presents a new hybrid improvement heuristic approach to simple straight and U-type assembly line balancing problems which is based on the idea of adaptive learning approach and simulated annealing. The proposed approach uses a weight parameter to perturb task priorities of a solution to obtain improved solutions. The weight parameters are then modified using a learning strategy. A hybrid simulated annealing algorithm was published by Cakir et al. (2011) [10]. This work deals with multi-objective optimization of a single-model stochastic assembly line balancing problem with parallel stations. The objectives were as follows: (1) minimization of the smoothness index and (2) minimization of the design cost. Ozbakira et al. (2011) [11] works on Multiple-colony ant algorithm for parallel assembly line balancing problem. Assembly lines are designed as flow oriented production systems which perform operations on standardized products in a serial manner. In this work, a novel multiple colony and algorithm was developed for balancing by objective parallel assembly lines. The proposed approach was extensively tested on the benchmark problems and performance of the approach is compared with existing algorithms.Hou and Kang (2011) [12] presented their work on online and semi-online hierarchical scheduling for load balancing on uniform machines. In their work they consider online and semi-online hierarchical scheduling for load balancing on m parallel uniform machines with two hierarchies. A work on assembly line balancing in garment industry was presented by Chen et al. (2012) [13]. A grouping genetic algorithm (GGA) was developed for ALBP of sewing lines with different labor skill levels.GGA can allocate workload among machines as evenly as possible for different labor skill levels, so the meanabsolute deviations can be minimized. Real data from garment factories and experimental design were used to evaluate GGA's performance. Rabbani et al. (2012) [14] works on mixed model U-line balancing type-1 problem. In this a new approach to balance a mixed model U-shaped production system independent was developed for any product sequences. This approach was based on minimization of crossover workstations. In balancing mixed model assembly lines in U-shaped line layouts was more complicated than that of straight lines. A model was developed in which minimizing the number of crossover workstations.Yoosefelahi et al. (2012) [15] published a work on type II robotic assembly line balancing problem: An evolution strategies algorithm for a multi-objective model. The aim of the study was to minimize the cycle time, robot setup costs, robot costs and a procedure was also proposed to solve the problem. In addition, a new mixed-integer linear programming model was developed. A hybrid PSO algorithm for a multi-objective assembly line balancing problem with flexible operation times, sequence-dependent setup times and learning effect was published by Hamta et al. (2013) [16]. In this a multi-objective (MO) optimization of a single-model assembly line balancing problem (ALBP) considered where the operation times of tasks were unknown variables and the only known information was the lower and upper bounds for operation time of each task. Three objectives were simultaneously considered as follows: (1) minimizing the cycle time, (2) minimizing the total equipment cost and (3) minimizing the smoothness index. A new solution method was proposed which is based on the combination of particle swarm optimization (PSO) algorithm with variable neighborhood search (VNS) to solve the problem. A simulated annealing algorithm for a mixed model assembly U-line balancing type-I problem considering human efficiency and Just-In-Time approach was presented by Manavizadeh et al. (2013) [17]. This work deals with balancing a mixed-model U-line in a Just-In-Time (JIT) production system. The research tries to reduce the number of stations via balancing the workload and maximizing the weighted efficiency. In this study two types of operators were

assumed: permanent and temporary. Both types can work in regular and overtime periods. Based on their skill levels, workers were classified into four types. The sign at each work station indicated types of workers allowed to work at that station. An alert system using the hybrid kanban systems was also considered. A Simulated Annealing algorithm was applied in the following three stages for solving this problem. First, the balancing problem was solved by determining number of stations; secondly workers were assigned to the workstations in which they were qualified to work and finally an alert system based on the kanban system was designed to balance the work in the process inventory. Tuncel and Topaloglu (2013) [18] works on assembly line balancing with positional constraints, task assignment restrictions and station paralleling: A case in an electronics companyThe main characteristics of the problem were as follows: (i) a set of operations are related to the front part of the work piece and others are related to the back part of the work piece, which in turn makes all tasks dependent on the position of the work piece, (ii) some of the tasks must be executed on the same station and no other tasks should be assigned to this station due to technological restrictions, (iii) parallel stations are allowed to increase the line efficiency at the required production rate and to overcome the problem of assigning tasks with operation times that exceed the cycle time.

Table 1: Summary of developments in Assembly Line balancing based on literature survey.

Ref. No.	Author Name (year)	Investigated problem type
01	S.G\Ponnambalam ,P.Arvindan and G.Mogleeswar Naidu(1999)	Comparative evaluation of six popular assembly line balancing heuristics, namely, ranked positional weight
02,03	Amen (2000), (2000)	Cost-oriented assembly line balancing
04	Jina and Wub (2002)	Mixed model assembly line balancing
05	S.B. Liu, H.L. Ong and H.C Huang(2002)	Heuristic algorithms for solving the assembly line balancing type II
06	Alexandre Dolgui and Nikolai Guschinsky (2003)	Heuristics Method of line balancing
07	Becker and Scholl (2006)	Assembly line balancing
08	Er-Fei,Wu YeJin,Jin-SongBao and Xiao-Feng HU (2007)	Two sided line balancing
09	Ugur Ozcan (2007)	A new hybrid improvement heuristic approach to simple straight and U-type assembly line balancing problems
10	Cakir et al. (2011)	Stochastic assembly line balancing
11	Ozbakira et al.(2011)	Multiple-colony ant algorithm for parallel
12	Hou and Kang (2011)	Scheduling for load balancing on uniform Machines
13	Chen et al.(2012)	Assembly line balancing
14	Rabbani et al.(2012)	Mixed model U-line balancing type-I
15	Yoosefelahi et al. (2012)	Robotic assembly line balancing type II
16	Hamta et al.(2013)	Multi-objective assembly line balancing
17	Manavizadeh et al. (2013)	Mixed model assembly U-line balancing type
18	Tuncel & Topalogu (2013)	Assembly line balancing with positional

Classification of assembly line balancing literature



4. DISCUSSION

- New cost reduction techniques are developed which focus precedence, conjoining tasks and increasing operation times; combined algorithms are tested for both solution quality and optimality verification, as well as to its computational efficiency.
- Backtracking branch-and-bound algorithm is developed and evaluates its performance via a large set of experiments and large-scale problems
- For maximizing the production rate of the line robot assembly line balancing problems are solved for optimal assignment of robots to line stations and a balanced distribution of work between different stations.
- New genetic algorithm is proposed to find the optimum solutions within a limited number of iterations.
- The generic algorithm mathematical model based on the assembly line balancing technology is adopted and results of real cases show that quickly and effectively than normal mathematical model.
- Numerical experiments on a newly developed heuristic algorithm i.e. variance algorithm shows better solution with more calculations ahead.
- An ant colony optimization algorithm is proposed to solve the assembly problem in which 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.

5. CONCLUSION

In the literature survey, it shows that research has made significant algorithm developments in solving simple problems (SALBP). Though SALBP is a class of NP-hard optimization problems, effective exact and heuristic algorithms are available which solve small and medium-size instances of problems. Nevertheless, further algorithmic improvement is necessary for solving large-scale problems. Recently, assembly line balancing research evolved towards formulating and solving generalized problem (GALBP) with different additional characteristics such as cost functions, paralleling, equipment selection, u-line layout and mixed-model production. In the literature survey on GALBP) shows that a lot of relevant problems have been identified and modeled but development of sophisticated solution procedures has just begun. Then, additional research is necessary to adopt state-of-the-art solution concepts like metaheuristics and highly developed algorithmsfor SALBP to the variety of GALBP. Moreover, standardized and realistic test beds are required for testing and comparing methodical enhancements.

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