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A Review on Assembly Line Production Process

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***Abstract*: Mass production system design is a key for the productivity of an organization. Mass production system can be classified into production line machining a component and production line assembling a product. In this paper, the production line assembling a product, which is alternatively called as assembly line system, is considered. In this system, balancing the assembly line as per a desired volume of production per shift is a challenging task. The main objectives of the assembly line design are to minimize the number of workstations for a given cycle time (type 1), to minimize the maximum of the times of workstations for a given number of workstations (type 2), and so forth. Because this problem comes under combinatorial category, the use of heuristics is inevitable. Development of a mathematical model may also be attempted, which will help researchers to compare the solutions of the heuristics with that of the model.**

In this paper, an attempt is made to present a comprehensive review of literature on the assembly line balancing. The assembly line balancing problems are classified into eight types based on three parameters, viz. the number of models (single-model and multi-model), the nature of task times (deterministic and probabilistic), and the type of assembly line (straight-type and U-type). The review of literature is organized as per the above classification. Further, directions for future research are also presented.

***Keywords*: assembly line, production process**

1. Introduction

Examples of the product layout. In the case of assembling a product, it will contain a set of tasks which are to be processed as per the relationship defined in the form of a precedence The production system is classified into mass production system and batch production system [7]. In mass production system, manufacturing facility is geared up to produce the products of interest in large volume, whereas in batch production system, manufacturing facility is geared up to produce the products in much smaller volumes. A flow line may be used for the mass production system, which produces the same product over a long period of time. The batch production is realized through job shop implementation.

Generally, product layout is used for mass production system [3]. The layout for assembling washing machine and that for machining connecting rod used in internal combustion engine constitute network. As per the network relationship, some of the tasks will be processed in serial order and some of them will be processed in parallel.

These tasks are to system to assemble a product mainly involves minimization of the number of workstations, balancing workload between workstations, etc., which helps a company to better utilize its facilities and produce exact number of units of a product to meet the demand of that product in the case of custom made product. If the product is made to stock in anticipation of future demand of that product, then the design of the assembly line helps the company to better utilize its facilities. This problem comes under combinatorial category, which requires more computational time to solve large-size problems. When a component is machined using a product layout, the necessary machines are to be arranged as per the process sequence of that component, whose layout design does not warrant a complex analysis. In this paper, the design of the assembly line system is considered.

The inputs for the design of the assembly line system are as listed below:

- Precedence network of tasks.
- Task times, which may be either deterministic or probabilistic.
- Cycle time or number of workstations

The precedence network defines the immediate precedence relationships among the tasks of assembling a product. The execution of each task requires certain time, which is known as task time. This may be deterministic or probabilistic. The cycle time is the time between consecutive releases of the assemblies at the end of the line or the total time (maximum time) allocated to each workstation in the assembly line. All workstations have the same cycle time.

The formula for the cycle time (CT) [11] is as given below:

$$CT1/4 = \frac{Effective\ time\ available\ per\ shift}{Production\ volume = Shift}$$

The cycle time and the number of workstations are expected to be inversely proportional. If the cycle time is more, the number of workstations is expected to be less and vice versa. If the objective is to minimize the number of workstations for a given production rate, it is usually referred in literature as SALB-1 (type 1) problem. If the goal is to maximize the production rate by minimizing the maximum of the sum of the task times of the workstations for a given number of workstations, then it is referred as SALB-2 (type 2) problem.

The formula to compute the balancing efficiency [13] is given below:

$$Balancing\ Efficiency1/4 = \frac{Sum\ of\ all\ task\ times}{Number\ of\ workstations\ cycle\ time}$$

In the formula for the balancing efficiency, the sum of all task times and cycle time is given as input. The cycle is computed based on a desired production volume of a product that is to be assembled in the line. The balancing efficiency is the ratio between the sum of the task times and the total time that is provided to execute all the tasks (Number of workstations ×Cycle time). From the formula, it is clear that the lesser the number of workstations, the more is the balancing efficiency, and the lesser is the requirement of resource (Operators).

The prime objectives of the assembly line balancing (ALB) problem are as listed below:

A given number of workstations without violating the precedence constraints among the tasks such that the cycle time is minimized (SALB-2 problem).

In this paper, a comprehensive review of literature of the assembly line balancing problem is carried out. The contributions of various researchers are presented in eight categories and an in-depth review of literature in each category is presented along with weaknesses, strengths, and directions for future researches. This review will help researchers to know the state-of-the-art assembly line balancing researches and to select topics for future researches.

In this paper, first the classification of the assembly line balancing problems is presented. It is followed by a major section on the review of literature of single-model deterministic assembly line balancing problems, which, in turn, consists of two subsections, viz. single-model deterministic straight-type problem and single-model deterministic U-type problem. The next section gives the review of literature of single-model probabilistic assembly line balancing problems, which consists of subsections on single-model probabilistic straight-type problem and single-model probabilistic U-type problem. It is followed by a section on multi-model deterministic assembly line balancing problems. This, in turn, consists of subsections on multi-model deterministic straight-type problem and multi-model deterministic U-type problem. The last section of the review is on multi-model probabilistic assembly line balancing problems, which, in turn, consists of subsections on multi-model probabilistic straight-type problem and multi-model probabilistic U-type problem. Within each of these eight subsections of the review, contributions of the researchers are further classified as per the methods used to solve the respective assembly line balancing problems. After the review of literature, a section on three different types of analysis of the assembly line balancing literature is presented. At the end, a quick recap of the review and directions for future researches are discussed in conclusion.

2. Classification of assembly line balancing problems

The assembly line balancing (ALB) problems can be classified based on the number of models produced in the line, the nature of task times (deterministic or probabilistic) and the nature of flow (straight-type or U-type). In the same assembly line, one or more models of a product may be assembled. If only a single model is assembled in the line, then the production system is defined as a single-model assembly system; otherwise, it is called a multi-model assembly system. The processing times of the tasks may be either deterministic or probabilistic. If the tasks are performed using all sophisticated tools and fixtures by highly skilled labors, then the processing times of the tasks may be approximated to deterministic quantity, because the variability in the processing times may be less under such situation. This is because of the facilitating nature of tools and availability of operators with required skills. But, normally, in assembly-type operations, the processing times will vary, which can be characterized in the form of some probability distribution. The arrangement of the workstations of the assembly line may be in a straight-line layout or in a U-shape layout [1], [3]. In the U-shape layout, an operator may manage more than one workstation.

In this paper, the hierarchy of classification based on these parameters of the ALB problems. The resultant categories based on the above parameters are listed below:

Single-model deterministic straight-type (SM_D_S) problem.
Single-model deterministic U-type (SM_D_U) problem.
Single-model probabilistic straight-type (SM_P_S) problem.
Single-model probabilistic U-type (SM_P_U) problem.
Multi-model deterministic straight-type (MM_D_S) problem.
Multi-model deterministic U-type (MM_D_U) problem.
Multi-model probabilistic straight-type (MM_P_S) problem.
Multi-model probabilistic U-type (MM_P_U) problem

Hou and Kang (2011) 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. The procedures for the time and space constrained assembly line balancing problem was presented by Bautista and Pereira (2011). The Time and Space Constrained Assembly Line Balancing Problem (TSALBP) is a variant of the classical Simple Assembly Line Balancing Problem that additionally accounts for the space requirements of machinery and assembled parts. The present work proposed an adaptation of the Bounded Dynamic Programming (BDP) method to solve the TSALBP variant with fixed cycle time and area availability.

Cheshmehgaz (2012) worked on accumulated risk of body postures in assembly line balancing problem and modeling through a multi-criteria fuzzy-genetic algorithm. A novel model of assembly line balancing problem was presented that incorporates assembly worker postures into the balancing. Also a new criterion of posture diversity was defined and contributes to enhance the model. The proposed model suggests configurations of assembly lines via the balancing and the assigned workers gets the opportunities of changing their body postures, regularly.

Times, sequence-dependent setup times and learning effect was published by Hamta et al. (2013). 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 multi manned assembly line balancing problem was presented by A bdolreza et al. (2013) [24]. In this work a simulated annealing heuristic was proposed for solving assembly line balancing problems with multi-manned workstations. The line efficiency, line length and the smoothness index were considered as the performance criteria. A work on an iterative genetic algorithm for the assembly line worker assignment and balancing problem of type-II was published by Mutlu et al. (2013). In this study, they considered the assembly line worker assignment and balancing problem of type-II (ALWABP-2). ALWABP-2 arises when task times differ depending on operator skills and concerns with the assignment of tasks and operators to stations in order to minimize the cycle time. An iterative genetic algorithm (IGA) was developed to solve this problem.

Christian Otto (2014): Work on general design principles on how to construct good-performing PRBMs, based on a thorough computational investigation. Our principles allow to construct are three types of entities: manufacturers, assemblers effective PRBMs already ad hoc, i.e. without time-consuming data mining algorithms. We conduct our analysis on the example of the NP-hard Simple Assembly Line Balancing Problem (SALBP), on which with small modifications most situations in the planning of assembly lines are based. We also provide a cross-validation of our results and illustrate the application of the formulated principles.

Najmeh Salehi (2015): A new model is proposed for the integrated problem of supply chain network designing and assembly line balancing under demand uncertainty. In this problem there and customers. Manufacturers provide assemblers with components and assemblers use these components to produce the final products and satisfy the demand of the customers. This problem involves determining the location of manufacturers and assemblers in the network, balancing the assembly lines, and transportation of materials and products throughout the network. A mixed integer nonlinear programming formulation based on two stage stochastic programming method is developed to solve this problem to optimality. Moreover, an outer approximation (OA) method is proposed to efficiently solve this problem. The computational results show efficiency of the proposed OA method.

Table 1
Literature

1	Ozcan and Toklu (2009)	Mixed-model two-sided assembly lines
2	Kara et al. (2009)	Single model straight and U-shaped assembly line balancing
3	Guschinskaya and Dolgui (2009)	Transfer line balancing
4	Che et al. (2009)	Supply chain network with line balancing technology
5	Abdulhasan (2009)	Assembly planning and line balancing
6	Ozcan and Toklu (2009)	Multiple-criteria decision-making in two-sided assembly line balancing
7	Essafi et al. (2010)	Transfer line with complex industrial constraints
8	Toksari et al. (2010)	Assembly line balancing problem
9	Roy and Khan (2010)	Assembly line balancing
10	Fan et al. (2010)	Balancing and simulating of assembly line
11	Essafi et al. (2010)	Balancing lines with CNC machines
12	Ozcan (2010)	Balancing stochastic two-sided assembly lines
13	Chica et al. (2010), (2011), (2011), (2012)	Time and space assembly line balancing problem
14	Yeh and Kao (2010)	Assembly line balancing

3. Conclusion

In all the categories, statistical comparisons of the performance of new approaches with that of existing approaches are not comprehensive in terms of applying design of experiment to test the effects of the factors/parameters of the problems on the response variable(s). So the comparison of the algorithms must be done using a complete factorial experiment by considering relevant factors with interaction effects, in which “Algorithm” is a factor to check the superiority of the proposed algorithm.

It is observed that very less work is done on multimodel assembly line balancing categories and the categories with U-type assembly line balancing problems. Future researches may be carried out in these categories for developing meta-heuristics with single/multi-objectives. Also, it is found that less work is carried out on SALB2 problem. Since it is also an important problem in assembly line balancing, efforts may be made to research more on this problem.

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