Volume 7, Issue 1, January 2020 ISSN: 2348-8565 (Online)
International Journal of Modern Engineering and Research Technology
Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

Assembly Line Balancing to Enhance Productivity Through Implementation of Ranked Positional Weight Method (RPWM)

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Abstract *—This paper presents a heuristic and pedagogical method to address the assembly line balancing problem and shows that how it has been computerized in such a way that the aim is to assign a set of tasks to the workstations to minimize the number of workstation for a given cycle times, idle time, balance delay and total operation cost of the line. The aim of this paper is to increase the line efficiency & productivity of the plant. The Ranked Positional Weight (RPW) heuristic rules and formulae are used for completion of the aim. The results of computerized system are illustrated by a case study.*

Keywords:— *Workstation; heuristic; expert system; line production.*

I. Introduction

The main objective of the assembly line is to minimize the number of workstations. At individual work-station the work may be manual, as in assembly job or it may be machine operation as in making part. Usually the product parts are moved from work station to work station either manually of by mechanical handling devices. For line production, it is always advisable to have high volume or mass production due to cost considerations. It is more important to balance the workloads of men along the line. If these are not balanced then there is wastage of time of each man and also wastage of money.

The assembly line production procedure was first applied in 1913 by henry Fort The first analytical statement of the assembly line balancing (ALB) problem was formulated by Helgeson et al. in 1954, while salvesson (1985) first published it in mathematical from and suggested a linear programming solution. Since then, the topic of line balancing has been of continuing interest to researchers and has somewhat parallel the development of assembly lines in mass manufacturing (e.g. multi-and mixed model lines).

However since the ALB problem falls into the NP hard class of combinatorial optimization problem (Gutjahar and Nemhausser 1964), it has consistently defied the development of efficient algorithms for obtaining optimal solutions. In addition to research concerned with developing, improving and comparing efficient line balancing methodologies, research efforts have progressed in incorporating: strategic issue(Chase 1975); process design and operating restrictions (Johanson 1983); processing alternatives (Pinto et al. 1983); facility design issues (Johnson 1983); task assignment and work-station design considerations (Carnall and

Wild 1976); work planning and behavioral concerns (Globerson and Tamir 1980); pacing, lot sizing and model scheduling decisions (Dar-El and Cother 1975); and economic considerations M(Boothroyd 1981) into the design, balancing and scheduling of single, multi-model and mixed-model assembly lines. Keytack H. Oh. (1997) presented an expert line balancing system (ELBS). The ELBS applied a heuristic method and computerized into expert system shell that performs as an expert in an interactive model. This system produced the number of substations in each major operational station, system cycle time, total number of stations in the system, total number of hour's required and overall efficiency.

II. THE PROBLEM: FORMULATION AND SOLUTION:

In an assembly line the problem is find out the optimum number the work-station. The assembly line balancing problem can be explained as the requirement to assign task elements according to precedence relations and some other constraints to each work-station on the production line in order to achieve specific objectives such as maximizing the production rate and minimizing the number of work-stations, cycle time, and idle time. The objective is to assign processes and tasks to individual station so that the total time required at each work-station is approximately same and nearer to the desired cycle time or production rate.

Assembly line problems have been conventionally classified into two types i.e. type I and type II .Most researches have focused either on minimizing the number of work-station for a given cycle time (called Type I problem) or on minimizing the cycle time for a given number a work-stations (called type II problems).

1. Constraints in line balancing problem
2. These Constraints must be followed in the line balancing problems.

- Precedence relationship.
- Restrictions on number of work-stations (n) which should lie between one and total number of work element (N). [1<=n<=N]
- Station time (Ts) must lie between cycle time (Tc) and maximum of all work element time (Tmax). [Tmax<=Ts<=Tc]
- Number of stations cannot be greater then the number of operations.
- No operation may be greater than the cycle time.

In the present work type I problem has been taken into consideration to develop system based on Ranked Positional Weight (RPW) heuristic rules and formulae. This approach can replace the manual calculations and incorporate the heuristic or mathematic procedures while still keeping the flexibility. The system logic is coded with the "C" programming language. This system can be used for any number of tasks that can be assigned to work-station. The priority to be followed is rank positional weight including tie condition to maximize the line efficiency.

III. ASSUMPTIONS FOR SYSTEM:

- A task (operation) cannot split among two or more station (cannot be broken down into finer elements)
- Task cannot be processed in arbitrary sequences due to precedence requirement
- All tasks must be processed
- Any tasks cannot process at any station.
- The line balancing is designed for

unique model of a single product

- The cycle time (production rate) is given.
- Operating cost per station per hour is same for all station(assigned station)
- The work method is fixed and the activity durations are constant.
- There is no operator learning or fatigue (adequate allowances are built into the activity duration)
- The cycle time must be greater than or equal to the maximum activity duration and the activities performed at one work-station cannot exceed the cycle time.
- The system will produce different number of work-stations for a given cycle time and line efficiency by reviewing the results of different cycle time. The decision maker can determine how much number of stations will balance the workload best and generate the highest efficiency.

The proposed computerised system based on Ranked Positional Weight heuristic has following steps:

- Develop a precedence matrix immediate from precedence diagram.
- Generate total precedence matrix from precedence matrix.
- Generate positional weight matrix from total precedence matrix.
- Calculate number of immediate predecessor for each task by adding each column in precedence matrix.
- Calculate number of immediate successor followers for each task by adding each row in precedence matrix.
- Calculate number of total predecessor for each task by adding each column in total precedence matrix.
- Calculate number of total successor (follower) for each tasks by adding rows in total precedence matrix.
- Calculate positional weight for each task by adding own task time and row total of task in positional weight matrix.
- Arrange positional weight for each task in descending order. Rank the task based on the positional weight, the task with the highest positional weight is ranked first.
- Select the tasks with the highest positional weight and assign it to the first work-station.

Check for tie conditions:

- If positional weights are tie in step 9 then assign those task having a longest processing time.
- If positional weight and processing time of two or more tasks are equal then select those tasks having a least number of predecessors.
- In step 10(2) least number of predecessors are also equal for two or more tasks, then select those tasks with maximum total number of following tasks.
- In step 10(3), if total number of following tasks is equal for two or more tasks, then select those tasks having a least number of immediate predecessors.
- In step 10(4) if least task number of immediate predecessors is also equal for two or more tasks, then select having least sequence (identity of task) number.

11. Calculate the unassigned time for the work

-station by calculating the cumulative time of all works units assigned to the station and subtract this sum from the cycle time.

12. Select the work unit with the next highest positional weight and attempt to assign it to the work-station after making the following check.

- Check the list of already assigned work units. If the immediate precedent work unit has been assigned it will not be violated; proceed to step 12(2) If the immediate precedent has not been assigned precedent has not been assigned proceed to step 13.
- Compare the work unit time with the unassigned time. If the work unit time is less than the work-station unassigned time, assign the work unit and recalculate unassigned time. If the work unit time is greater than the unassigned time proceed to step 13
- Continue to select, check and assign if possible unit one of the two conditions are met:
- A combination is obtained where the remaining unassigned time is less than or equals the slacks units available (proceed to 14)
- No unassigned work unit remains that can satisfy both the precedence and the unassigned time requirements.
- Assign the unassigned work unit with the highest positional weight to the second work-station, and proceed through the preceding steps in the same manner.
- Continue assigning work units to the workstation. At this time a solution to the assembly line balancing problem will be found.

Priority rules (Heuristics):

- Tasks with the longest operations times have the highest priority.
- The tasks with the lowest number of predecessor are allocated first.
- Select task with the most following tasks.
- Select the task with the most immediate following tasks.
- Select the tasks with the lowest sequence number.

The major inputs for the System are:

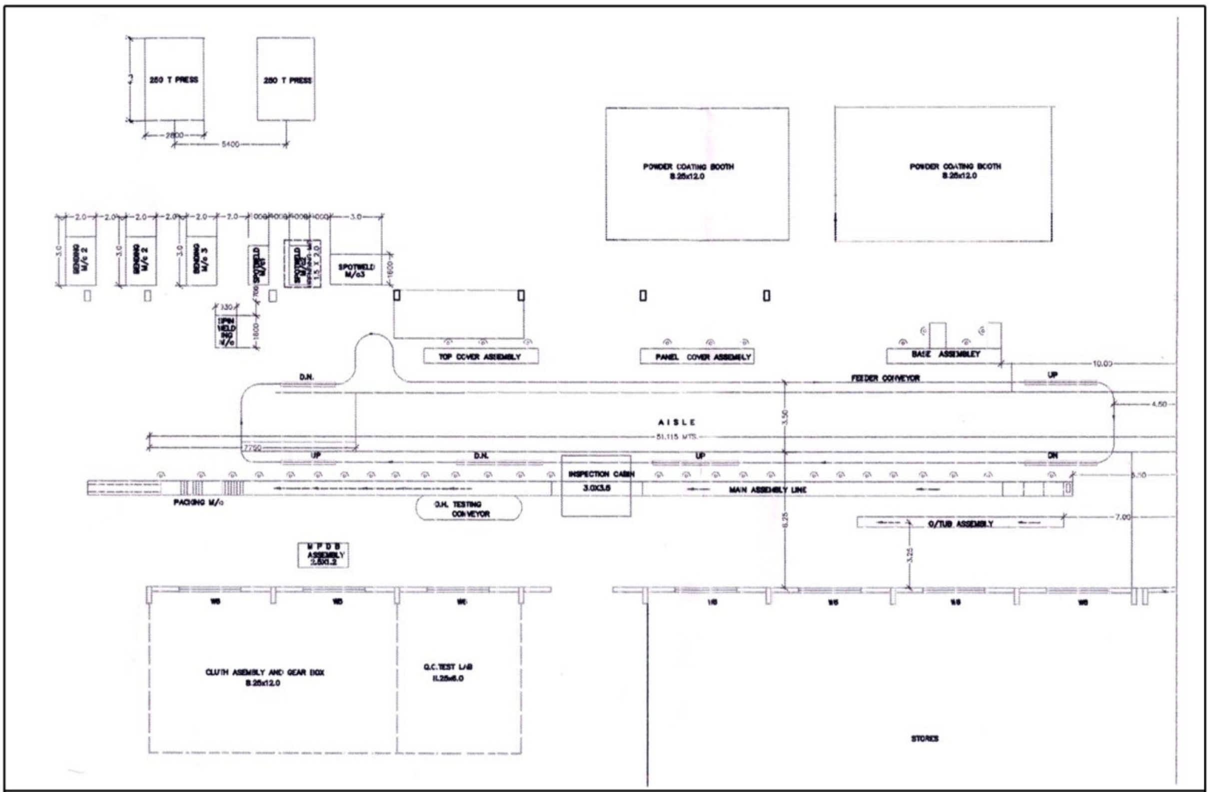
- System cycle time.
- Number of operations steps.
- Task times for all operations.
- Operation sequence (precedence diagram).

The major outputs from the System are:

- Total number of work-stations in the system with assigned element or activity
- Line efficiency
- Balance delay
- Production rate

Application of proposed computerised system (A case study):

The data is used for this system is taken from Electrolux Kelvinator Ltd., Butibori that produced the different models of washing machine. Plant layout shown in figure shows different sections like press shop, paint shop, store, assembly line and open space etc. Assembly line layout used in the plant is straight-line which shown in figure 1. Data for the present work have been collected from this firm for Smart soak model of washing machine, it consider total 107 activities with precedence constraints, which are as follows:



Sub -Assembly & Main Assembly Line Diagram at electrolux kelvinator limited ,butiboori(m.s)

Figure: 1 Assembly line layout

(I) Smart soak (Twin tub) washing machine has a production rate of 557 unit per shift with 90.02% line efficiency, 26 work-stations, 47 second cycle time and 22 operators are required for production.

I. Standard time and precedence of the various activities performed on assembly line for Smart Soak washing machine beginning from activity no.1 (Arrange outer case on conveyor) to activity no.107 (Logo fixing) in the succeeding order is used for system.

We have tested our computerized system for several numbers of workstations and several desired cycle times. It shows the total number of workstation, cycle time, line efficiency, and balance delay and production rate. The cost of a workstation is not taking in to account. The line is better balanced for higher cycle times, for slight difference of line constraints. The result of the computerized system is presents in next topic.

IV. Result and Conclusion

- The following results are obtained by a computerized approach.
- The number of work-stations is reduced to 22 from 26 work-stations.
- Line efficiency is increased up to 93.14 % from 90.02%.

And a production rate is also increased to 571 units from 557 units at the same cycle time of 48-second by changing some precedence constraints that means minimize the number of workstations and also increase the line efficiency & production rate.

In the present study, computerized system has been developed for single model assembly line balancing. This computerized system can be used for assigning the number of tasks to the workstations in such a way that idle time at workstation can be reduced and hence line efficiency and production rate can be increased.

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