Application of Line-balancing to Minimize the Idle Time of Workstations in the Production Line with Special Reference to Automobile Industry

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ABSTRACT

In the present economic scenario, the competition has increased significantly. The fierce global competition, poor responsiveness, low flexibility to meet the uncertainty of demand, and the low efficiency of traditional assembly lines are adequate motives to persuade manufacturers to adopt highly flexible production tools. Line balancing is an effective tool to improve the throughput of assembly line while reducing non-value-added activities’ cycle time. This paper mainly focuses on application of line balancing to minimise idle time of work station in production line. The methodology adopted includes calculation of cycle time of process, identifying the non-value-added activities, calculating total work load on station and distribution of work load on each workstation by line balancing, in order to improve the efficiency of line.

Key words
Line balancing (LB), Non value added activities (NVA), assembly line balancing (ALB)

INTRODUCTION

Assembly-line balancing often has implications for layout. This would occur when, for balance purposes, workstation size or the number used would have to be physically modified. The most common assembly-line is a moving conveyor that passes a series of workstations in a uniform time interval called the workstation cycle time (which is also the time between successive units coming off the end of the line). At each workstation, work is performed on a product either by adding parts or by completing assembly operations. The work performed at each station is made up of many bits of work, termed tasks, elements, and work units. Such tasks are described by motion-time analysis. Generally, they are groupings that cannot be subdivided on the assembly-line without paying a penalty in extra motions.

REVIEW OF RELATED LITERATURE

Balancing assembly lines is a very important mission for manufacturing industries in order to improve productivity by minimizing the cycle time or the number of workstations. The balancing problems manage the assignment of tasks to workstations to achieve the purpose objectives. The general practice in the assembly line balancing is to assign tasks to workstations in such a way that each total time of assigned tasks to each workstation has an equal line cycle time [6]. Assembly Line Balancing (ALB) is defined as to be a number of workstations placed along of a conveyor or table which used to transfer the products between the stations. Input raw materials or semi-finished product enter the operation line through the workstations to the output store. Cycle time is determined for each workstation depends on the target product demand. It’s computed as the hourly available time of work per demand during that particular period. The two goals for the Simple Assembly Line Balancing (SALB) are to minimize both the cycle time and workstation numbers in order to reach at the target demand [7]. Pinto and Khumawala [8] proposed an integer programming formulation to decide which processing alternative from the existing station to use in order to shorten the task duration for a given total cost. Due to, the type of process is a manual assembly and each task can be performed at any station, this proposal has been created to achieve the target objectives of minimizing the cycle time or the cost or either minimize or maximize the work stations. Malakooti and Kumar [9] used a multi-criteria decision-aid method for Assembly Line Balance (ALB) problems where emphasized on the number of stations, the cycle time, the buffer size and the total cost of the operations. For the Simple Assembly Line Balance Problem (SALB), Minzu and Henrioud [1] proposed a ‘kangaroo’ algorithm (a stochastic descent method) to treat the problem of assembly line with a fixed number of stations. The stochastic descent method aims to minimize the maximum work content of the stations, which leads to a well balanced line. Carnahan et al.[10] proposed a methodology for the Assembly Line Balance (ALB) considering both production objectives cycle time and number of station as well as worker physical constraints. Bukchin and Tzur [11] developed a heuristic algorithm to design flexible assembly line when several equipment alternatives are available. The objective was to minimize the equipment cost by controlling parameters determines how many nodes could be skipped in the tree and reducing the size of precedence graph. The Largest Candidate, Kilbridge and
West (column) and Ranked Positional Weights (RPW) are different heuristic methods commonly utilized to arrange and distribute the description element time along the workstations in the system. Each of those methods could be results in a different type of workstations layout[4]. Mat, Muhamad, and Law [12] from University Technology Malaysia in their thesis are used three manual line balancing method (Largest Candidate Rule, Kilbridge and Wester Method and Ranked Positional Weight) and four generated alternatives had been used to balance assembly line of car manufacturing company to improve the efficiency of its situation. Results revealed that productivity increases about three times higher than the assembly line efficiency before the study. Kamlekarl, Gupta, and Dalpati [13] developed an improved layout for a manufacturing company with the objective of productivity improvement. The methodology adopted for the study includes identification of problems associated with the existing that is layout redesigned for each workstation. The need to identify workstations by their position along the line is illustrated by the typical need of line managers to define unmovable operations and zoning constraints. This improved assembly line is further verified by time study techniques. The goal is to obtain an optimum layout in terms of line efficiency and productivity rate. Mahto, and Kumar [14] used two commonly procedures namely the Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach to design an assembly line starting from the work breakdown structure to the final grouping of tasks at work stations. The specific objectives of the paper was to optimize crew size, system utilization, the probability of jobs being completed within a certain time frame and system design costs. These objectives were addressed simultaneously, and the results obtained were compared with those of single-objective approaches.

An assembly line consists of workstations that produce a product as it moves successively from one workstation to the next along the line, which this line could be straight, u-line or parallel until completed. To balance an assembly line, some methods have been originally introduced to increase productivity and efficiency. These objectives are achieved by reducing the amount of required manufacturing time to produce a finished product, by reduction in number of workstations or both of them [3]. This study involved applying the three heuristic algorithms to study the two-stage gear box process planning gaining a reduced production time. In this paper, three assembly balancing methods were studied: largest Candidate Rule (LCR), Kilbridge and Wester (KWC), and Ranked Positional Weight (RPW) to select best one for Manual Assembly Line of Two Stages Gearbox.

A. Largest Candidate Rule (LCR) Method

Known as the main aim of the Line Balance is to distribute the total workload on the assembly line as evenly as possible, despite the reality in which it is impossible to obtain a perfect line balance among the workers. It is then the role of line balance efficiency which is related to the differences in minimum rational work element time and the precedence constraints between the elements. The Largest Candidate Rule (LCR) accounts for work elements to be arranged in a descending order (with reference to the station time Ts, and work elements) to each station Tek value which is not exceeding the allowable preceded Ts [4].

B. Kilbridge and Wester Column (KWC) Method

Kilbridge and Wester (column) method is a heuristic procedure that selects work elements for assignment to stations according to their positions in the precedence diagram. This methods known for its reliability in overcoming the difficulties such as encountered in Largest Candidates Rule method where an element could be selected with respect to high Te value but irrespective of its position in the precedence diagram [4]. However in the column method the elements are arranged into columns.

C. Ranked Positional Weight (RPW) Method

Ranked positional Weight Method (RPW) was introduced by Helgeson and Birnie in 1961 [5], which it’s a value to be computed for each element in the system. The RPWek accounts for each Tek and its position on the raw chain in the precedent diagram. Tek is a time to perform work element k, minute and hence these values of Tek are additives.

PROBLEM STATEMENT

The addressed problem here is to minimize the Idle Time of workstations in the production line of the manufacturing unit under study. Here our objective is to reduce the idle time, identifying the cycle time and optimal method of production. Line balancing and its implication must be explored to improve the productivity of the machine as well as organisation as a whole.

OBJECTIVE OF THE RESEARCH

The main objective of this paper is to application and assessment of the line balancing and in the light of the Idle Time of Workstations in the Production Line automobile firm under study.

RESEARCH METHODOLOGY

The sum of the tasks assigned to that workstation is equal to the total work to be performed at a workstation. In the line-balancing to a series of workstations all tasks are to be assigned where each workstation has no more than one job can be done in the workstation cycle time, and so that the unassigned (idle) time across all workstations is minimized. Depending upon the precedence relationship,
which specifies the order in which tasks must be performed in the assembly process, the steps in balancing an assembly line are:

1. Specify the sequential relationships among tasks using a precedence diagram.
2. Determine the required workstation cycle time \( C \), using the formula
   \[
   C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}
   \]
3. Determine the theoretical minimum number of workstations \( N_t \) required to satisfy the workstation cycle time constraint using the following formula.
   \[
   N_t = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}
   \]
4. Select a primary rule by which tasks are to be assigned to workstations and a secondary rule to break ties.
5. Assign tasks, one at a time, to the first workstation until the sum of the task times is equal to the workstation cycle time or no other tasks are feasible because of time or sequence restrictions. Repetition of the process for workstation 2, workstation 3, and so on until all tasks are assigned.
6. Evaluate the efficiency of the balance derived using the following formula
7. If efficiency is unsatisfactory, rebalance using a different decision rule.

In the present study a process of production is segmented in 8 critical tasks are identified and understanding the interdependency between the tasks and the task that must be ended before another task begins are observed and recorded. The precedence diagram of all the tasks is shown in Fig-1.

**ANALYSIS AND FINDINGS**

A particular component of the car under study is assembled on a conveyor belt. Five hundred such components are required per day. Production time per day is 420 minutes and the assembly steps and times for the component are given below.

For the 8 workstations, subject to cycle time and precedence constraints the observation so obtained is given in Table-1.

### Table-1

<table>
<thead>
<tr>
<th>Task</th>
<th>Task time (in seconds)</th>
<th>Description</th>
<th>Tasks that must precede</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>45</td>
<td>Position rear axle support and hand fasten</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
<td>Four screws to nuts</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>Insert rear axle</td>
<td>B</td>
</tr>
<tr>
<td>D</td>
<td>50</td>
<td>Tighten rear axle support - screws to nuts</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>15</td>
<td>Position front axle assembly and hand</td>
<td>D</td>
</tr>
<tr>
<td>F</td>
<td>12</td>
<td>Fasten with four screws to nuts</td>
<td>C</td>
</tr>
<tr>
<td>G</td>
<td>12</td>
<td>Tighten front axle assembly screws</td>
<td>C</td>
</tr>
<tr>
<td>H</td>
<td>12</td>
<td>Position rear controller 1 and fasten hubcap</td>
<td>E</td>
</tr>
<tr>
<td>I</td>
<td>12</td>
<td>Position rear controller 2 and fasten hubcap</td>
<td>E</td>
</tr>
<tr>
<td>J</td>
<td>8</td>
<td>Position sensor panel and fasten hubcap</td>
<td>F, G, H, I</td>
</tr>
<tr>
<td>K</td>
<td>9</td>
<td>Position electronics and fasten hubcap</td>
<td>J</td>
</tr>
</tbody>
</table>

The interdependency of the tasks and the task that must be ended before another task begins are observed and recorded. The precedence diagram of all the tasks is shown in Fig-1.

**Fig-1**

Secondly an attempt is made to compute the workstation cycle time. Here we have converted production time to seconds because our task times are in seconds.

\[
C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}
\]

\[
= \frac{420 \text{ min } \times 60 \text{ sec}}{500 \text{ cars}}
\]

\[
= \frac{25200}{500}
\]

\[
= 50.4 \text{ secs}
\]
Since the objective is to minimise the idle time, using the workstation cycle time the theoretical minimum number of workstations required should be:

\[ N_t = \frac{T}{C} \]

=195 seconds/ 50.4 seconds =3.87 = 4 (rounded up)

Then the tasks were prioritized using the assignment rules. Prioritization of tasks was in order of the largest number of following tasks. Then the secondary rule was invoked where ties exist from the observation after applying our primary rule. Tasks were prioritized in order of longest task time thus, that task D was assigned before B and task E was assigned before C using the tie-breaking rule (Table-2).

Keeping the precedence and cycle time requirements, the assignments are made. Tasks are assigned from workstation 1, workstation 2 and so forth until all tasks are assigned (Table-3).

Efficiency of the production line is computed as:

Efficiency =195/5*50.4= .77 or 77%

An efficiency of 77 per cent indicates an imbalance or idle time of 23 per cent (1.0 – .77) across the entire line. In addition to balancing a production line for a given cycle time, it is observed that the managers must also consider pacing for the movement of products from one station to the other after the lapse of the cycle time. If the lines are unplaced the required inventory storage areas are to be placed between stations. But the paced lines are more efficient when it comes to the requirement of buffer inventory.

CONCLUSION

The key outcome of this paper is the reduction in cycle time for single model assembly line when line is balanced; efficiency increases by reducing non value added activities and other outcomes were that assembly line balanced by recommending new layout. The most controversial aspect of product layout is behavioural response. Studies have shown that paced production and high specialization lower job satisfaction. One study has shown that productivity increased on un-paced lines. Hence more studies in this area under different production environments and production variables may enable to understand the most beneficial method of reducing cost and increasing efficiency.

REFERENCES


