ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 9, September 2015

Developing New Heuristic Method to Balance Single Model Assembly Line

Israa Dhiaa Khalaf, Dr. Sawsan Sabeeh Al- Al-Zubaidy, Dr. Mahmoud Abbas Mahmoud

Asst. Prof., Production Engineering and Metallurgy Dept/ Industrial Engineering,

University of Technology, Baghdad, Iraq

Abstract: As a part of manufacturing system, the balancing of assembly lines has been one of the most valuable research areas to accomplish the real problems related to them. There are several types of assembly lines. In this paper, new heuristic method for solving single model assembly lines balancing problem are described. The objective of balancing in this paper is increasing the efficiency of the line by assigning the tasks to stations such that the number of stations is minimized for a given cycle time. This method is computerized (programmed) and coded in C# (C sharp) language. This program is called (Assembly line balancing-Method of Merging Shortest and Longest Operation) symbolized by (MMSLO), which is based on merging two of the most common heuristic methods " Shortest Operation Time" and "Longest Operation Time" methods. In this paper, the method is implemented on three theoretical cases that taken from scientific references. The results of the (MMSLO) program compared with the results of the separate basic method (shortest operation time and longest operation time) that existed in (production and operations management, quantitative methods) software that symbolized by (POM-QM) for all cases. The results show that method in (MMSLO) program is better than the basic two methods in (POM-QM) software.

Keywords: Assembly line balancing; single model assembly lines; heuristic methods; Shortest Operation Time; Longest Operation Time.

I. INTRODUCTION

The Assembly Line Balancing Problem is one of the most studied problems in the literature related to industrial systems. It is both of an old and new problem; because there are many researchers still try to find an optimized ways, methods to assembly lines balancing.

Line Balancing means to arrange the tasks at the stations so the total time at each station is relatively will be the same so that the organization does not face the problem of idle time or congestion time that is caused by the task time variability from one station to another [1]. The congestion occurs when products flow through a station faster than the worker can complete them, while the idle time can occur when the worker is kept idle and waiting for work to enter the limits where he is allowed to work [2]. The assembly line balancing is the search for the perfect assignment of (assembly) tasks to stations with precedence constraints according to a predefined single or multi-objective goal [3]. There are some constraints that should be considered when assigning tasks to each station such as (Precedence relationships, the number of stations couldn't be more than the number of tasks and the minimum number of stations is one, the cycle time should be more than or equal to the maximum of any station time and any task time) [4].

The assembly line balancing problem is classified according to Becker and Scholl in to the following [5]:

- SMALBP: Single-model assembly line balancing problems, when just one product is assembled.
- MuMALBP: Multi-model assembly line balancing problems means there is more than one model of the same basic product that assembled in the line as batches.
- MMALBP: Mixed-model assembly line balancing problems, several models of same basic product are assembled simultaneously in the line.

In this study, new heuristic method to balance single model assembly line is developed and computerized to facilitate the calculations

II. LITRITURE REVIEW

This section presents different studies published in the last years which start from the oldest to the current years in ascending order that utilize different heuristic methods (These methods are simple that are used to solve complicated problems. Heuristic methods provide most likely but not optimal solutions, which are good enough from a practical point of view) for balance single model assembly line

Riyadh & Jassim (2013) [6]: they have presented a procedure of a Two Stages Gearbox assembly line layout. There are three balancing methods (Rank position weight, Longest Operation Time, and Column method) are studied in which Two Stages Gearbox is assembled. The selection feature was based on minimum assembly time for all method.

Batool (2013) [7]: her research aims at studying the problem of balancing single lines and the most important methods adopted to solve it and applied it in the assembly line cookers in light Industrial Company, the Software (POM-QM) used to solve the problem and to compute the result by choosing the shortest operation time method (arranging the tasks in ascending order according to their task time) to increase the efficiency from (78.24%) to (81.64%).

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 9, September 2015

Jaganathan (2014) [8]: focused specifically on line balancing and layout modification. The aim of assembly line balance in sewing lines is to assign tasks to the stations, so that the machines of the station can perform the assigned tasks with a balanced loading. Longest operation time method (arranging the tasks in descending order according to their task time)

III. MATHIMATICAL MODEL for BALANCING (SMAL)

The new heuristic method for balancing the single model assembly line is based on merging two traditional heuristic methods (shortest operation time and longest operation time) methods, to gives better result than these methods. The steps of this method are:

Step 1: the first step contains the input data of the problem which is (number of tasks, time of each task, precedence diagram of product, cycle time).
Step 2: Arrange all the tasks in ascending order according to their task time in list (A) according to (shortest operation time) method. Then arrange all the tasks in descending order according to their task time in list (B) according to (longest operation time) method.
Step 3: Open new station with unassigned time which is = cycle time.
Step 4: Select the first unassigned task at the top of list (A), according to the shortest operation time method.
Step 5: If the immediate predecessors for the selection task have been assigned, then go to step 6, if not go to step 7.
Step 6: if the time of the selection task ⩽ the unassigned station time, then assign the task to this station, go to step 9, if not go to step 7.
Step7: If this task is at the end of list (A), that means the station is complete then select the next station, go to step 4, if not go to step 8.
Step 8: If it's not at the end of list (A), then select sequentially the next task from list (A), go to step 5.
Step 9: Update the station time by removing the sum of time for the assigned tasks in this station from the station time

Unassigned station time = unassigned station time- Σ assigned task time (1-1)

Step 10: Update the lists by Remove the assigned tasks from both list (A) & list (B). If all tasks have been assigned, then go to step 18, if not go to step 11

Step 11: Select the first unassigned task at the top of list (B), according to the longest operation time method.
Step 12: If the immediate predecessors for the selection task have been assigned, then go to step 13, if not go to step 14.
Step 13: If the task time ⩽ the unassigned station time of this station, then assign task to this station, go to step 16, if not go to step 14.
Step 14: If the task is at the end of list (B), that means the station is complete then select the next station, go to step 11, if not go to step 15.
Step 15: If it's not at the end of list (B) then select sequentially the next task from this list, go to step 12.
Step 16: Update the station time by removing the sum of time of the assigned tasks in this station from the station unassigned time as equation (1-1).
Step 17: Update the lists by Remove the assigned task from both list (A) & list (B). If all the tasks have been assigned, go to step 18, if not then go to step 4.
Step 18: Store the solution results, max station work time as the min time for balancing the line, actual number of stations (n), idle time (I), Balance delay (BD) & the efficiency of line (E). it is shown in figure 1.

The suggested method is programmed and coded in C# language to exploit the high speed of the digital computer to perform the solution and giving a feasible good solution. This suggested method program is called "Assembly Line Balancing-Method of Merging Shortest and Longest Operation" (MMSLO). The main screen opens at the beginning of program which represents the introduction of basic information of the program as it is shown in figure 2

The result of the problem using the suggested method is presented after inter all the problem data then press (Execute) at input data window, it shows result screen, the distributing of tasks among the station in the line with its time, and the quality of the solution can be measured, using the following equations [9]:

1. Maximum station work time ($T_{m\ max}$): that calculates which station has the highest (maximum value) work load among the stations in the line.
Where: m=1, 2, 3, …, n (station number)
n= the number of stations

2. Time allocated: that can be represented by multiply the ($T_{m\ max}$) with the number of station.

$$\text{Time allocated} = T_{m\ max} * n \quad \text{.................} \quad (1\text{-}2)$$

3. Time needed: which is represented by the sum of all tasks time.

$$\text{Time needed} = \Sigma\, T_j \quad \text{...................} \quad (1\text{-}3)$$

Where: j= 1, 2, 3, …, L (task number)
T_j = time of task $_j$

4. Balance efficiency (E): shows the percentage utilization of the line. It is expressed as ratio of the time needed to the time allocated.

$$E = (\text{Time needed} / \text{Time allocated}).100\% \quad \text{......} \quad (1\text{-}4)$$

5. The idle time (I): The idle time or imbalance associated with the assembly line is:

$$I = \text{Time allocated} - \text{Time needed} \quad \text{................} \quad (1\text{-}5)$$

6. Balance delay (BD): This is the measure of the time efficiency and the total idle time of all stations as a percentage of total available working time of all stations.

$$BD = 1 - \text{Balance efficiency} \quad \text{...................} \quad (1\text{-}6)$$

These equations are applied and calculated in the program as it is shown in figure 3

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 9, September 2015

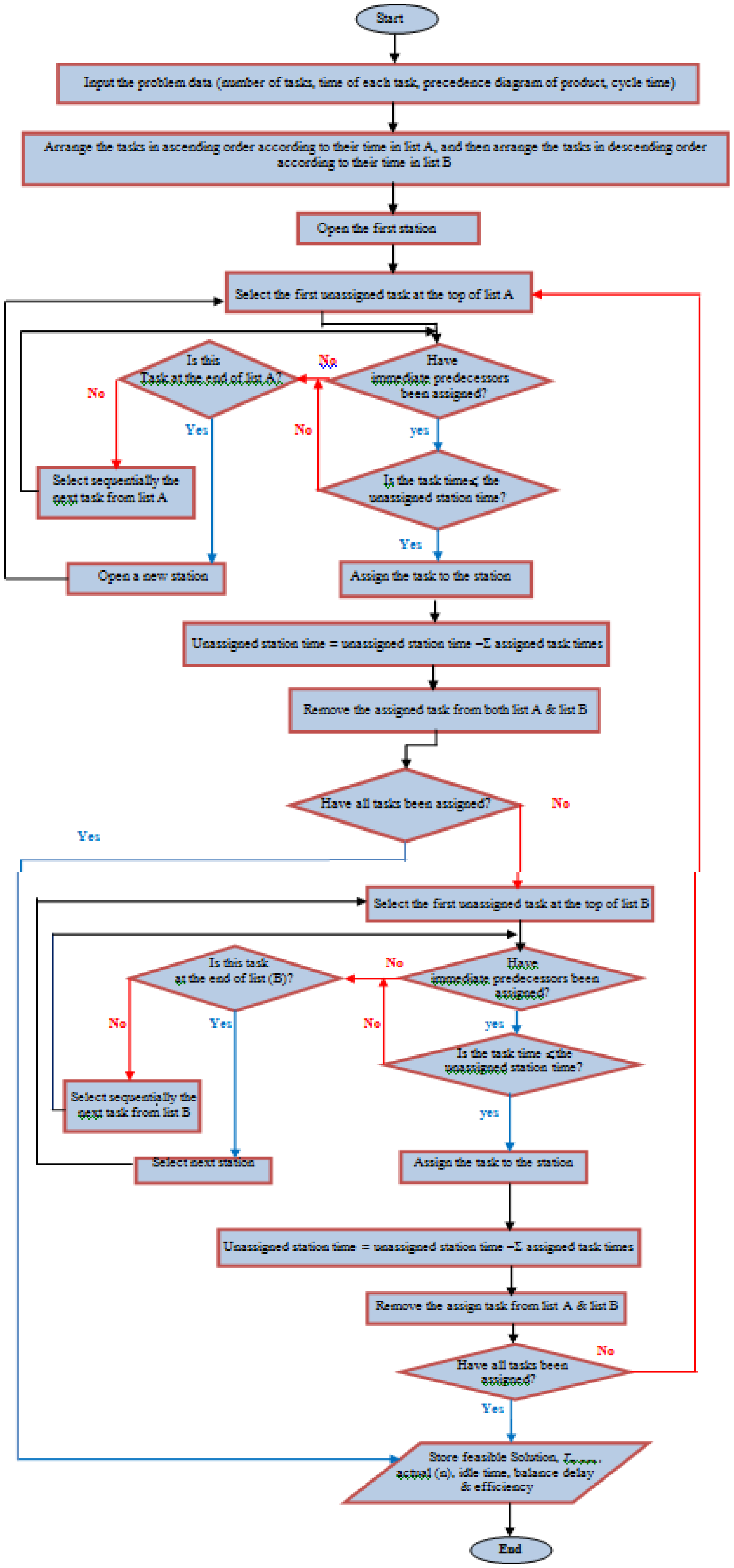

Figure 1: Suggested method algorithm

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 9, September 2015

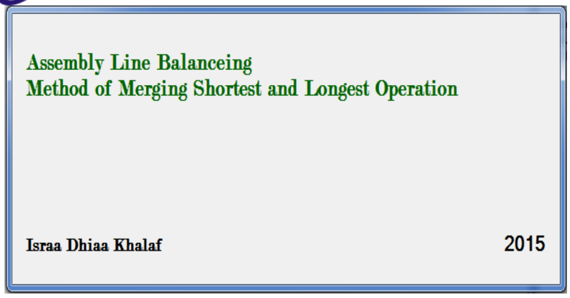

Figure 2: Main screen of (MMLSO) program

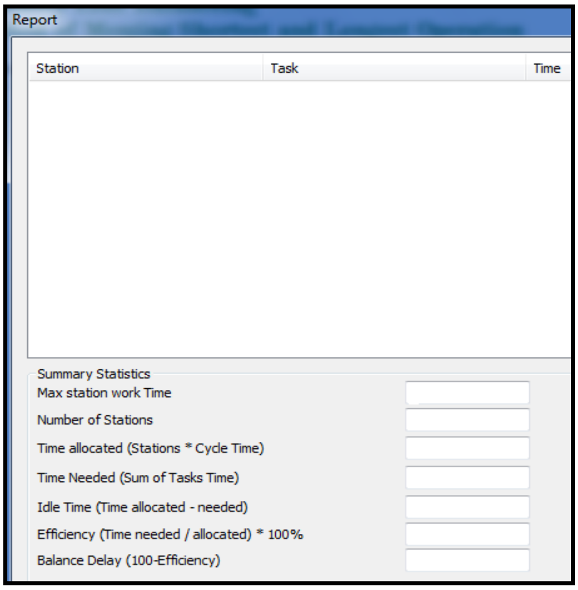

Figure 3: Report of results screen of (MMLSO) program

IV. THEORATICAL CASES DESCRIPTIONS

The suggested method with (MMSLO) program is applied theoretically on three cases that are taken from scientific references. The results of (MMSLO) program are compared with the result of (shortest operation time and longest operation time) methods that exist in (POM-QM) software. The solutions of the theoretical cases are shown as following:

Case 1 [10]:

TABLE I: Balancing Measures Comparison between Suggested, LOR and SOR Method for Single-Model Case 1

Balancing Measures	Suggested method	LOR. Method	SOR. Method
Max. station cycle time (min)	0.93	1.0	1.0
number of stations	5	5	5
Time allocated (min)	4.65	5	5
Idle time (min)	0.65	1	1
Efficiency	86.02 %	80 %	80 %
Balance Delay	13.98 %	20%	20%
Number of tasks (L) =12 Total time (Σtt) = 4 min C = 1.0 min			

This is a single-model case, the total tasks number is 12, this case is balanced to get a feasible solution with cycle time = 1.0 min, the comparison of balancing measures for all methods is shown in table 1.

Case 2 [11]:
This is a single-model case, the total tasks number is 15, this case is balanced to get a feasible solution with cycle time = 40 min, the comparison of balancing measures for all methods is shown in table 2.

TABLE II: Balancing Measures Comparison between Suggested, LOR and SOR Method for Single-Model case 1

Balancing Measures	Suggested method	LOR. Method	SOR. Method
Max. station cycle time (min)	35	40	39
Number of stations	5	5	5
Time allocated (min)	175	200	195
Idle time (min)	22	47	42
Efficiency	87.43 %	76.5 %	78.46%
Balance Delay	12.57 %	23.5 %	21.54 %
Number of tasks (L) =15 Total time (Σtt) =153 min C = 40 min			

Case 3 [12]
This is a single-model case, the total tasks number is 15, this case is balanced to get a feasible solution with cycle time = 13 min, the comparison of balancing measures for all methods is shown in table 3.

TABLE III: Balancing Measures Comparison between Suggested, LOR and SOR Method for Single-Model Case 3

Balancing Measures	Suggested method	LOR. Method	SOR. Method
Max. station work time (min)	12	13	13
Time allocated (min)	60	65	65
Idle time (min)	6	11	11
Efficiency	90 %	83.08 %	83.08 %
Balance Delay	10 %	16.92 %	16.92 %
Number of tasks (L) =15 Total time (Σtt)= 54 min C = 13min			

V. DISCUSSION AND EVALUATION

The obtained results of these theoretical cases using the suggested method with (MMSLO) program are compared with the results of the traditional methods (shortest and longest operation time methods) that exist in (POM-QM) software. In all cases the suggested method of (MMSLO) program gives better results than traditional methods in (POM-QM) software. Table 4 shows the efficiency measurement of each method for all cases.

TABLE IV: Efficiency Measurement of Each Method for All Cases

Cases	Suggested method	LOT method	SOT method
1	86.02 %	80 %	80 %
2	87.43 %	76.5 %	78.46 %
3	90 %	83.08 %	83.08 %

VI. CONCLUSIONS and FURTHER RESEARCH

From the results, none of stations of the suggested method solutions had idle time equal to zero which means none of stations is uploaded with 100% working time. The cycle time value is changed to maximum station work time. In this case, the maximum station work time is equal to the cycle time value and the maximum station work time is different from the cycle time value and they are considered without mistakes. Therefore, It has been proved the ability of the suggested method to give a better solution than the traditional methods (SOT) and (LOT) after applying it in three theoretical cases of single model assembly line to get a feasible solution in which the efficiency has been increased at a ranged from (6.02% to10.93%).
In the future studies, a real case study should be investigated for solving SMALB problem since the problem is widely encountered in practice. Furthermore, extend the practical cases to more large number of cases with different size and criteria of case problem.

REFERENCES

[1] A. S. Gonge, and D. S. Ingole, "Particle Swarm Optimization Approach for Line Balancing", International Journal of Innovative and Emerging Research in Engineering, vol. 2, Iss. 1. 2015.
[2] L. Fernandes and C. J. Lâeger, "Heuristic Methods for the Mixed-Model Assembly Line Balancing and Sequencing", M. Eng. Thesis, Manufacturing Systems Engineering, Lehigh University. 1992.
[3] Hu et al. "Assembly system design and operations for product variety", CIRP Annals - Manufacturing Technology, (2011) journal homepage: http: / /ees.elsevier.com/cirp/default.asp.
[4] P. Chutima, and H. Suphapruksapongse, "Practical Assembly-Line Balancing in a Monitor Manufacturing Company", ThammasaInt t. J. Sc.T ech.,Vol. 9, No. 2. 2004.
[5] S. Pallavi, G. Thakar, et al. "Evaluation of Multi Criteria Assembly Line Balancing by MCDM Approaches: A Conceptual Review", International Journal for Quality Research Vol. 8, No. 1, PP. 87–106, ISSN 1800-6450. 2014.
[6] H. M. Riyadh, and Y. A. Jassim, "Selection of Balancing Method for Manual Assembly Line of Two Stages Gearbox", Global Perspectives on Engineering Management, Vol. 2, Iss. 2, PP. 70-81. 2013.
[7] I. Batool, "Production Flow in Gas Cooker Assembly Line". Journal of Babylon University, Engineering Sciences, Vol. 21, No. 5. 2013.
[8] Jaganathan, "Line Balancing Using Largest Candidate Rule Algorithm A garment Industry: A case Study", International Journal of Lean Thinking, Vol. 5, Iss. 1. 2014.
[9] D. Mahto, and A. Kumar, "An Empirical Investigation of Assembly Line Balancing Techniques and Optimized Implementation Approach for Efficiency Improvements", Global Journal of Researches in Engineering Mechanical and Mechanics Engineering, Vol. 12, Iss. 3. 2012.
[10] K., H. Yeoh, "Efficiency Improvement of Assembly Line: Case Study of Bus Seat Manufacturer". M.Eng. Thesis, Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia. 2013.
[11] A. Dolgui, and J. M. Proth, "Supply Chain Engineering, Useful Methods and Techniques", Springer-Verlag London Limited. 2010.
[12] G. Waledmar, and B. Michal, "Quality Estimation of Assembly Line Balance". Advances in Mathematical Models and Production Systems in Engineering, ISBN: 978-960-474-387-2. 2014.