Balancing a Parallel Assembly Line Using Kilbridge and Wester Method: A Case Study on a Garments Factory of Bangladesh

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Abstract

Kilbridge and Wester method is a heuristic method, which is used for balancing an assembly line. Efficient and effective solution could be found by using this method. However, it is being observed that garments factories of Bangladesh are mostly on parallel assembly line. In bottleneck processes, smooth flow of materials is ensured by parallel assembly line. However, this assembly technique is found less efficient and costly. Here we have focused on a Bangladeshi factory's assembly line, which was making T-shirts for world-renowned brands. Here in this paper, existing assembly line's performance is compared with Kilbridge and Wester method. A much better result is found using Kilbridge and Wester method than parallel assembly line. Its efficiency is found 82%; 34% higher than parallel line. And also 50% less labor cost is needed comparing with the other one. A clear view of assembly line problems in Bangladeshi garments factory is observed from this study. And, to deal with the problem this paper also discussed ways. In future, other heuristic methods should be applied and compared with conventional methods.

Keywords— Kilbridge-wester method, heuristic, parallel line, line balancing, assembly

1. Introduction

Line balancing is a production strategy that involves balancing operator and machine time to match the production rate to the takt time. Takt time is the rate at which parts or products must be produced in order to meet customer demand. For a given production line, if production time is exactly equal to takt time, then the line is perfectly balanced. Otherwise, resources should be reallocated or rearranged to remove bottlenecks or excess capacity. In other words, the quantities of workers and machines, which are assigned to each task in the line, should be rebalanced to meet the optimal production rate. In Bangladesh, parallel assembly lines are used by most of the factory to tackle the bottleneck. Because a temporary solution could be found using parallel assembly line. However, it is found less effective and costly. Instead of conventional method, a heuristics method called Kilbridge and Wester method is applied here. Its main objective is to divide tasks into stations so that the idle time can be reduced.

Lusa has showed in his paper that parallel assembly lines are costly. There are many heuristics methods for balancing lines [1]. A new path was discovered by Kilbridge and Wester for balancing lines by reducing the idle time [2]. They proposed a method, which assigns tasks into some stations, which is calculated based on cycle time and bottleneck phenomenon. Balanced delay function was introduced by them. They showed that poor selection of cycle time is one of the main reasons for balanced delay problems. This paper is dated back in 1961. After that in recent times, many researchers have worked using Kilbridge and Wester method [3]. Türkmen, Yesil and Kayar applied Kilbridge-Wester method in T-shirts production and showed that this method increase efficiency but for Mat Lab simulation Hoffman method found better. Stephanie and Lina in their paper they showed that Kilbridge-Wester method is found better than Largest candidate rule [4] [5]. Jaturanonda, Nanthavanij and Das have used Kilbridge and Wester method for balancing line with postural load smoothness [6]. Mahto and Kumar in their paper they have balanced assembly line using two approaches. One of them was Kilbridge and Wester.

2. Methodology

Here first existing line was studied. For that, the data collected from the factory was analyzed. Apart from factory data, the data from the line was collected directly and analyzed. After that, Kilbridge and Wester method is applied and its performance on the factory's assembly line is calculated.

2.1. Existing problems

The operation breakdown sheet is provided by FTML that they calculated earlier. Also cycle times from directly collected data are calculated in this study. All data are presented below.

2.1.1. From FTML's MIS report

Buyer- [Hidden for Clause]
Style- [Hidden for Clause]
Format target-1498
Daily target-1870
Hourly target-187
Daily production-1050
Daily team production (poly)-1050
Daily sewing production-1050
Total produces hrs-156.98
Order quantity-
Daily input-1454
Cumulative input-4701
Cumulative production (poly)-3480
Daily QC pass-1050
Cumulative production QC pass-3725
End line WIP-976
WIP-1221
Output days-5

Current manpower-22
Current no. of machine-20

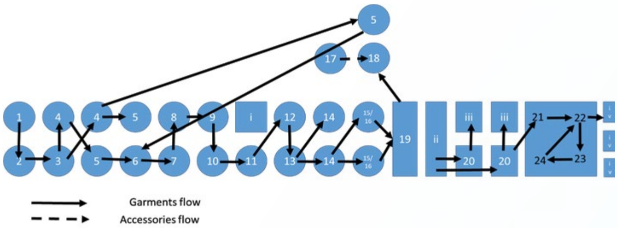

Figure 1: FTML team 21's current situation

We have also observed the materials flow. This is what have been found:

1. Pair with both shoulder join and fitting with mobilion tape
2. Both shoulder T/S and cut
3. Sleeve underarm join and cut
4. Side seam without sleeve and body turn (.72+.06)
5. Sleeve join and trim (Round)
6. Neck piping and cut
7. Neck piping measure, cut, stitch, open and tack
8. Neck mouth close and trim
9. Back tape measure, cut, attach and trim
10. Front neck T/S and trim
11. Back tape close and trim
12. Body hem
13. Sleeve hem (Round)
14. Armhole T/S and trim (Round)
15. Armhole safety tack and trim
16. Sleeve and bottom safety tack and shaking (.54+.06)
17. Care label make and cut
18. Care label attach and trim (top)
19. Body size and PO wise distribution
20. Body iron
21. Sticker attach with hang tag and hang tag attach (.08+.19)
22. Body folding
23. Tissue attach (2 side fold)
24. Body poly and mouth close

And

i. Cutting table (only for this style) (1 person)
ii. Sewing quality (2 persons)
iii. Finishing quality (2 persons)
iv. Bins

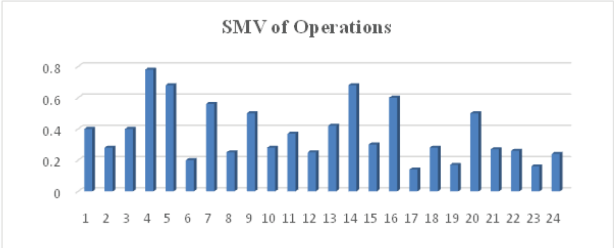

Figure 2: FTML team 21's current SMV value of each process

2.1.2 Analysis

Here precedence diagram and capacity flow of FTML's team 21 are analyzed first. After that its cost and effectiveness are calculated.

2.1.2.1 Precedence diagram

This diagram is made from the operation breakdown sheet of FTML's team 21 sewing line.

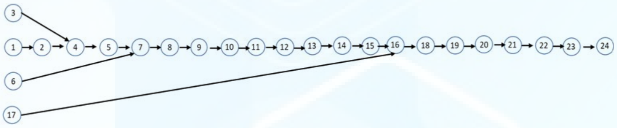

Figure 3: Precedence diagram

2.1.2.2 Capacity flow diagram of parallel station's

This diagram is made from the current layout of FTML team 21's sewing line. Parallel station or assembly method is used by FTML.

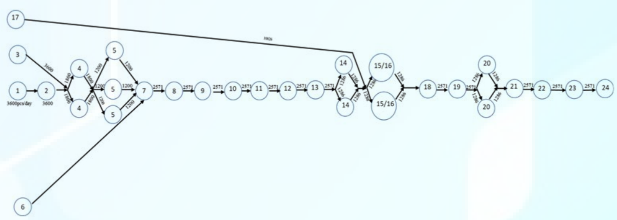

Figure 4: Capacity flow diagram

Table 1: SMV and per day capacity

Process No	SMV		Per day capacity
1	0.4	Per Day Capacity $=\frac{\text{Working time in a day}}{\text{SMV}}$	3600
2	0.28		5143
3	0.4		3600
4	0.78		1846
5	0.68		2118
6	0.2		7200
7	0.56		2571
8	0.25		5760
9	0.5		2880
10	0.28		5143
11	0.37		3892
12	0.25		5760
13	0.42		3429
14	0.68		2118
15	0.3		4800
16	0.6		2400
17	0.14		10286
18	0.28		5143
19	0.17		8471
20	0.5		2880
21	0.27		5333
22	0.26		5538
23	0.16		9000
24	0.24		6000

2.1.2.3 From the calculation of FTML designed layout

Therefore, 2571 pcs per day capacity can be achieved by FTML designed layout (parallel station model). The daily need can be fulfilled by this layout.

2.1.2.4 Cost calculation

Per hour salary = 60TK

Working hour in a day = 24hr

Minimum labor needed = 28

Labor cost per day= 60×24×28tk = 40320tk

2.1.2.5 Effectiveness

Max line balancing efficiency,

$$= \frac{\text{Total processing time}}{\text{No of stations} \times \text{Cycle time}} \% = \frac{8.96}{24 \times .78} \% = 48\%$$

2.1.2.6 From my calculation (after studying FTML's team 21 line)

SMV of each processarestudiedandfound the

T-shirt's SMV of 8.76 value

$$\text{Target output} = \frac{3\times8\times60}{.86} = 1675 \text{ [at 80\% performance rating]}$$

Max line balancing efficiency=

$$\frac{\text{Total processing time}}{\text{No of stations} \times \text{Cycle time}} \% = \frac{8.76}{\times .86} \% = 42.4\%$$

2.2 Applying heuristics method

$$\text{Desired cycle time} = \frac{\text{Total operating time per day}}{\text{Desired output rate}}$$

$$= \frac{3\times8\times60}{1870} = 0.77\text{min (approx)}$$

But,

Maximum cycle time =8.97min

Minimum cycle time= 0.78min

As we know desired cycle, time cannot be lower than min cycle time or bottleneck process's time.

∴ cycle time = 0.78min

$$\text{Daily target output rate} = \frac{\text{Total operating time per day}}{\text{Cycle time}}$$

$$= \frac{3\times8\times60}{8.97} = 160 \text{ approximately}$$

[if there is one station with one worker. Cycle time is equal to total sum of smv's]

$$\text{Daily Target output rate} = \frac{\text{Total operating time per day}}{\text{Cycle time}}$$

$$= \frac{3\times8\times60}{.78} = 1846 \text{ approximately}$$

[as there are 24 stations. Cycle time is equal to bottleneck's smv]

∴ Maximimum achievable output=1846

Theoretical min number of stations

$$= \frac{\text{Total number of task time}}{\text{Cycle Time}} = \frac{8.96}{0.78} = 12$$

[∵ cycle time= 0.78min]

2.2.1. Assigning stations

Table 2 Assinging task into Stations

Work Station	Time Remaining	Eligible	Assigning Task	Revised Time Remaining	Station Idle Time
1	0.78	1,3,6,17,2	1	0.38	
	0.38	2,6,17	2	0.1	
	0.1	None	-	-	0.1
2	0.78	3,4,6,17	3	0.38	
	0.38	6,17	6	0.18	
	0.18	17	17	0.04	
	0.04	None	-	-	0.04
3	0.78	4,5	4	0.0	
	0.0	None	-	-	0.0
4	0.78	5,7	5	0.1	
	0.1	None	-	-	0.1
5	0.78	7	7	0.22	
	0.22	None	-	-	0.22
6	0.78	8,9	8	0.53	
	0.53	9	9	0.03	
	0.03	None	-	-	0.03
7	0.78	10,11	10	0.5	
	0.5	11,12	11	0.13	
	0.13	None	-	-	0.13
8	0.78	12,13	12	0.53	
	0.53	13,14	13	0.11	
	0.11	None	-	-	0.11
9	0.78	14	14	0.1	
	0.1	None	-	-	0.1
10	0.78	15	15	0.48	
	0.48	None	-	-	0.48
11	0.78	16	16	0.18	
	0.18	None	-	-	0.18
12	0.78	18	18	0.5	
	0.5	19	19	0.33	
	0.33	None	-	-	0.33
13	0.78	20	20	0.28	
	0.28	21	21	0.01	

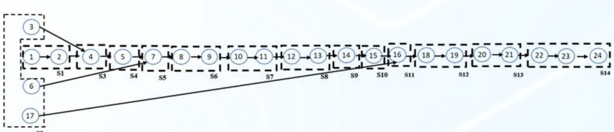

Figure 5: Proposed model (using heuristics method)

2.2.2 Effectiveness

$$\%\ \text{Idle time} = \frac{\text{Total idle time}}{\text{No of station} \times \text{Cycle time}} = \frac{1.95}{14\times0.78} = 0.18 = 18\%$$

Line Balancing Efficiency= 82%

2.2.3 Cost calculation

Per hour salary = 60tk

Working hour in a day = 24hr

Minimum labor needed = 14

Labor cost per day = 60×24×14 tk = 20160 tk

3. Result

After applying Kilbridge and Wester method, the percentage-idle time is found 18% or line balancing efficiency is found 82%. On the other hand, labor cost per day is reduced by 50%. Whereas previously with parallel line assembly the efficiency was found 48%. Therefore, after applying Kilbridge and Wester method instead of parallel assembly line, a better result is found.

4. Discussion

Kilbridge and Wester method is a heuristic method where idle time is dealt by it. Tasks are divided into stations here. So that the idle time is reduced. As a result, the line balancing efficiency is increased. In the case of parallel line balancing, many problems are encountered. More machines and operators are needed in parallel assembly line. As a result, the labor cost is increased. Team 21's line balancing efficiency is found around 42.4 to 48 %. It can be better. As it isknown that bottleneck process is considered the most critical part of product making. For making a more balanced line out of their existing process, some proposals on these parameters are made. Layout structure: From figure 2, it is seen that number four process is the bottle neck process. Two machines at bottleneck point can be introduced if output needs to be increased. However, cost should be considered in this regard. Work aids: In many research papers, it has been proven that work aids make line more balanced. Various work aids and accessories for critical points in production can be introduced [7]. It will help workers and save time. As the SMV, goes down the output should improve. In future, other heuristics methods and advance simulations should be used.

5. Conclusion

Kilbridge and Wester methodis applied here instead of parallel assembly line for making T-shirts. The result is found better than previous. In parallel line, the efficiency was found 48% as per data gathered from the factory. From our collected data, it is found that the efficiency rate is almost 43%. On the other hand, 82% efficiency is obtained by using Kilbridge and Wester method and the labor cost is reduced 50%.

Acknowledgement

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Reference

[1] A. Lusa, "A survey of the literature on the multiple or parallel assembly line balancing problem," Eur. J Ind. Eng., vol. 2, no. 1, p. 50, 2008, doi: 10.1504/EJIE.2008.016329.

[2] M. Kilbridge and L. Wester, "The Balance Delay Problem," Manag. Sci., vol. 8, no. 1, pp. 69–84, Oct. 1961, doi: 10.1287/mnsc.8.1.69.

[3] A. Türkmen, Y. Yesil and M. Kayar, "Heuristic production line balancing problem solution with MATLAB software programming," Int. J. Cloth. Sci. Technol., vol. 28, no. 6, pp. 750–779, Nov. 2016, doi: 10.1108/IJCST-01-2016-0002.

[4] S. Alexandra and L. Gozali, "Line Balancing Analysis on Finishing Line Dabbing Soap at PT. XYZ," IOP Conf. Ser. Mater. Sci. Eng., vol. 1007, no. 1, p. 012030, Dec. 2020, doi: 10.1088/1757-899X/1007/1/012030.

[5] C. Jaturanonda, S. Nanthavanij and S. K. Das, "Heuristic Procedure for the Assembly Line Balancing Problem With Postural Load Smoothness," Int. J. Occup. Saf. Ergon., vol. 19, no. 4, pp. 531–541, Jan. 2013, doi: 10.1080/10803548.2013.11077017.

[6] D. Mahto and A. Kumar, "An Empirical Investigation of Assembly Line Balancing Techniques and Optimized Implementation Approach for Efficiency Improvements," p. 15, 2012.

[7] H. Rahman, P. K. Roy, R. Karim and P. K. Biswas, "EFFECTIVE WAY TO ESTIMATE THE STANDARD MINUTE VALUE (SMV) OF A T-SHIRT BY WORK STUDY," p. 9, 2014.