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Case Study

Line Balancing on Wiring Harness Assembly Line: A Case Study

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Abstract

This paper adopts a multifarious approach combining lean manufacturing, line balancing and layout improvement to effective improvements in the productivity on the Wiring Harness Cable assembly line of cable assembly manufacturing company for automobile industry. A comprehensive methodology is adopted to systematically analyse and effect productivity improvements. A pilot study of the assembly line is done to estimate line imbalance. This is followed by waste identification and elimination and de-bottlenecking to balance the line and optimize utilization of resources. Modification in layout is effected to switch over from batch and queue system to single piece flow. The results of implementation are summarized in the conclusion part of the paper.

Keywords: *Line Balancing, Wire Harness Assembly*

1. Introduction

The company is engaged in the assembly of wiring harnesses such as HVAC, Steering wheel, Air-Bag, Sensor assemblies supplied to the original equipment manufacturers (OEM's) in automobile industry. A majority of these products happen to be of high volume – low variety type and fall in the ATO (Assembled to Order) category. The company has 32 assembly lines from which 12 are dedicated to HVAC wiring harness assembly.

Out of these 12 assembly lines, one of the Wire Harness assembly line was selected for productivity improvement being one of the highest runner lines which accounts for almost 45% of total HVAC cable assembly production. Components required for the assembly of Wiring Harness are crimped leads, tapes, housings, back cover, brown cover, body clip, splice leads and white tape. The company was facing problems due to increased demand, excessive back tracking of material, imbalanced assembly line, huge in-process inventories underutilization of human resources and delays in deliveries. The main source of these wastes was batch and queue process.

2. Methodology

Methodology used for the improvement is given below

- Pilot study of Wiring Harness assembly line
- Bottleneck identification & elimination
- Line balancing & resource optimization
- Layout modifications

2.1 Pilot study of Wiring Harness assembly line

A walk-through on Wiring Harness assembly line enabled to understand the process in terms of work content, sequence of operations, and cycle time on each workstation. A detailed time study accurately estimated production possibility and the extent of line imbalance. Cycle time was recorded for five cycles. Based on the monthly demand, tact time for present demand and target rate (tact time for future demand) were calculated. The operations at the bottleneck stations were further categorized into value-added and non-value-added (wastes) activities. The primary focus was on elimination of non-value-added (wastes) activities.

Table 1 shows detailed cycle time study for workstation 1. The average and minimum cycle time (sec.) for each of the twenty-six operations and entire workstation is shown along with the categorization of each operation into value-added and non-value-added. Similar calculations are done for all seventeen workstations on the assembly line.

Table 2 shows detailed cycle time for all workstations on wiring harness assembly line. Here total Line of balance is found to be 51%. Workstation 02 with maximum cycle time (72.74 sec) is peak bottleneck station. Tact time of line is 43.48 sec. & hence the target rate of the line becomes 36.62 sec. Workstations 1, 2, 7, 8, 11 & 12 are bottlenecks that need to be attended on priority.

2.2 Bottleneck Identification & Elimination

De-bottlenecking of workstation 1 & 2 i.e. sub-assembly process which is offline hence they are kept for next stage LOB. All the other workstations from 3 to 13 are from moving carousals all the Non-value aided time is due to the transportation & motion waste. Every time operator

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Table 1: Present Method (cycle time study for workstation no-1)

Opr. Seq	Description	1	2	3	4	5	Avg sec.	Min sec.	VA/NVA
1.1	Travel to take wire	2.98	1.97	2.84	2.84	2.91	2.71	1.97	NVA
1.2	Take blue/white wire	2.01	1.93	2.14	1.98	2.12	2.04	1.93	VA
1.3	Travel to take 16 P Hsg	2.92	2.79	2.89	2.95	3.02	2.91	2.79	NVA
1.4	Take 16 P Housing from bin	1.98	1.96	2.83	1.93	1.85	2.11	1.85	VA
1.5	Insert blue/white wire into Hsg	2.04	1.94	2.94	2.11	2.84	2.37	1.94	VA
1.6	Travel to take 2 wire	2.89	2.17	3.02	3.12	2.94	2.83	2.17	NVA
1.7	Take 2 wire from rod	2.13	2.16	2.03	2.21	1.95	2.10	1.95	VA
1.8	Insert brown wire Hsg	2.92	2.18	2.73	3.91	2.17	2.78	2.17	VA
1.9	Move to take 3rd wire	1.92	1.28	1.21	2.81	1.92	1.83	1.21	VA
1.1	Take 3 wire from rod	2.82	2.13	1.93	2.34	2.43	2.33	1.93	VA
1.11	Insert yellow wire into Hsg	2.35	1.78	2.14	2.42	2.56	2.25	1.78	VA
1.12	Move to take 4th wire	1.93	1.6	1.93	2.04	2.03	1.91	1.6	NVA
1.13	Take 4th wire	1.13	1.28	1.28	2.17	2.03	1.58	1.13	VA
1.14	Insert white wire into Hsg	2.95	2.34	1.94	2.19	2.31	2.35	1.94	VA
1.15	Move to take 5th wire	3.29	2.87	2.66	2.37	1.94	2.63	1.94	NVA
1.16	Take 5 th wire	2.34	3.04	2.93	2.17	1.95	2.49	1.95	VA
1.17	Insert Red/white wire into Hsg	2.02	2.1	2.24	3.04	2.38	2.36	2.02	VA
1.18	Move to take 6th wire	2.93	1.57	1.68	1.84	1.85	1.97	1.57	NVA
1.19	Take 6 th wire	2.45	2.76	2.38	1.94	3.06	2.52	1.94	VA
1.2	Insert blue wire into Hsg	2.38	2.37	3.93	3.24	2.38	2.86	2.37	VA
1.21	Move to take 7th wire	2.46	1.68	2.38	2.15	2.38	2.21	1.68	NVA
1.22	Take 7th wire	1.96	1.58	2.05	1.47	2.05	1.82	1.47	VA
1.23	Insert green wire into Hsg	2.95	2.32	2.75	2.86	2.04	2.58	2.04	VA
1.24	Turn back	2.95	2.86	2.57	2.16	2.14	2.54	2.14	NVA
1.25	move to keep the sub	1.5	1.75	1.86	1.4	1.5	1.60	1.4	NVA
1.26	Keep the sub on rod	1.95	1.47	1.58	2.47	2.9	2.07	1.47	NVA
	Average Time:	62.15	53.88	60.86	62.13	59.65	59.73	48.35	

Table 2: Present Method (cycle time for all workstations)

WS	Description	No of Operator	Time/ 10 pc(sec)	Time per piece	Unit Time (sec)
1	Sub-1	1	482.0	48.2	48.2
2	Sub-2	1	721.1	72.1	72.1
3	Laying of 16 Pole & 10 Insertion.	1	377.6	37.8	37.8
4	Laying of 16 Pole & 7 Insertion	1	381.2	38.1	38.1
5	Brown splice 8 wire insertion	1	360.9	36.1	36.1
6	Violet splice 6 wire insertion & 6 Retainer insertion	1	332.6	33.3	33.3
7	Branch spiral taping	1	467.3	46.7	46.7
8	Branch spiral taping	1	482.8	48.3	48.3
9	Spiral tapping till main Branch (left)	1	338.1	33.8	33.8
10	Spiral tapping till main Branch (right)	1	423.2	42.3	42.3
11	Final spiral taping of & branch taping	1	605.2	60.5	60.5
12	White point taping & Body clip fixing	1	304.7	30.5	30.5
13	Visual Inspection	1	316.7	31.7	31.7
14	EOL testing	1	221.2	22.1	22.1
15	Labeling	1	106.2	10.6	10.6
16	Folding	1	183.2	18.3	18.3
17	FG	1	159.6	16.0	16.0
	Total	**17**	**6264**	**626**	**626**
Total no of workstations:					**17**
Bottleneck time:					**72**
Cycle Time:					**1226**
Available Time (Min.):					**420**
O/P per shift:					**349**
LOB:					**51%**

Table 3: Proposed Method (After Line balancing stage-01)

WS	Description	No of Operator	Time/ 10 pc(sec)	Time /piece	Unit Time (sec)
1	Sub-1	1	480.0	48.0	48.0
2	Sub-2	1	523.1	52.3	52.3
3	Laying of 16 Pole & 10 Insertion.	1	360.2	36.0	36.0
4	Laying of 16 Pole & 7 Insertion	1	360.1	36.0	36.0
5	Brown splice 8 wire insertion	1	354.5	35.5	35.5
6	Violet splice 6 wire insertion & 6 Retainer insertion	1	32.7	3.3	3.3
7+8	Branch spiral taping	1	519.0	51.9	51.9
8+9	Spiral tapping till main Branch (left)	1	502.3	50.2	50.2
8+10	Spiral tapping till main Branch (right)	1	512.1	51.2	51.2
11	Final spiral taping of& branch taping	1	435.5	43.5	43.5
12	White point taping & Body clip fixing	1	320.9	32.1	32.1
13	Visual Inspection	1	207.8	20.8	20.8
14,15 & 16	EOL Testing+ Labeling + Folding	1	221.2	41.5	41.5
17	FG	1	168.0	16.8	16.8
	Total:	**14**	**4997**	**519**	**519**
Total no of workstations:					**14**
Bottleneck time:					**52**
Cycle Time:					**732**
Available Time (Min.):					**420**
O/P per shift:					**482**
LOB:					**71%**

Table 4: Proposed Method (After Line balancing & Elimination of wastes)

WS	Description	Cycle Time (sec)	Action Taken (Improvement Code)	Elimination of waste
1	Sub-1	45.3	D	-
2	Sub-2	46.2	D	-
3	Laying of 16 Pole & 10 Insertion.	33.8	-	T,M,W
4	Laying of 16 Pole & 7 Insertion	34.8	-	T,M,W
5	Brown splice 8 wire insertion	31.4	-	T,W
6	Violet splice 6 wire insertion & 6 Retainer insertion	29.3	-	T,M,W
7+8	Branch spiral taping	48.3	C, D	-
8+9	Spiral tapping till main Branch (left)	47.4	C, D	-
8+10	Spiral tapping till main Branch (right)	47.3	C, D	-
11	Final spiral taping of & branch taping	41.2	-	-
12	White point taping & Body clip fixing	31.3	-	W
13	Visual Inspection	18.0	-	-
14,15 & 16	EOL Testing+ Labeling + Folding	40.1	A,B	-
17	FG	16.3	B	-
		511		
Total no of workstations:				**14**
Bottleneck time:				**48**
Cycle Time:				**676**
Available Time (Min.):				**420**
O/P per shift:				**522**
LOB:				**76%**
Improvement Code:				
A: Workstations Merged (Reduction in Manpower)				
B: Modification of Layout & Relocation of Workstation (Reduction in Material Handling & Operator Movement)				
C: Workstations Split (Balance work content and match cycle time with tact time)				
D: Work Content balanced amongst work stations				

have to pick the sub-assembly from back side line storage , now the work station 1 & 2 are clubbed on line & directly feed on the line. This are reduced operator movement shown before after photos infig.1. The small housing storage was at the top of the carousal which was not within the reach this are also improved by hanging the bins with each carousal as shown in fig 1 (a) & improved in fig 2. The bins are hanged to every moving boards hence once the bins are filled it will cater the demand of one day which is shown in fig 2.

Figure 1: Material handling improvement on line for workstation no. 3, 4, 5 & 6. **Figure 2**: Housing & retainer storage improvement on line.

Workstations are not merged but the work content between them is split to reduce the bottleneck.

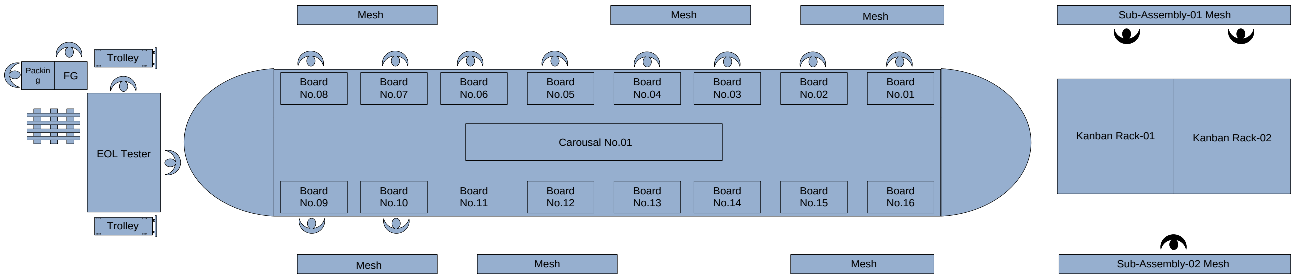

Figure 3: Present Method (Line Layout)

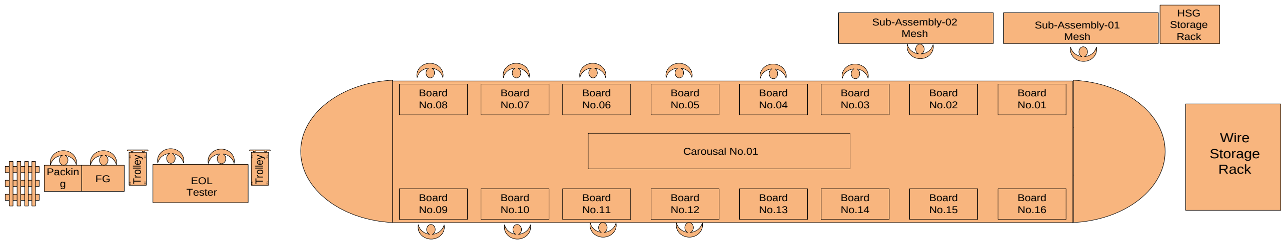

Figure 4: Proposed Method (Line Layout)

Table 5: Line Balancing (Stage-2)

WS	Description	Cycle Time (sec)	Action Taken (Improvement Code)	Elimination of waste
1	Sub-1	39.5	D	-
2	Sub-2	40.9	D	-
3	Laying of 16 Pole & 10 Insertion.	33.8	-	T,M,W
4	Laying of 16 Pole & 7 Insertion	34.8	-	T,M,W
5	Brown splice 8 wire insertion	31.4	-	T,W
6	Violet splice 6 wire insertion & 6 Retainer insertion	29.3	-	T,M,W
7+8	Branch spiral taping	46.2	C, D	-
8+9	Spiral tapping till main Branch (left)	47.4	C, D	-
8+10	Spiral tapping till main Branch (right)	47.3	C, D	-
11+12	Final spiral taping of & branch taping+ White point tape	43.9	C, D	-
12+13	Body clip fixing+ Visual inspection	46.4	C, D	W
14,15 & 16	EOL Testing+ Labeling + Folding	40.1	A,B	-
17	FG	16.3	B	-
		497		
Total no of workstations:				13
Bottleneck time:				47

Cycle Time:	616
Available Time (Min.):	420
O/P per shift:	532
LOB:	81%
Improvement Code:	
A: Workstations Merged (Reduction in Manpower)	
B: Modification of Layout & Relocation of Workstation (Reduction in Material Handling & Operator Movement)	
C: Workstations Split (Balance work content and match cycle time with tact time)	
D: Work Content balanced amongst work stations	

Table 6: Summary of Improvement

				Benefits Derived after LOB Stage 2		
	Present Method	LOB (Stage-1)	LOB (Stage-2)	Impact	Measurement	%
Production/Shift	482	522	532	Increase	50 units	10.37
Manpower	17	14	13	Reduction	4 Operators	23.52
Production/men/shift	28	37	41	Increase	13 units	46.42
Space (Sq. M)	165	155	155	Reduction	10 Sq. M.	6.06
LOB (%)	71	76	81	Increase	10	14.08

Figure 5: Present & Proposed method for sub assembly

2.3 Line Balancing (Stage-01) & Resource Optimization

The next step is to analyse line and minimize line imbalance by explore possibilities to clubbing, rearranging workstations and operators. Accordingly workstations 1 & 2 were kept for the stage-2 LOB. Clubbing is done for workstations 14, 15 & 16 & work content of work station no. 8 is divided into workstation no. 7, 9 & 10. As a result, the Line of balance ratio has increased from 51% to 71%, manpower reduced from 17 to 14 and substantial reduction in material handling and operator movement. The proposed rearrangement of workstations after line balancing is shown in Table no.3.

Further reduction in cycle time at various workstations can be achieved by elimination of wastes at individual workstations. Workstation no. 14 was brought closed to 13 to eliminate material handling and operator movement. All such improvements at all workstations are summarized in table 4.

2.4 Layout Modification

Figure 3 shows the present layout of the line and the Manpower utilized at each workstation. The total area occupied now is 165 Sq. m. (33*5m).

Figure 4 shows the proposed layout of the line where is sub-assembly workstation are integrated into carousals. Layout is modified for the reduced material handling & operator movement. The total area occupied now is 155 Sq. m. (31*5m).

2.5 Line Balancing (Stage -02)

For further LOB process the sub-assembly work station is modified to reduce the cycle time of operation & ergonomic ease of operation. The before & after photo as below. Due to this the LOB of the line has increased from 76 to 81%.

Conclusions & Findings

It is evident from the improvements effected that practical line balancing problems often needs in-depth investigation of work content on the entire line in order to find practical solutions that are often found by rearranging the work content across workstations, merging / splitting the workstations (as the case may be). The basic principles of lean such as waste identification/elimination, cellular approach and layout modifications further supplement the productivity improvements. The benefits derived as a result of all improvements are summarized in table 6.

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