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Research Article

Line Balancing on AUDI B8 Cable Assembly Line using MUDA: 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 HVAC (Heating, ventilating and air conditioning) AUDI B8 Cable assembly line of cable assembly manufacturing company for automobile industry. A comprehensive methodology is adopted to systematically analyses and effect productivity improvements. A pilot study of the assembly line is done to estimate line imbalance. This is followed by waste (MUDA) 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 HVAC cables, Steering wheel cables, Air-Bag cables, Sensor cable 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 cable assembly.
Out of these 12 assembly lines, Audi B8 HVAC cable assembly line was selected for productivity improvement being one of the highest runner lines. Audi B8 HVAC harness has four different variants produced on two dedicated lines. The one line only one high runner paper was produced whereas the remaining three parts on the other line. Components required for the assembly of Audi B8 HVAC cable are crimped leads, tapes, housings, back cover, body clip & splice leads. 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 Audi B8 HVAC cable assembly line
- Bottleneck identification & elimination
- Line balancing & resource optimization

2.1 Pilot Study of Audi B8 HVAC Assembly Line

A walk-through on Audi B8 HVAC assembly line enabled to understand the process in terms of work content (manual and machine), 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, takt time for present demand and target rate (takt 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 for each of the four 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 eleven workstations on the assembly line.

Table 2 shows detailed cycle time for all workstations on AUDI B8 HVAC assembly line along with categorization of work content into value-added and non-value-added. Takt time for present demand and target rate (Takt time for future demand) along with the line of balance (LOB) ratio are also shown in the table. Workstation 7 with maximum cycle time (64.67 sec) is bottleneck station. The table also shows

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Table 1 Present Method (Cycle Time Study for Workstation-1)

Opr. Seq.	Operation	No of Cycles					Avg.	Min.	VA/NVA
		1	2	3	4	5			
1.1	Take sub & Br/Bk wire	9.3	10.11	10.08	9.36	8.86	9.54	8.86	NVA
1.2	laying of sub	29.79	25.84	26.37	30.29	27.17	27.89	25.84	NVA
1.3	Take brown wire	7.2	8.6	7.15	6.57	8.32	7.57	6.57	NVA
1.4	Laying of brown wire & insertions	15.66	19.93	16.86	19.94	21.42	18.76	15.66	VA
	Average Time	61.95	64.48	60.46	66.16	65.77	63.764	56.93	

Table 2 Present Method (cycle time for Audi B8 line)

WS	Workstation Description	VA	NVA	Cycle time	Wastes (MUDAs)						
					T	I	M	W	O	O	D
1	Sub-Assembly Laying	18.76	45	63.76	▯	▯	▯			▯	▯
2	Red splice laying	4.6	54.4	59		▯	▯	▯			▯
3	Single lead insertions	54.6	9.8	64.4			▯				▯
4	Node tapping	45.9	13.74	59.64				▯	▯		
5	Node tapping	38.16	18.28	56.44				▯	▯		
6	Node tapping & Branching	36.87	16.87	53.74				▯	▯		
7	Node tapping	49.3	15.37	64.67					▯		
8	Main Branching	33.43	16.37	49.8				▯	▯		
9	Body clip fixing & Cover Locking	36.17	13.29	49.46							▯
10	Final Node tapping & branching	42.52	18.23	60.75							
11	Visual Inspection	0	51.94	51.94				▯			
	Max cycle time(Sec):			64.67	**Takt time(Sec):**						91
	Throughput time(Sec):			633.6	**Target Rate(Sec):**						77
	LOB ratio:			89%							

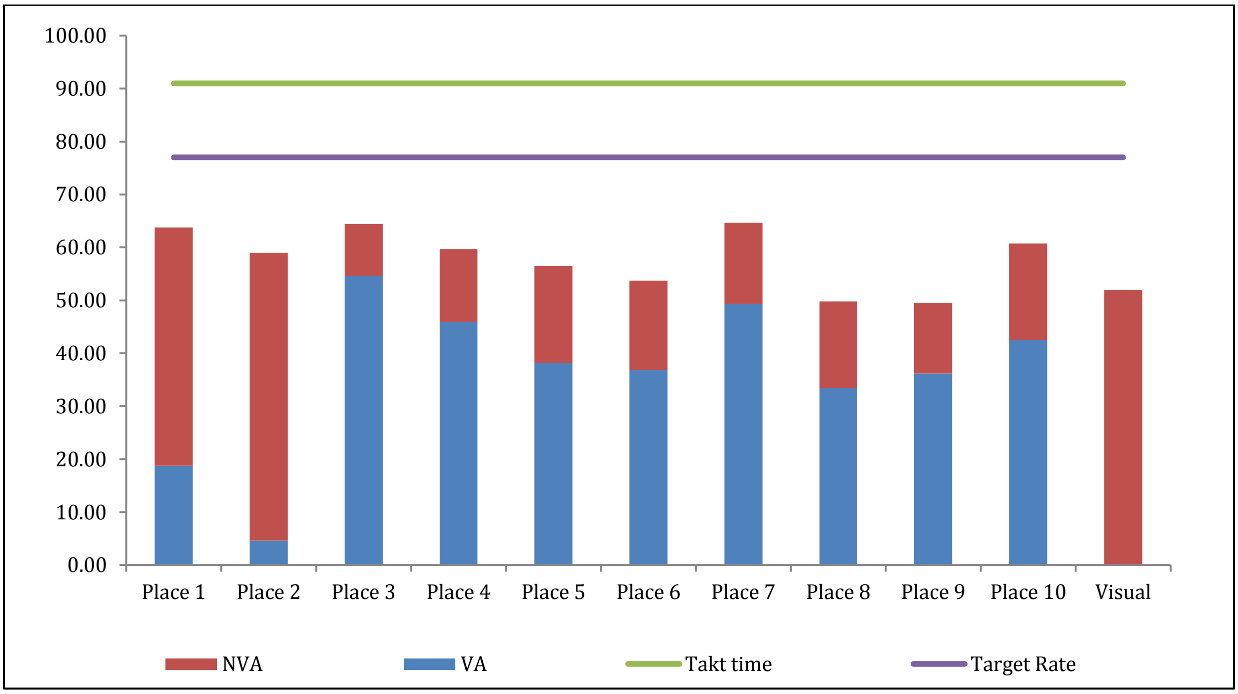

Figure 1 Present Method: Cycle Time Analysis with respect to Takt Time

the 7 wastes popularly abbreviated as i.e. TIMWOOD (Transportation, Inventory, Motion, Waiting, Overproduction, Over processing and Defect) that are observed at individual workstations.

Figure 1 shows cycle time of each workstation on AUDI B8 assembly line along with Takt time for present demand and target rate. There is no any bottleneck Workstations but there is scope of line balancing by

Table 3 Cycle time of respective workstations before & after combing the operations

Sr. No.	Description	Before	After Combing the operations
1	Sub-Assembly Laying	63.76	63.76
2	Red splice laying	59	47.28
3	Single lead insertions	64.4	77.85
4	Node tapping	59.64	78.05
5	Node tapping	56.44	76.13
6	Node tapping & Branching	53.74	79.66
7	Node tapping	64.67	78.47
8	Main Branching	49.8	53.57
9	Body clip fixing & Cover Locking	49.46	51.94
10	Final Node tapping & branching	60.75	-
11	Visual Inspection	51.94	-

Table 4 Proposed Method after Line Balancing

WS	VA	NVA	Cycle time
1	18.76	45	63.76
2	6.07	41.21	47.28
3+5	61.95	15.9	77.85
4+2	59.31	18.74	78.05
5+6+7	47.76	28.37	76.13
6+7	46.73	32.93	79.66
8+9	58.93	19.54	78.47
7+9	17.29	36.28	53.57
10+11		51.94	51.94
Max cycle time:			79.66
Throughput time:			606.71
Theoretical no of operators:			9 (9)
LOB ratio:			92%

Table 5 Proposed Method (after Line Balancing & Reducing & eliminating wastes) following figure shows graphical representation of the cycle time of workstation along with dividing the work content into different workstation and operators

WS	Workstation Description	VA	NVA	Cycle time	Action Taken (Improvement code)	Elimination of wastes
1	Sub-Assembly Laying	41.28	13.28	54.56	B,C	T,M,I,W
2	Red splice laying	34.96	12.32	47.28	B,C	T,M,I,W
3+5	Single lead insertions + point Tapping	61.95	15.9	77.85	D,E	W
4+2	Node tapping + cover locking	59.31	18.74	78.05	D,E	-
5+6+7	Node tapping + branching	47.76	28.37	76.13	D,E	-
6+7	Node tapping & Branching	46.73	32.93	79.66	D,E	-
8+9	Node tapping	58.93	19.54	78.47	D,E	-
7+9	Node tapping + Body clip fixing & Cover Locking	17.29	36.28	53.57	D,E	-
10+11	Branching + Visual Inspection		51.94	51.94	D,E	W
Max cycle time:				79.66		
Throughput time:				597.51		
Theoretical no of operators (Actual):				9 (9)		
LOB ratio:				92%		
Improvement Code:						
A: Workstations (Reduction in Manpower)						
B: Modification of Layout & Relocation of Workstation (Reduction in Material Handling & Operator Movement)						
C: Relocation of feeding station (sub-assembly operation) near workstation 1 & 2						
D: Workstations Split (Balance work content and match cycle time with Takt time)						
E: Work Content balanced amongst work stations						

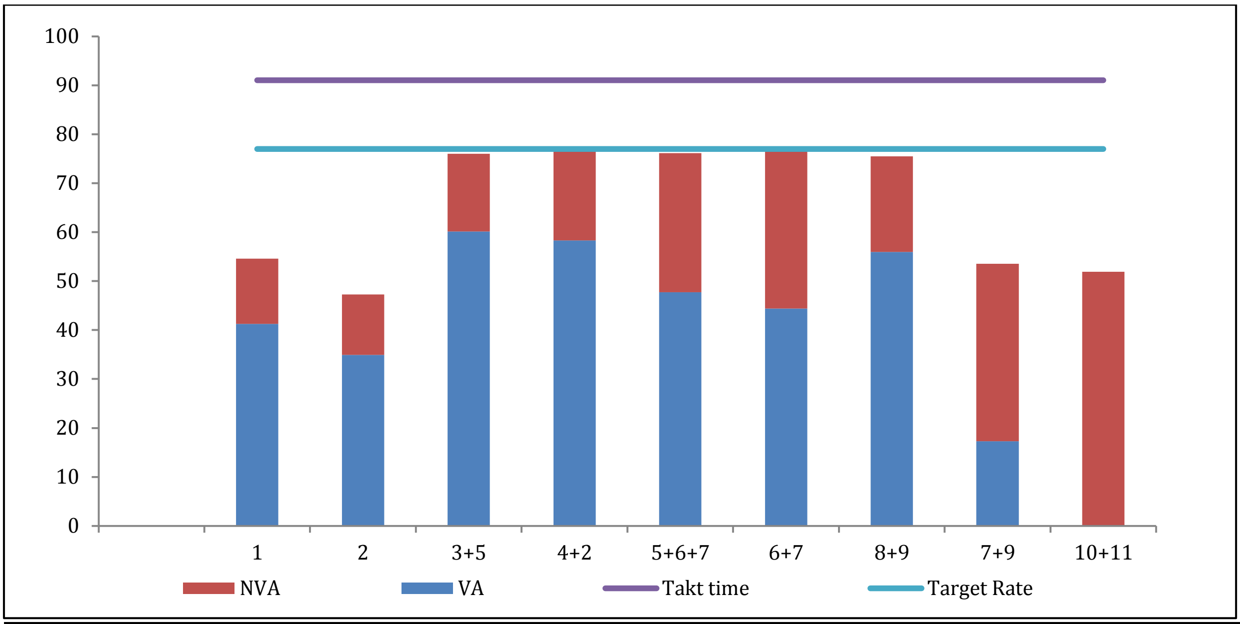

Figure 2 Proposed Method: Cycle time Analysis w.r.t. Takt Time (After Line Balancing)

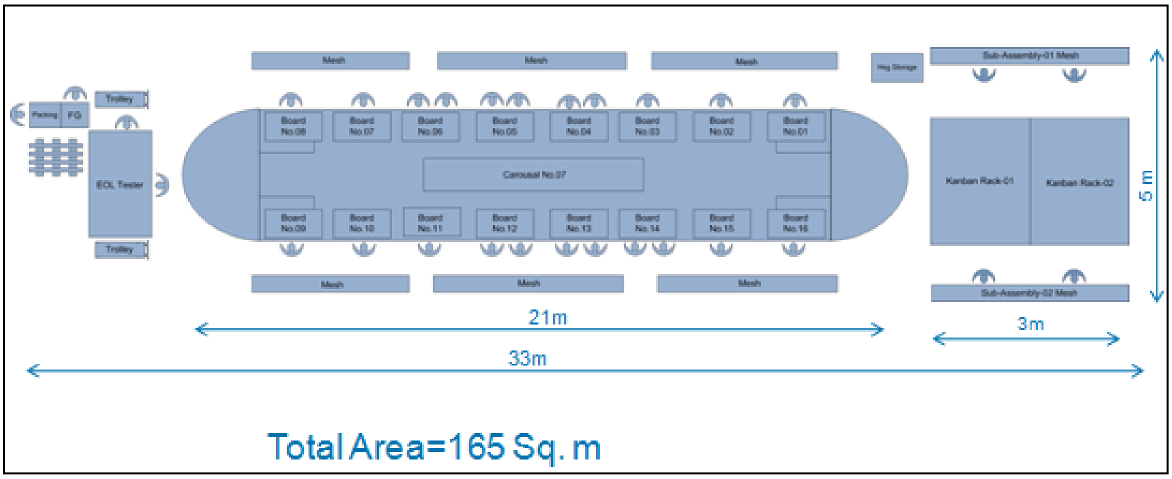

Figure 3 Present Method (Line Layout)

increasing the work content as each workstation and reduce some workstations.

2.2 Bottleneck Identification & Elimination

As such there is no any bottlenecking workstation but here work content can be added & no of workstations can be reduced. Table 3 shows the cycle time of respective work stations before & after combining the work content.

2.3 Line Balancing & Resource Optimization

The next step is to analyze line and minimize line of balance by explore possibilities to clubbing, rearranging workstations and operators. Accordingly workstations work content was clubbed by assigning one operator to carry out all operations on the combined workstation. Some workstations work content was divided into two or more workstations. Similar clubbing is done for workstations 3 & 5, 2 & 4, 6 & 7, 8 & 9, 7 & 9, 5, 6 & 7 and 10 & 11. As a result, the Line of Balance ratio has increase from 89% to 92%, manpower reduced from 11 to 9 and substantial reduction in material handling and operator movement. The proposed rearrangement of workstations after line balancing is shown in table 5. Further reduction in cycle time at various workstations can be achieved by elimination of wastes at individual workstations. For instance, shifting sub-assembly station next to workstation 1 eliminates material handling and operator movement. All such improvements at all workstations are summarized in table 5.

2.4 Layout Modification

Figure 3 shows the present layout of the line and the manpower utilized at each workstation with double

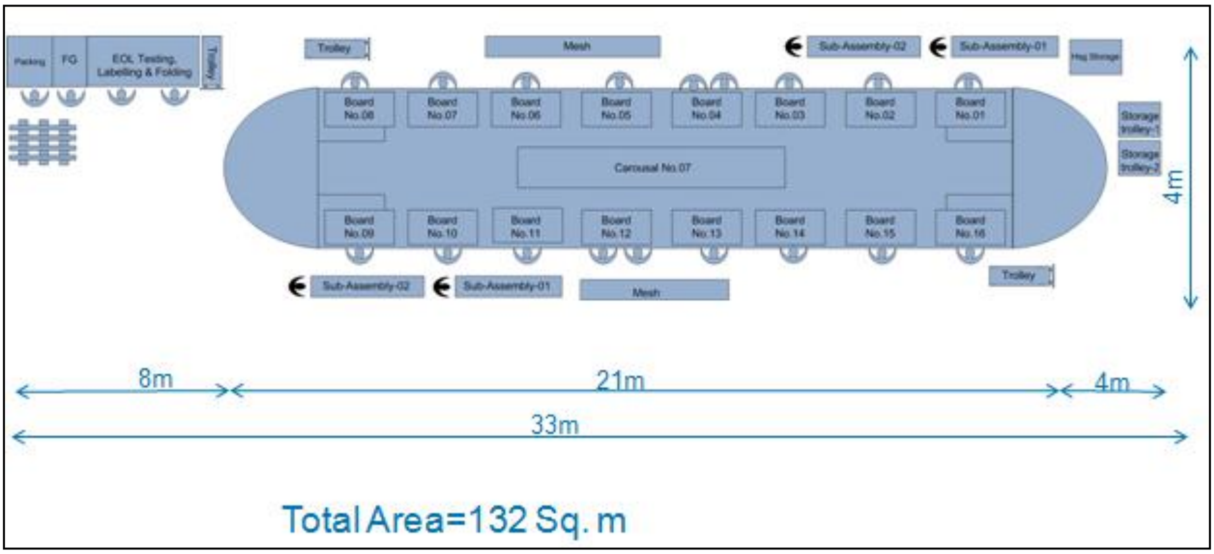

Figure 4 Proposed Method (Line Layout)

Table 6 Summary of Improvements

	Present Method	Proposed Method	Benefits Derived after LOB		
			Impact	Measurement	%
Production/Shift	350	325	Reduced	25 units	7.15%
Headcount used	13	11	Reduced	2 operators	15.38%
Production/HC/Shift	27	30	Increased	3 units	10%
Space Optimized	165	132	Reduced	33 sq. mtrs	20%
Line of Balance	89	92	Increased	3%	3%

exit. As the demand is high it is not able to cater with the single exit (11+2 operators) hence this line is always run double exit (22+4 operators) as shown in below figure 3.

Figure 4 shows the proposed line layout after modifications. After clubbing the operator and manpower, layout is modified for the reduced material handling and operator movement.

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 the workstations. The basic principles of lean such as waste (MUDA) 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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