Productivity Improvement in Sub-assembly lines of Electric car using Lean Layout Concepts

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Abstract - *This project mainly aimed to improve productivity by improving the assembly line set-up at automotive company. All necessary data are collected and necessary spaghetti diagrams, relationship charts and multi-operators charts are developed and analyzed to understand the current layout performance in terms of space utilization, material and operator flow, wastes etc. Lean layout concepts such as SLP and LLD approaches are used to redesign the assembly line based on developed flow diagrams and relationship charts. Design changes are recommended to eliminate the waste during assembly. Layouts are redesigned using AutoCAD software based on spaghetti diagram and relationship charts. By redesigning the layout and reducing wastes such as motion and transportations by lean concepts, these helped to improve space utilization by 46.80% for drive train assembly line and 44.40% for electric box assembly line and 45.45% for battery box assembly line. These approaches helped to improve productivity by 22.22%, 25% and 20% of drive train, electric box and battery box respectively. Due to these improvements, when the company works for 3 shifts, savings could be as high as Rs.1,24,000 per year. These layouts are recommended for implementation.*

Key Words: *Assembly line, AutoCAD, LLD, Relationship charts, SLP, Spaghetti diagram.*

1. INTRODUCTION

In every industry assembly line layout design is important task (6), which are affects the productivity of the company. A good layout can provide real competitive advantage by facilitating material and information flow processes (3). Layout involves the allocation of space and arrangement of equipments in such a manner that overall operating costs are minimized (3). Type of layout selection to develop assembly line is mainly depends on production rate and the demand (1), which decides the preferable layout type (2). In present situation space utilized improperly and the operator and material flow is more, which affecting the productivity. Lean concepts mainly aimed to improve productivity and reduce wastes (5). So SLP and Lean concepts are used to improve productivity. SLP considered as effective approach to redesign assembly line (7) (8) and lean production system are used to reduce the waste times in process (4) (5). All necessary data are collected and analyzed based on collected data and developed diagrams. Proposed layouts are developed and recommended for implementation.

2. PROBLEM DESCRIPTION

In this company current assembly line has set for their current product, but company assigned to produce other components in same line. Problem identified in line set-up of the assembly line of the sub-assemblies, which affecting the demand of the company. The major problems identified are

- More operator flow during the assembly, which causing more motion during assembly.
- Congested space for performing the assembly.
- Not proper space utilization.
- No proper tooling.

The present work mainly aimed to achieve

- Better space utilization and effective layout design
- Better movement of men and material
- Improve productivity

3. DATA GATHERING

The necessary data are collected to analyse the current layout performance in terms of space utilization, operators flow and productivity.

The fallowing data are collected

- Present assembly line layouts with space consumption, operator’s motions in between stations.
- Product details and process sequence.
- Observed time to analyse the current productivity.

4. METHODOLOGY

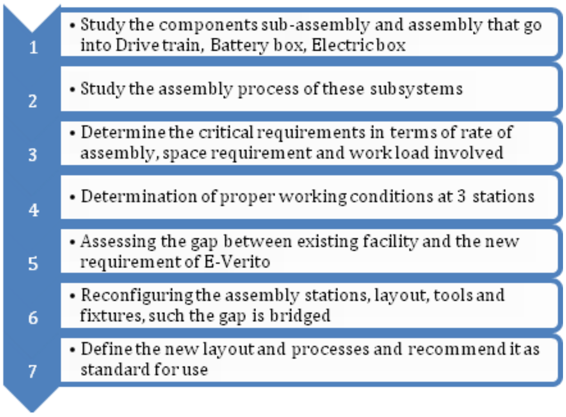

Figure.1. Methodology

5. PROCESS ANALYSIS AND RECOMMENDATIONS

By collecting all necessary data, some recommendations are made to reduce waste times. Table 1 shows the major time consuming activities with recommended actions.

Table.1. Identified major time consuming activities with time taken and action considered

Sl. No	Identified major time spent activities	Time (in minute)			Actions considered to reduce time
		DT	EB	BB	
1	Searching for tools and adjusting tool with air point (Motion + set-up time)	3.5	7	3.75	Design changes in fixtures
2	Motion - Operator flow in between stations	12	22	15	Layout changes
3	Searching and Applying yellow marker (Considered as over inspection)	4.4	5	4.98	
4	Adjustment during assembly	1.8			Design changes

6. ANALYSIS OF CURRENT LAYOUTS

In this section, product and current assembly line are described. Table 2 shows the area consumed by all 3 components assembly line.

Table.2. Area consumed by components assembly lines

Area consumed	
Components assembly areas	Existing layout
Drive train	41.40 m^2
Electric box	49.50 m^2
Battery box	77.00 m^2

6.1. Product A:

Figure 2 shows the Product A components

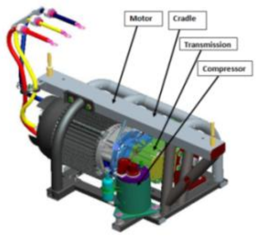

Figure.2. Product A with its major components

6.1.1. Current assembly line:

Figure 3 shows the current assembly line for the Product A assembly, area consumed is shown in table 2.

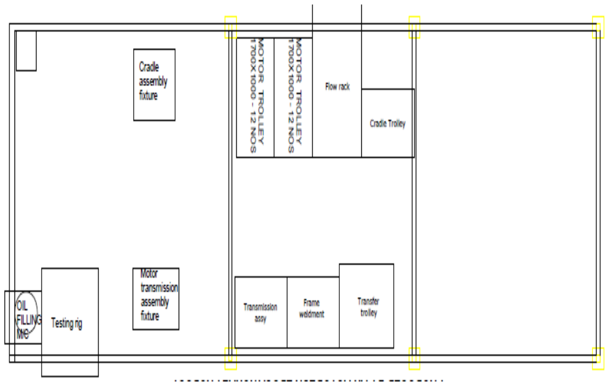

Figure.3. Current assembly line of the Product A

6.1.2. Operators flow between stations

Spaghetti diagram is created to analyse the operator's flow while performing assembly of Product A. Figure 4 shows the spaghetti diagram of operator for Product A assembly.

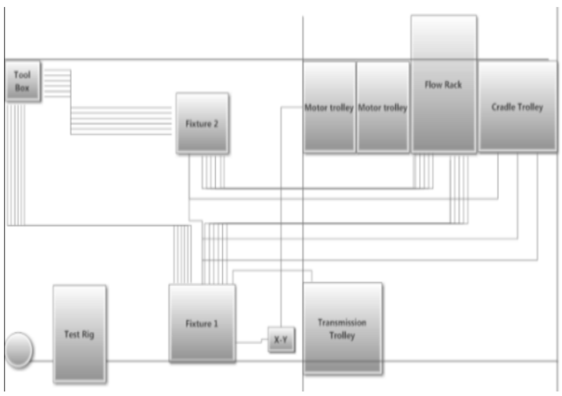

Figure.4. Spaghetti diagram for Product A assembly

By Spaghetti diagram, operator motion is calculated and is shown in table 3.

Table.3. Operator's travelled distance in between stations with distance between stations

PRESENT LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Travelled distance (m)
Transmission trolley	Fixture 1	3	1	3
Motor trolley	Fixture 1	3.7	1	3.7
Motor trolley	X-Y crane position	3	1	3
Fixture 1	Fixture 2	2.5	2	5
Fixture 1	Flow rack	5.5	6	33
Fixture 1	Cradle trolley	7.45	1	7.45
Fixture 1	Tool box	4.5	6	27
Fixture 1	X-Y crane position	1	2	2
Fixture 2	Flow rack	5	6	30
Fixture 2	Cradle trolley	3	1	3
Fixture 2	Tool box	2.75	6	16.5
Fixture 2	X-Y crane position	3.5	2	7
Total distance travelled (In meters)				140.65

6.2. Electric box:

Figure 5 shows the electric box with its components

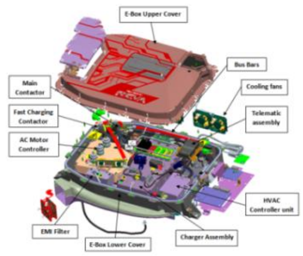

Figure.5. Product B with its major components

6.2.1. Current assembly line

Figure 6 shows the current assembly line for the Product B assembly, area consumed is shown in table 2.

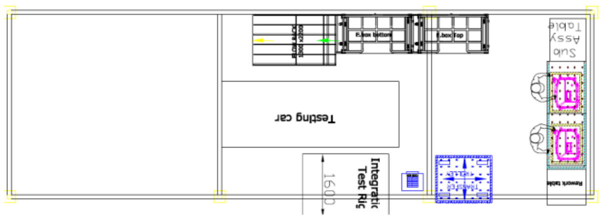

Figure.6. Current assembly line of Product B

6.2.2. Operators flow between stations:

Spaghetti diagram is created to analyse the operator's flow while performing assembly of electric box. Figure 7 shows the spaghetti diagram of operator for Product B assembly.

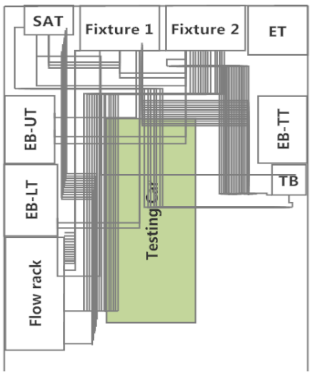

Figure.7. Spaghetti diagram for Product B assembly

By Spaghetti diagram, operator motion is calculated and is shown in table 4.

Table.4. Operator's travelled distance in between stations with distance between stations

PRESENT LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Travelled distance (m)
EB - Lower trolley	Fixture 1	3.8	2	15.2
EB - Upper trolley	Fixture 1	2.5	1	5
EB - Upper trolley	Fixture 2	3.25	2	13
Fixture 1	Fixture 2	1.5	2	6
Fixture 1	Flow rack	5	14	140
Fixture 1	Sub-assembly table	1.25	3	7.5
Fixture 1	Tool box	4.25	12	102
Fixture 2	Flow rack	5	16	160
Fixture 2	Sub-assembly table	2.75	1	5.5
Fixture 2	Tool box	3.5	15	105
Flow rack	Sub-assembly table	5	16	160
Sub-assembly table	Tool box	5	8	80
Total distance travelled (In meters)				799.2

6.3. Product C:

Figure 8 shows the battery box with its components

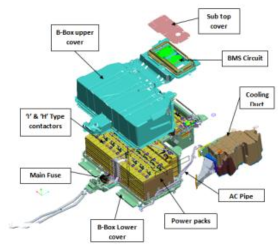

Figure.8. Product C with its major components

6.3.1. Current assembly line

Figure 8 shows the current assembly line for the Product C assembly, area consumed is shown in table 2.

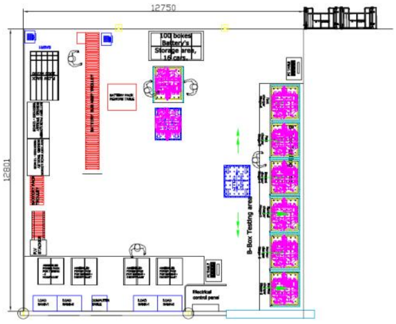

Figure.9. Current assembly line Product C assembly

6.3.2. Operators flow between stations:

Spaghetti diagram is created to analyse the operator's flow while performing assembly of electric box. Figure 10 shows the spaghetti diagram of operator for electric box assembly.

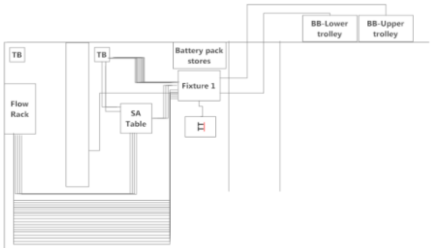

Figure.10. Spaghetti diagram for Product B assembly

By Spaghetti diagram, operator motion is calculated and is shown in table 5.

Table.5. Operator's travelled distance in between stations

PRESENT LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Travelled distance (m)
BB - Lower trolley	Fixture 1	5.15	1	5.15
BB - Upper trolley	Fixture 1	7.15	1	7.15
Fixture 1	Sub-assembly table	2.4	4	9.6
Fixture 1	Tool Box	3.8	10	38
Fixture 1	Flow rack	9.25	18	166.5
Fixture 1	Transfer trolley	1.5	2	3
Sub-assembly table	Tool Box	2.9	3	8.7
Sub-assembly table	Flow rack	7.45	4	29.8
Total distance travelled (in meters)				267.9

7. ANALYSIS OF LAYOUT BASED ON SLP APPROACH

7.1 Product A:

7.1.1 Activity relationship chart:

These are developed based on Spaghetti charts using Muthur's SLP approach. Figure 11 shows the relationship chart for Product A assembly line.

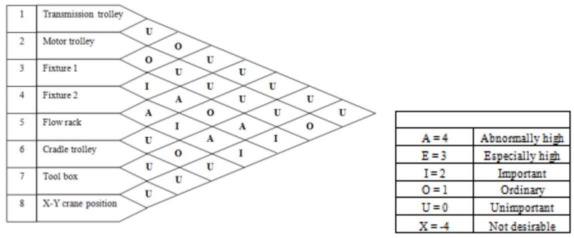

Figure.11. Activity Relationship chart for Product A assembly

7.1.2. Proposed layout:

Proposed layout is developed for the Product A assembly based on figure 4&11. Figure 12 shows the proposed layout for drive train assembly.

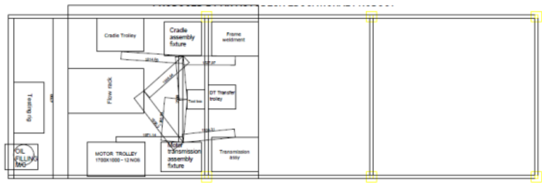

Figure.12. Proposed layout for Product A assembly

Based on proposed layout the operator travelable distance is calculated and is shown in table 6.

Table.6. Operators travelling distance in proposed layout

PROPOSED LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Travelled distance (m)
Transmission trolley	Fixture 1	1.75	1	3.5
Motor trolley	Fixture 1	1.7	1	3.4
Motor trolley	X-Y crane position	0.5	1	1
Fixture 1	Fixture 2	2.5	2	10
Fixture 1	Flow rack	1.9	6	22.8
Fixture 1	Cradle trolley	2.5	1	5
Fixture 1	Tool box	1	6	12
Fixture 1	X-Y crane position	0.5	2	2
Fixture 2	Flow rack	1	6	12
Fixture 2	Cradle trolley	0.5	1	1
Fixture 2	Tool box	1	6	12
Fixture 2	X-Y crane position	2.7	2	10.8
Total distance travelled (in meters)				95.5

7.2. Product B:

7.2.1 Activity relationship chart:

These are developed based on Spaghetti charts using Muthur's SLP approach. Figure 13 shows the relationship chart for Product B assembly line.

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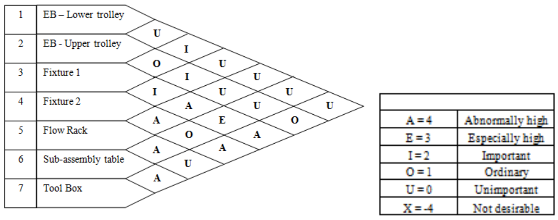

Figure.13. Activity Relationship chart for Product B assembly

7.2.2. Proposed layout:

Proposed layout is developed for the Product B assembly based on figure 7&13. Figure 14 shows the proposed layout for Product C assembly.

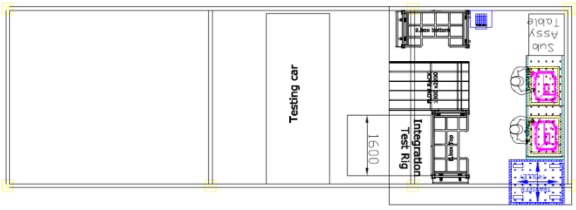

Figure.14. Proposed layout for Product B assembly

Based on proposed layout the operator travelable distance is calculated and is shown in table 7.

Table.7. Operators travelling distance in proposed layout

PROPOSED LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Travelled distance (m)
EB - Lower trolley	Fixture 1	1.58	2	6.32
EB - Upper trolley	Fixture 1	3.35	1	6.7
EB - Upper trolley	Fixture 2	1.52	2	6.08
Fixture 1	Fixture 2	1.5	2	6
Fixture 1	Flow rack	1.8	14	50.4
Fixture 1	Sub-assembly table	1.25	3	7.5
Fixture 1	Tool box	1.75	12	42
Fixture 2	Flow rack	1.6	16	51.2
Fixture 2	Sub-assembly table	2.75	1	5.5
Fixture 2	Tool box	3	15	90
Flow rack	Sub-assembly table	2.2	16	70.4
Sub-assembly table	Tool box	1.5	8	24
Total distance travelled (in meters)				366.1

7.3. Product C:

7.3.1. Activity relationship chart:

These are developed based on Spaghetti charts using Muthur's SLP approach. Figure 15 shows the relationship chart for Product C assembly line.

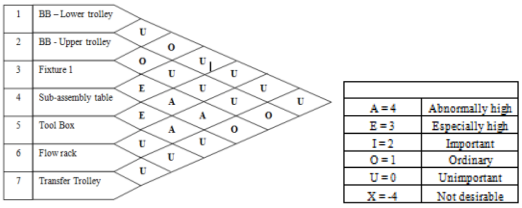

Figure.15. Activity Relationship chart for Product C assembly

7.3.2. Proposed layout

Proposed layout is developed for the Product C assembly based on figure 10&15 Figure 16 shows the proposed layout for Product C assembly.

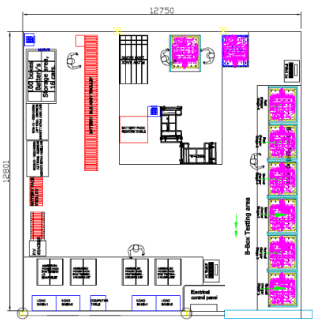

Figure.16. Proposed layout for Product C assembly

Based on proposed layout the operator travelable distance is calculated and is shown in table 8.

Table.8. Operators travelling distance in proposed layout

PROPOSED LAYOUT				
Distance between stations and operator distance travelled in line				
From	To	Travelable Distance(m)	Frequency × 2	Total Travelled distance (m)
BB - Lower trolley	Fixture 1	2.9	1	5.8
BB - Upper trolley	Fixture 1	3.5	1	7
Fixture 1	Sub-assembly table	2	4	16
Fixture 2	Tool Box	1.3	10	26
Fixture 3	Flow rack	2	18	72
Fixture 4	Transfer trolley	1	2	4
Sub-assembly table	Tool Box	1.2	3	7.2
Sub-assembly table	Flow rack	1.5	4	12
Total distance travelled (in meters)				150

8. DESIGN IMPROVEMENTS TO ELIMINATE WASTE

8.1. Product A

Earlier the fixture shown in figure 17 was fitted over the sliding plate. While assembling, it needed adjustment to perform assembly. To avoid this adjustment fixture has been fixed by considering assembly operation. So this helped to reduce the time taken to assemble from 108 seconds to 20 seconds.

In present situation searching for tool and adjustment were consuming 3.5 minutes for one drive train assembly. To eliminate these waste time and to provide proper tooling during assembly fixture design changes are recommended. Figure 18 shows the fixture's design changes.

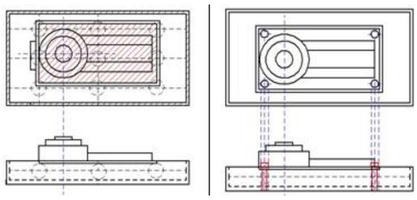

Figure.17. Product A fixture design change

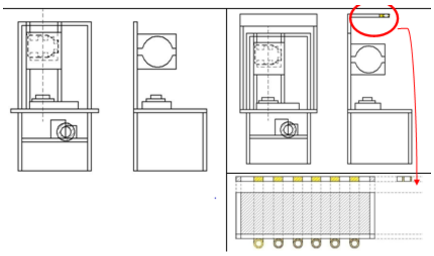

Figure.18. Product A assembly fixture's design changes

8.2. Product B

In present situation searching for tool and adjustment were consuming 7 minutes for one Product B assembly. To eliminate these waste time and to provide proper tooling during assembly fixture design changes are recommended. Figure 19 shows the fixture's design changes.

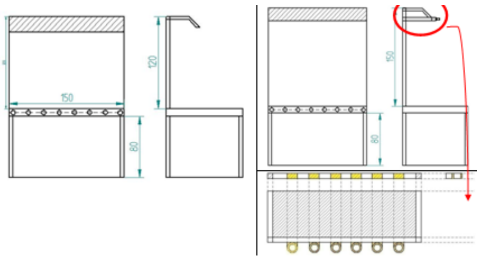

Figure 19. Product B assembly fixture's design changes

8.3. Product C

In present situation searching for tool and adjustment were consuming 3.75 minutes for one Product C assembly. To eliminate these waste time and to provide proper tooling during assembly fixture design changes are recommended. Figure 20 shows the fixture's design changes.

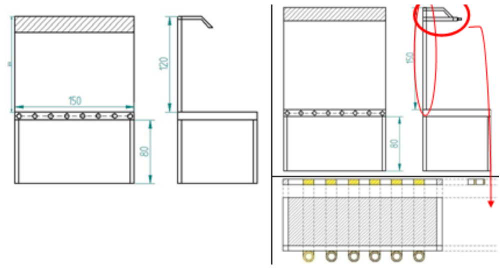

Figure.20. Product C assembly fixture's design changes

9. Results & Discussion

By redesigning the assembly line based on the SLP approach and by recommending the design changes in fixtures to eliminate wastes, operator's travelling distance is reduced from 140.65 m to 95.5 m in drive train assembly line, from 799.1 m to 366.1 m in electric box assembly line and from 267.9 m to 150 m in battery box assembly line. And further improvements are shown in table 9.

Table.9. Improvements observed

	Space utilization improvement (%)	Motion improvement (%)	Total time reduced (minutes)	Productivity improve (%)	Time improvement (%)
DT	46.80	49.16	7.33	22.22	16.74
EB	44.40	73.69	16.2	25	19.10
BB	45.45	56.48	8.5	20	11.10

10. CONCLUSION

Due to improvements observed by redesigning the assembly line, savings could be as high as Rs.1,24,000 per year when the company works for 3 shifts/day.

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