

Integrating Assembly Lines based on Lean Line Design Concept

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Abstract

In today's competitive business scenario manufacturing industries are under the pressure to reduce cost and cycle time. It is a lean manufacturing concept with a systematic approach to identify and eliminate waste through continuous and sustained improvements by manufacturing the product at the pull of the customer in pursuit of perfection. This paper is to Design and Integrate Assembly Lines 'A' and 'B' based on 'Lean Concept' using MTM/UAS analysis for determine the time and to identify the improvement. The study was carried out in 2 assembly lines in a reputed manufacturing industry. The paper concentrates only on assembly line and where assembly line 'B' is to be accommodated into assembly line 'A'. The main focus of the paper is to study the existing system and designing the new solution based on Lean Line Design concept which would follow the standards of the manufacturing industry

Keywords: Integration, manual work system, line balancing, manual time.

Abbreviations:

- LLD- Lean line design
- CTT- Customer takt time
- OEE- Overall equipment effectiveness
- PC/T- Planned cycle time
- OBC- Operator balance chart
- SW- Standardized work
- CIP- Continuous improvement process

I. Introduction

The aim of the paper to integrate 2 assembly lines by reducing space and operator which results in effectively utilization of space and the manpower. Different tools like takt time, line balancing, and MTM/UAS analysis are used to achieve the purpose. The integration of the 2 lines is based on the LLD technique. [4] The expected benefit is to effectively utilize the space and manpower by 50% and 30%.

A. Method time measurement (MTM) and universal analysis system (UAS) - is a "Predetermined Time Systems" used primarily in industrial settings to analyze

the methods used to perform any manual operations or task & as a product of that analysis, let the standard time in which a worker should complete the task.

B. Lean Line Design- Lean Line Design is a method for implementing manufacturing industries principles like process orientation, perfect quality, standardization, flexibility, waste elimination, transparent process, associate involvement etc. LLD technique is as shown in fig 1 while planning the new design of manual and semi-automated work systems this LLD technique is required to result in the better line. The qualitative aim is to redesign production and logistics according to manufacturing industries criteria. The quantitative aim is to increase productivity and flexibility, as well as lowering the investment ratio, space requirements and through-put times.

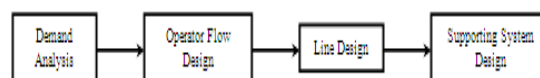


Fig 1: LLD Technique

C. Approaches to LLD- Designing the lean line means to rearrange the stations in the existing line which would be meeting the manufacturing industries standards. [3] LLD which is used for rearranging is a step by step approach, the approaches flow is shown in fig 2.

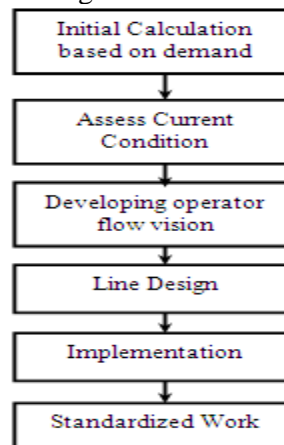


Fig 2: Flow chart of LLD approaches

II. Problem Statement

In recent days ‘A’ elements has encountered with a fluctuation in demand i.e., from high demand to moderate demand, and there is a moderate demand for ‘B’ elements, therefore there is no effective utilization of the line and the man power in both the Pumps.

III. Initial Calculation

A. Customer Takt Time (CTT) - It is the rate at which products or parts must be produced to fulfill customer orders. Equation to calculate CTT is as below in e.q. 1.

$$\text{Customer Takt Time} = \frac{\text{planned operating time per day}}{\text{demand per day}}$$

E.q. 1: CTT

B. Planned Cycle Time (PC/T) - It is the Customer Takt Time taking into accounts all influencing parameters and losses (included in OEE) at maximum capacity of the line. Equation to calculate CTT is as below in e.q. 2.

$$\text{Planned Cycle Time} = \text{Customer Takt Time} * \text{OEE}$$

E.q. 2: PC/T

Note: Planned cycle time need to be at least 10% less than CTT, so that the product could be delivered on time

The CTT and the PC/T for the A and B line is calculated as shown in the table 1. Which shows us how the CTT and PC/T for A and B line is done.

	Planned Operating Time / day	Volume A	Working days B	Demand per day = A/B	CTT	PC/T
A	25200 seconds	9812 units	24 days	409 units	62 Seconds	52 Seconds
B	25200 seconds	840 units	24 days	35 units	720 Seconds	612 Seconds

Table 1: CTT and PC/T calculation for A and B line

IV. Asses Current Condition

A. Current Layout

Current layout of ‘A’ and ‘B’ elements can be referred to the fig 3 and 4 shows the current layout, where B line need to be accommodated into A line

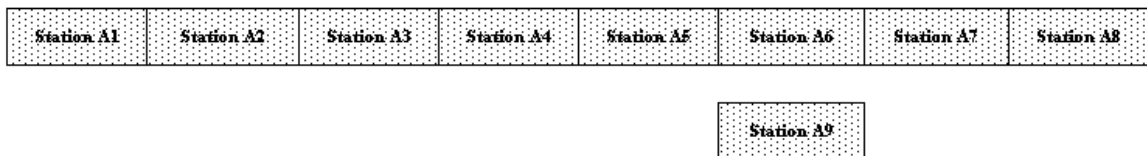


Fig 3: Existing layout of ‘A’ assembly line



Fig 4: Existing layout of ‘B’ assembly line

B. Process Flow

Process flow would help us to know the flow carried out in the assembly line. [1] The below fig 5 and fig 6 shows us the process flow currently carried out in ‘A’ and ‘B’ lines respectively.

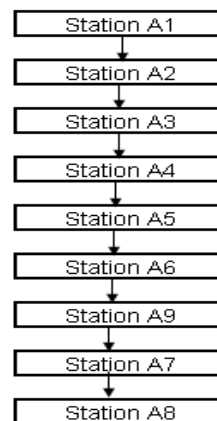


Fig 5: Process flow of ‘A’ assembly line

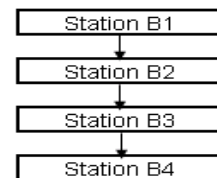


Fig 6: Process flow of ‘B’ assembly line

C. Work Distribution Diagram

Time studies of manual times and process times for each station/operator will be copied into the operator balance chart. The time studies can be obtained by time study method or method time measurement/ universal analysis system (MTM/UAS) methods.

MTM Method (Method Time Measurement) - Time determination MTM basic method is a “Predetermined Time Systems” that is used primarily in industrial settings to analyze the methods used to perform any manual operations or task & as a product of that analysis, let the standard time in which a worker should complete the task

UAS (Universal Analysis System) - UAS is a procedure for dividing a manual task into so called basic procedures, which consists of a combination of frequently recurring basic sequences of motion. The basic procedures are assigned standards time values, the amount of which is equal to the mean value to the mean value of the MTM basic sequences of motion included.

The time measurement unit for the MTM and UAS is in TMU (Time measurement unit) it's converted to seconds using the following table 2

Time Units- TMU (Time Measurement Unit)				
→	TMU	Sec	Min	Hrs
TMU	1	0.036	0.0006	0.00001
Sec	27.8	1	0.0167	0.000278
Min	1666.7	60	1	0.0167
Hrs	100000	3600	60	1

Table 2: Conversion of TMU to Seconds

a. Stack Diagram

A stack diagram is prepared for all manual operations in 'A' and 'B' elements assembly line, which are put in a stack in a scaled manner completely independent from the physical work station, the MTM study of each station is carried out an example of some station using MTM and UAS is shown in the table 2A (not covering all the station) and arranged in stack diagram as shown in table 3A and 3B. Each loop is identified in different color.

Line	Station	Type	Manual Time	
			In TMU	In Sec
A	Station A2	MTM	135.1	4.9
A	Station A7	UAS	117.7	4.2
B	Station B2	MTM	510.1	18.3
B	Station B3	UAS	1005	36.2

Table 2A: Example of MTM and UAS analysis

Station	In Seconds	
	Manual	Auto
Station A1	2.2	0
Station A2	4.9	0
Station A3	30	0.6
Station A4	8.7	0
Station A5	4.3	2
Station A6	17.1	0.5
Station A9	4.2	0.1
Station A7	2.6	3.5
Station A8	12.3	0
Total	86.5	6.7

Table 3A: A line operator time

Station	In Seconds	
	Manual	Auto
Station B1	20.5	0
Station B2	36.2	0
Station B3	4.2	0.1
Station B4	35	3.5
Total	96	3.6

Table 3B: B line operator time

b. OBC

Operator Balance Chart, time studies of manual times and process times for each station/operators result will be copied into the operator balance chart as shown in the fig 7 and 8.

Note: target cycle time is 15% less than the CTT so that the product could be delivered within the time

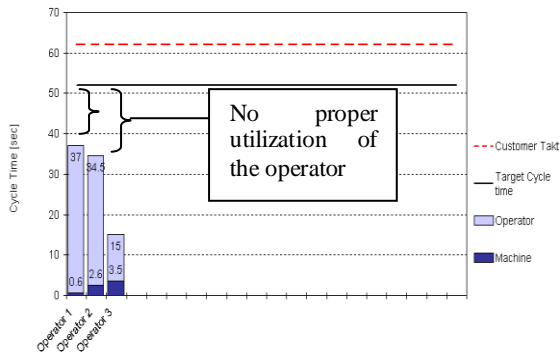


Fig 7: OBC of 'A' line

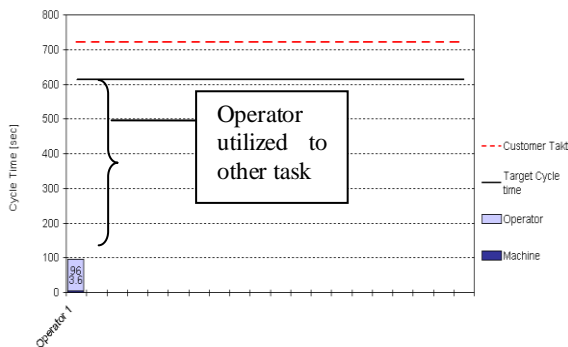


Fig 8: OBC of 'B' line

Interpretation from fig 7, it's clearly visible from the line balancing that the operator 1 and 2 are not utilized completely and operator 3 can be utilized for other task completion. From fig 8 the operator can be utilized for other task completion

V. Developing Operator flow vision

A. Paper Kaizen and Timing the work Element

Improvements were identified to eliminate the waste in the manual operations; improvements were identified based on the MTM/UAS analysis and observation. Improvements are classified into 4 types they are.

- Ergonomic improvement
- Workplace arrangement
- Method
- Out sourcing

The improvements identified are summarized in the table 4 and 5

SLNO	Types for A line	No
1	Methods improvement	8
2	Workplace arrangement	4
3	Ergonomic improvement	2
4	Outsourcing of operation	5

Table 4: A line improvements

SLNO	Types for B line	No
1	Methods improvement	11
2	Workplace arrangement	2
3	Ergonomic improvement	2
4	Outsourcing of operation	0

Table 5: B line improvements

The improvements identified are considered and the work elements are timed as shown in the table 6 and 7. In the table below we are comparing the before and after Kaizen value where 'before' refer to initial manual time and 'after' refers to the manual time after the elimination of waste i.e. after paper Kaizen.

Station	In Seconds	
	Before	After
Station A1	2.2	2.2
Station A2	4.9	4.9
Station A3	30	24.6
Station A4	8.7	8.7
Station A5	4.3	4.1
Station A6	17.1	15.2
Station A9	4.2	
Station A7	2.6	2.6
Station A8	12.3	12.3
Total	86.5	74.6

Table 6: Timed work element for A line

Station	In Seconds	
	Before	After
Station B1	20.5	50.2
Station B2	36.2	
Station B3	4.2	3.5
Station B4	35	35
Total	96	88.6

Table 7: Timed work element for B line

B. Creating Single Operator Stack

Description of sequence for 1 operator like recording of work contents at each station, listing them to scale (regarding time) in sequence of building one part (one-operator flow), the single operator is created as in the table 8 and 9.

IA	In Seconds	
Station	Manual	Auto
Station A1	2.2	0
Station A2	4.9	0
Station A3	24.6	0.6
Station A4	8.7	0
Station A5	4.1	2
Station A6	15.2	0.5
Station A7	2.6	3.5
Station A8	12.3	0
Total	74.6	6.7

Table 8: Single operator stack for A line

2B	In Seconds	
Station	Manual	Auto
Station B1 & B2	50.2	0

Station B3	3.5	0
Station B4	35	3.5
Total	88.6	3.6

Table 9: Single operator stack for B line

VI. Line Design

A. Rough Line Concept

Rough line concepts helps us to plan and design the new line according to the manufacturing industries principles, we would be following 4 steps to draw the new line,

a. Step 1: Start with a simple, straight-line sketch of workstations

- Design the line so the operator can flow as intended not necessarily to scale yet
- Design the line independent of the number of operators, as shown in fig 9.

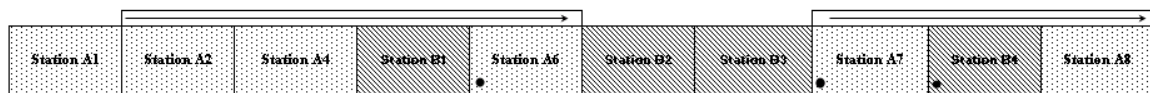


Fig 9: Rough Line step 1

b. Step 2: Write the operator cycle times above each station as shown in fig 10

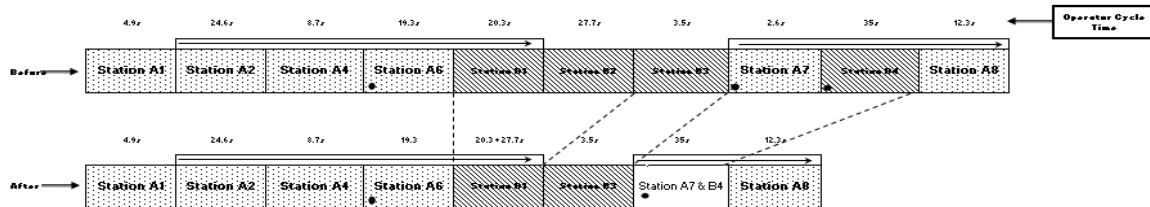


Fig 10: Rough Line step 2

c. Step 3: list the parts needed under each station as shown in fig 11

d. Step 4: list cycle time of automatic process underneath the station as shown in fig 11

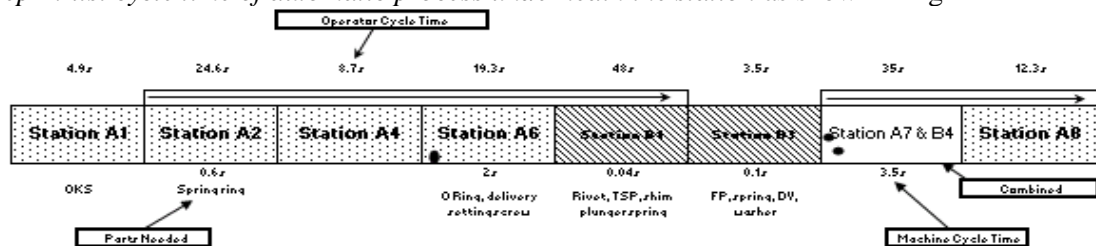


Fig 11: Listing the parts and the auto time underneath the station

Fig 11: Rough Line step 3 & 4

B. Detailing and Finalizing the Layout

With knowledge of operator flow, rough line layout and supply of components we can detail the layout and draw to scale

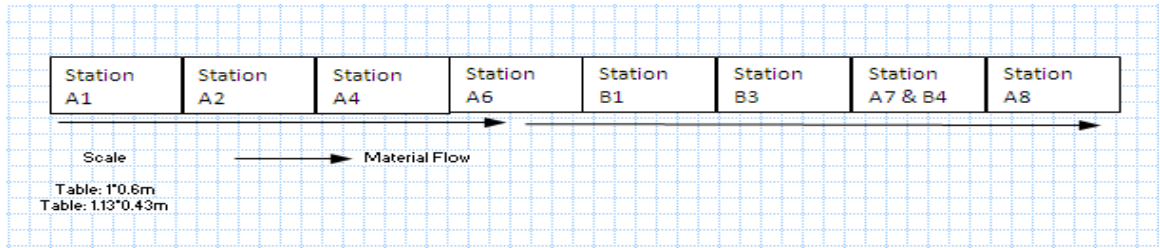


Fig 12: Integrated detailed layout

C. Developing Work Distribution

a. Calculating Number of Operator

Finally we calculate the target number of operators as in table 10, which will help us to

$$\text{Number of Operators} = \frac{\text{total time of manual work steps}}{\text{Planned Cycle Time}}$$

E.q. 3: Number of operator

know how many number of operator's are required to complete the task at the given time. The equation 3 shows how to calculate the number of operator

	Total Operator Time (A)	Planned Cycle Time (B)	Avg no of operator = A / B
A	74.5	52	1.433
B	88.6	612	0.145

Table 10: Number of operator calculation

b. Creating of Operator Balance Chart (OBC)

- Distribution of work content to operators (target), take stack diagram as in table 11 and 12 and cut to fit to planned cycle time to draw OBC as in fig 12 and 13. Hand-off points can be inside a station
- Assign walk paths according to distribution of work content on layout as in fig 14

Station B3	3.5	0
Station B4	35	3.5
Total	88.6	3.6

Table 12: Stack for OBC for B line

IA	In Seconds	
	Manual	Auto
Station A1	2.2	0
Station A2	4.9	0
Station A3	24.6	0.6
Station A4	8.7	0
Station A5	4.1	2
Station A6	15.2	0.5
Station A7	2.6	3.5
Station A8	12.3	0
Total	74.6	6.7

Table 11: Stack for OBC for A line

2B	In Seconds	
	Manual	Auto
Station B1 & B2	50.2	0

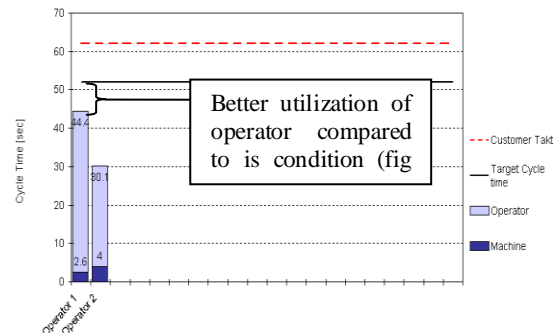


Fig 12: OBC of 'A' assembly line

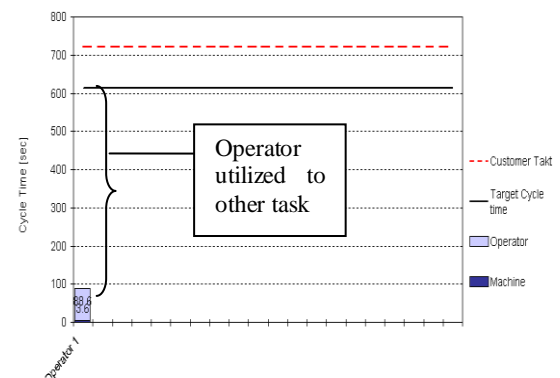


Fig 13: OBC of 'B' assembly line

Interpretation from fig 12, it's clearly visible from the line balancing that the operator 1 is better utilized compared to is condition and

operator 2 can be utilized for other task completion. From fig 8 the operator can be utilized for other task completion

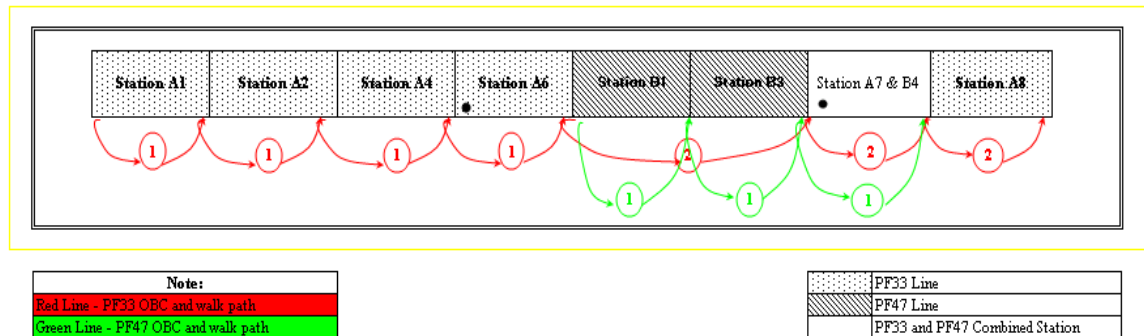


Fig 14: Walk path

Interpretation from fig 14: The walk path specifies only the movement of the operator which is recursive in nature i.e. once the operator 1 finish his work then his work again starts from the scratch

VII. Implementation

→ Work with Equipment Vendor

- Think of equipment vendors as machine builders, and yourself as the line/flow designer. The flow is your responsibility.
- Design the line in a way that allows further refinement after installation. Improvement will continue -- build the line accordingly.
- Involve the machine vendor in the process design steps. He will better understand your concept and get trained at the same time.
- Work with the equipment vendor during his process, in order to avoid surprises. This is not a hand off.

of Work Sheets:

→ Realization

- new concept should be realized as fast as possible

VIII. Standardized Work and CIP

A. Standardized Work

Standardization is an important principle that has to be implemented in any of the manufacturing industry. Standardized Work creates transparency in the workflow and thus provides the basis for the continuous improvement process. Stab sheets are prepared so that we can get the idea how the operator flow is, the Stab sheets are shown in fig 15 and 16, its shown only for 1 operator, rest can be created as same as fig 15 and 16

Preparation

Cycle Time				PC/T	
Operators total / Sequence		Supervisor	Planner	Date	Target Cycle Time [sec]
Number of Work Sequences		Import	STAB start	Time unit	Performance Rate [%]
5				seconds (s) minutes (m)	85
Language					
english					
No.	Description	manual	automatic	manual 2	walk time
1	Station 1	2.2			
2	Station 2	4.9			
3	Station 3	24.6	0.6		
4	Station 4	8.7			
5	Station 5	4.1			
Sum [sec]		44.5	0.6	0.0	0.0
Total Cycle Time [sec]		44.5			

Fig 15: Data input for worksheet

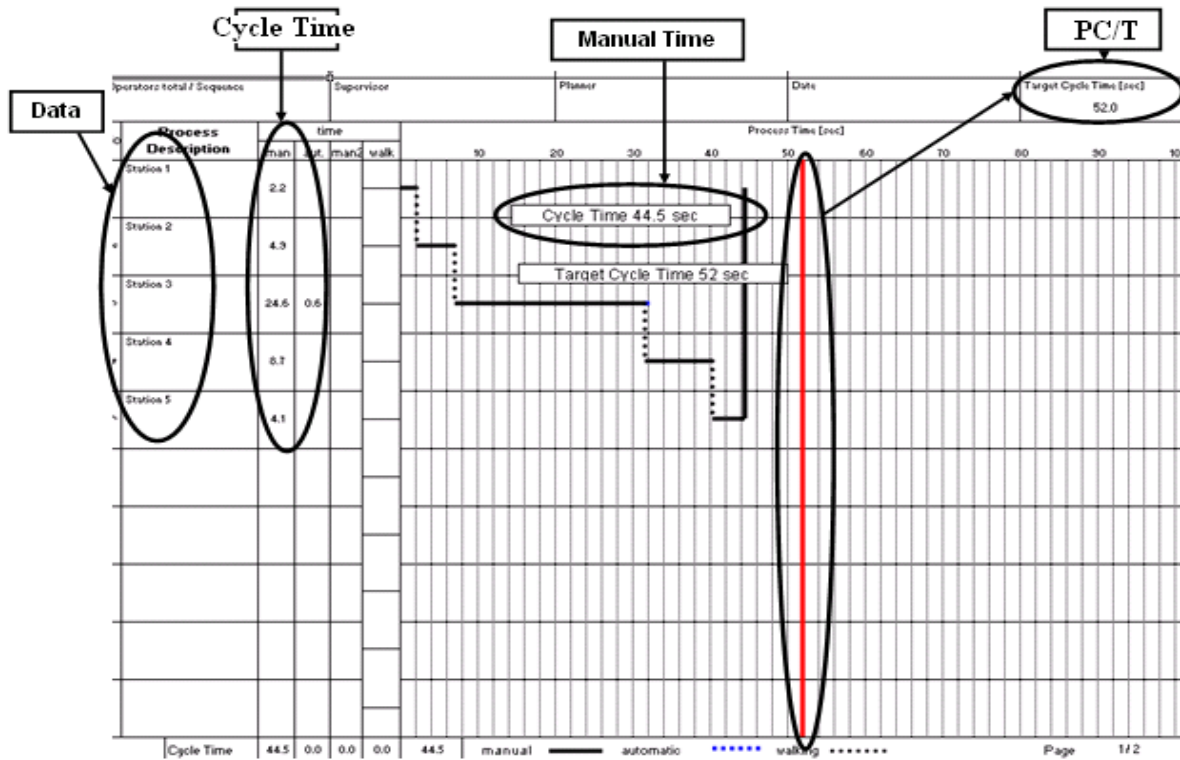


Fig 16: STAB

B. Point CIP

Continuous improvement process (CIP), description of the work sequence according to the current standard need to be implemented which can be carried out by informing and training of the employees of the line based on the operator time. Fig 17 shows us the implementation of the point-CIP.

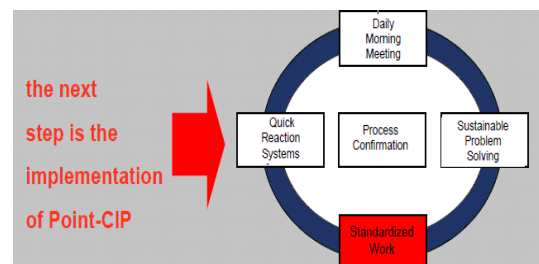


Fig 17: Point CIP

IX. Results

The results of integrating the 2 lines A and B are as shown in the table 13

SL No	Action	Existing	Integrated	
1	Area in sq meters	A	618	
		B	311.4	
		Total	929.4	481.2
2	Material Movement in meters	A	938	
		B	360	
		Total	1298	800
3	Operator Cycle Time	A	86.5	
		B	96	
		Total	182.5	157.1
4	Number of Operators	A	3	2
		B	1	1
		Total	4	3
6	Productivity	A	24.8	37.1
		B	10	10

Table 13: Results

X. Conclusion

The aim of the paper to integrate 2 lines by reducing space and operator results in effectively utilization of space by 48% and the manpower by 33% was achieved. Different tools like takt time, line balancing, MTM/UAS analysis etc. were used under LLD technique. The integration carried out on parameters like number of operators, cycle time, space. Integrated layout is simulated and validated through trial runs. The project yielded good results in terms of space and manpower utilization.

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