# DESIGNING AND INTEGRATING ASSEMBLY LINES BASED ON LEAN CONCEPT USING MTM/UAS METHOD

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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

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SW- Standardized work

CIP- Continuous improvement process

## I. Introduction

The aim of the paper to integrate 2 lines by reducing space and operator results in effectively utilization of space and the manpower was achieved. Different tools like takt time, line balancing, MTM/UAS analysis. 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.

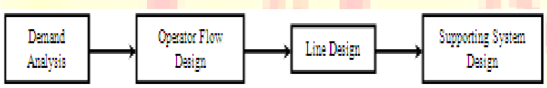


Fig 1: LLD Technique

***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.

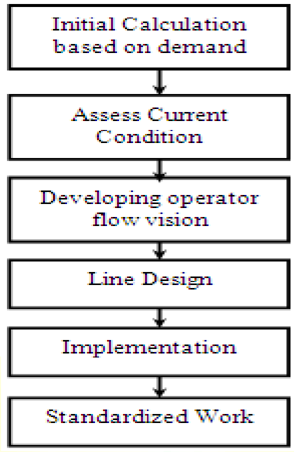


Fig 2: Flow chart of LLD approaches

## 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

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

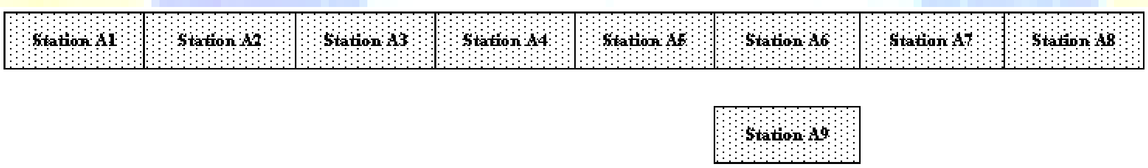


Fig 3: Existing layout of ‘A’ assembly line

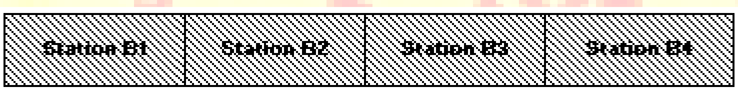


Fig 4: Existing layout of ‘B’ assembly line

### 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.

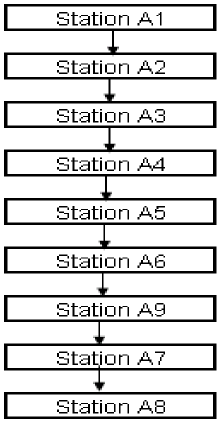


*Fig 5: Process flow of 'A' assembly line*

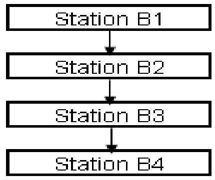


*Fig 6: Process flow of 'B' assembly line*

### 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.

### 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 and arranged in stack diagram as shown in table 2 and 3. Each loop is identified in different color.

| A | In Seconds | |
|---|---|---|
| **Station** | **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 2: A line operator time

| **B** | **In Seconds** | |
|---|---|---|
| **Station** | **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 3: 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.

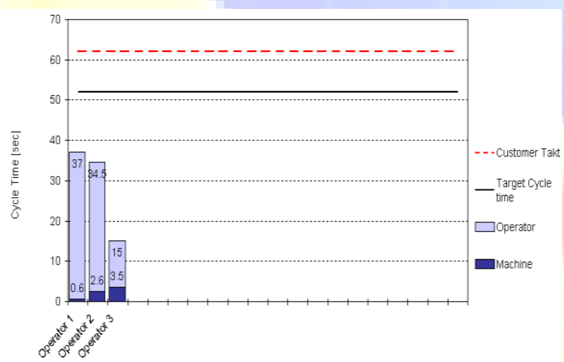


Fig 7: OBC of 'A' line

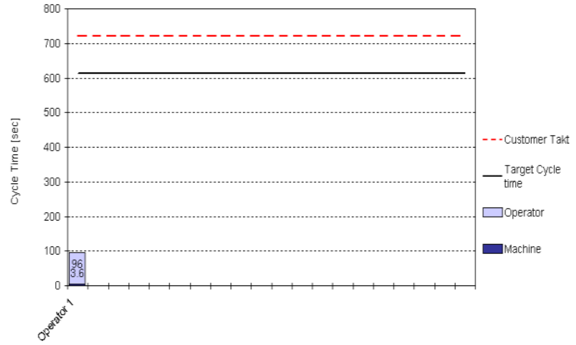


Fig 8: OBC of ‘B’ line

## 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 | 2 |

| | | |
|---|---|---|
| | improvement | |
| 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.

| **A** | **In Seconds** | |
|---|---|---|
| **Station** | **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

| **B** | **In Seconds** | |
|---|---|---|
| **Station** | **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.

| 1A | 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.

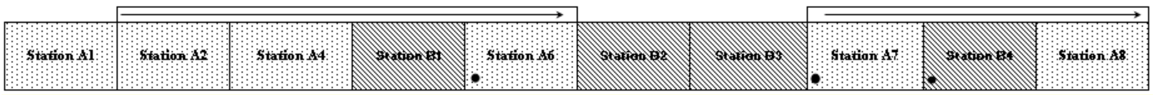


Fig 9: Rough Line step 1

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

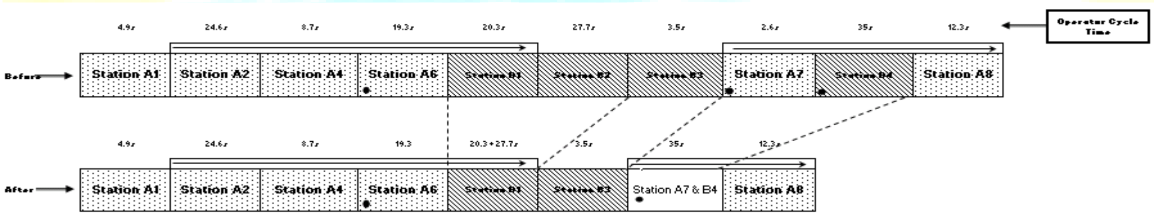


Fig 10: Rough Line step 2

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

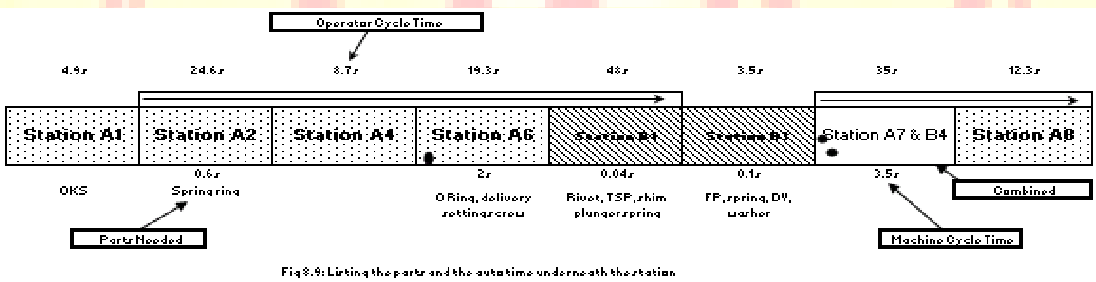


Fig 11: Rough Line step 3 & 4

**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

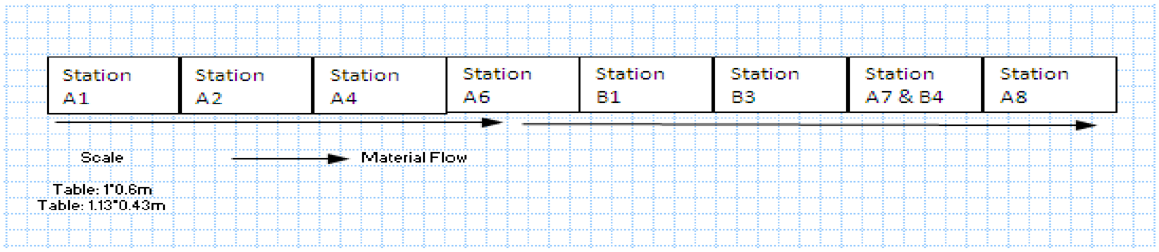


Fig 12: Integrated detailed layout

**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 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

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

E.q. 3: 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

| **1A** | **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 11: Stack for OBC 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 12: Stack for OBC for B line

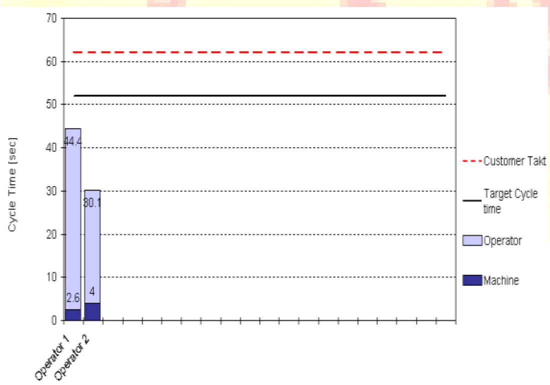


Fig 12: OBC of 'A' assembly line

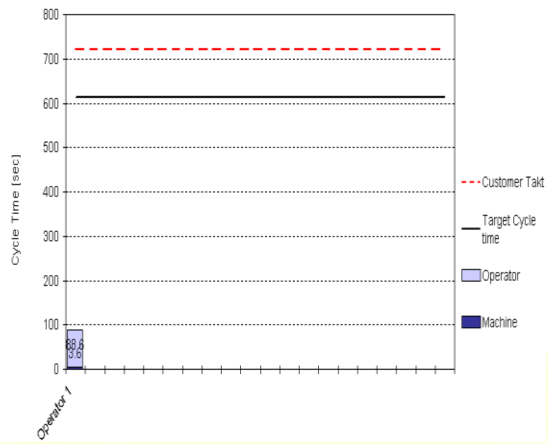


Fig 13: OBC of 'B' assembly lin

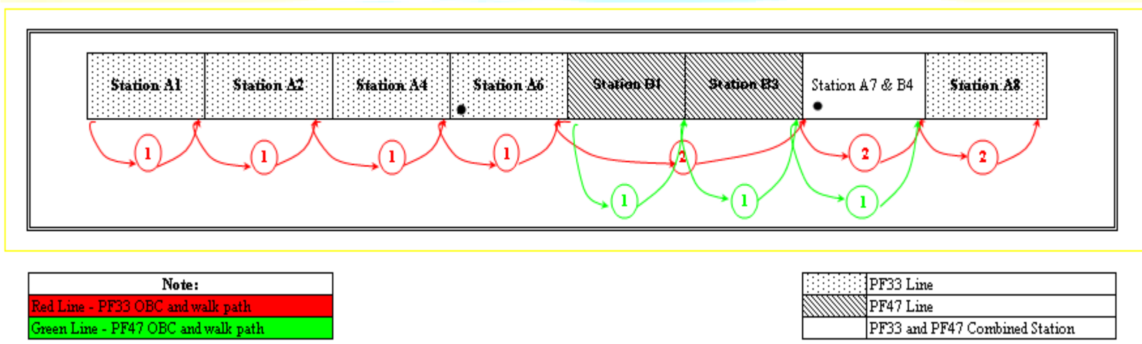


Fig 14: Walk path

## 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.

→ 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 of Work Sheets:

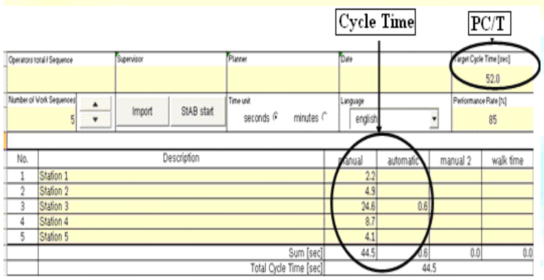


Fig 15: Data input for worksheet

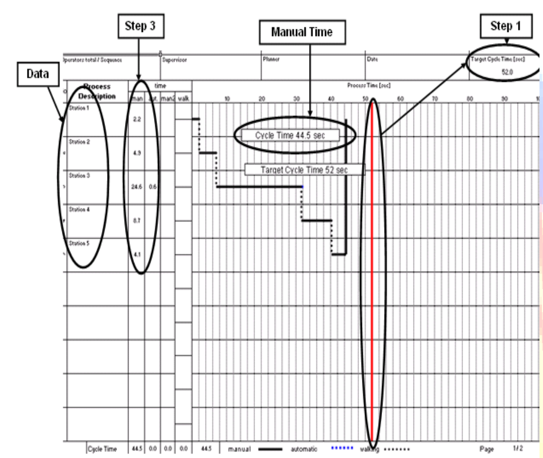


Fig 16: STAB

### 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.

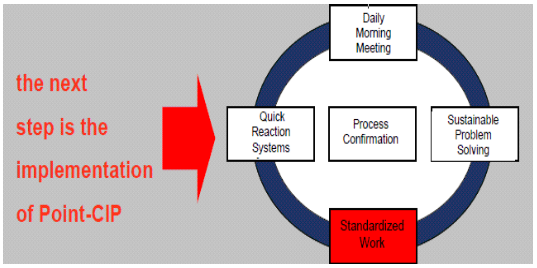


Fig 17: Point CIP

## 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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