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Improving Productivity and Efficiency of a Manufacturing Facility using Industrial Engineering Tools: Case Study

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ABSTRACT: Nowadays, companies have to compete to sustain themselves in the fast-moving market, and therefore, product demand, quality, and availability are the essentials for today's customers. Whereas, when a product becomes successful then it creates an opportunity for the company to increase its production to replenish the sudden escalated demand. But, the company cannot easily do it just by increasing its workforce and resources. The company has to maintain all the influencing parameters like material flow, quality, and services when increasing the production rate, and hence Industrial engineering tools should be used to balance everything for smooth manufacturing. This paper consists of applications of some Industrial Engineering tools like Line Balancing, Simulation, LEAN manufacturing, and Computerized Relative Allocation of Facilities Technique (CRAFT) on a real assembly production line. These tools were used to analyze and increase the efficiency and productivity of a production system by reducing waste, optimizing the material flow, and soaring the production rate. Undoubtedly, real-time data was used to analyze and improve the production line of a company by creating robust manufacturing and workplace design, capable to double the production rate of the assembly line. In addition, the paper also includes the data after implementing the proposed design.

KEYWORDS: Industrial Engineering, LEAN Manufacturing, Line Balancing, assembly line, productivity, efficiency, production, CRAFT, material flow.

I. INTRODUCTION

Production system is the most crucial element for any type of industry as customer's demand, product quality and resource utilization are highly dependent on it. Therefore, the sequence, cycle time and method of work stations should be adjusted optimally to improve the production rate of a system. However, various MSMEs lag to optimize their production system because of limited resources and this showcases the need of introducing industrial engineering tools which are applicable to any conditions.

Many industries face problem of meeting the high demands without getting its product quality compromised. This happens because they are unable to design a standardized work flow. Also, the workstations should be placed and sequenced in such manner that every resource (including work force) is utilized effectively and efficiently.

In this paper we are going to present the implementation of Line Balancing and lean manufacturing at an actual manufacturing facility. Firstly, all the processes in assemblies and subassemblies were observed thoroughly and then the mentioned industrial engineering tools were shortlisted after a detailed study. This paper is all about the way we have applied these tools to enhance the productivity of the company.

Line Balancing: Line balancing or production levelling is a way to distribute the workload in each workstation in an attempt to increase the efficiency of the production flow. It is applied with an objective to match the production time with the takt time.



Heuristic Method: It is one of the methods to practice line balancing, in this approach the activities or processes are grouped together so as to balance the assembly line by taking cycle time into consideration.

Takt Time: Time required to produce products in order to meet customer's demand.

Lean Manufacturing: A method to maximize productivity of a production system by minimizing the waste. There are various categories in a production system where lean manufacturing wastes can be identified:

1. Transport
2. Inventory
3. Motion
4. Waiting
5. Overproduction
6. Over-processing
7. Defects
8. Talents

CRAFT (Computerized Relative Allocation of Facilities Technique): It is a technique to improve the existing layout. CRAFT majorly aims to reduce excess transportation of man and material therefore the centroids of the workstations and precedence of activities are taken into consideration to design the optimum layout.

To maintain the secrecy, we have not disclosed the name of the company, product, parts, and processes. Rather, they are given alternative names (numerically & alphabetically) to make the readers understand our project with ease. However, we have presented the real data of cycle time, wastes observed, and layout plan of every workstation and processes that are required to understand the implementation of industrial engineering tools in this paper.

II. METHODOLOGY

Sequence of methods and techniques used in this project with their description:

1. Understanding the company

- a. Objective: To increase the production rate to meet the customer demand.
- b. Customer demand: Total production time was almost double than the TAKT time. That means the company was able to produce only half of the customer demand per day.
- c. Initial production rate: The assembly unit produced 30 units/shift.
- d. Future goal: The company seeks to standardize all the sub-assemblies in order to eliminate the random working of a worker.
- e. Limitations from the company

2. Understanding and recording the manufacturing processes

- a. Assemblies and Sub-Assemblies: All the processes in the assembly section are done manually. In the initial assembly, the worker was meant to pickup any kind of work on his personal discretion. He was just given a target and this made him work randomly which was unprofessional for a manufacturing process. Therefore, the manufacturing process needs to be standardized within the workers and workstations. If the worker has to follow the job that is already allotted to him/her at the day start then more time and energy of the worker is not wasted in thinking about their job. Also, this may increase their efficiency.
- b. Initial Material movement: Following diagram shows the material movement of the facility.

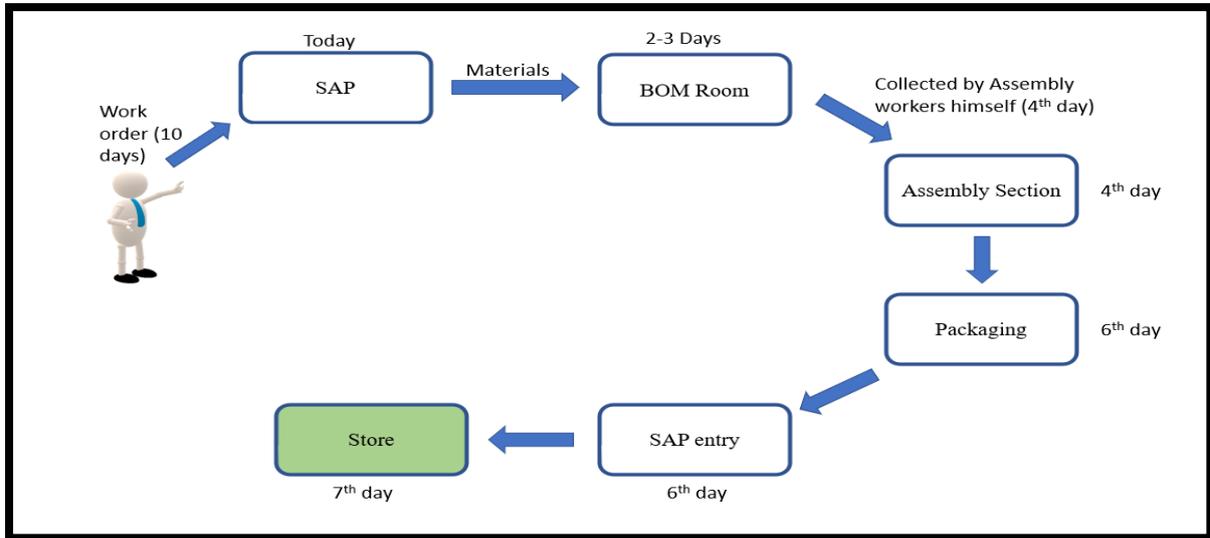


Fig 1: Initial material movement of the facility

Description of the process figure:

- i. Assembly Manager issues work order for following 10 days.
- ii. Materials then comes to the BOM room in 2-3 days. (BOM: Bill of Material)
- iii. Then the Assembly worker collects his requirements for assembly from the BOM room in 4th day.
- iv. The assembly and quality testing are done in the 4th day itself and is kept in stock for further process.
- v. Packaging is then done in the 6th day followed by its SAP entry.
- vi. At last, the final product reaches the store in the 7th day.

The main objective of an industrial engineer is to keep the materials flowing. If the materials are in WIP (Work in process) in the assembly section then it doesn't add any value to the company. This unnecessary storage and delays have to be eliminated by a perfect assembly plan to improve the material flow of the company which in turn may ease their management and scheduling process.

- c. Method study: All the processes of every workstation were recorded and studied thoroughly. There are 4 major components of the product which needs a separate sub assembly. The components are named I, II, III and IV. The following diagram illustrates the process flow of the assembly line:

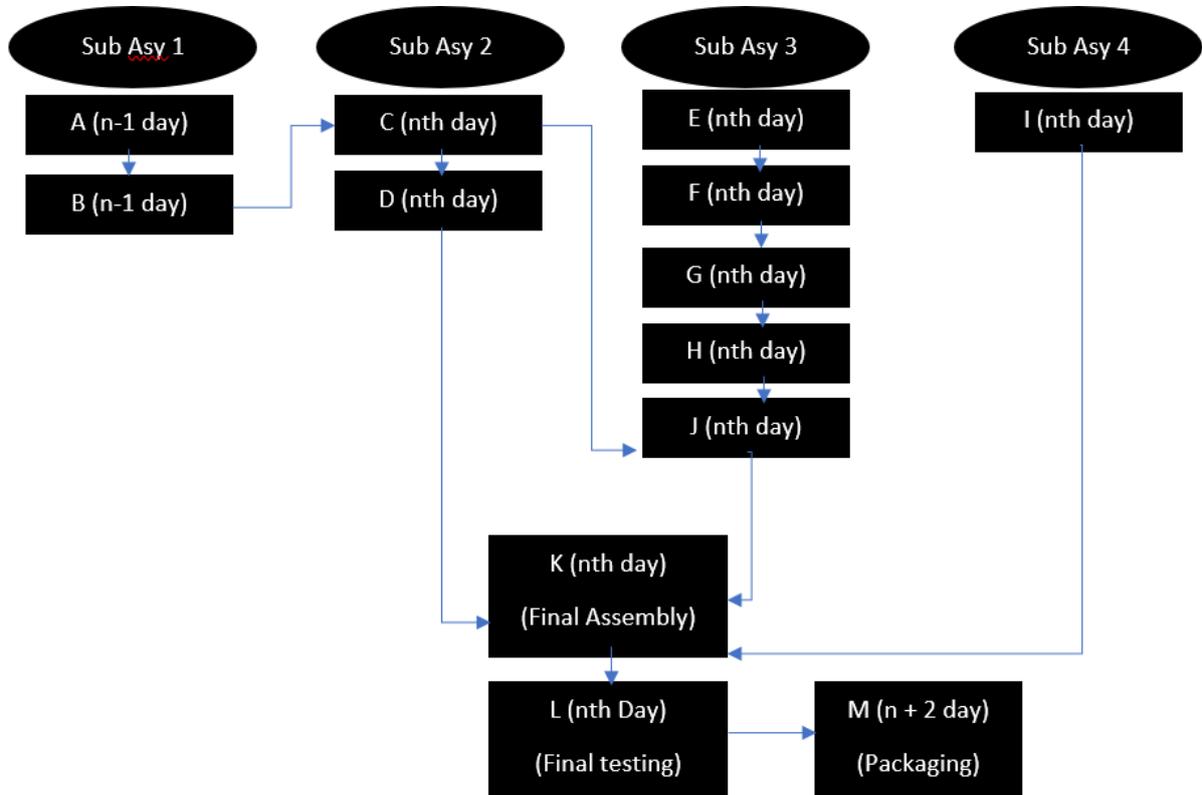


Fig 2. Flow process chart of the assembly line

Following is the table for pre-requisites and necessities for some components and processes:

Table no.1: Pre-requisites and necessities for some components.

Sr no.	Process	Precedence	Process type	Component no.	Remarks & Requirement
1	A	-	Assembly	I	Component I have to be assembled tested and then reassembled. But this process should be done a day before the further use of component I. Because the sticking agent applied in the process takes 24 hours to make the assembly dry and sturdy.
2	B	A	Component testing and Assembly	I	
3	C	B	Matching of Component, I and II	I and II	Matching is done for better compatibility of two components in touch.
4	D	-	Assembly	II	C is not the necessary precedence of D. But, component I and II has to be matched because of variation in sizes. This process can be done either after or before the assembly of D.
5	E	-	Assembly	III	No special requirements.
6	F	E	Assembly	III	No special requirements.
7	G	F	Component testing	III	No special requirements.
8	H	G	Assembly	III	No special requirements.
9	I	-	Assembly	IV	No special requirements.



10	J	C & H	Assembly	I + III	Components I and III are assembled on nth day.
11	K	D, J & I	Final Assembly	I + II + III +IV	All the components are brought together for final assembly
12	L	K	Final Testing	-	Needs a qualified worker for final testing and rework.
13	M	L	Packaging	-	No special requirements.

d. Workforce and working style:

Initially, 5 workers were working in 6 workstations.

- i. 3 workers in assembly
- ii. 1 worker for final testing
- iii. 1 worker for packaging

Working style: The workers assemble the components in batches. There is not a continuous flow of product and this is one of the things that slows down the process and decreases the efficiency of the assembly line. If the process is not standardised and the material and components is been kept idle for a long time then it occupies the space unnecessarily. Since,space is the most important factor in an assembly line, an unorganized space management leads to distraction, confusion and physical difficulties within the worker. Therefore, the materials should be kept flowing to reduce the burden on workers and management.

e. Initial Layout: (W#: - Workstation number)

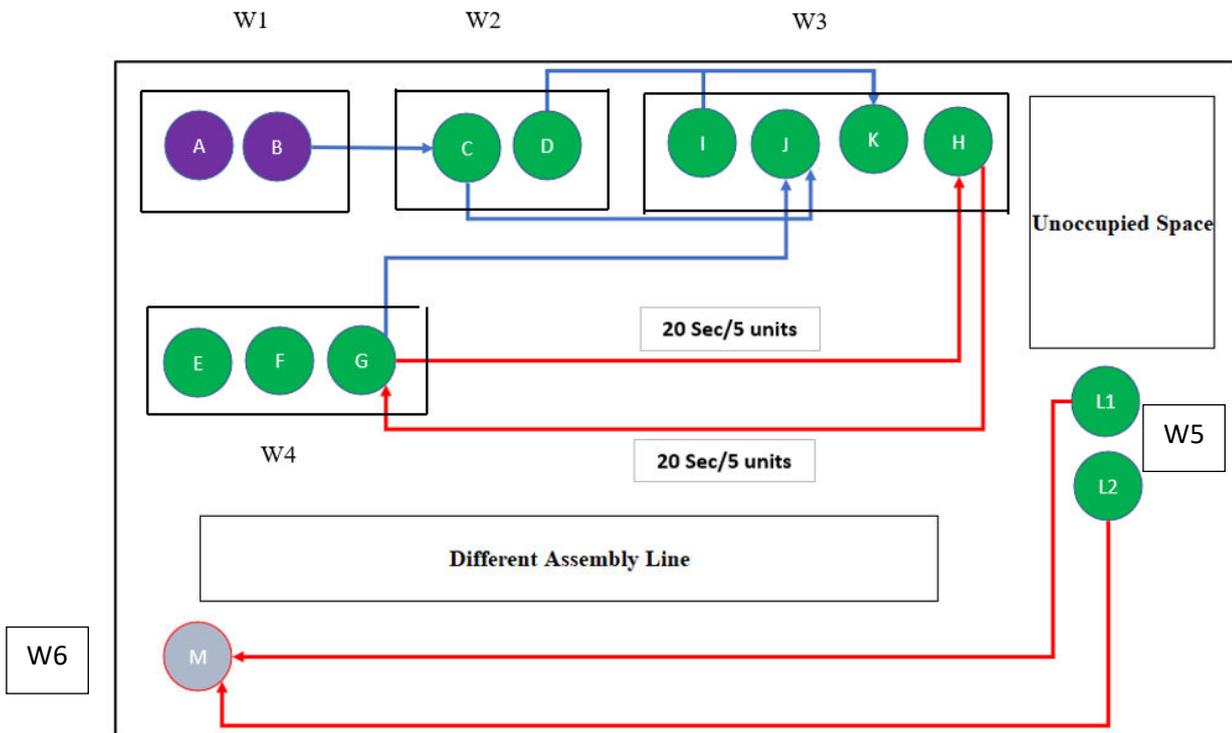


Fig 3. Initial layout of assembly line with material movement



Table no. 2: Reference to colour coding and symbolsfig 3.

	n - 1 Day Operation
	n+2 day operation
	nth Day Operation
	Movement of material
	Non Value Adding Movement

In method study, H is the precedence of J but due to insufficiency of appropriate tools in the workstation, the worker has to go all the way to the workstation no.3 to do a specific operation.

- f. Identification of wastes: Various types of wastes were identified:
 - i. Non-value adding works
 - ii. Delays
 - iii. Unavoidable delays
 - iv. Unnecessary movement of workers and materials
 - v. Defects
 - vi. Talent: The talent of an experienced worker was not utilized properly as he had to do the work which was meant to be done by someone with an inferior post.

- g. Data Collection: The cycle time for each element was recorded by taking following points into consideration:
 - i. For credible data, the readings of an element should be taken for different workers, different days, and in different shifts.
 - ii. Break time and the allowances should be considered.
 - iii. Non-value adding time of a particular worker must be added in the cycle time.

Table no.3 was referred to determine the required number of observations for all the cycle times. The data present in the table guides us to get sufficient number of observations for different time intervals.

Table no.3: Table to determine recommended number of observations (Table taken from Niebel's Methods, Standards and Work Design, 12th Edition)

Cycle Time (min)	Recommended number of observations
0.10	200
0.25	100
0.50	60
0.75	40
1.00	30
2.00	20
2.00 - 5.00	15
5.00 – 10.00	10
10.00 – 20.00	8
20.00 – 40.00	5
Above 40.00	3



Table no.4: Average cycle time for respective number of observations

Process	Average Cycle Time / unit (seconds)	Number of observations taken
A	70	30
B	220	15
C	80	30
D	180	15
E	66	30
F	147	15
G	181	15
H	35	60
I	269	15
J	40	60
K	123	15
L	330	10
M	370	10

3. **Implementation of Line Balancing:** Implementation of line balancing technique consists of various iterations of grouping the activities in a particular workstation. Firstly, we need to calculate the following:

Cycle time: Total cycle time = 2111 seconds (35 minutes 11 seconds)

Maximum cycle time: 370 seconds for process M.

Takt Time: The company wants to double their production rate (60 units/shift). So, the takt time as per the 7 hours work shift would be:

Formula: - $T = T_a / D$

Where, T = Time required to fulfil the demand, T_a = Available to working time & D = Customer demand

$T_a = 7 \text{ hours} = 25200 \text{ seconds}$

$D = 60 \text{ units/day}$

$T = 25200 \text{ seconds} / 60 \text{ units} = 420 \text{ seconds}$

But we can certainly increase the production rate by considering the process with maximum cycle time (Process M = 370 seconds) because the maximum cycle time is less than the Takt time.

Number of products can be produced = $25200 / 370 = 68.108 = 68 \text{ units/day}$. So, we should arrange the activities such that all the workstations would have their cycle time below 370 seconds.

No. of workstations required:

Formula: - no. of workstations \geq Total cycle time / cycle time for each workstation

So, No. of workstations required $\geq 2111 \text{ seconds} / 370 \text{ seconds} = 5.705$

Therefore, no. of required workstations = 6

Hereafter, by applying the principles of heuristic method, the mentioned assembly was balanced successfully which resulted in increasing the production rate by around 226%. Also, this result was established only when the following requirements were met:

- i. Production rate was calculated only for 7 hours/shift working time as idle time and allowances of a worker was equal to or less than an hour/shift.
- ii. There should be 4 workers for assembly line. (Initially, there were 3 workers at assembly section)
- iii. 4 Workstations for assembly line and the rest 2 should be allotted for testing and packaging.
- iv. Process A, B, C, D and E should be completed and accumulated a day before the final assembly. This is done because of their pre-requisites (Refer table no.1) and this would not affect the flow of assembly line because it was considered as a future shift necessity. Lastly, it helped us to reduce the delays in the work flow.



- v. Packaging should be done at n+1 shift because the final assembly needs some time to dry and drain the oil used for testing.
- vi. Worker no. 2 was utilised in two workstations because he was still left with some time after working on the process D and E. This improvement changed our perspective towards line balancing—if the cycle times are not getting arranged properly because of some limitations and pre-requisites then you should try arranging the workers within different workstations. As sometimes there would be situations where the idle time of a particular worker would be more than enough and at the same moment the other worker working in different workstation won't be able to complete his daily demand on time because of excess cycle time. So, the former should be accommodated (after completion of their task) to continue with the latter for meeting the daily demand. But this solution should only be implemented for the last workstation in assembly line as they don't have the pressure to be a bottleneck in between.

Optimal Iteration in Heuristic method:

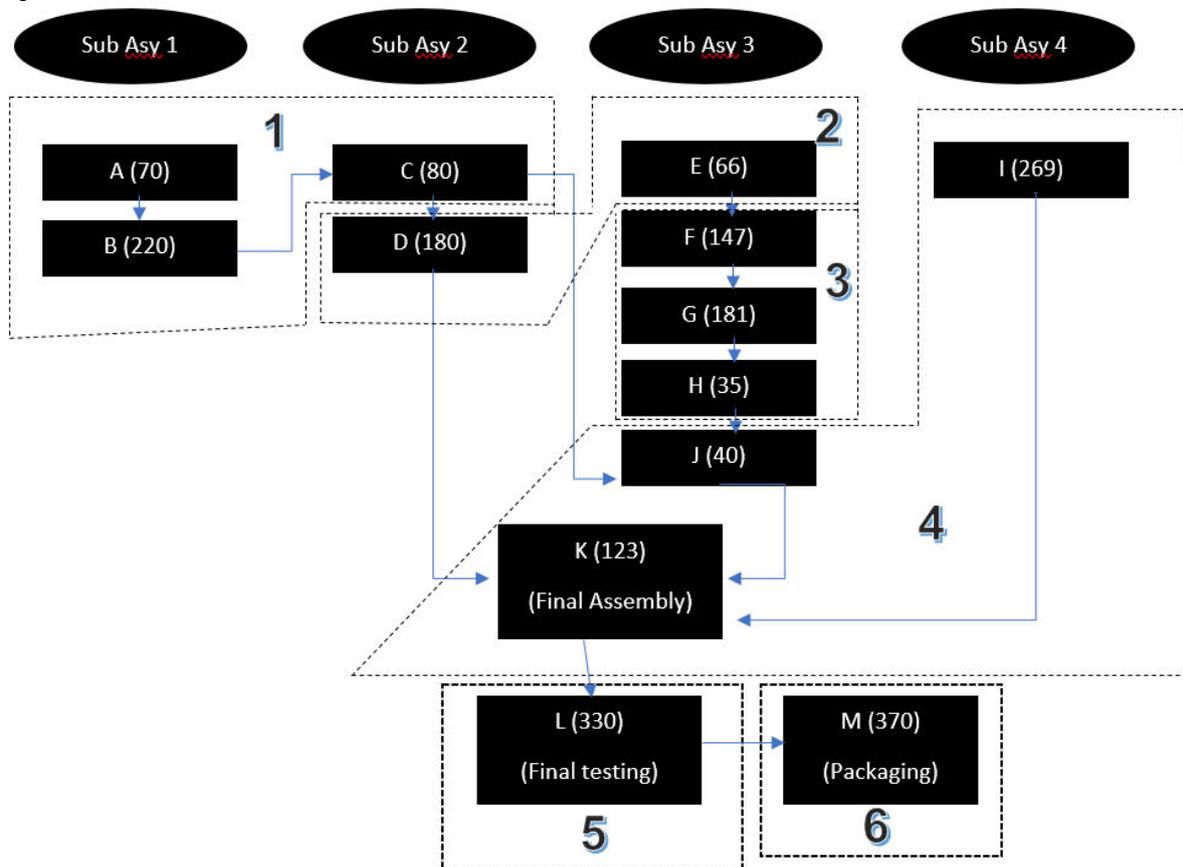


Fig 4. Iteration of heuristic method



Table no. 5: Details about the line balancing done (1 worker/workstation)

Process	Cycle Time / unit (Sec)	Total Time	Can produce in total time	Actual number of units	Worker no.	Start Time (n = Shift)	Remark
A	70	5.5 hours	68	68	1	n -1 shift	The worker will perform the process a & b in his first 5 hrs 30 min then he will shift to the process c in the remaining 1 hrs 30 min of his shift)
B	220						
C	80						
D	180	3 hours 25 min	68	68	2	n -1 shift	Worker 2 will achieve his target in 6 hours 20 min. In the remaining 40 min he will do the process f.
E	66	1 hour 15 min					
F	147	7 hours	69	68	3	n = 0	In 6 hrs 20 min worker 3 can make 57 units. In the remaining 40 min worker 2 & 3 together can make 9 more units. Process will be done in sequence for 1 unit. (f -> g ->h)
G	181						
H	35						
I	269	7 hours + 2 hours	69	68	4	n = 0	Process will be done in sequence for 1 unit. (i -> j ->k)
J	40	20 min remaining					
K	123	time of worker 2					

Efficiency of Assembly line: Formula: Line Efficiency = Total task time / (number of workstations * cycle time)
 Line Efficiency = 2111 / (6 * 370) = 0.9509 (95.09 %)

4. **Simulation:** (Courtesy: SIMUL8)

The improvisations were then tested first in a simulating tool before the implementation. The tool predicted almost same results as it was calculated through line balancing.

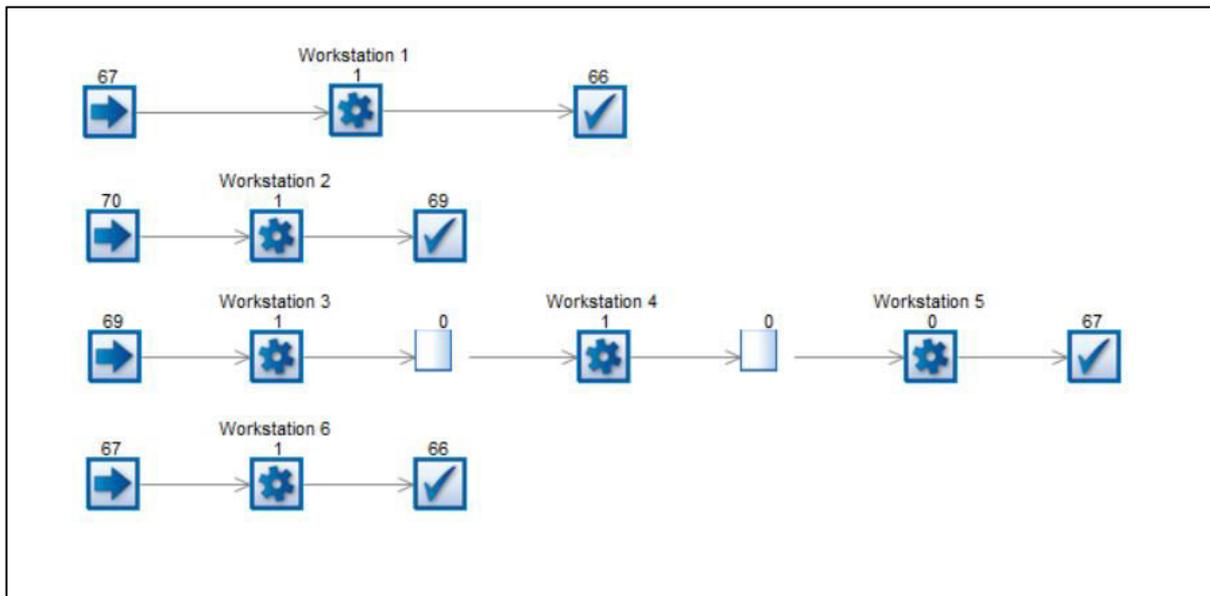


Fig 5. Simulation of assembly line in SIMUL8

5. **Modified layout:** (Refer table no. 2 for colour coding and symbols)

CRAFT (Computerized Relative Allocation of Facilities Technique) was used to improve the former layout.

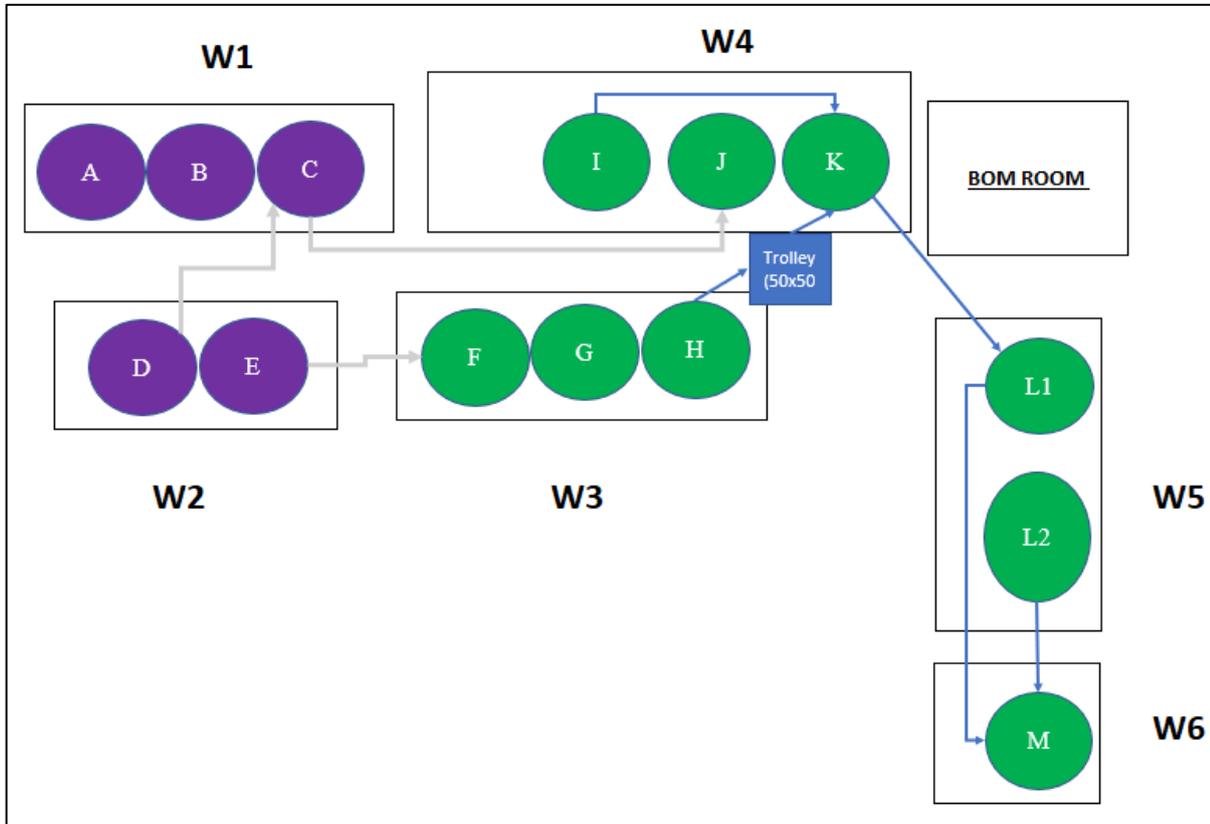


Fig 6. Modified layout of assembly line

Table no. 6: Reference to colour coding and symbols

	n - 1 Day Operation
	nth Day Operation
	Movement of material
	Non Value Adding Movement
	One Time Movement

Arrangements with respect to the previous layout have been changed with the aim of supporting line balancing and reducing the material handling. Since, the material flow between W3 and W4 is continuous therefore a trolley is installed between them to reduce material movement.

Following table shows the changes done in the former layout.



Table no. 7: Difference between initial and improved layout.

Sr no.	Previous Layout	Improved layout
1	W1: A & B W2: C & D W3: I, J, K & H W4: E, F & G	W1: A, B & C W2: D & E W3: F, G & H W4: I, J & K
2	4 non value adding movement	0 non value adding movement
3	BOM room is outside the assembly section, thus more travelling.	BOM room is adjusted inside the BOM room by rearranging the workstations and utilizing the unoccupied space.
4	No one time n-1 shift subassemblies movement.	One time movement for n-1 shift subassemblies hence it helps to reduce the material handling.
5	W6 position is very far to reach.	W6 position is now installed at a closer distance by rearranging the assembly line and to keep the material in flow.

III. EXPERIMENTAL RESULTS

Implementation of line balancing and lean manufacturing gave us following outcomes:

1. The daily production rate increased from 30 units/shift to 68 units/shift just by increasing one worker in the assembly section. (Increased by 226 %)
2. Material handling is reduced and non-value adding movements are eliminated.
3. Talent utilization was successfully done in the improvised format.
4. The industry got a standardized work flow system, which effectively reduced their unnecessary management.
5. The efficiency of the assembly line was estimated to be 95.09 %.

IV. CONCLUSION

In this research paper line balancing aided to standardize the assembly process, increase its efficiency, and reduce management efforts. This technique of industrial engineering has transformed the material flow system significantly. However, an assembly line can never be 100 % efficient but the implementation of concepts like lean manufacturing, line balancing, and facilities planning has conclusively helped them to increase their efficiency majorly.

Many facilities in India use a random procedure to manufacture their goods and therefore they are unable to fulfil the customer demand even if they double the frequency of working staff. The basic mathematical concept may not work every time for the effective functioning of assembly lines. Every process has to be observed, recorded, and analyzed to get a clear image of the scope of improvement and the selection of appropriate methods.

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