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PRODUCTIVITY IMPROVEMENT OF AN ASSEMBLY LINE USING LEAN MANUFACTURING TOOLS IN AN ELECTRONICS CONNECTORS MANUFACTURING FACILITY

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Abstract

Lean manufacturing system is currently being viewed as an important managerial strategy by companies since it focuses on reducing the non value added activities along with meeting customer demands. In an electronic parts manufacturing company; assembly line of a certain cable which is a high priority, high demand product is unable to meet the required production output. The main objective of the study is to improve the productivity of the assembly line by applying lean manufacturing techniques and discrete event simulation (DES). It mainly includes identifying and eliminating the non value added activities. The proposed methodology includes root causes analysis, identifying bottlenecks using DES, simulation of current and proposed assembly lines. Line balancing the new assembly line and a feasibility study to be performed if required. Line balancing of the current assembly line is conducted to identify the need for in depth study. The current assembly line selected for study showed a lower efficiency of 42.4% and 52.4%. Lean tools namely, fishbone diagram, 5 why analysis, spaghetti diagram were used to identify and analyse the existing non value added activities. Bottlenecks were identified which caused excess inventory and waiting in line, unwanted motion due to layout and extended lead time for transportation between plants were identified as current problems. Simulation of the current line and proposed line was conducted. Proposed model showed an efficiency of 83.10% and 83.98% without addition of additional labour and a payback period of 15 months for investment proposed. Few suggestions were proposed based on the gemba walk.

Keywords: Lean manufacturing, Assembly line balancing, Ranked position weighted method, Simulation, productivity improvement

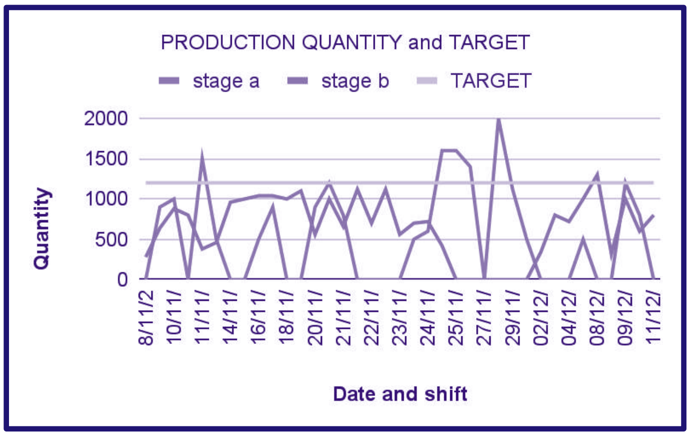
INTRODUCTION

1.1 General Background

With ever increasing competition in the electronic industry and fast paced change in nature of customer demand, the companies are focusing more on improving their productivity along with meeting the fluctuating demand. Lean manufacturing system is currently being viewed as an important managerial strategy by companies since it focuses on reducing the non value added activities along with meeting customer demands.

Assembly line balancing is a method of ensuring balanced workload among workstations. The line efficiency could be maximised by either reducing the cycle time for producing one part or increasing the number of workstations available or both. Sometimes it may not be economically feasible to rebalance the line based on cycle time requirements or the overall efficiency of the line may get reduced without much value addition. On such occasions, using lean manufacturing techniques has become a promising method. Lean manufacturing has identified three main wastes (3M). MUDA, MURA, MURI. Muda refers to a process which doesn't add value in consumer's view. There are seven types of waste identified in Lean thinking, Motion, Inventory, Overprocessing, Overproduction, Waiting, Transport, Defects; often referred to as TIMWOOD.

Fig 1.1. production data



1.2 Problem Definition

The current assembly line for the cable has a production demand of 1200 units per shift. The line is running extra shifts with workers from other lines to meet the demand since it fails to meet a demand of 1200 units per shift with current design. This causes the company loss economically and issues in day to day activity planning. The line needs to be checked for rebalancing and the root cause of lowered production output needs to be analysed.

1.2.1 Increase in production cost

Labour cost as per planned production = 10,000*24 = ₹ 2,40,000

Labour cost as per actual production = 10,000*34 = ₹ 3,40,000

Loss incurred by company in a month = 340000 - 240000 = ₹1,00,000

Loss incurred by company in an year = **₹ 100000*12 = ₹12,00,000**

LITERATURE REVIEW

2.1 Lean Manufacturing

Lean manufacturing is a method of manufacturing which focuses on elimination of non value added activities.[7] Lean aims to establish a workplace culture where the norm is to actively seek out and eliminate wastes, rather than merely addressing the symptoms, as is often the common practice in real-life scenarios. Most engineers often prefer opting for familiar, secure, and reliable materials and processes for a product rather than choosing cheaper alternatives. However, this inclination can lead to reduced profits for the organisation, increased costs for the engineer, and heightened economic risks [8][9]. Several factors contribute to motion waste, such as a poorly designed workstation layout causing excessive walking, bending, and reaching, inefficient method design involving unnecessary part transfers, large batch sizes, and the reorientation of materials[4][5].

2.2 Line Balancing

The most common two objectives for the ALB are minimising the number of workers or workstations (type-1) and minimising the cycle time (type-2). Though many heuristic, meta heuristic and algorithms were developed for solving SALBP, ranked position weighted method (heuristic) remains to be easy and mostly used. It considers both precedence relationship and task time. Qattavi [5] offers a comprehensive survey of assembly flow shop models along with their solution methodologies. The two most frequently utilised solution procedures are heuristics (38.8%) and hybrid algorithms (19.4%). SALBP mainly uses Heuristic solution methods in which ranked positional weight (RPW) algorithms are most widely used.[1]. Implementation of lean six sigma in an automotive assembly plant in order to reduce/eliminate non-value added processes in the assembly line.[3]

2.3 System Simulation

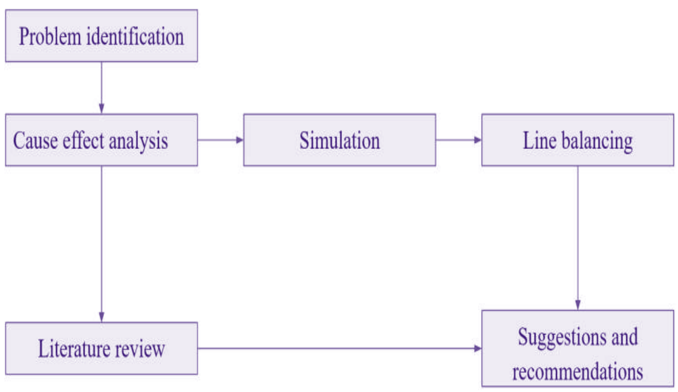
Statistical simulation is a powerful tool for system improvement, allowing the evaluation of proposed scenarios before implementation, which is crucial for decision-makers aiming to enhance systems. It's important to note that simulation itself is not an optimization process but provides system responses to various operating conditions. For optimization in their study, Opt Quest was used to evaluate various solutions.

Validation ensures the model behaves similarly to the real system, while verification ensures the model operates according to its assumptions. The model must reliably produce accurate results that align with the existing system.[8]. The utilisation and management of data generated by Discrete Event Simulation (DES) have not been extensively explored. Key Performance Indicators, such as daily throughput and Overall Equipment Effectiveness (OEE) were used with help of Internet Of Things[3].

Another article employed a combined discrete event simulation and optimization approach to address the assembly line balancing problem (ALBP) in the apparel industry. [2]. Studies examining the effects of various influencing parameters, such as layout, resource utilisation, automation, setup time, and inventory, on output gave a much broader light to ALBP.[3][4].

RESEARCH METHODOLOGY

Fig 3.1. Research methodology



4.3 Detailed Methodology

Primary data collection led to the conclusion that the current system is incapable of meeting the required production output even if rebalancing is performed. This calls for an in depth study about the root causes for the lowered production output than required. It involves identifying the non value added activities by analysing the system in detail. For conducting the study several input data are required. They are:

- Individual time of each operation and workstation
- Material and operator movement

4.3.2 Time study

A time study is a systematic process of observing and recording the time it takes for a person to perform a specific task or set of tasks using a timekeeping device such as a stopwatch or videotape camera.

4.3.4 Root cause analysis

Root Cause Analysis (RCA) is a method used to identify the underlying causes of problems. It involves the following steps :Brainstorming, document the possible causes identified during brainstorming, narrow down the most probable causes for the problem in the current situation from the possible causes, identify and analyse the presence of probable causes and draw a cause effect diagram to validate the finding using various root cause analysis tools (eg : why why, fishbone diagram, pareto chart), suggest improvement and document the effect of the same by applying them.

4.3.5 Simulation

Simulating involves creating a virtual model that replicates the real-world processes and activities of the assembly line. Simulation allows you to analyse and optimise the performance of the processes without the need for physical implementation or experimentation. The steps involved in simulating the system is:

1. **Define Objectives**
2. Model the System: Use simulation software to create a detailed model of the assembly line. Define the processes, flows, and interactions between different components. Simulation tools often provide graphical interfaces for designing and configuring the model.
3. Define Resources and Constraints: Specify the resources available at each workstation, such as machines, tools, and human operators. Consider any constraints or limitations that may impact the flow of materials or the production process.
4. Set Initial Conditions
5. Run the Simulation
6. Verification and validation

4.4 Assumptions Of The Project

- Enough number of worker are available
- No shortage of raw materials
- Flexible workers

DATA COLLECTION

4.1 Work Breakdown Structure

Tasks performed in the assembly line is break downed into work elements. Due to the nature of assembly; the main assembly line is split into two stages: stage a and stage b. The assembly process includes: completion of stage a – over moulding process - stage b assembly.

Standard time was calculated using formula:

Standard time = normal time*(1+ allowances)

Where; Normal time = mean value of sample*performance rating

performance rating is taken based on speed of the worker in comparison with standard worker. An allowance of 12% and 15% is provided depending on task

- personal allowance = 9%
- Repetitive task = 1%
- Fine concentration = 2% (or) Very fine concentration = 5%

Table 4.1. Standard time obtained

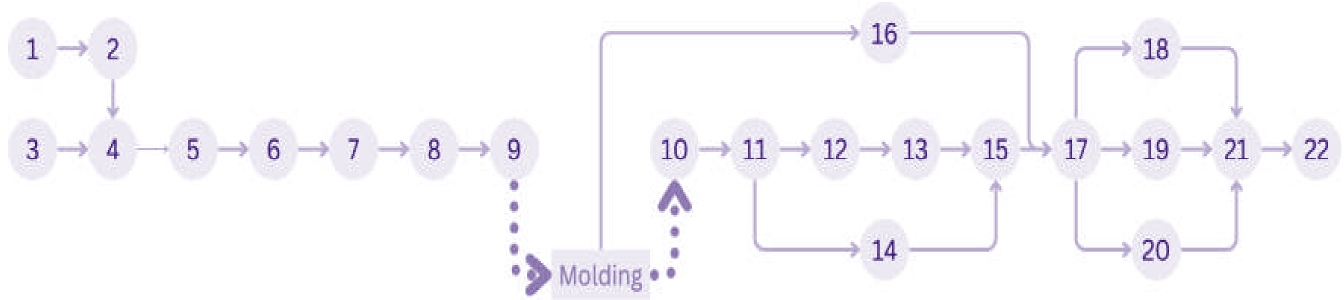
task no	task	standard time	throughput 7.5hr
1	Contact cutting	5.50	4909.09
2	dummy contact placement	8.73	3092.78
3	contact and housing sub assembly	42.17	640.27
4	primer application	4.87	5544.15
5	sealant application and curing	39.15	689.66

6	heat seal placement	9.30	2903.23
7	heat shrink application	12.25	2204.08
8	QC application	2.22	12162.16
9	packing	1.00	27000.00
task no	task	standard time	throughput 7.5hr
10	boot assembly and inspection	8.20	3292.68
11	cable jacket and wire insulation strippin	33.10	815.71
12	contact crimping	20.38	1324.83
13	inspection	11.80	2288.14
14	white strip removal	16.00	1687.50
15	contact and housing assembly	48.00	562.50
16	seal assembly	6.30	4285.71
17	100% electrical and mating load testing	17.70	1525.42
18	100% dimension measurement	13.20	2045.45
19	Label wrapping 1	17.80	1516.85
20	Label wrapping 2	15.70	1719.75
21	QC inspection	17.00	1588.24
22	final packing	1.30	20769.23

PRECEDENCE RELATIONSHIP

Precedence relationships explore the predecessor activity for each activity. An activity can be performed only after all its predecessors are completed.

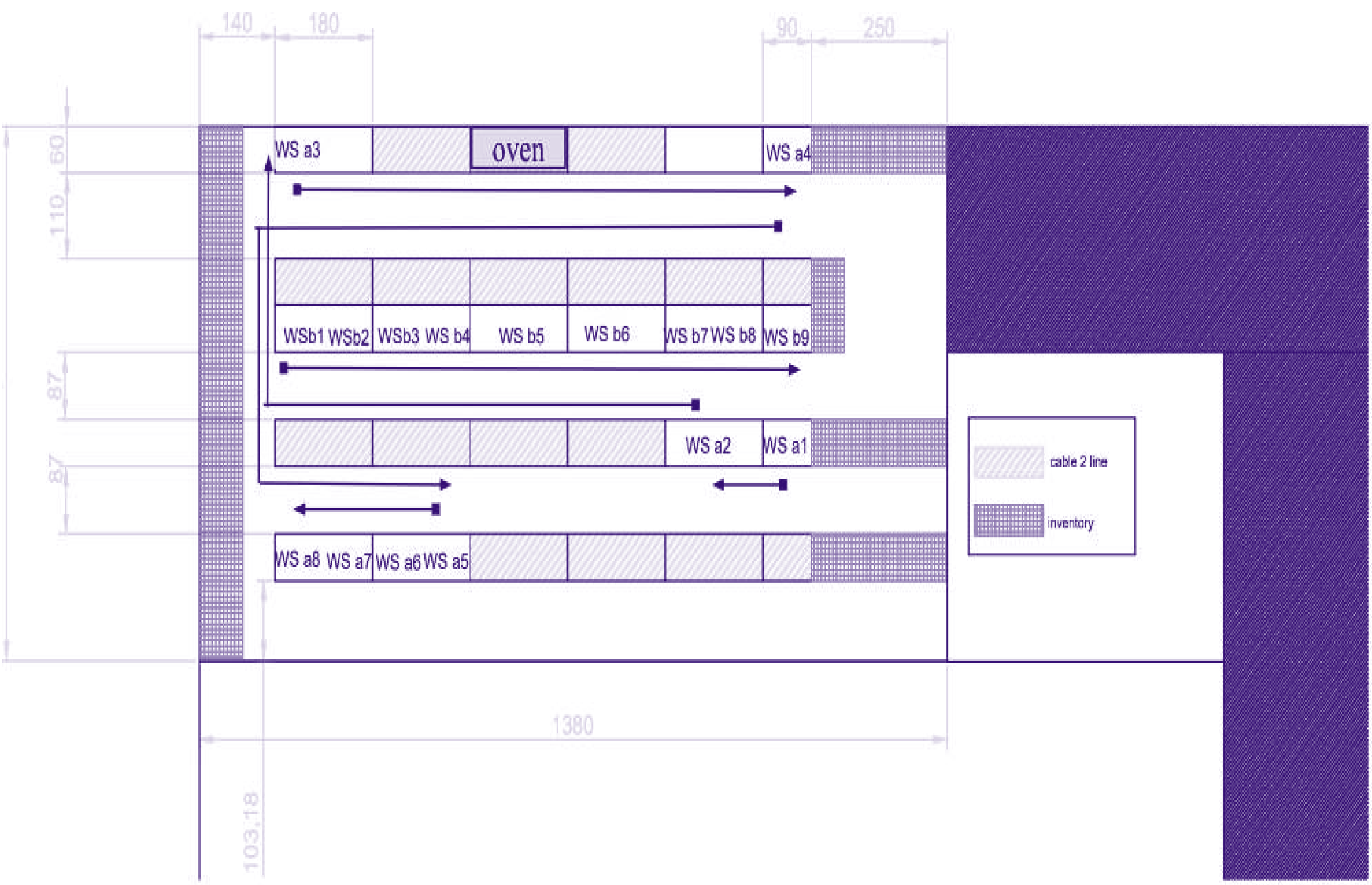
Fig 4.1. Precedence diagram



1) Dummy contact extract	5) Sealant application	9) packing	13) inspection	17) 100% electrical and mating load testing	21) QC 2
2) dummy contact assembly	6) Heat seal placement	10) boot assembly and inspection	14) white strip removal	18) 100% dimension measurement	22) final packing
3) housing sub assembly	7) Heat shrink	11) cable jacket and wire insulation stripping	15) contact and housing assembly	19) Label wrapping 1	
4) primer application	8) QC 1	12) contact crimping	16) seal assembly	20) Label wrapping 2	

4.3 Layout Layout plays an important role in the assembly line since it defines how the flow happens, the space constraints, workstation location etc.

Fig 4.2. Assembly line layout



DATAANALYSIS

5.1 Bottleneck Identification

The standard time calculation helped to identify the processes which may act as a bottleneck to meet the current production output. Contact and housing sub assembly, sealant application and curing, cable jacket and wire insulation stripping, contact crimping were identified as the processes with processing time higher than required takt time of 24 sec.

5.2 Current Efficiency

STAGE a ASSEMBLY: Demand per shift (r)= 1200 Working hours = 7.5 hr Takt time, c= 1/r = 1/1200 = **22.5 sec** Theoretical minimum station = ∑t/c = 125.2/22.5 = 5.564 = **6 workstations** Maximum theoretical efficiency = ∑t*100/nc = 125.2*100/(6*22.5)=**92.741%** Current line efficiency = 125.2*100/(7*42.17)=**42.413%**	STAGE b ASSEMBLY: Demand per shift (r)= 1200 Working hours = 7.5 hr Takt time, c= 1/r = 1/1200 = **22.5 sec** Theoretical minimum station = ∑t/c = 226.5/22.5 = 10.067 = **11 workstations** Maximum theoretical efficiency = ∑t*100/nc = 226.5*100/(11*22.5)= **91.515%** Current line efficiency = 226.5*100/ (9*48) = **52.431%**

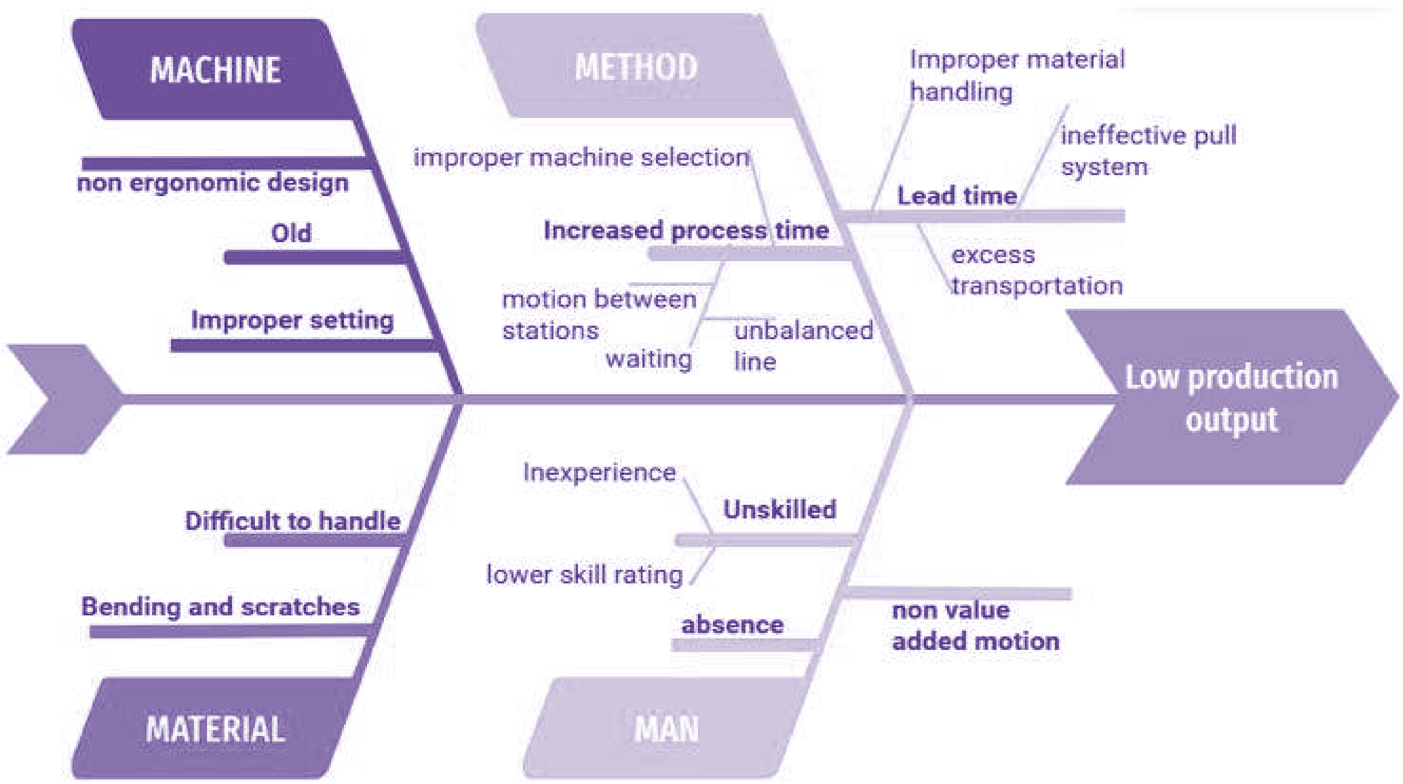
5.3 Root Cause Analysis

5.3.1 Cause identification

A fishbone diagram was drawn after brainstorming with members from different departments such as industrial, production, supply chain management; including people from different hierarchies - managers, process engineers, workers, supervisors etc.

The team reported the main issues of lowered production to be unbalanced line; causing waiting at some workstations and worker unavailability. The poor ergonomics of the crimping machine and dummy extractor were also mentioned.

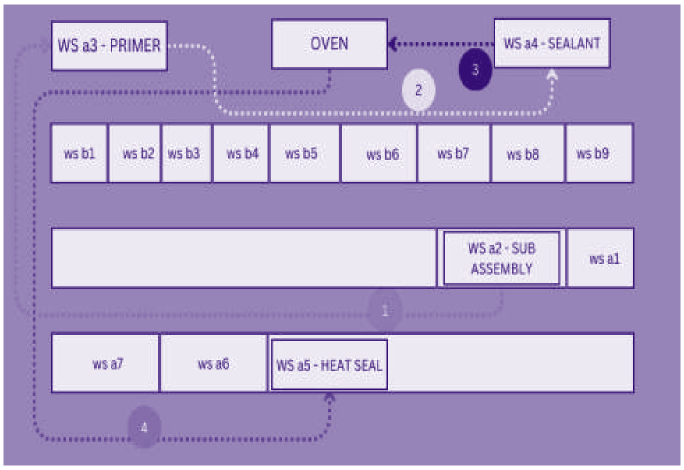
Fig 5.1. Fishbone diagram



5.3.2 Root cause analysis

Unwanted motion identified (shown in Fig 6.2):

Fig 5.2. Spaghetti chart



Routes :

Route 1 - WS2 to WS3 - 35 steps

Route 2 - WS3 to WS4 - 20 steps

Route 3 - WS4 to oven - 10 steps

Route 4- oven to WS5 - 30 steps

As a batch of 40 units

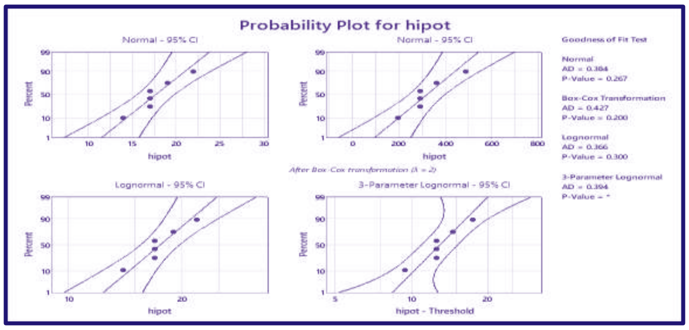
Waste in the form of unnecessary motion is detected. Waiting : time study helped to identify the waiting occurring at different workstations.

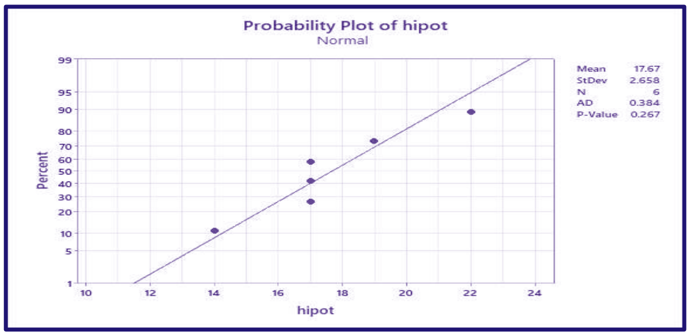
5.4 Simulation Analysis

5.4.1 Input Modelling

Input modelling constitutes a critical step in simulation design, encompassing the selection and characterization of random variables that influence the system under

Fig 5.4 : Probability plot for hipot testing.



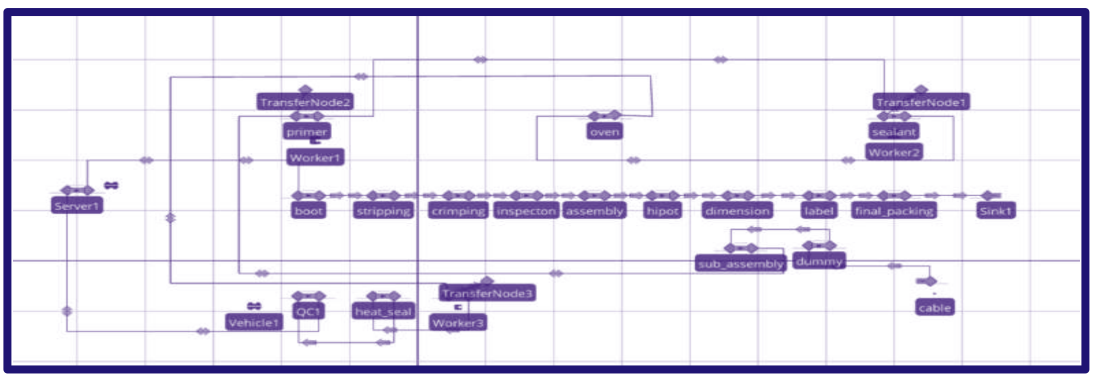


investigation. These variables represent the inherent stochasticity within the system, such as customer arrival times in a retail setting or machine failure rates in a manufacturing environment. By meticulously selecting probability distributions that accurately depict the behaviour of these input variables, the construction of a more realistic and reliable simulation model is facilitated. Input modelling is performed using MINITAB software. The cycle time collected is checked for goodness of fit across various probability distributions using hypothesis testing and best fit is selected for each of the data. Fig 5.4 shows Probability plot for hipot testing. Distribution with highest AD value and lowest p value is selected.

5.4.2 Simulation Modelling.

SIMIO software is used for simulating the assembly line. The software requires parameters namely: number of workstations (denoted as servers in model), capacity of each workstation, processing time and its distribution, relationship between workstation, path of flow of product are obtained by input modelling and real life data collection.

Fig 5.5. (a) Simulation model of current assembly line, (b) Throughput (c) Utilisation across workstations



Object Type	Object Name	Data Source	Category	Data Item		8_6_24_1 Average	...	...	Half Width
Server	assembly	Processing	Throughput	NumberExited	...	562.9000	56	56	0.9204
	boot	Processing	Throughput	NumberExited	...	500.0000	50	50	0.0000
	crimping	Processing	Throughput	NumberExited	...	615.1000	58	64	12.8156
	dimension	Processing	Throughput	NumberExited	...	562.9000	56	56	0.9204
	dummy	Processing	Throughput	NumberExited	...	1,784.9000	1,	1,ı	34.5501
	final_packing	Processing	Throughput	NumberExited	...	563.0000	56	56	0.8921
	heat_seal	Processing	Throughput	NumberExited	...	637.5000	61	64	7.0832
	heat_seal_cap	Processing	Throughput	NumberExited	...	637.4000	62	64	4.4760
	hipot	Processing	Throughput	NumberExited	...	562.6000	56	56	1.0228
	inspecton	Processing	Throughput	NumberExited	...	615.9000	58	64	13.0529
	label	Processing	Throughput	NumberExited	...	562.6000	56	56	1.0769
	oven	Processing	Throughput	NumberExited	...	638.8000	63	64	4.7063
	primer	Processing	Throughput	NumberExited	...	639.6000	60	67	13.1603
	QC1	Processing	Throughput	NumberExited	...	637.6000	61	64	7.1467
	sealant	Processing	Throughput	NumberExited	...	638.7000	62	64	4.8520
	Server1	Processing	Throughput	NumberExited	...	500.0000	50	50	0.0000
	stripping	Processing	Throughput	NumberExited	...	614.5000	58	64	12.8457
	sub_assembly	Processing	Throughput	NumberExited	...	639.0000	63	65	4.6480
Source	Source1	Processing	Throughput	NumberExited	...	1,783.9000	1,ı	1,ı	34.9265

Simulation model of the existing line was created from the above said data. Each workstation is represented as a server with dedicated input, processing and output logic.

After running the system for 100 hrs with 92.5 hrs warm up period and 10 replications. This data is used to verify and validate the simulation model.

A new layout is proposed by eliminating the unnecessary motion between workstations identified in the previous section. This required redesigning STAGE 1 assembly line. Total of 30 units were produced extra per shift due to the new layout.

fig 5.5. (c) Improvement obtained due to layout change

Object Type	Object Name	Data Source	Category	Data Item		Scenario 8_6_24_1 Average	Minimum	Maximum	Half Width
Server	assembly	[Resource]	Capacity	ScheduledUtilization	...	100.0000	100.0000	100.0000	0.0000
	boot	[Resource]	Capacity	ScheduledUtilization	...	15.1900	15.1416	15.2801	0.0283
	crimping	[Resource]	Capacity	ScheduledUtilization	...	46.3532	44.0521	47.8086	0.9488
	dimension	[Resource]	Capacity	ScheduledUtilization	...	27.4387	27.1883	27.7003	0.1249
	dummy	[Resource]	Capacity	ScheduledUtilization	...	57.7026	55.0194	60.0276	1.0858
	final_packing	[Resource]	Capacity	ScheduledUtilization	...	38.2086	37.7681	38.6106	0.1784
	heat_seal	[Resource]	Capacity	ScheduledUtilization	...	28.8798	28.0397	29.3660	0.2628
	heat_seal_cap	[Resource]	Capacity	ScheduledUtilization	...	22.2604	21.7381	22.5560	0.1616
	hipot	[Resource]	Capacity	ScheduledUtilization	...	50.0640	49.4514	50.3999	0.1934
	inspecton	[Resource]	Capacity	ScheduledUtilization	...	63.3474	60.4329	66.2090	1.3698
	label	[Resource]	Capacity	ScheduledUtilization	...	69.8360	69.2373	70.2805	0.2435
	oven	[Resource]	Capacity	ScheduledUtilization	...	26.0132	25.6913	26.4402	0.1935
	primer	[Resource]	Capacity	ScheduledUtilization	...	11.7782	11.1048	12.4180	0.2269
	QC1	[Resource]	Capacity	ScheduledUtilization	...	7.5903	7.3092	7.7157	0.0878
	sealant	[Resource]	Capacity	ScheduledUtilization	...	92.9349	91.0290	94.5058	0.8182
	Server1	[Resource]	Capacity	ScheduledUtilization	...	3.6931	3.6292	3.7398	0.0223
	stripping	[Resource]	Capacity	ScheduledUtilization	...	75.1171	71.8345	78.3083	1.5489
	sub_assembly	[Resource]	Capacity	ScheduledUtilization	...	100.0000	100.0000	100.0000	0.0000
Vehicle	Vehicle1[1]	[Resource]	Capacity	ScheduledUtilization	...	95.4616	95.0333	95.7554	0.1994
	Vehicle2[1]	[Resource]	Capacity	ScheduledUtilization	...	3.6898	3.6253	3.7354	0.0219
Worker	Worker1[1]	[Resource]	Capacity	ScheduledUtilization	...	100.0000	100.0000	100.0000	0.0000
	Worker2[1]	[Resource]	Capacity	ScheduledUtilization	...	99.8584	99.5122	100.0000	0.1151
	Worker3[1]	[Resource]	Capacity	ScheduledUtilization	...	100.0000	100.0000	100.0000	0.0000

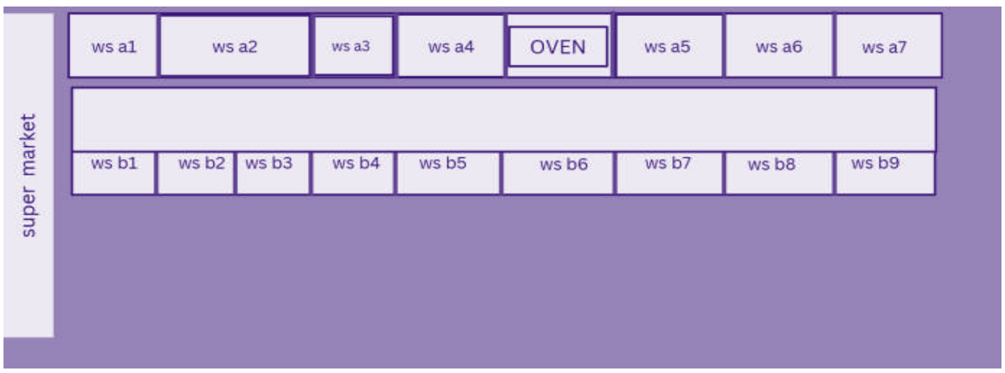
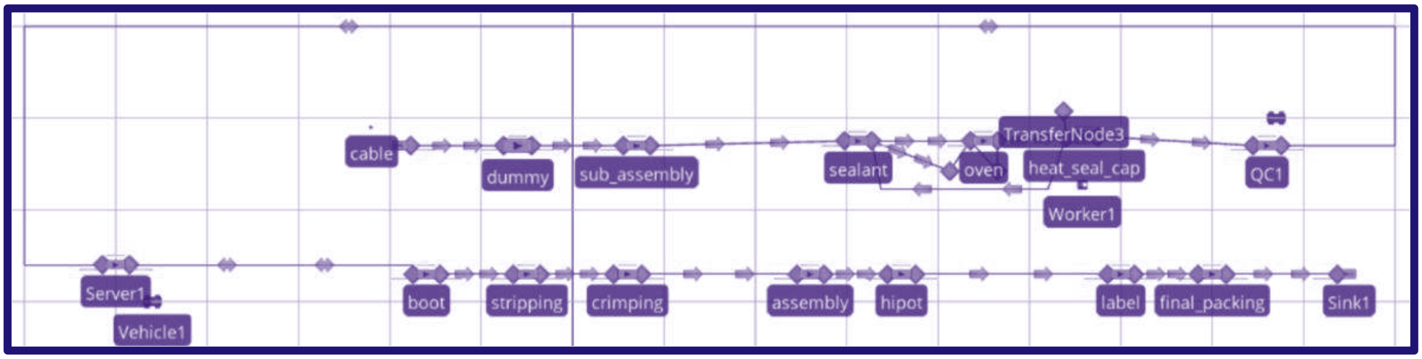


Fig 5.5.(a). New layout model



5.5(b) shows a model of the same, table 5.2 shows improvement obtained due to layout change.

Sl. No.	Route	time (sec)	no of trips	total time/shift (min)	Throughput @ 22.5sec
1	sub assembly - primer	31.93	30	15.96	42.57
2	primer - sealant	21.22	30	10.61	28.29
3	sealant - oven	19.73	30	9.86	26.31
4	oven - heat seal cap	31.33	30	15.67	41.78

In the next step, possible bottleneck workstations identified through throughput analysis were given extra capacities. The capacity assessment was transformed into an optimisation problem and was solved using inbuilt platform optquest. The details of optimisation problem are:

Parameters, objective function, constraints, warm up period, run time.

Scenario run:

- Introducing new labelling machines to model before running.
- Objective: Maximise throughput
- Control parameters: No of parallel machines/workers for bottleneck processes
- $1 \leq$ Control parameters ≥ 4

Fig 5.6.(a) Utilisation of new model before introducing strip-crimp machine

Object Type	Object Name	Data Source	Category	Data Item		Average	...	...	Half Width	Average	...	...	Half Width
Server	assembly	[Resource]	Capacity	ScheduledUtilization	...	74.5135	73	75	0.1302	100.0000	10	10	0.0000
	boot	[Resource]	Capacity	ScheduledUtilization	...	75.0551	72	76	0.2332	77.0084	76	78	0.3568
	crimping	[Resource]	Capacity	ScheduledUtilization	...	74.5352	73	75	0.1222	79.8594	79	80	0.3386
	dummy	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000
	final_packing	[Resource]	Capacity	ScheduledUtilization	...	85.0450	83	86	0.1857	76.2224	75	76	0.2612
	heat_seal_cap	[Resource]	Capacity	ScheduledUtilization	...	43.7473	43	44	0.0977	43.7244	43	44	0.1936
	hipot	[Resource]	Capacity	ScheduledUtilization	...	82.5027	81	83	0.1512	73.6047	73	74	0.2184
	label	[Resource]	Capacity	ScheduledUtilization	...	98.5464	97	99	0.1461	88.1389	87	88	0.2716
	oven	[Resource]	Capacity	ScheduledUtilization	...	50.9936	50	51	0.0697	51.0170	50	51	0.0997
	QC1	[Resource]	Capacity	ScheduledUtilization	...	71.7726	70	72	0.1180	71.6930	71	72	0.3358
	sealant	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000
	Server1	[Resource]	Capacity	ScheduledUtilization	...	56.4263	54	58	0.2197	50.2206	48	51	0.5942
	stripping	[Resource]	Capacity	ScheduledUtilization	...	97.8243	96	98	0.1591	53.1396	52	53	0.2293
	sub_assembly	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000

Rebalancing of the lines obtained from selected solutions was done since work imbalance was noted across workstations. Precedence relationships were followed and these lines were run for observing changes.

Fig 5.6.(b) shows throughput of the new model before introducing the strip-crimp machine.

Object Type	Object Name	Data Source	Category	Data Item	Statistic	Average	Minimum	Maximum	Half Width
Server	assembly	Processing	Throughput	NumberExited	Total	1,298.0000	1,272.0(	1,314.00	8.7931
	boot	Processing	Throughput	NumberExited	Total	1,324.7000	1,307.0(	1,337.00	7.5479
	crimping	Processing	Throughput	NumberExited	Total	1,298.2000	1,273.0(	1,314.00	8.5359
	dummy	Processing	Throughput	NumberExited	Total	1,707.9000	1,704.0(	1,711.00	1.4871
	final_packing	Processing	Throughput	NumberExited	Total	1,257.4000	1,239.0(	1,269.00	6.6438
	heat_seal_cap	Processing	Throughput	NumberExited	Total	1,250.6000	1,240.0(	1,260.00	6.4086
	hipot	Processing	Throughput	NumberExited	Total	1,298.0000	1,272.0(	1,313.00	8.7542
	label	Processing	Throughput	NumberExited	Total	1,257.2000	1,238.0(	1,268.00	6.9171
	oven	Processing	Throughput	NumberExited	Total	1,250.0000	1,244.0(	1,257.00	2.9971
	QC1	Processing	Throughput	NumberExited	Total	1,252.9000	1,237.0(	1,265.00	6.6459
	sealant	Processing	Throughput	NumberExited	Total	1,251.8000	1,244.0(	1,256.00	2.8373
	Server1	Processing	Throughput	NumberExited	Total	1,278.7000	1,254.0(	1,307.00	11.8070
	stripping	Processing	Throughput	NumberExited	Total	1,327.9000	1,306.0(	1,346.00	8.8411
	sub_assembly	Processing	Throughput	NumberExited	Total	1,282.1000	1,274.0(	1,291.00	3.4130
Source	Source1	Processing	Throughput	NumberExited	Total	1,790.5000	1,712.0(	1,833.00	25.9013
Worker	Worker1[1]	[Resource]	ResourceState	TimeBusy	Average (Hou...	0.0522	0.0512	0.0526	0.0003
					Occurrences	62.8000	62.0000	64.0000	0.4524
					Percent	43.6686	43.2260	44.1678	0.2210
					Total (Hours)	3.2751	3.2420	3.3126	0.0166

Fig 5.7.(a) shows throughput

Object Type	Object Name	Data Source	Category	Data Item		Average	...	...	Half Width	Average	...	...	Half Width
Server	assembly	[Resource]	Capacity	ScheduledUtilization	...	74.5135	73	75	0.1302	100.0000	10	10	0.0000
	boot	[Resource]	Capacity	ScheduledUtilization	...	75.0551	72	76	0.2332	77.0084	76	78	0.3568
	crimping	[Resource]	Capacity	ScheduledUtilization	...	74.5352	73	75	0.1222	79.8594	79	80	0.3386
	dummy	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000
	final_packing	[Resource]	Capacity	ScheduledUtilization	...	85.0450	83	86	0.1857	76.2224	75	76	0.2612
	heat_seal_cap	[Resource]	Capacity	ScheduledUtilization	...	43.7473	43	44	0.0977	43.7244	43	44	0.1936
	hipot	[Resource]	Capacity	ScheduledUtilization	...	82.5027	81	83	0.1512	73.6047	73	74	0.2184
	label	[Resource]	Capacity	ScheduledUtilization	...	98.5464	97	99	0.1461	88.1389	87	88	0.2716
	oven	[Resource]	Capacity	ScheduledUtilization	...	50.9936	50	51	0.0697	51.0170	50	51	0.0997
	QC1	[Resource]	Capacity	ScheduledUtilization	...	71.7726	70	72	0.1180	71.6930	71	72	0.3358
	sealant	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000
	Server1	[Resource]	Capacity	ScheduledUtilization	...	56.4263	54	58	0.2197	50.2206	48	51	0.5942
	stripping	[Resource]	Capacity	ScheduledUtilization	...	97.8243	96	98	0.1591	53.1396	52	53	0.2293
	sub_assembly	[Resource]	Capacity	ScheduledUtilization	...	100.0000	10	10	0.0000	100.0000	10	10	0.0000

Fig 5.7.(b) shows utilisation of the new model after introducing the strip-crimp machine.

Object Type	Object Name	Data Source	Category	Data Item		Average	...	...	Half Width	Average	...	...	Half Width
Server	assembly	Processing	Throughput	NumberExited	...	1,257.6122	1,	1,	2.0327	1,149.8000	1,	1,	2.1273
	boot	Processing	Throughput	NumberExited	...	1,334.1429	1,	1,	3.9541	1,397.0000	1,	1,	5.5305
	crimping	Processing	Throughput	NumberExited	...	1,257.5918	1,	1,	2.0413	1,377.2000	1,	1,	5.6605
	dummy	Processing	Throughput	NumberExited	...	1,708.8367	1,	1,	0.5180	1,747.2000	1,	1,	1.6450
	final_packing	Processing	Throughput	NumberExited	...	1,255.0816	1,	1,	2.0982	1,149.8000	1,	1,	2.2316
	heat_seal_cap	Processing	Throughput	NumberExited	...	1,253.6531	1,	1,	2.5490	1,280.6000	1,	1,	7.1068
	hipot	Processing	Throughput	NumberExited	...	1,257.7347	1,	1,	2.0224	1,149.6000	1,	1,	2.0288
	label	Processing	Throughput	NumberExited	...	1,255.1429	1,	1,	2.0784	1,150.2000	1,	1,	2.0732
	oven	Processing	Throughput	NumberExited	...	1,251.5306	1,	1,	1.6079	1,280.2000	1,	1,	2.8172
	QC1	Processing	Throughput	NumberExited	...	1,252.5306	1,	1,	1.7848	1,279.7000	1,	1,	4.0611
	sealant	Processing	Throughput	NumberExited	...	1,252.0204	1,	1,	0.7105	1,279.9000	1,	1,	1.8910
	Server1	Processing	Throughput	NumberExited	...	1,267.5918	1,	1,	4.8897	1,153.8000	1,	1,	12.7549
	stripping	Processing	Throughput	NumberExited	...	1,257.6327	1,	1,	2.0197	1,397.5000	1,	1,	5.4606
	sub_assembly	Processing	Throughput	NumberExited	...	1,278.6939	1,	1,	2.2042	1,308.5000	1,	1,	7.3355
Source	Source1	Processing	Throughput	NumberExited	...	1,800.0204	1,	1,	14.2526	1,856.9000	1,	1,	33.4158

The output of the final workstation is considered as the shift output. The model produced a total of 1257 units during a shift. Fig 5.7.(a) shows throughput of the new model after introducing strip-crimp machine, Fig 5.7.(b) shows utilisation of the new model before introducing the strip-crimp machine. The model produced a total of 1255 units during a shift. Fig 5.8, table 5.3 shows scenario run output. The throughput doesn't increase much with respect to manpower increase. Introduction of new strip-crimp machine will make it possible to achieve the required throughput with existing manpower; 16. Fig 5.9 shows the average utilisation of workstations for new models after introducing strip-crimp machine. Manpower requirement is given in the bracket.

Stage a line utilisation: 83.10 % (current line utilisation : 42.4%) Stage b line utilisation : 83.98 % (current line utilisation : 52.4%)

Table 5.3. Scenario run output

Sl. No.	sub.	assembly	stripping	sealant	label	Throughput	Manpower
1	2	3	2	2	1	1257.5	17
2	2	4	2	2	1	1253.5	18
3	2	3	3	2	1	1261.0	18
4	2	3	2	3	1	1272.5	18
5	3	3	2	2	1	1261.2	18
6	3	3	2	3	1	1272.2	19
7	4	3	2	2	1	1256.2	19
8	2	3	2	4	1	1272.7	19
9	3	4	2	2	1	1256.0	19
10	2	3	4	2	1	1260.8	19
11	2	4	3	2	1	1255.3	19
12	2	4	2	3	1	1272.8	19
13	2	3	3	3	1	1272.2	19

5.5 Economic Analysis

The incorporation of new labelling processes necessitates the acquisition of dedicated labelling machines, resulting in an incremental cost burden. Similarly, the implementation of stripping and crimping activities requires the procurement of new, specialised machines. An extra set of machines is already installed in the premise for primer and sealant applications. Thus they add no extra cost. Existing personnel can manage the proposed improvement without additional workload.

5.5.1 Cost

Table 5.4. Investment proposed

SL NO	MANCHINE	SPECIFICATIONS	PURPOSE	COST (RS)
1	Cable Labeler	1800 pcs/hr	Label 1	520000
2	Semi-automatic Wrap-around-Labeler	1400 psc/hr	Label 2	200000
3	velcro	6*0.05 m	managing batch of cable	150
4	stripping	9*80 mm	stripping	200000
5	Crimping	7mm	Crimping	600000
6	strip&crimp	14mm	strip&crimp	900000

Recommended purchase: One unit of each machine 1,2,4,5 or 1,2,6 along with eight units of 3

Total cost of ₹ 15,00,000 - ₹ 16,21,000

6.5.2 Benefits

- Total investment: ₹ 16,21,000
- Labour charge saved by avoiding extra shift: ₹ 1,00,000 per month
- 1255 units production achievable; one lesser shift.
- Labour charge saved: ₹ (1,00,000 + 10,000) per month = ₹ 1,10,000
- Payback period: ₹ 16,21,000 / ₹ 1,10,000 = 14.73 ≈ 15 months

Table 6.8 shows investment proposed for the assembly line in order to implement the new model proposed. Fig 6.12 is a graph denoting the payback period of the same. Table 6.9 on the other hand shows an alternative approach, where no new label machine, strip-crimp machine is introduced; but additional labours are provided to meet the demand. Both methods demand a payback period of 15 months.

CONCLUSION

The current assembly line selected for study showed a lower efficiency of 42.4% and 52.4%. The line was selected since it produces a high demand, high priority product. The assembly line was split into two stages (stage a before molding and stage b after molding) for ease of working. Work elements were identified. Standard time was calculated and a precedence relationship was established. A methodology involving identification and elimination of 7 defects of lean was undertaken which involved root cause analysis and simulation. Tools such as fishbone diagram, 5 why analysis, spaghetti diagram were used to identify and analyse the existing non value added activities. Method study was conducted to identify unwanted motions while performing each work element. Bottlenecks were identified which caused excess inventory and waiting in line; unwanted motion due to layout and extended lead time for transportation between plants were identified as current problems. Improvements for the existing line were proposed. Simulation of the current line and proposed line was conducted; since it may not be viable to try them in real world firsthand. Simulation run of the current line helped to verify and validate the model. The proposed line was simulated in three stages. Initially a layout change; which showed an improvement of 30 units of extra production per shift, followed by a model where a label machine was introduced. A situation analysis was conducted to identify the optimal number of labours and/or machines required to attain the target production. Later on another model was analysed which involved combining stripping and crimping machines. The throughput results were similar. A feasibility study was conducted which calculated a payback period of 15 months.

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