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ORIGINAL ARTICLE

The Assessment of Man and Method Toward the Assembly Line Improvement in Automotive Manufacturing

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ABSTRACT – This research deal with root cause analysis of using Lean Manufacturing principle for assembly line at X manufacturing automotive company in Malaysia. This research aims to improve the process and manpower allocation in the T-Model assembly line and to increase the productivity efficiency of Man and Method toward production output. Movement waste and waiting waste were subjects that were studied in this research. Data was collected through the interview process, observation, photos and calculating the current total production process time related to the assembly process. Process flow in the actual layout, process setup and simulation of the existing design using Witness Software were used to determine the section or method with the highest idle percentage or setup time. The witness Software was also used to simulate the improved layout, and the improvement then is suggested. In conclusion, the entire production process is presented, which initially offered very low productivity. With the line balancing and discrete event simulation model combination, productivity is increased from 3 units per shift initially to 6 units per shift manufactured product at the end. 40% increase in the production output. The proposed layout and practice are done, and the improvement was highlighted at an assembly line.

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Manufacturing
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Assembly line

INTRODUCTION

To respond to the increase in customer needs, accelerated lead times, tight delivery times and shorter product life cycles, companies have widely increased their product to the highest capacity of the assembly line. Lean manufacturing is a method to reduce waste in every aspect of automotive production. Root cause analysis (Man: Machine: Method: Material) is the best technique to identify the condition that initiates an undesired activity or state besides other techniques line Quality Circle, 5S Housekeeping, Kanban and many others.

Modern manufacturing systems are becoming more and more flexible by making multiple products is typical in many production systems. To ensure efficient production to satisfy the demands of different products, optimal control and scheduling play a critical role in responding to increasing customer needs, accelerated lead-time, fast delivery and shorter life cycles [1]. The companies have widely increased the variety of their products. The increasing variety has several reasons, including customers' constant demand for new products, regional requirements and industry regulations, and market fragmentation with different needs and certification specifications. Consequently, to deal with product variety and demand fluctuations, industries should develop changeable manufacturing systems that help to produce a more comprehensive product variety [2]. Technology innovation and economic internationalisation move globalisation toward new opportunities for many companies [3]. Cooperating with partner companies in supply chain management is crucial to increase efficiency. Increased societal demand for sustainability has resulted in attention to sustainable manufacturing [4]. According to Parvez et al., line balancing is "design of a smooth production flow' by allotting processes to workers to allow each worker to complete the allotted workload within a given time [5]. Assembly line balancing is a family of combinatorial optimisation problems that have been widely studied in the literature due to its simplicity and industrial applicability [6].

RESEARCH BACKGROUND

Company X is an automotive CKD automotive plant manufacturing company in Malaysia. The company produces different car segments, and the market demand grows yearly. The CKD production plant is increasing the volume of production based on demand. The impact of the demand, the study needs to propose the best solution to increase the volume for the particular model, which is the T-model. This research is to improve the assembly line based on Man and Method, the lean manufacturing method of 4M analysis. The Witness Software will be conducted based on the layout

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process, allocation of human resources, and station cycle time. Figures 1 shows the current layouts of the assembly for Station 9, which is the focus of the study.

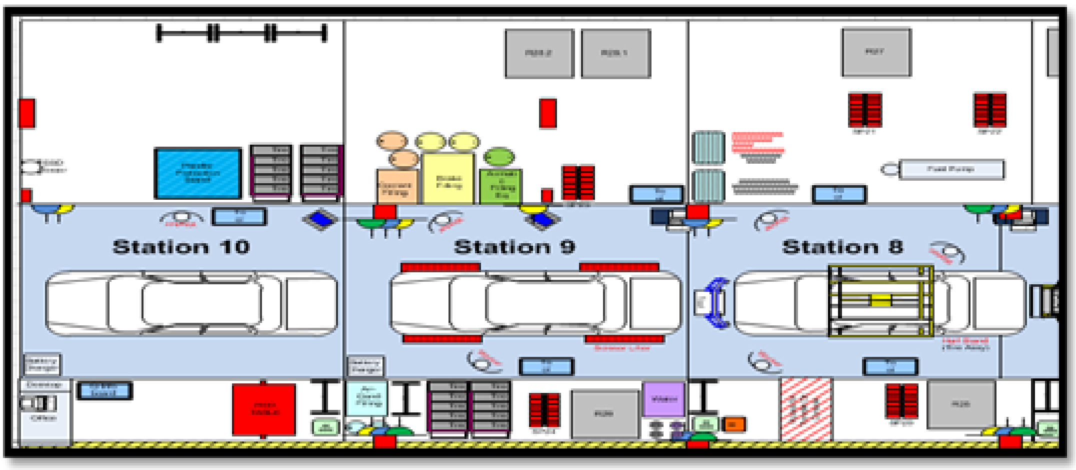


Figure 1. Assembly layout for Station 9

The production output target for this particular T-Model is six units per day (UPD). Nevertheless, based on the current set-up, the assembly line's capacity for the T-Model can only produce three UPD. To achieve the current demand of six UPD, the 4M root cause analysis is used to find the best solution to improve the assembly line for T-Model. Therefore, this study aims to improve the process and manpower allocation at Station 9 for the T-Model assembly line. The improvement shall increase the productivity efficiency of Man and Method toward achieving production output.

The study started with literature reviews as in Figure 2, on root cause analysis such as 4M, Kaizen, Takt Time, Assembly Line Process and Setup Time Improvement. Then, the study proceeded with data collection at automotive company X by analysing the situation at the assembly line. The study focused on the factory's T-Model assembly line, a low-output assembly line.

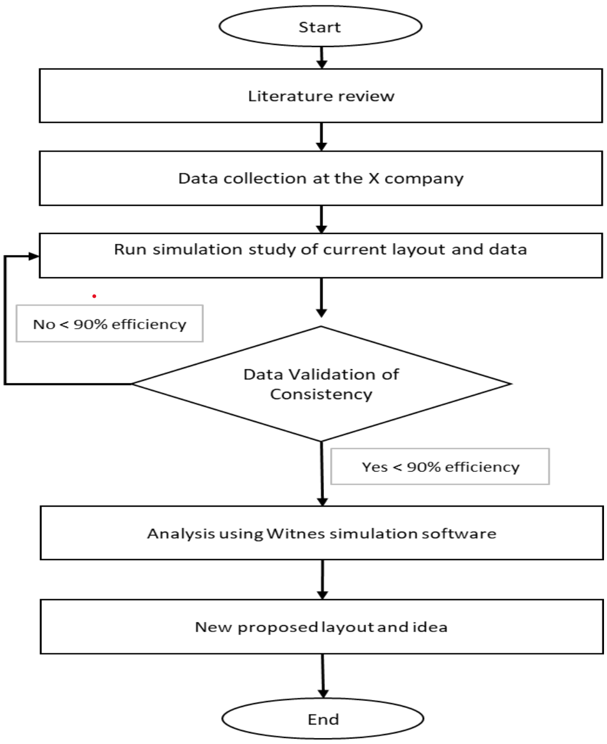


Figure 2. Research flow chart

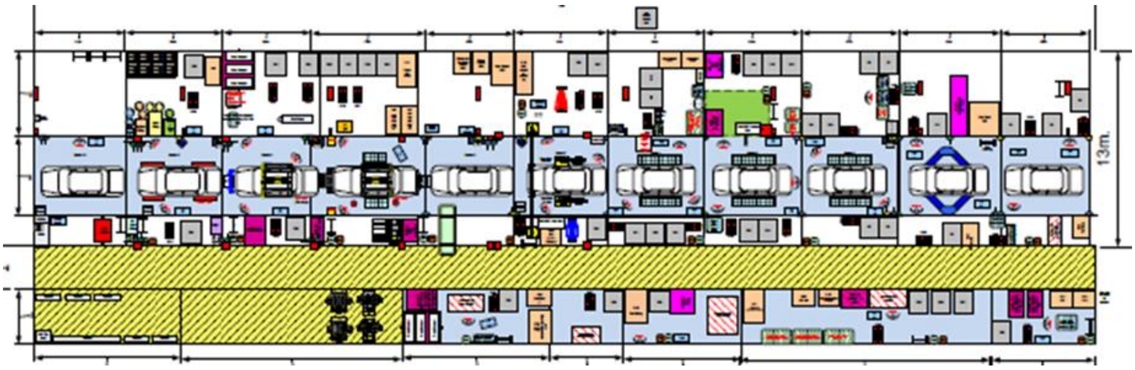


Figure 3. Assembly layout for T-Model

This assembly line has ten stations with different processes for every station, such as painted body, assembly shop and end-of-line assembly line, as shown in Figure 3. This section thoroughly reviews the methods used to complete the assembly process. The cycle time data and vehicle testing using the interface equipment will be analysed using the Witness simulation software. The simulations showed what the weaknesses of the current assembly setup were. The setup time is studied, and continuous improvement tools are applied to improve the process.

RESULTS AND DISCUSSION

The current layout of the T-Model assembly line is studied to get more critical information regarding the setup of the process and to get the crucial data, such as cycle time for each process and flow. The activities involved in the process, such as assembling parts from station preparation until station 10 of quality check, contributed to the production output's productivity.

DESCRIPTION	ST 0	ST 1	ST 2	ST 3	ST 4	ST 5	ST 7	ST 8	ST 9	ST 10 (QG)	RR Wall Module	COCKPIT	CONSOLE	HEADLINING	FR MODULE	DOOR	PANORA
OPERATOR A	50.42	63.75	72.50	55.75	83.75	81.75	65.67	83.67	36.04	51.42	31.49	36.83	15.17	22.49	39.83	71.05	52.00
OPERATOR B	66.83	56.75	63.92	69.25	85.67	73.00	84.08	63.33	43.08	45.67	0.00	51.92	0.00	0.00	0.00	73.67	25.68
OPERATOR C	0.00	0.00	84.50	71.25	76.33	52.67	53.67	58.33	46.21	0.00	0.00	0.00	0.00	0.00	0.00	77.30	40.30
OPERATOR D	0.00	0.00	0.00	0.00	0.00	67.75	59.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	76.83	0.00
HIGHEST TIME	66.83	63.75	84.50	71.25	85.67	81.75	84.08	83.67	46.21	51.42	31.49	51.92	15.17	22.49	39.83	77.30	52.00
MANPOWER	2	2	3	3	3	4	4	3	3	2	0.5	1.5	0.5	0.5	1	4	3
CAPACITY (UNIT/DAY)	6.23	6.53	4.93	5.85	4.86	5.09	4.95	4.98	9.01	8.10	13.23	8.02	27.46	18.52	10.46	5.39	8.01
TAKT TIME 5 UPD (85%)	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30

Critical Stations:
ST02
ST03
ST04
ST05
ST07
ST08

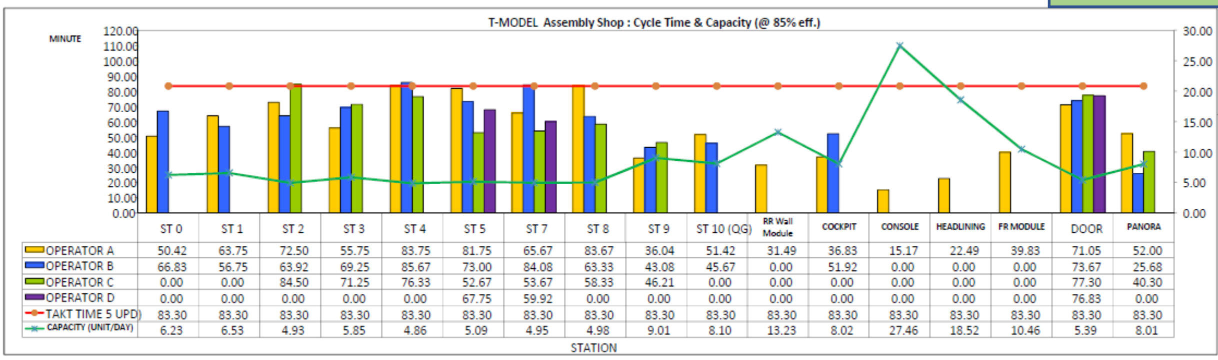
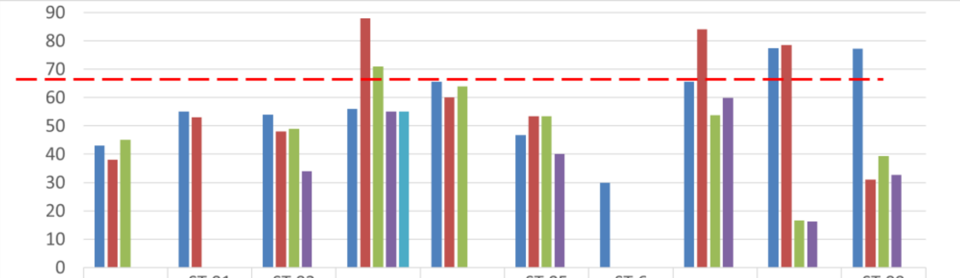


Figure 4. Current Cycle time T-Model

Figure 4 above shows six critical stations from the T-Model assembly line: ST 02, 03, 04, 05, 07 and 08. Each station has its specific process, and the process assembly part depends on the station and how many operators are allocated for every station. The cycle time for every station also shows in Figure 4.



	ST 0 (Engrave)	ST 01 (Underbody)	ST 02 (Control Unit)	ST 03 (Wiper)	ST 04 (Cockpit)	ST 05 (Windshield)	ST 6 (QM Check)	ST 07 (Engine)	ST 08 (Axle)	ST 09 (Mechanical Test)
Opt A	43	55	54	56	65.5	46.8	30	65.67	77.43	77.17
Opt B	38	53	48	88	60	53.4		84.08	78.55	31
Opt C	45	0	49	71	64	53.4		53.67	16.67	39.33
Opt D	0	0	34	55	0	40		59.92	16.33	32.67
Opt E	0	0	0	55	0	0		0	0	0

Figure 5. Current Takt Time

Figure 5 shows the takt time of the T-Model before improvement is made. Takt time refers to the frequency of a part or component that must be produced to meet customers' demands. Therefore, workable production hours will be divided into units required. Below is the detail of the calculation of takt time for this process.

$$\textbf{Takt time} = \frac{Workable\ Production\ Hours}{Units\ Required\ (customer\ Demand)} \quad (1)$$

Production Hours (8.00 until 5.30 pm) – 490 min
Production consideration of Downtime/Quality stop – 15%
Units required (customer demands) – 6 units per day

$$Downtime = \frac{15}{100}\ X\ 490 = 73.5 min$$

$$\textbf{Workable Production Hours} = \text{Production Hours - Downtime/Quality stop} \quad (2)$$
$$= 490\ \text{min} - 73.5\ \text{min}$$
$$= 416.5\text{min}$$

Therefore, the current takt time for this process is calculated below;

$$\textbf{Takt time} = \frac{416.5\ min}{6\ UPD} = 69.4\ min/unit$$

The average takt time for every station is 69.4 minutes per vehicle. This takt time was set up according to the process. Based on the graph, we can see that the five critical stations are involved and need improvement to increase production output. This data was taken when the manpower thrived in training at every station. Figure 3 shows the differences compared with Figure 4 for the critical stations. However, the bottlenecks are still at ST 03, 07, 08 and 09. Based on the critical station cycle time, the part that is difficult to assemble and the imbalance workload among the manpower and the process related are the main reason for the bottlenecks for the critical ST.

Simulation results for the current layout

Figure 6 shows the simulation results for the current layout using Witness Software. Ten stations are arranged in parallel, with three to four staff in each station. Each man power is responsible for their task during the process. To complete the process at every station, the operator must finish their task under a takt time of 69.4 minutes. Some activities involved and participated during the process, which is machine setup. Of all the stations, Station 9 involved brake bleeding, air conditioning and interface machines. These activities affected the cycle time standard at this station.

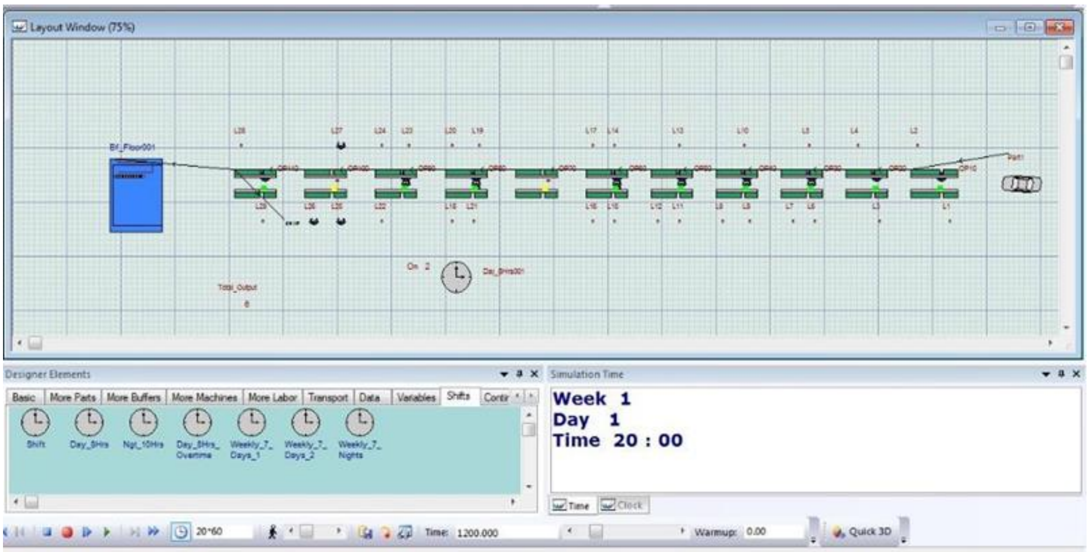


Figure 6. Current layout and cycle time using Witness Software

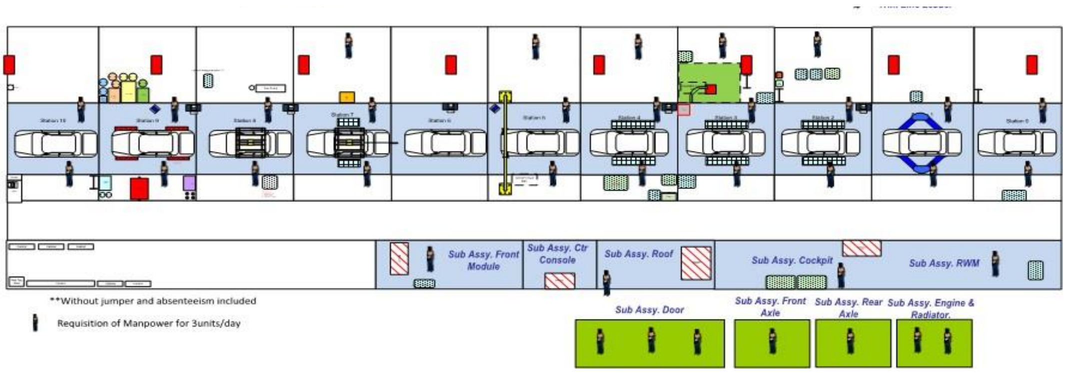


Figure 7. Manpower allocation for T-Model

The Witness simulations suggested that some improvements or adjustments in the process must be made. The changes related to an imbalanced workload for every station. The improvement was focused on the 4M analysis, for instance, the method used in the improvement activity. It was suggested to transfer the adjustments process and QM check to ST11 from ST10. Furthermore, the Brake Bleeding and ISTK processes were transferred to ST10 from ST09. For the manpower requirement, the simulations suggested adding one operator for every station to imbalance the workloads.

Balancing the operations

Figures 8 and 9 show that the workload was rearranged with the additional workforce at Stations 07, 08, and 09. All the rearranged processes involved stations ST07 until ST11. The balancing workload ensures that the process will be faster than before.

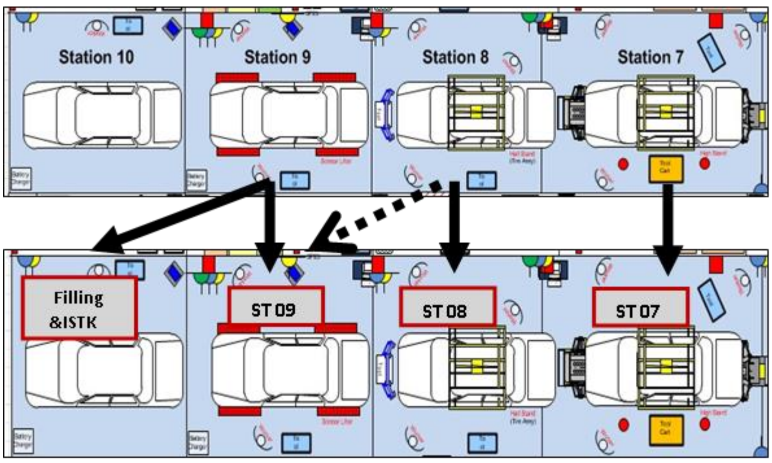


Figure 8. Imbalance work load process layout

Target : To achieve <69.4mins (takt time)	ST 07				ST 08			ST 09		
	A	B	C	D	A	B	C	A	B	C
Time analysis (vs 3UPD design)	+4.3	-14.08	+16.3	+10.08	-13.67	+6.7	+11.7	+33.96	+26.92	+23.79
Manpower for 3 UPD	4				3			3		
Manpower actual	5				4			4		
Problem	Imbalance workload between operator				Imbalance workload between operator / New operator on site			ISTK process consume high takt time		

Figure 9. Imbalance workload process

A new recorded cycle time proved that additional manpower and rearranging the process for every station could significantly impact cycle time. Man, and Method's improvement activities impact the stations' run according to takt time. The additional station, as shown in Figure 10, is essential because if the assembly line is longer than before, it reduces the cycle time for every station.

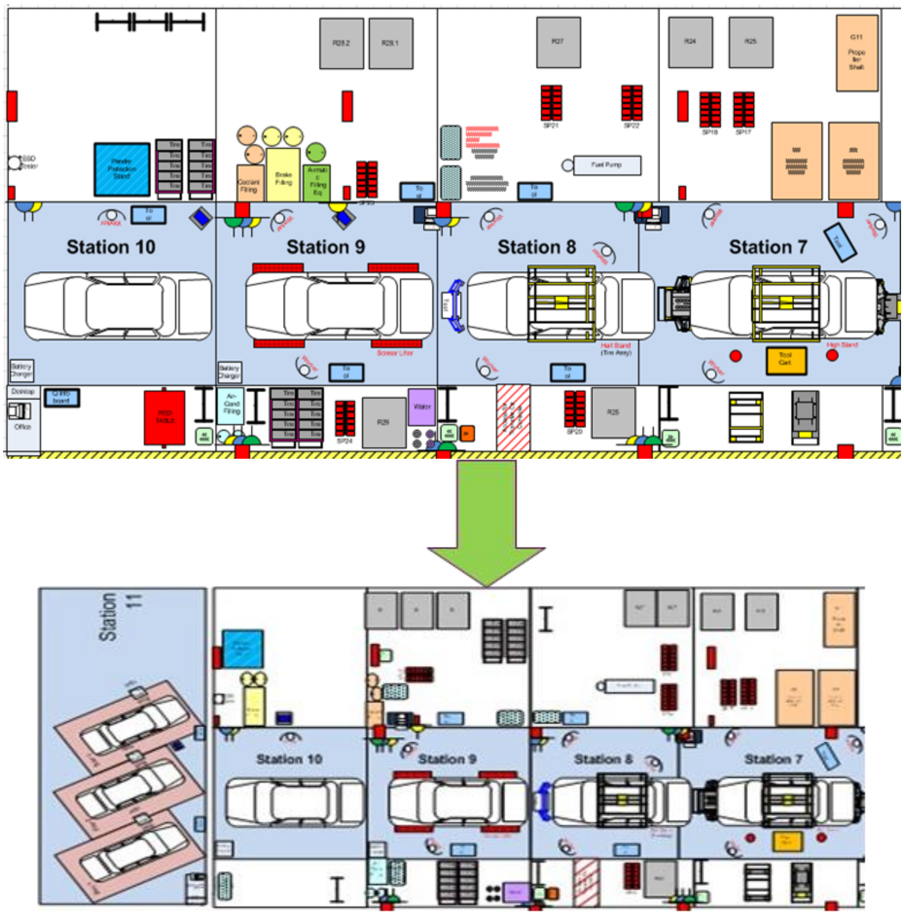
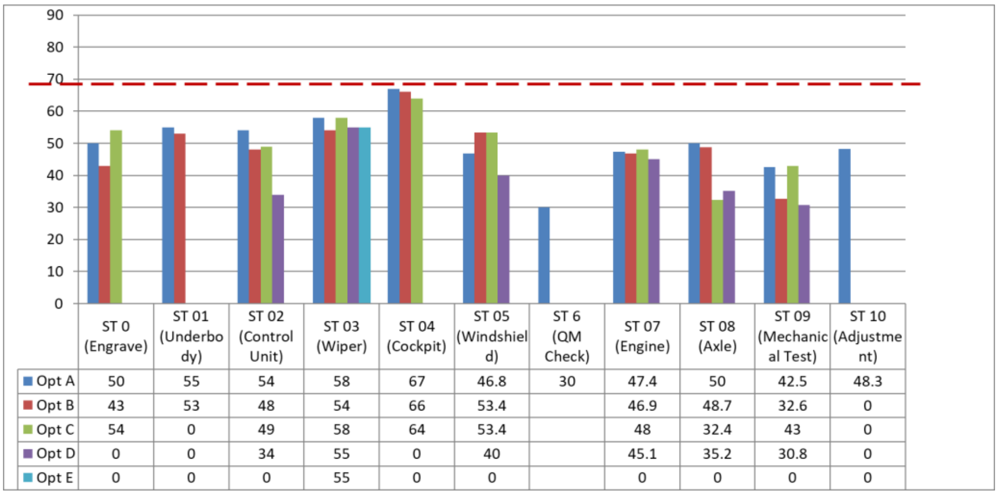


Figure 10. New layout after improvement

With additional ST11, the equipment at ST09 can be moved to ST10, significantly reducing cycle time at ST09. Equipment setup is crucial because the cycle time for using the equipment is always the same. Therefore, additional ST11 impacts the production output and achieves the target of 6 UPD based on the new cycle time.

Simulation results after improvement

Figure 11 shows the new cycle time after improvement. The takt time for 6 UPD is 69.4 minutes per station. Therefore, the new cycle time shows that all station achieves their cycle time after the improvement, such as rearranging the imbalance workload from Station 02 until Station 10 and an additional one station for QM bay. Compared with the previous cycle time, the bottlenecks happened at Stations 02, 03, 04, 07, 08 and 09. With the new cycle time, almost all stations have reasonable cycle times.



	ST 0 (Engrave)	ST 01 (Underbody)	ST 02 (Control Unit)	ST 03 (Wiper)	ST 04 (Cockpit)	ST 05 (Windshield)	ST 6 (QM Check)	ST 07 (Engine)	ST 08 (Axle)	ST 09 (Mechanical Test)	ST 10 (Adjustment)
Opt A	50	55	54	58	67	46.8	30	47.4	50	42.5	48.3
Opt B	43	53	48	54	66	53.4		46.9	48.7	32.6	0
Opt C	54	0	49	58	64	53.4		48	32.4	43	0
Opt D	0	0	34	55	0	40		45.1	35.2	30.8	0
Opt E	0	0	0	55	0	0		0	0	0	0

Figure 11. New cycle time after improvement

Figure 12 shows the proposed improvement layout based on the Witness Software simulation for the assembly line of the T-Model. It shows that 11 stations are arranged in parallel, with additional manpower for every station.

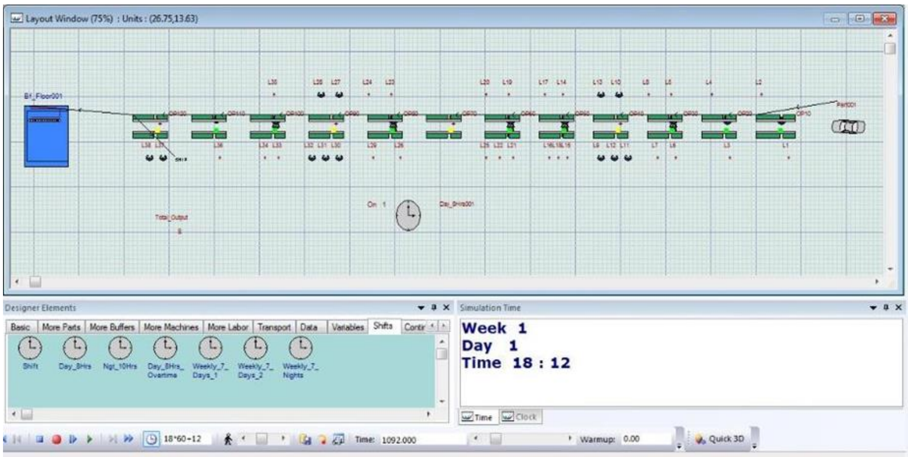
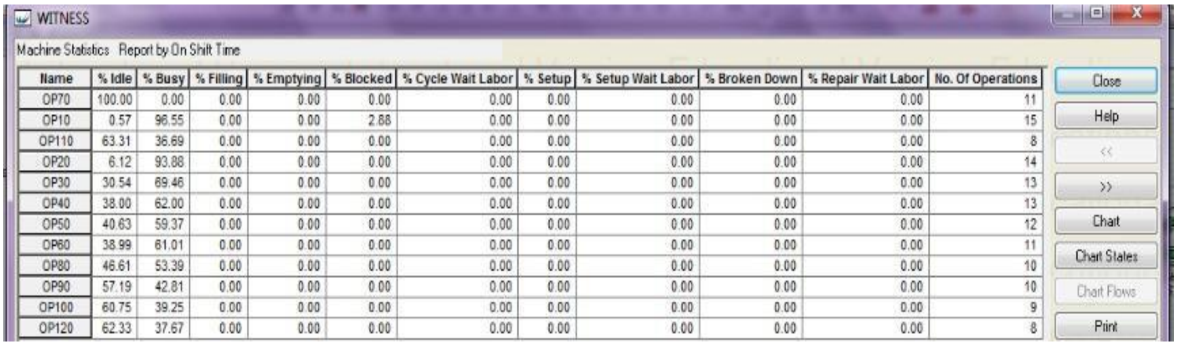


Figure 12. Proposed layout



WITNESS

Machine Statistics Report by On Shift Time

Name	% Idle	% Busy	% Filling	% Emptying	% Blocked	% Cycle Wait Labor	% Setup	% Setup Wait Labor	% Broken Down	% Repair Wait Labor	No. Of Operations
OP70	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11
OP10	0.57	96.55	0.00	0.00	2.88	0.00	0.00	0.00	0.00	0.00	15
OP110	63.31	36.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8
OP20	6.12	93.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14
OP30	30.54	69.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13
OP40	38.00	62.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13
OP50	40.63	59.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12
OP60	38.99	61.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11
OP80	46.61	53.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10
OP90	57.19	42.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10
OP100	60.75	39.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
OP120	62.33	37.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8

Figure 13. Operator statistics for the new process

Figure 13, shows the percentage of busy and idle operators. The percentage of busy for operator number three, 62%, is the lowest, followed by operator number one (OP30), which is 69.46%. The percentage of busy for operator number two (OP20) is the highest which, is 93.88%. Therefore, the cycle time for the new setup process decreased by 23% compared to the existing layout. Moreover, the production increased the output from three to six units per shift, a 50 % increase in production output. Based on the trial run simulation, the proposed future output time to complete eight units per day is 18 hours and 12 minutes for 11 stations. In the current practice, it takes 20 hours to complete six units per day.

$$\textbf{\textit{by using formula output productivity}} = \frac{Total \frac{time}{operation}}{Target\ Takt\ Time} \tag{3}$$

$$\textbf{\textit{Current labor productiviy}} = \frac{416.5\ min}{138.8\ min/station}$$

$$= 3 \text{ units/shift}$$

$$\textbf{\textit{New labor productiviy}} = \frac{416.5\ min}{69.4\ min/station}$$

$$= 6 \text{ units/shift}$$

Based on the output productivity calculation above, the labor productivity percentage is increased in new layout improvement and process change for balancing the operator workload. Using the proposed practices, productivity is increased from 3 units per shift initially to 6 units per shift (50% increase in the production output) manufactured products at the end.

CONCLUSION

This paper presents the case of the actual production process, which initially offered very low productivity. With the help of the combination of the line balancing and discrete event simulation model, productivity is a 50% increase in the production output. It shows that root cause (4M) analysis is a tool for continuous improvement towards lean in the manufacturing industry. The improvement process (Method) and manpower (MAN) allocation in the T-Model assembly line has significantly impacted the production output. The current practice's waste and non-value-added activities had been identified and optimised using simulation analysis.

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