Integrating discrete event simulation and value stream map in improving body shop production performance

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Abstract—Value stream mapping (VSM) is a lean tool used to reflect the current state of an operation by visualizing the value added activities and widely used across industries. This study takes place in automotive industry which emphasizing on addressing waste that arise in the production. VSM is traditionally a powerful paper and pencil tool however, the static representation on the map urges the use of computer simulation as the complementary tool. DES is introduced to create dynamic on the VSM and addresses variability that exist in the system and to propose improvement design for the future state VSM.

Keywords—automotive; discrete event simulation; value stream map; value added; waiting time

I. INTRODUCTION

The Malaysian Gross Domestic Product (GDP) have experienced 5.3% of growth contributed by the manufacturing sector, along with 6.4% growth from the Transport Equipment and Other Manufacturers [1]. These statistics shown the vitality of the sectors towards the nation's economy. Automotive industry is the largest manufacturing business in the world and it is one of the most resource intensive industries of all industrial system [2]. Therefore evaluating the performance of the system is a vital task for manufacturers.

Being a vital sector requires the manufacturers to constantly evaluate on the capability of the operation system towards handling fluctuated demands or the capability fulfill demands under various pressured scenarios. However foreseeing the performance of a system with bare eyes is inadequate and rather challenging due to the nature of the operation system itself which is subjected to variability, interconnected and complexity [3]. The natures pinpointed on the needs of using simulation as it is capable in analyzing complex manufacturing system with dynamic and uncertainty [4].

Computer simulation is capable of imitating a real-process production system for the purpose of analyzing and experimenting without distracting the real system. Discrete event simulation (DES) is crucially used in supporting decision to avoid system inabilities and to improve overall capacity.

Although various studies have proven the contribution of simulation in improving operational performances and support for decision making however, simulation has yet been used widely in Malaysian industries. In this study a simulation model is constructed to evaluate the performance of body shop production line.

II. BACKGROUND OF RESEARCH

A. Discrete Event Simulation (DES)

Regulated in NAP 2014, the capability of enhancing value added into performance has becoming one of the vital measure in developing company's competitiveness, apart of being able to fulfill customers demand. Thus to fulfill the policy, company have adapted VSM to streamline the production performance by looking into the total value added time and production lead time. Although the company manufactures based on "Make to Order" (MTO) in managing the inventory without waste, however the current production is incapable of managing fluctuated demands.

Despite of having higher production capacity, the line is often underproduced and bottlenecks occurred at processes which contributed to high waiting time and prolonged the production lead time.

Although value stream map (VSM) is a powerful tool, however the static mapping on the map is deficient to verify the problem areas and validate the potential improvement plans. Since it is acknowledge the natures of the production line are variability, interconnected and complexity [3] hence it was rather difficult to promptly analyze and quantify the performance gap between the improvement design plans. Due to this lacking, the problems that arise in the production is hard to be addressed accordingly. Thus this study emphasized to improve the Body Shop production performance by using DES and VSM.

III. RESEARCH METHODOLOGY

As the dynamic is lacking in VSM, thus simulation is used to assist in enhancing the dynamic in the operation flow. Apart from being able to promptly analyzing the performance of a system, it is also enhanced with animation which is handy in reflecting any movement that occurs in the operation. Fig. 1. depicts the methodology that integrates DES and VSM.

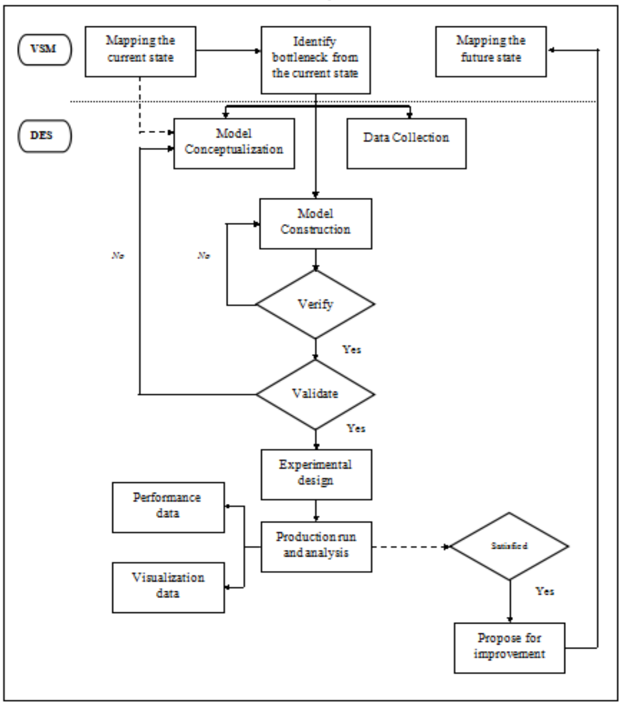

Fig. 1. The integration of DES and VSM

A. *Current Value Stream Map (CVSM)*

VSM is a tool which helps in visualizing a system by representing both material and information flow for both manufacturing and transactional processes. It visualizes the flow of the products coming from the supplier through the processes and to the loading dock.

However this research only emphasized on the Body Shop operation, which is the first processing station prior to Paint Shop and Trim Fit Assembly. This is because Body Shop consists of numerous processes and being the first station, the bottleneck that exist ought to be addressed initially, in regards to ensure the smoothness of the subsequent stations.

Fig. 2. depicts the CVSM of the Body Shop. Based on the map, it is realized that the work-in-process (WIP) between the processes are high, followed by high variation of process time which leads to WIP inventories. Hence the issues lead to high production lead time.

As the bottleneck from the CVSM is identified, the map is used to construct the conceptual model prior to develop the simulation model.

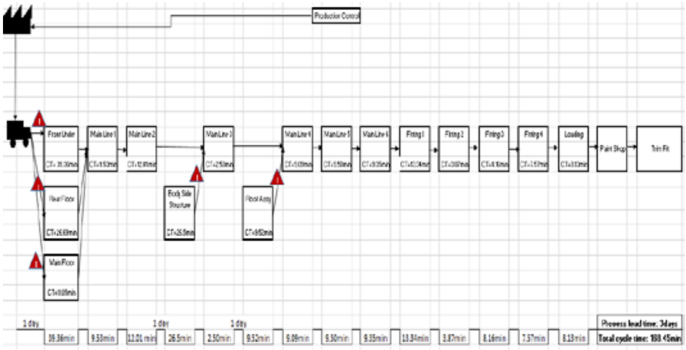

Fig. 2. Current state VSM

B. *Discrete Event Simulation (DES)*

The Body Shop conceptual model is constructed based on CVSM and followed by obtaining sufficient and relevant data regarding the number of operators and process time. Towards constructing the conceptual model, the CVSM is transferred into a simulation software to proceed with simulation model construction.

Arena simulation software is chosen as it is user friendly [5], featured with the most comprehensive modules and processes hence making it applicable for problems of all areas [6] and developed with reliable SIMAN language designated for discrete event and continuous simulation.

The Body Shop consists of five workstations, thus for a better representation of the model, some modules were eliminated yet remaining the original function and concept of the model. Fig. 3. shows the Body Shop Arena model.

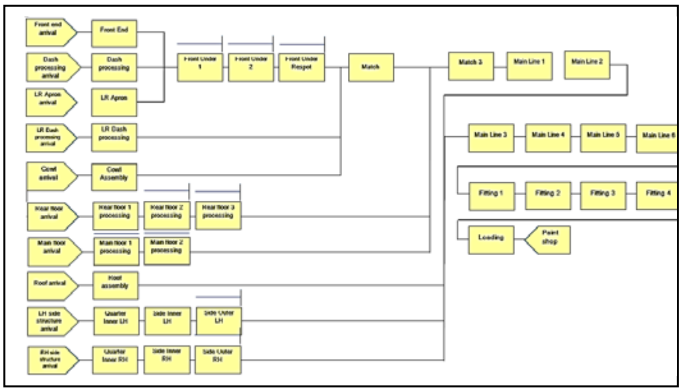

Fig. 3. Body Shop Arena model.

C. *Model Verification*

Model verification is a vital stage where it ratifies the constructed model is accurately translated with respect to the conceptual model. Hence it ensures the construction of the model is correct, matches the assumptions and specification as per actual system. In this research, the verification techniques adapted in verifying the constructed model are:

- Model Animation [7]: Animation reflects the operational behaviour of a system hence it can be used to verify a simulation model to be valid without error upon testing [8]. Hence constructing the accurate simulation model is shown by the animation which is reflected by the commands and sequences made onto the model.
- Face Validity: A technique which the experts are referred to judge the accuracy of the constructed model [9]. In this research, the constructed body shop model was referred to the related Body Shop operation expert in order to gain confidence on the accuracy of the constructed model prior to the experimental design phase is initiated.
- Performance Analysis [10]: It is a process which evaluates the ability of the system to meet requirement with respects to throughput times, resource utilization and entities inter departure time [11]. By comparing the performance from the mentioned parameters, the analysis verifies the model as accurate as the values from the throughput estimators were similar.

D. Model Validation

Model validation is defined as ensuring the model behaves and operates similarly to the real system [12]. In validating the model, the standardized difference to be obtained ought to be within the range of ±10% of the actual output [13]. The difference between the simulation output and the actual output is calculated as expressed in (1).

$$Difference\ (\%) = \frac{(SimulationOutput - ActualOutput)}{ActualOutput} \times 100\% \quad (1)$$

Thus in this research, model validation was done by comparing the output and the percentage of Overall Equipment Efficiency (OEE) of the Body Shop simulation model against the actual production. Table I shows the validation data.

TABLE I. VALIDATION DATA ON OUTPUT AND OEE

	Production Time (Min)	***Output (Unit)***	***Difference (%)***	***OEE (%)***	***Difference (%)***
Actual	480	24	0.21	100.00	4.17
Simulation		23.95		95.83	
Actual	420	21	6.75	100.00	9.52
Simulation		19.38		90.48	

As the production time was set to 480 minutes and 420 minutes, the table showed the percentages obtained from the differences in output are 0.21% and 6.75% whereas the difference in OEE are 4.17% and 9.52%. These figures fall within the range of standardized difference as asserted by [13]. Hence the figures validated the model resembled the actual Body Shop system and can be proceeded with the design experimenting.

E. Experimental Designs

The result of the model performance is showed in Table II. From the result, the current Body Shop total completion time is 479.29 minutes, followed by 255.55 minutes of the total process time and 223.74 minutes of total waiting time.

TABLE II. BASE MODEL PERFORMANCE

Parameters	***Total Time (Minutes)***
Total completion time	479.29
Process time	255.55
Waiting time	223.74

The result depicts high waiting time and improvement ought to be designed to address the matter. As the actual production only allocates one manpower at each workstations thus some workstations might encounter longer processing time which then cause the subsequent resources to starve, creates waiting time which prolonged the lead time of the overall production, and hence incapable of completing fluctuated demands.

Waiting time is one of the waste recognized in Lean, thus the improvement is ought to be focusing on reducing waiting time. As waiting time causes bottleneck to occur, various improvement activities can be suggested however, the consequences of each improvement plan is ought to be proven suitable and rational to be implemented. Hence this section requires the use of simulation in experimenting the potential improvement plans. Consequently, each proposal made was based on bottleneck encountered. Table III shows the designed improvement activities.

$\alpha + \beta = \chi$. (1) (1)

TABLE III. EXPERIMENT DESIGNS

Scenario	***Issue***	***Improvement Activity***
1	Lengthy process handled by one operator	FU1 combined with Apron LRH Dash combined with FU Respot
2	MF2 operator was under-utilized	MF1 handles Main Floor Assembly 1 and Main Floor Assembly 2. MF2 remained unassigned
3	Bottleneck occurred to due lengthy process time	Qtr Inr LH combined with Side Outer LH RH Quarter combined with Outer RH
4	UB 3 was underutilized Delay in transporting car body on trolley to Fitting 1	Reassigned with additional task from Mainline 4 New operator was assigned to take charge of the trolley
5	Bottleneck occurred in Fitting 1 due to lengthy process time	Assigned operator from Fitting 2 to assist in Fitting 1

(*mybrain15 Scholarship by Ministry of Higher Education).*

6		Combine all activities in Scenario 1-5

IV. Result and Analysis

The model was run for five replications and the designs as per in Table III were tested onto the base model. The results generated from Arena are tabulated in Table IV and graphed in Fig. 4., on the other hand the percentage of improvement yielded from respective scenarios are tabulated in Table V.

TABLE IV. RESULTS GENERATED FROM ARENA

Time (Minutes)	***Base***	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***	***Scenario 5***	***Scenario 6***
VA Time	255.55	225.03	260.53	183.99	219.10	223.27	210.61
Wait Time	223.74	240.93	255.59	239.85	249.77	246.96	201.78
Total Time	479.29	465.96	516.12	423.84	468.87	470.23	412.39

TABLE V. COMPARISONS ON SCENARIOS IMPROVEMENT

Time (Minutes)	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***	***Scenario 5***	***Scenario 6***
VA Time	-14.62	+0.04	-15.70	-5.78	-8.59	-44.94
Wait Time	+1.29	+36.79	-39.75	-4.64	-0.47	-21.96
Total Time	-13.33	+36.83	-55.45	-10.42	-9.06	-66.90

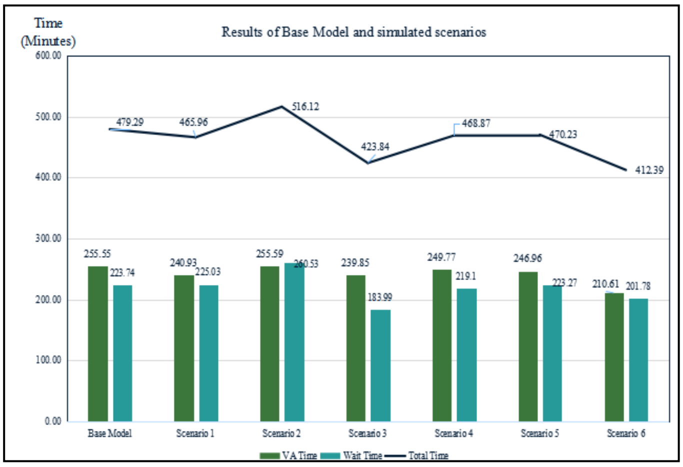

Fig. 4. Graph of time comparison between base model and proposed scenarios.

Based on the result, the designs were tested and yielded with respective output. However, Scenario 6 which is the scenario that proposed to combine all of the improvement activities showed the biggest improvement with 66.90 minutes of reduction in total time, 44.94 minutes of reduction in process time and also a total of 21.96 minutes of reduction in wait time. Scenario 6 emphasized on addressing the bottleneck caused by the matching process in Front Under by assigning manpower to the Apron process, completes the apron assembly process faster and reduces the waiting time at the matching process. This also includes addressing manpower relocation in Side Assembly, Main Line and Fitting Line, which reduced the process time and wait time in respective areas.

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi resolution TIFF or EPS file with all fonts embedded) because this method is somewhat more stable than directly inserting a picture.

To have non-visible rules on your frame, use the MSWord "Format" pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.

Consequently, Scenario 6 also tackles the transporter issue where the underutilized operator in Main Floor 2 assigned to handle the transporter. By doing so, the waiting time for the trolley transporting the car body is reduced and enhances the completion time of the Body Shop production.

As due to fluctuated monthly demands, the current setting of production could produce mostly 480 units of car body monthly. However by applying the setting as in Scenario 4, productivity is increased. On top of that, the expected units of car body that could be produce is 540 units per month hence able to cater demands more than the existing capacity. On top of that, Scenario 6 only make use of the existing resources hence no additional cost is involved in adding resource into the production.

Scenario 6 is proposed as the suitable improvement design for the Body Shop production as the improvement reduces the waiting time which is crucial in reducing the production lead time. Upon proposing the improvement plan, the design is then used to construct the Future VSM (FVSM).

V. Conclusion

This study aimed to integrate the existing usage of value stream mapping with simulation to assist the management towards selecting the best improvement plans in reducing waste for a better production performance.

Using simulation enables the potential improvement plans to be experimented prior to execution. Simulation is a powerful tool that is capable of analyzing and generates reliable results in experimenting complex systems. Hence it is a useful technique to be introduced towards improving the performance of the industries in Malaysia.

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