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Simulation of Assembly Line Balancing in Automotive Component Manufacturing

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Abstract. This study focuses on the simulation of assembly line balancing in an automotive component in a vendor manufacturing company. A mixed-model assembly line of charcoal canister product that is used in an engine system as fuel's vapour filter was observed and found that the current production rate of the line does not achieve customer demand even though the company practices buffer stock for two days in advance. This study was carried out by performing detailed process flow and time studies along the line. To set up a model of the line by simulation, real data was taken from a factory floor and tested for distribution fit. The data gathered was then transformed into a simulation model. After verification of the model by comparing it with the actual system, it was found that the current line efficiency is not at its optimum condition due to blockage and idle time. Various what-if analysis were applied to eliminate the cause. Proposed layout shows that the line is balanced by adding buffer to avoid the blockage. Whereas, manpower is added the stations to reduce process time therefore reducing idling time. The simulation study was carried out using ProModel software.

1. Introduction

Nowadays, customers worldwide are starting to demand higher quality cars at lower price with fast delivery. Mass production is a common method used by most automotive companies in producing automotive to gain higher production rate at the lowest cost. In mass production, assembly lines are required to manage the workload, make proper arrangement of humans and machine to gain better efficiency in results [1]. Efficiency is formulated as the time needed divide by the time allocated. In line balancing application, there are two common issues to address. First, reducing the task time or processing time that have been assigned to all workstations to suit and not exceed the cycle time that has been given. Second is minimizing the highest workload assigned to a specific workstation when the number of workstation and line cycle time are fixed. This study focuses on balancing the assembly line of an automotive component using simulation techniques. Through simulation modeling, a company can save cost to improve the assembly line performance compared to the traditional way of trial-and-error on the actual production system. Simulation is defined as a powerful tool for the analysis of new system designs, retrofits to existing systems and proposes changes to operating rules

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[2]. It is a tool that is preferable to use in large areas because it does not interrupt the current existing system. On the other hand, simulation has the weakness of fully imitating one hundred percent the actual production line for the inconsistent variables. This will cause the percentage of error occurred. It also does not take into account human error or skills which are difficult to measure thus considered as qualitative data. In China, a study using Discrete Event Simulation which focused on reducing the bottleneck was carried out where it improved balance ratio by 13.07% [3]. The study was done at an Automotive Interior Assembly Line using Technomatix em-Plant simulation to detect the bottleneck process and work in process (WIP) among 23 stations. Results showed improvement of line balance ratio from 78.38% to 65.31%. Arena simulation has also been used in the Garment Industry where it was able to do predictions and increase productivity while meeting unstable market demands [4]. With the implementation of Planning Manager using simulation based, it could test new systems without disturbing real time production.

In addition, fact-model simulation has also shown an increase in line balancing ratio that leads to the improvement of work efficiency [5]. Fact-model is a simulation that was created by Haeryip Sihombing and Habibullah Akbar from Universiti Teknikal Melaka (UTeM), Malaysia. It is used to map data of the working time related to quantity and network path. Results showed that the balancing ratio and efficiency improved from 79.44% to 69.24%. Meanwhile, in an assembly line of Two Stages Gearbox, by using three different types of Heuristic Method gave positive results by increase the production rate and work efficiency [6]. Which are Largest Candidate Rules (LCR) Method, Kilbridge and Wester Column (KWC) Method and Ranked Positional Weight (RPW) Method. Based on that particular assembly line, results showed the RPW method is the best layout plan with the highest line efficiency of 96% and the highest labor efficiency of 88.84%. In this paper, the simulation study was done at one of the automotive component assembly line in an automotive vendor manufacturing company. The focus of the study is to evaluate different scenarios by various 'what-if' analysis to eliminate blockage and idling time, hence increasing productivity and line efficiency using the ProModel software.

2. Problem definition

The simulation of assembly line balancing was done at a vendor manufacturing company which specializes in the production of filters, engineering plastic parts and specialty fluids, and is widely regarded as the number one original equipment manufacturer (OEM) filter manufacturer in the country. Currently, the company applies automated and manual system in their production line. This study was carried out at the line producing charcoal canister that is used in an engine system as fuel's vapour filter. Based on a preliminary study of the current production line there exist two major problems. Firstly, the production rate is not satisfying customer demand by 8%. Secondly, the line is experiencing low line efficiency. There is a blockage in the system because of imbalance in line production cycle time. It was observed that the line cycle time is lesser than the cycle time of the workstation. Due to that, the company produces stock storage for two days to avoid supply shortage. Having said that, the objective of this study is to evaluate the throughput system using simulation technique and to monitor the status of the production line in terms of resource utilization, blockage and idling time. After that, to identify the root cause for any imbalance of the line, and to propose several improvement plans through simulation modelling hence producing the most efficient production line with low cost impact and give improvement options to the company.

The existing flow of the charcoal canister process and the total entries at each workstation is depicted in Table 1. The production line consists of nine workstations with a combination of fully manual and semi-manual operation. The amount of part entries (units) by workstation was collected based on 2 shifts for 3 days of production run.

Table 1 Charcoal Canister process

W/S	Process	Operation	Total entries (units)
	Arrival Area		1161
1	Assembly 1	Manual	1032
2	Paper Stamping	Semi-auto	1032
3	Spin Welding	Semi-auto	951
4	Assembly 2 & Carbon Filling	Manual	950
5	Vibration Welding	Semi-auto	950
6	Water Leak Test	Semi-auto	950
7	Valve Test & Laser Printing	Semi-auto	949
8	Vent Foam & Cap Assembly	Semi-auto	950
9	Packing, Tagging & Inspection	Manual	950

This production line is based on five main characters of process which are assembly, marking, sealing, testing, inspection and packing. The first workstation which is Assembly 1 assembles child parts of the charcoal canister that is assembling the ball, spring, plug and case. The combination of these child parts is then will be sent to the spin welding workstation for sealing purpose. The second assembly process involves carbon filling and filtration parts installation. The amount of carbon to be filled is controlled and decided by machine depending on the parts performance requirements. Meanwhile the filtration component installation is done manually. The final assembly process in the production line is vent foam and cap assembly. Vent foam is a component to filter outside air from foreign materials and a cap is used to protect the foam. The cap is sealed using a clip method. All of the assembly process' times are based on operator's skills and the workstation's ergonomic performance. The main parameter controls for this line is the operators work time.

3. Methodology

Statistical analysis is used to check the mean, confidence interval and variance of the raw data before applying the simulation system. A warm up period is necessary in order to gain accurate results. A warm up period is the amount of initial time the simulation spends in a warm up state. In a steady state simulation, we are interested in the steady-state behaviour of the model. Since the model starts out empty, it usually takes some time before steady-state is reached. To determine a satisfactory warm-up period, one or more key response variables should be monitored over a period of time, in this case, the average number of entities (production rate). The framework of this study consists of five phases. It starts with the preliminary study phase then the simulation study phase, experimentation, analysis of results, and finally discussion, conclusion and recommendation. The overall approach of the simulation study is presented in Figure 1. The beginning phase it starts with a problem statement and setting of objectives which indicate the questions that are to be answered by the simulation study. After that, the actual production system is converted into a conceptual model. In this phase, the basic model such as workstation, buffer, and material handling is constructed. At the same time, the important data such as arrival time, set up time and processing time are collected. The conceptual model constructed is then coded into a computer recognizable form utilizing Promodel software. Next is to verify the model which is extremely important in determining whether the computer implementation of the conceptual model is correct. Verification is to ensure that each element in the model has been coded and behave in the right way. Then the output from the simulation is validated by comparing to the actual system. This is to make sure that the model is a representative copy of the real system under investigation. Once validated, experimentation to understand the 'what-if scenario' is performed. A proper experimentation planning is needed such as determining the length of the simulation run and the number of runs (replication) for each simulation. Once the results are analyzed and satisfactory, the findings are presented and documented, and can be implemented in the real system.

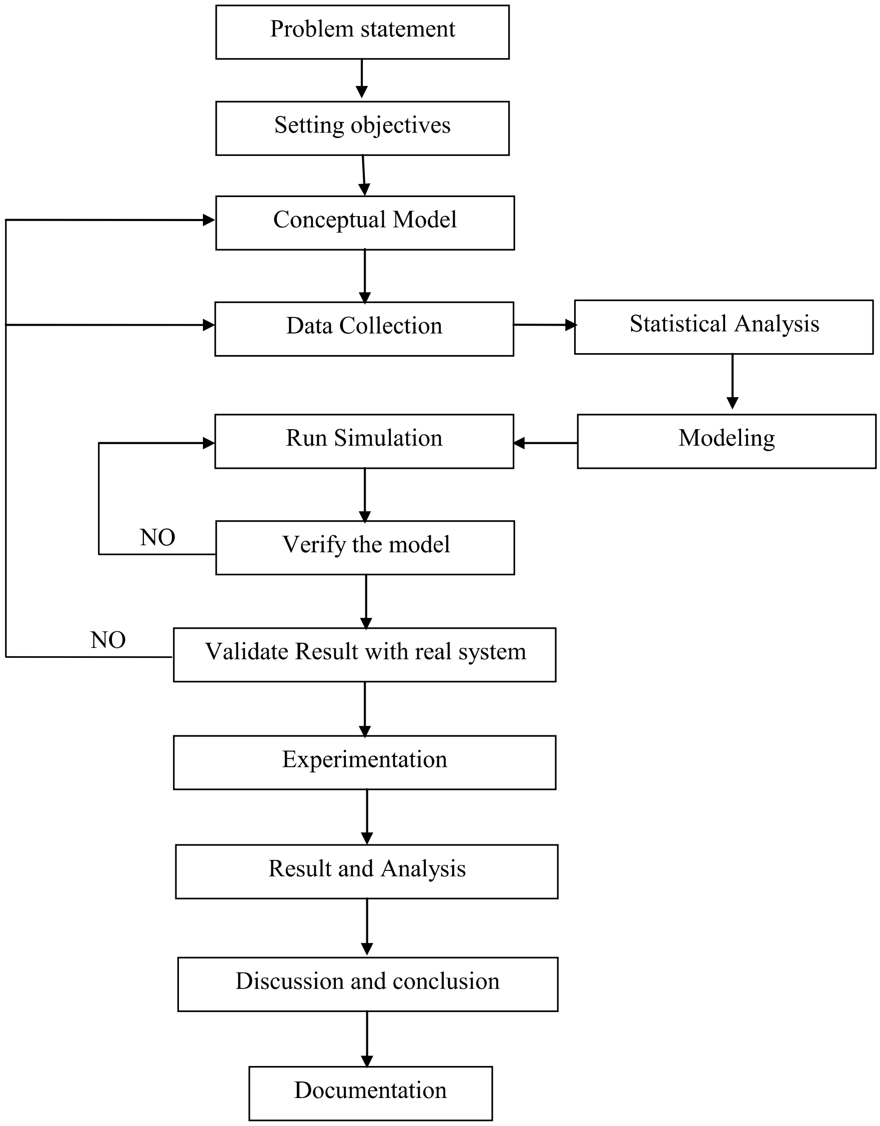

Figure 1. Methodology of simulation study [7]

3.1 Design of experiment

The Design of experiment (DoE) method was chosen to figure out the relation between three factors and the idle time. Those factors are arrival parts frequency, entity speed movement and arrival parts quantity. The focus is on which factors that give the most impact towards the idle time for further improvement of the system. Table 2 list out the related factors been chosen for DOE and the level limit for each factors accordingly.

Table 2. Related Factors and Level Setup

Factor Name	Factor Letter	Low Setting	High Setting
Arrival Frequency	A	10	60
Entity Speed	B	50	100
Arrival Quantity	C	129	250

4. Results and discussion

Sixty data were collected from the production line during the preliminary study and the mean and standard deviation of production rate were calculated based on 95% of Confidence Level. The actual production rate calculated is 119 units/hour while the production rate obtained from the simulation is 118 units/hour. Therefore, it can be stated that the error between the actual system and simulation is 1%. This comparison is essential to verify that the model constructed is mimicking the real system. The current production rate of 119 units/hour does not satisfy the customer demand of 129 units/hour. Based on Table 1, it is observed that the bottleneck of the production line occurs at the spin welding workstation with only 951 parts were capable to enter the workstation compared to 1032 pieces that were arranged to enter in the first place. It is also observed that the highest processing time occurs at the spin welding process. Thus this workstation is determined as the bottleneck workstation. Table 3 shows a general report generated from the ProModel software as the most utilized workstation in this production line is the spin welding process with a percentage of 84.40%.

Table 3. Output from the simulation for current layout (before improvement)

Name	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down	% Utilization
Arrival							10.54
Assy 1	58.72	0	16.43	0	24.85	0	84.06
Paper Stamping	27.99	0	16.6	0	55.41	0	83.81
Spin Welding	83.19	0	16.35	0	0.46	0	84.40
Assy 2	58.63	0	41.36	0	0.01	0	58.10
Vibrate Welding	28.49	0	70.29	0	1.22	0	29.94
Water Leak Test	59.91	0	40.09	0	0	0	59.63
Laser Print	27.04	0	72.96	0	0	0	26.14
Cap Assy	30.82	0	68.26	0.01	0.91	0	33.81
Pack Inspect	59.21	0	40.79	0	0	0	59.45

Two improvement layouts were proposed in the simulation model in order to reduce blockage, improve production rate and line efficiency. The proposal involved installing a buffer to detain parts from being blocked for the next workstation which could cause the production line to stop. Another proposal was adding resources (operators) that operate the workstations or move parts from one workstation to another. The addition of resources at the manual workstation is balanced the processing time. The before and after improvement layout is depicted in Figure 2a and Figure 2b respectively. Table 4 shows the two different improvement carried out and results from the simulation.

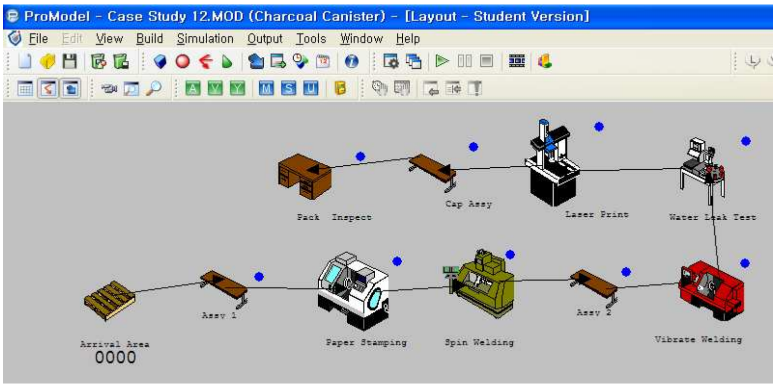

Figure 2a. Layout before improvement

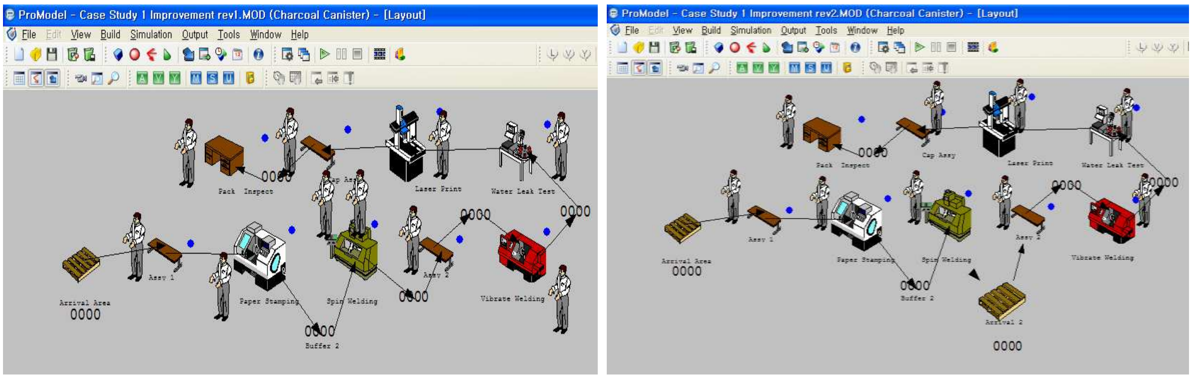

Figure 2b. Layout after improvement

Table 4. Summary of simulation results after improvement

Items	Detail	Line Efficiency (%)	Production Rate (unit/hour)	Line Utilization max (%)	Idle Time max (%)	Blockage max (%)
Current Production Line	9 workstation Semi-manual assembly line	81.1%	118	84.40%	73.86%	55.83%

Table 4. (Continued)

Items	Detail	Line Efficiency (%)	Production Rate (unit/hour)	Line Utilization max (%)	Idle Time max (%)	Blockage max (%)
Improvement 1	Add 5 buffer workstation and 1 resource with new machine	88.9%	129	65.44%	70.32%	0%
Improvement 2	Add arrival area, create stock in advance, 3 buffer	90.4%	131	83.69%	69.78%	0%

4.1 Design of experiment

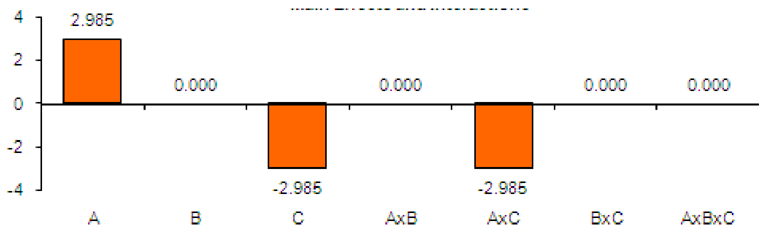

Figure 3. Main effect and interactions

After running DOE based on the factors and limit in Table 2, Figure 3 demonstrates that Factor A (arrival frequency) gives the biggest impact with 2.985 whereas and entity speed does not have any impact towards the idle time. The same situation goes for the other interactions except factor A x C and arrival quantity. Both factors give impact towards idle time of -2.985. This means that by reducing frequency time and increasing arrival quantity it can reduce the idle time. The relation of A x C interaction is shown in Figure 4. Negative interaction occurs when the value of arrival frequency is high whilst the arrival quantity is low.

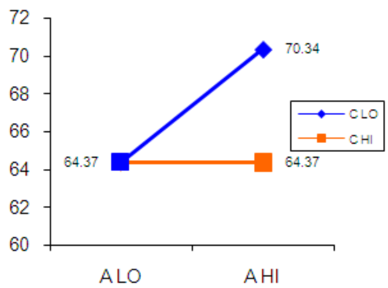

Figure 4. Interaction A x C relation

5. Conclusion and Future Works

Data showed that line balancing give positive impact towards the production line with a few improvements. It also shows that by using simulation time can be save in the process to simulate the line balancing. Line balancing not only can reduces the bottleneck but increased output too. As a results, costs of cars can be reduced which is ultimately the main purpose for this study as per shown in Figure 5.

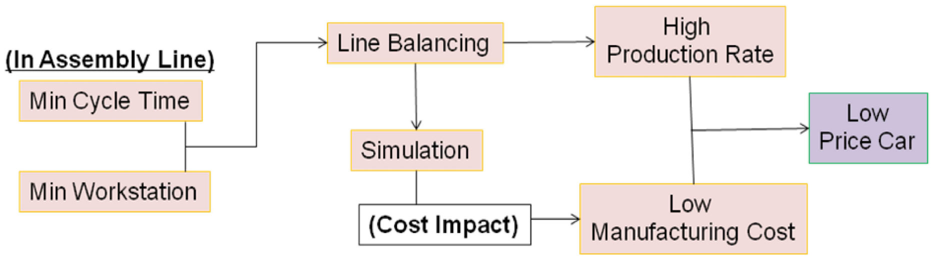

Figure 5. Impact of application line balancing towards vehicle price

In order to apply line balancing at a manufacturing company, there are some circumstances that cannot be change in order to control the product's quality and the process requirement. Therefore, it is impossible to totally eliminate idle time. Based on the design of experiment done, idle time can be reduced by increasing the part's arrival frequency after balancing out the production line. Line balancing give positive impact towards the production efficiency that been the main aim for the Malaysia automotive companies.

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