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Simulation and Re-engineering of Truck Assembly Line

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Abstract

Simulation is one of tools that has been used widely in several manufacturing areas and organizations as well as in automotive industries. Using a valid simulation model may give several advantages in creating better manufacturing design in order to improve the system performances. This paper presents result of implementing a computer based simulation model to design Manufacturing Process Re-engineering for performances improvement. The basic problem is that the current manufacturing system performances have to be improved to deal with the business environment. Projects objective is to design four improvement alternatives design using valid computer simulation model. Three approaches applied as the foundation in creating improvement alternative of the real system are Line Balancing, Facilities re-layout and process enhancement, and manufacturing process. Simulation models were developed using ARENA version 7.1 while Statfit and Microsoft Excel were used for statistical analysis. The case study was taken from the Job Shop Manufacturing line of Body Welding and Metal Finish operations of truck assembly line. The result derived from simulation model of current system and four proposed simulation models that are based on three approaches are analyzed and presented to be considered as new strategy in improving the truck assembly line.

1. Introduction

Simulation is a contemporary Information Technology (IT) based technology that was raised to minimize risk and speed-up problems solutions. In order to develop a valid simulation model, companies can conduct experimental design to get a new design of their manufacturing system without disturbing the working system. Computer simulation model accommodates implementation of various Manufacturing Process Re-engineering Designs into computer based model and simulate it as well as justifying the performances.

Manufacturing and material handling systems provide one of the most important applications of simulation. Simulation has been used successfully as an aid in the design of new production and manufacturing facilities, warehouses, and distribution centers as well as in automotive industries. It has also been used to evaluate suggested improvements to existing systems [1]. Generally, engineers and analysts have found that simulation is very valuable to evaluate the impact of capital investments in equipment and physical facility, and to assist in proposing changes to material handling and layout. They have also found it useful to evaluate staffing and operating rules, and proposed rules and algorithms to be incorporated into warehouse management control software and production control systems. Furthermore, simulation is very useful in providing a "test drive" before making capital investments, without disrupting the existing system with untried changes.

This paper presents how simulation can be applied into Manufacturing Process Re-engineering Design in Automotive industries sub system in order to improve their performances using certain manufacturing performance improvement approaches. Each design will represent the solution alternative that is proposed based on particular manufacturing improvement technique.

This paper is divided into five sections. Section 2 gives literature review and definition few terms, Section 3 presents the current system while Section 4 presents the simulation model and the analysis on the model. Section 5 concludes the paper.

2. Literature Review

This section presents few definitions that related to the discussion. Four definitions given are what is simulation and its application in manufacturing industry, definition of line balancing, facility layout, and automated production system.

A system is defined as a collection of entities, usually people and machines, which act and interact toward the accomplishment of some logical end [2]. Simulation, according to Shannon [3], is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies. Carson [4] stated that simulation is most useful in seven situations; for example when there is no simple analytic model that is sufficiently accurate to analyze the situation.

The use of computer simulation in design and operation of automotive industries is very helpful especially in car and truck assembly plants. Most of the automotive manufacturers world-wide, such as Toyota [5], General Motors [6], Ford [7], and Mercedes-Benz [8] currently require new and modified manufacturing system designs to be verified by simulation analysis before they are approved for final manufacturing design. An integrated approach of how simulation being used in

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designing and evaluating a new manufacturing facility layout was show by Shady *et al.* [9].

In this paper, the impact of a new work cell design in improving manufacturing productivity is presented. The work focused on an assembly line consisted of many separate and distinct work elements. The sequence in which these elements can be performed is restricted, at least to some extent, and the line must operate at a specified production rate, which reduces to a required cycle time. Given these conditions, the line-balancing problem is concerned with assigning the work elements to workstations so that all workers have an equal amount of work. The objective in line balancing is to distribute the total workload on the assembly line as evenly as possible among the worker [10]. Two important concepts in line balancing are the separation of the total work content into minimum rational work elements and the precedence constraints that must be satisfied by these elements. .

Facilities design for manufacturing systems is also important for a company because of the productivity dependence on manufacturing performance. Since manufacturing is a value-added function, the efficiency of the manufacturing activities will make a major contribution to the company productivity. Greater emphasis on improved quality, decreased inventories, and increased productivity encouraged the design of manufacturing facilities that are integrated, flexible, and responsive. Tompkins *et al.* [11] wrote that the effectiveness of the facility layout and material handling in these facilities will be influenced by a number of factors, including changes in product mix and design, processing and materials technology, handling, storage, and control technology, production volumes, schedules, and routings, and management philosophies. Tompkins *et al.* [11] stated that the manufacturing plant or facilities layout might be differentiate into four types which are fixed position layout, process layout, cellular/group technology layout, and product layout.

Automation is the technology that the process or procedure is accomplished without human assistance. It is implemented using a program of instructions combined with a control system that executes the instructions. Groover [10] divides manufacturing automation into three types namely Fixed, Programmable, and Flexible automation. Fixed automation refers to the use of custom-engineered equipment to automate a fixed sequence of processing or assembly operations. Programmable automation refers to the design of equipment to accommodate a specific class of product changes, and modifying the control program can change the processing or assembly operations. Flexible automation refers to the design of equipment to manufacture a variety of products or parts and very little time is spent on changing from one product to another. These concepts is important in determine the type of automation of a manufacturing process.

3. The Truck Assembly Line

This section presents the current practice of the truck assembly line and problems faced by the management. The current manufacturing processes of the truck assembly line consist of 12 main processes. First half of the processes are made up of two sequences. The first sequence is Body Shop, Metal Finish, Paint Shop, and Trimming Cabin process while the second sequence are Rivet, Axle, Trimming Chassis and Engine Drop process. These sequences are conducted in parallel and combine at cabin drop section. The following processes are Final Assembly, Quality Control, Recty, and lastly is Delivery. Figure 1 shows model of the truck assembly line. Figure 2 shows the production flow process that is the detail of processes in Figure 1.

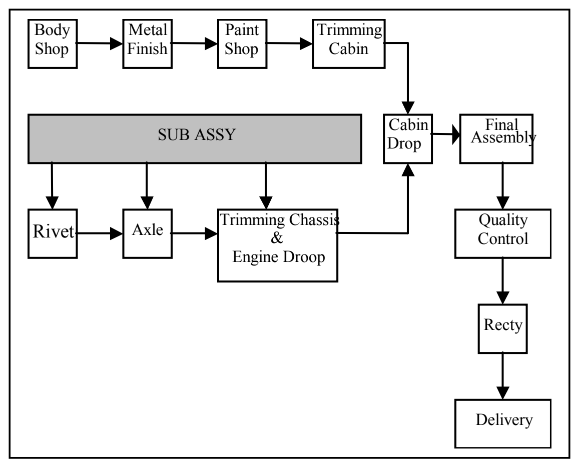

Figure 1 : General truck assembly processes

The company grand total production capacity of whole type is 15000 units per year, whereby the truck production is limited only about 6900 units annually. Since the significant rise of product demand in the past 3 years, so the company is facing the problem in improving the truck production capacity. From the current manufacturing layout, conclusion might be taken that there are still significant possibilities to improve the current layout. Another problem that could be found in the current system is the significant discrepancies of periodic production capacity. It indicates that the current manufacturing system was not well standardized. Studies also shows that there might be concluded that every workstation seemed have different number of component types to be assembled. Since the different number component types between every workstation is quite significant, it can be presumed that there is possibility that every workstation might have different workload of each others, in another ways it can be presumed that the body welding operations might have balance workloads that drive less manufacturing line efficiency.

There are four types of primary data collected for this project. Figure 3 describes the classification diagram of the primary data. The first type is the Factory layout and dimension. These data are used as primary consideration in developing a new proposed layout for the improvement system. The second data type is operation time. The operation time covers the workstation operation processes and transfer time. Manufacturing standard time (STT) parameter is used to represent workstation operation time while transfer time is divided into inter–workstation transfer time and inter-section transfer time that describe the time required to transfer work in process product from Body Welding section to Metal Finish section. After that, the data will be examined to ensure the validity to be used for simulation model and model analysis. Data validity that is based on these two types is data sufficiency and data quality. The other two types of primary data that collected are number of daily finish product or called Output standard and number of additional Work-in-process in buffer area. Both data are used in the model validation phase and to compare the system performance.

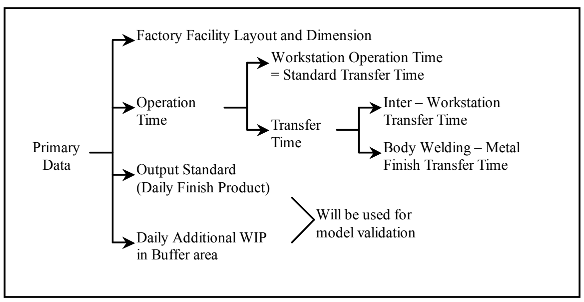

Figure 3 : Primary Data Collection

4. Simulation Model and Analysis

This section presents four proposed simulation models of the current truck assembly line and analysis of the models based on three performance indicator. The models are line balancing, parallel operation, separated material handling system (MHS), and full synchronized MHS as shown in Figure 4, Figure 5, Figure 6 and Figure 7 respectively. The performance indicators are output standard, finish product cycle time, and manufacturing line efficiency.

4.1 Output Standard

The first performance indicator is output standard which is a common normal daily production capacity of manufacturing line. Figure 8 shows comparison between current and simulation model.

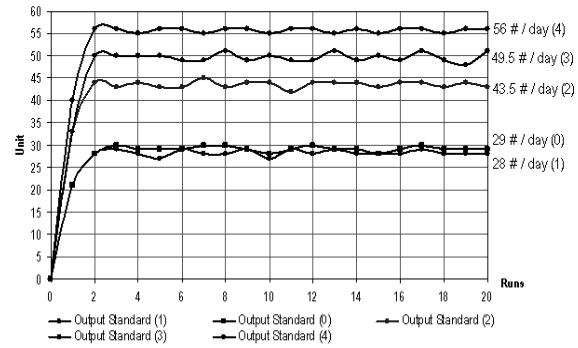

Figure 8: Comparison of output standard

The current model produced 29 products per day while the first model only accommodates 28 units daily. Although the first model might possible have higher line efficiency but the production capacity is lower than the current model. The confidence intervals for output standard for each model are also compared. For second model, the output standard increased dramatically until 43.5 unit per day or around 50% higher than the initial model. This proved that parallel operation in Metal Finish section could significantly improve the production capacity. The third model might give 6 additional product daily or about 14% higher than the second model. With this proposed system, 49.5 unit of daily production capacity can be achieved satisfactorily. The fourth model can boost the daily output standard at 56 units per day, which is 13% higher, that previous model and more than 93% higher from the initial model. This result is also justified that process breaking down and process automation might increase the production capacity radically.

4.2 Product Cycle Time

The second performance indicator is product cycle time, which are the interval time between finish products created at the end of the manufacturing processes. Workstation standard time and transfer time are the most important elements in finish product cycle time formulation. Figure 9 illustrated the comparison of the finish product cycle time for simulation and current model. As stated in Figure 9, initial model cycle time is 22.5 minutes per product. The simulation models seemed could reduce the cycle time from first model until fourth model that is: 20, 17.9, 9, and 8 minutes per product respectively. It means that the product cycle time totally might reduce until 60% by fourth model.

Comparison of the first and second parameter shows few conclusions. Third model gave the most significant improvement from 17.9 minute reduced almost 50% to 9 minute per product. Since the second model apply parallel processing while third model apply automated process, so it can be determined that parallel processing will improve significantly the production capacity, but process automation will mainly effect the cycle time. As shown in Figure 9, since automated workstation processes are applied in the third and fourth model, the cycle time for those two models are fully standardized with almost no variability.

Model	Average	Standard Deviation	Half Width	Lower Limit	to	Upper Limit
Initial Model	22.53	5.05	10.11	12.42	<-->	32.64
First Scenario	20.00	0.76	1.51	18.49	<-->	21.51
Second Scenario	17.87	0.52	1.03	16.83	<-->	18.90
Third Scenario	9.00	0.00	0.00	9.00	<-->	9.00
Fourth Scenario	8.00	0.00	0.00	8.00	<-->	8.00

Figure 9 : Comparison of product cycle time

4.3 Manufacturing Line Efficiency

The third performance indicator is manufacturing line efficiency that describes the total system utility. The higher line efficiency means that the manufacturing system is more efficient and utilized, at the same time also means less idle time. Figure 10 illustrated the manufacturing line efficiency between current model and each simulation model. Figure 10 likely explained that first model that apply line balancing gave the most significant line efficiency improvement from 61.5 % in the current model until 84.55% in second model (37.5 % improvement).

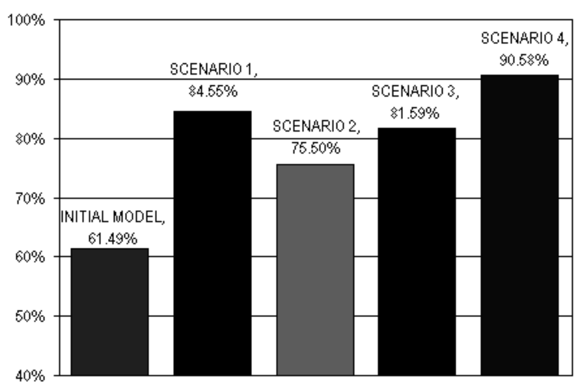

Figure 10: Comparison of manufacturing line efficiency

5. Conclusion

The solutions is designed based on four approaches and principles that cater how to minimize imbalance workloads in assembly line, to improve material handling capabilities through facilities re-layout, and to automate the processes. The initial model has been developed in term of process logic, animation and interfaces using ARENA version 7.1 Simulation application package. The model meet all requirement of ARENA model verification standard and the simulation run characterization have been determined to fit the non-terminating system behavior characteristic. Warm-up time, simulation length, data collection cycle, and starting method during replication are the chosen parameters for simulation run characterization. All four simulation models are successfully simulated in 20 working days runs with 5 working days as warm up period. The comparison of system performance indicators for each model successfully describe the behavior and characteristic of each model, and give more comprehensive understanding among simulation model and current model. The proposed solutions are expected to give benefits to the company in implementing new design of layout or strategy specifically the truck assembly line.

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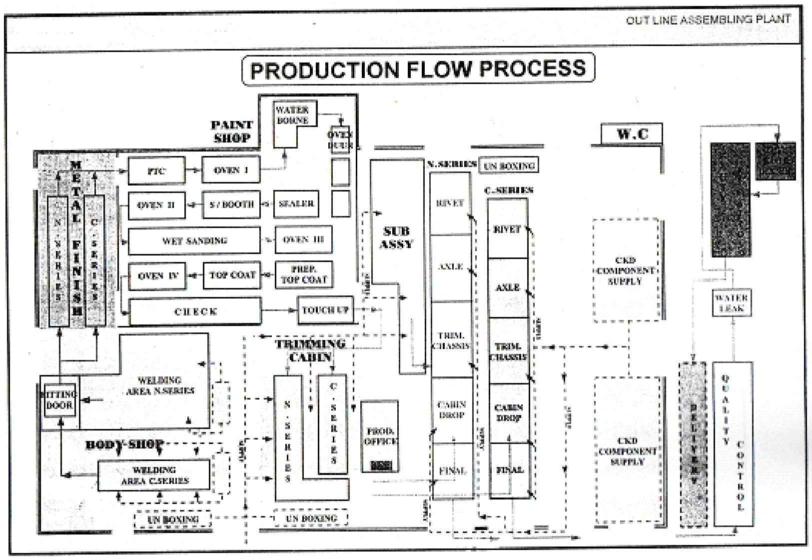

Figure 2: Production Process Flow

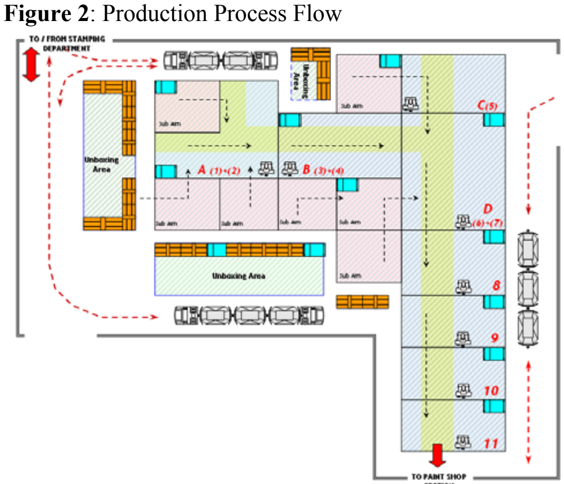

Figure 4: Line Balancing Strategy (First model)

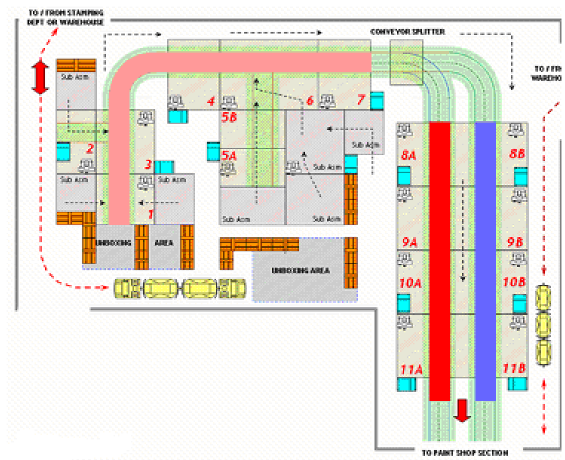

Figure 6: Separated MHS (Second model)

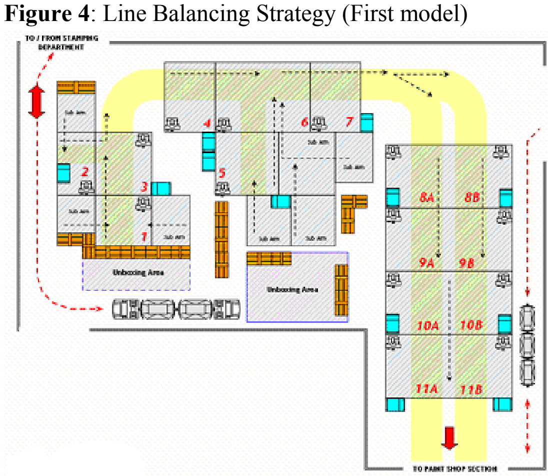

Figure 5: Parallel Operation Strategy (Third model)

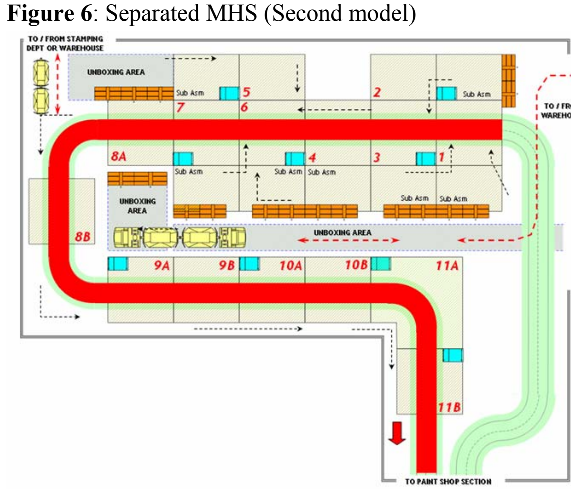

Figure 7: Full Synchronized MHS (Fourth model)