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DISCRETE EVENT SIMULATION IN AUTOMOTIVE FINAL PROCESS SYSTEM

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ABSTRACT

The Final Process System is an important part of the entire quality assurance system in the automobile manufacturing process. Operators and machines perform a series of crucial testing procedures before shipping a vehicle. Many complex factors impact the system throughput. The important ones are first time success rate, repair and service routing logic, process layout, operator staffing, capacity of testing equipment and random equipment breakdown. Discrete Event Simulation is a tool of choice in analyzing these issues in order to develop an effective and efficient process to ensure the system throughput. Using a case study from the automotive industries, this paper discusses the methodology of modeling and studying the Final Process System. The concepts and methods presented here are also applicable to other discrete manufacturing processes.

1 INTRODUCTION

The Final Process System is an important part of the entire quality assurance system for automotive manufacturing systems. The routing logic and the percentage repairs rates makes the system a very complicated one. Manufacturing and Industrial Engineers need to conduct analysis to answer the following questions:

- What is the impact of percentage repairs on the throughput?
- What is the best layout for the system?
- How many repair stations are required to meet the throughput?
- What are requirements for driver and operator staffing?

Discrete Event Simulation is widely used to answer these types of questions in manufacturing process design and operations (Harrell and Tumay 1995). It is a highly effective tool for the design of a manufacturing system relative to its ability to meet throughput goals within constraints of operational complexity. Discrete Event Simulation has been successfully used in the design and implementation of different automotive manufacturing systems (Ulgen et al. 1994, Upendram and Ulgen 1995, and Jayaraman et al. 1997). This paper focuses on the use of simulation for Final Process Systems.

We first present in section 2 an overview of the pertinent Final Process system and operations. Next in section 3, we present details of simulation model construction, verification and validation; and in section 4 the results of experimentation and analysis undertaken with the help of validated model. The conclusions of the study are presented in section 5.

2 SYSTEM DESCRIPTION

Final Process System is the last major process in the assembly of a vehicle. It is physically located following the Final Line of General Assembly. The system usually consists of a series of activities for vehicle testing (such as Dynamic Vehicle Test, Wheel Alignment), manual/visual quality inspections and repairing. The activities can either take place in a stand-alone station or a conveyor line. The vehicles are either moved on conveyors or driven by operators from location to location. A typical flow diagram for the system is shown in Figure 1:

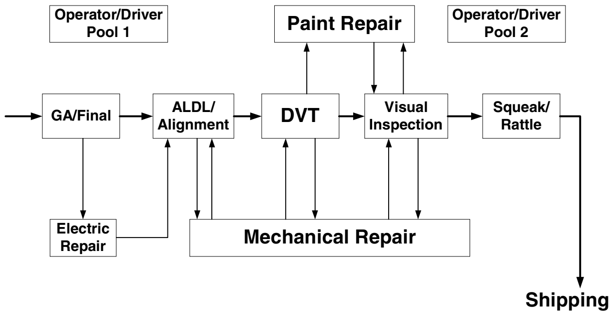

Figure 1: Typical Flow Diagram of Final Process

As shown in Figure 1, after the last functional test is performed on the vehicle on the Final Line flat top conveyor, an operator drives the vehicle off to an Alignment Station most of the time, occasionally to Dead Head Repair (Electric Repair) station based on the testing results.

In the Alignment Station, Wheel Alignment, Headlamp Aim and VAST (Vehicle Audio System Tester) are performed to the vehicle. Normally the driver performs the latter two operations. After the operation, the driver drives off to DVT Station if the tests are successful, otherwise to Mechanical Repair Station. After repair, the vehicle needs go back to test again.

DVT (Dynamic Vehicle Test) is a functional verification of the vehicle performed on a roll-test machine. It may include tests for emission controls, engines, transmission, brakes ABS/Traction control, cruise control, final drive ratio and so on. In DVT Station, the driver stays in the vehicle and performs the tests according to the prompts displayed on a test head video monitor. After the test, the driver drives off to the Visual Inspection Line conveyor if successful, otherwise to the Mechanical Repair Station. After repair, the vehicle needs to go back to test again. Sometimes, the driver takes the vehicle to the Paint Repair station, as marked by GA Final Line inspection.

In the Visual Inspection Line, the vehicle moves through a series of inspection stations on flat top conveyors where inspections are performed to detect any visual defects. After the Visual Inspection Line, the vehicle will be taken to off-line Water Leak Test and Squeak and Rattle Audit, and then to Shipping Dock if successful, otherwise it goes to Paint Repair Station or Mechanical Repair Station. In this case, the Squeak and Rattle Audit is performed on every vehicle on a track approximately 300 feet long.

Typically, there are two pools of operators in the process: operators in Pool 1 are responsible for moving vehicles from GA/Final conveyors through DVT operation, while operators in Pool 2 take vehicle from Visual Inspection area through squeak and rattle to shipping dock. They also perform tasks in the respective process areas.

3 METHODOLOGY

Simulation models are developed through various stages, such as determining the scope and objectives, collection of data, model construction, verification and validation, and output analysis. These steps are very important for success of a simulation project. (Jayaraman and Agrawal 1996, Robinson and Bhatio 1995, Ulgen et al. 1994)

3.1 Scope and Objectives

In this case, since Manufacturing Team strongly agreed that Process Layout, Testing Station, Repair stations and Operators have the most direct impact to the system throughput, we focused our analysis on capacities of these elements.

The decision variables were (1) number of repair stations; (2) number of operators; (3) number of testing equipment and (4) configurations of layout. Given the key performance measure as the system throughput, manufacturing engineers were eager to determine the best process layout and optimal capacity of testing stations, repair stations and operator staffing. They were also interested in evaluating different process options and utilizations of the costly testing equipment.

3.2 Data Collection

The Manufacturing Engineering teams provided the process data and layout. Key data items used in the development of the simulation model were repair rates at various process areas (i.e., GA/Final, ALDL (Assembly Line Diagnostic Link), DVT and so on), vehicle pick-up and drop-off times, vehicle repair times, equipment breakdown frequencies, equipment repair times and capacity of the testing equipment. The manufacturing engineers also supplied the routing logic.

3.3 Model Construction and Validation

Rockwell's ARENA was used for model constructions and analysis in this study. As a first step, a base model was developed which depicted a system without process variation. Model verification and validation was done by structured walkthroughs of model logic, extensive use of execution traces and by reasonableness of the animation (Porcaro 1996). The second model added stochastic variation, consisting of rejection probabilities, randomness of vehicle repair times, unscheduled downtime occurrences, randomness of equipment repair times. The initial results were also discussed with manufacturing engineers and compared with previous plant performance.

3.4 Documentation

It is extremely important to document the simulation projects in order to be successful. The simulation group has developed a set of standardized documentation to be used throughout the corporation in vehicle development process. These documents include information on: 1) Project objectives, scope and assumptions; 2) input data and their sources; 3) Experiment designs and results; and 4) conclusions and recommended actions. Microsoft Office and Visio templates have been developed to accurately and properly document each simulation project.

4 EXPERIMENTAL ANALYSIS AND RESULTS

Although the Final Process System operates on a shift basis and runs five days a week, it is modeled as a steady state system, because there is no transient state between shifts once the system is in steady state. A warm-up time of 8 hours is chosen to eliminate initial bias (Banks and Gibson 1996). Following this warm-up time, all the replications are run for 1000 hours of production. The system performance is measured in average number of vehicles shipped per hour (JPH). All repair areas operate in an off-line manner, where vehicles are moved in for repairs if the testing results are unsuccessful. It is assumed that the rejected vehicles can be repaired in the repair area. In other words, no vehicle will be scrapped. The time to repair a vehicle at Electrical Repair is assumed to be triangularly distributed with a mean of 26 minutes (the minimum and maximum value of 5 minutes and 120 minutes respectively). The repair time at Mechanical Repair and Paint repair are also assumed to be triangularly distributed with a mean of 36 minutes (7.5 minutes and 300 minutes as the minimum and maximum value). These assumptions are based on past performance data for a similar system.

As stated in Section 3, the objective of the study is to determine the best system, which in reality means that it should be capable of handling a first time success rate of 70% or higher. The system throughput largely depends on the following factors:

- First time success rate, which is a function of all the repair rates. It is assumed the repair rates to be normally distributed with a mean and stand deviation.
- Number of testing equipments, such as DVT and ALDL, whose capacity is impacted by the processing time and repair rates.
- Number of Repair Booths for all repair areas, whose capacity is impacted by the repair times and repair rates.
- Number of operators, whose capacity is impacted by the layout and processing time.

With the validated simulation model, we have conducted the following experiments and analysis to study the above factors and derive an optimal system.

4.1 Determine The Desired Level of Capacities

4.1.1 Optimizing Pool 1 Operators

Here all other constraints are removed from the system except for Pool 1 operators. Experiments are conducted by varying number of operators in Pool 1, the simulation results is shown in Figure 2, indicating that optimal number of operators required for Pool 1 is 9 to meet system throughput.

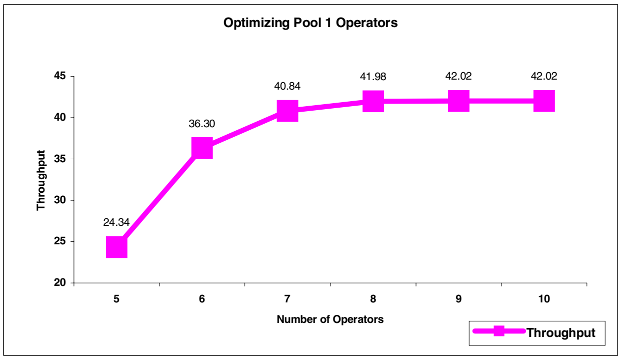

Figure 2: Impact of Operator Pool 1

4.1.2 Optimizing Pool 2 Operators

Using 9 operators for Pool 1 and removing the constraints concerning to repair stations, the same procedure is applied to determine the optimal number of operator in Pool 2. The result is show in Figure 3, indicating the desired number of operators should be 12.

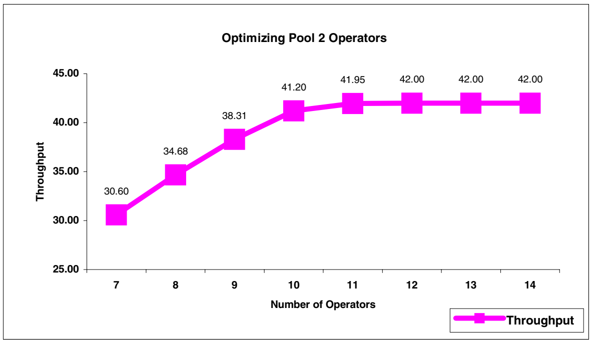

Figure 3: Impact of Operator Pool 2

4.1.3 Optimizing Heavy Repair Stations

After optimizing the operators for Pool 1 and Pool 2, number of simulation runs was conducted by varying the number of repair stations in the Heavy Repair area. Figure 4 indicates that optimal number of heavy repair stations required should be 9 in order to handle the system first time success rate of 70% or higher.

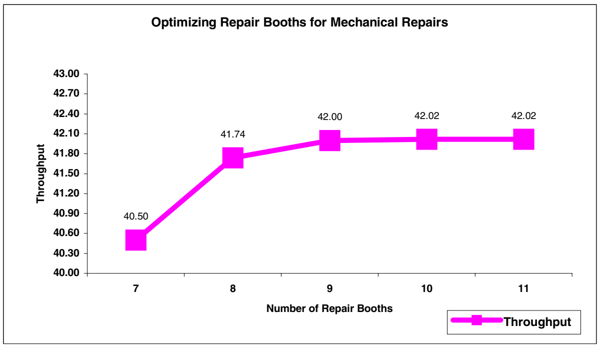

Figure 4: Impact of Mechanical Repair Stations

4.1.4 Optimizing Paint Repair Stations

After determining the numbers of operators and heavy repair stations, the same procedure was applied to obtain the number of repair stations in the Paint Repair area. Figure 5 indicates that optimal number is 5.

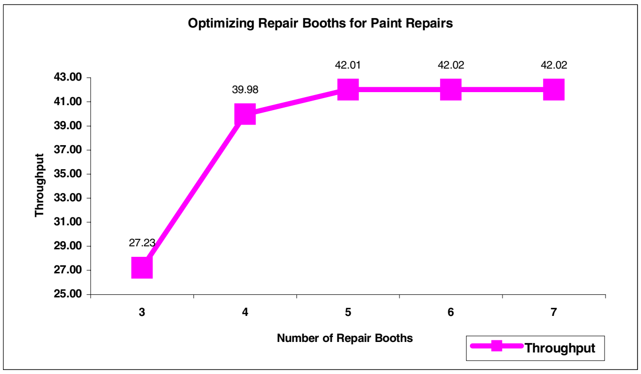

Figure 5: Impact of Paint Repair Stations

4.2 Determine the Impact of Routing Logic

In a separate simulation study, the capacity for Alignment and DVT Testing had been determined to be 3 and 5 respectively. In this case study, it is requested to study the impact of the routing logic. Specifically, the following two scenarios are given:

Scenario 1: The vehicle is routed to designated DVD station only as shown in Figure 6.

Scenario 2: The vehicle can go to any DVT station as it becomes available.

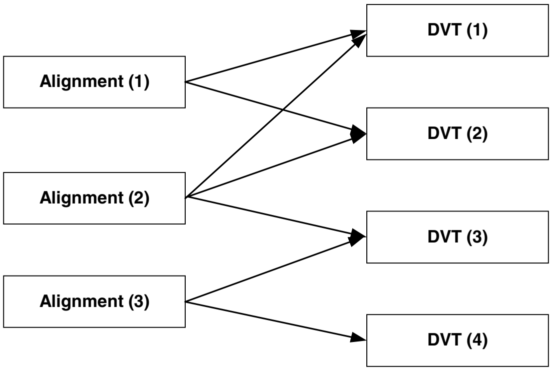

Figure 6: Routing Logic

Based on the simulation experiments on routing procedure, there is no significant difference in either scenario in terms of their impact on overall system throughput.

4.3 Identify Potential Resource Constraint

It is obvious that the overall throughput of the Final Process System is constrained by the GA/Final capacity, however, we are also interested to know if it is necessary to adjust the capacities of testing equipment and repair stations when the production volume is increased. Thus, the simulation experiment is conducted at the following conditions:

- Keep all the parameters of Final Process System the same as before.
- Increase the GA/Final throughput by a fixed percentage, such as 2.5%, 5% and so on.

The results are shown in Figure 7, which demonstrate that the Final Process System is able to handle twelve percent volume increase by GA/Final without changing the configurations of any elements in the system. However, if the production volume is increased by more than twelve percent, then Alignment area will become the system bottleneck.

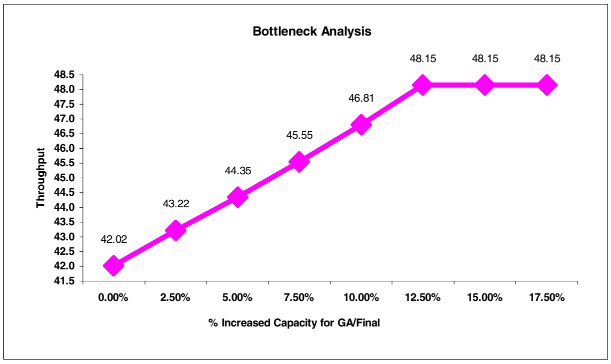

Figure 7: Bottleneck analysis

5 CONCLUSION

Discrete Event Simulation (DES) has been widely used in the automotive industries and other manufacturing environment for a long time. The general methodology of system analysis using DES is also well established. We need to emphasize the importance of asking the right questions in the beginning of any simulation project and keeping the focus on the analytical aspects of the project. The experiments in the case study demonstrate the ability to use simulation for optimizing resources and identifying constraints. Since the Final Process System is a common component in most automotive assembly plants, it is desirable to build a simulation template to speed up the model construction and simulation run.

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