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Discrete Events Simulation

Manufacturing Systems and Simulations ACMA6002

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1 Introduction

Discrete Events Simulation (DES) can be used for a plethora of applications especially within manufacturing. It's a computer modelling system that represents a sequence of individual events occurring over time. It can show how processes interact, resources are distributed, where queues form and the movements of materials. This makes it extremely useful in modelling production lines, production layouts and material distribution. It can help with optimizing lines to reduce bottlenecks and improve efficiency without having to physically change the production system (Qiao and Wang, 2021). For this study DES was used to model the FESTO 14.0 CP Laboratory which is an automated production system that is meant to represent a real world smart factory. It comprises of different components that travel through interconnecting stages such as inspection, drilling, dispensing, pressing and labelling. The aim of this study is to develop a current state DES model of the CP Laboratory to understand throughput, waiting times, resource utilisation and value adding time. Which will therefore mean an opportunity to do a lean evaluation of the process and understand where improvements could be made.

2 Literature Review

2.1 Discrete Events Simulation in Manufacturing

Discrete Events Simulation (DES) is increasingly used to support the design and optimisation of manufacturing systems. By creating a virtual representation of a production environment, proposed process changes can be evaluated before being physically implemented on to the factory floor, helping to reduce the cost and risk associated with production trials. Rather than assessing individual processes independently, DES can represent the interactions between equipment, resources and material flow, allowing engineers to predict systems behaviour and evaluate alternative solutions. This can support the early identification of issues such as bottlenecks, queues, resource conflicts and potential collision risks during the planning stages (Goyal, Yamamoto and Aslanidou, 2026). Another advantage of DES is its ability to represent variability within manufacturing processes, as processing and arrival times may fluctuate rather than remain constant. This enables performance measures such as throughput, cycle time, waiting time, queue length and resource utilisation to be evaluated under varying operating conditions. However, the reliability of simulation results depended on the quality of the input data and the assumptions used when developing the model. Inaccurate or unrealistic inputs may result in a model that does not accurately represent the real system, highlighting the importance of appropriate model verification and validation (Alsaadi, 2022).

2.2 Lean Manufacturing and Process Improvement

Lean manufacturing is a systematic approach to process improvement focused on maximising customer value while minimising waste within a production system. The principle of lean manufacturing is improving efficiency without adding additional resources to compensate. This is done by reducing waste, understanding resource utilisation and process flows. For example, resources should be used only where they contribute towards what the customer requires therefore not wasting time and money on activities that don't add value to the finished product. Lean manufacturing also emphasizes continuous improvement, requiring processes to be regularly reviewed and refined rather than left unchanged after initial implementation. The Toyota production system was at the forefront of modern lean manufacturing demonstrating how you can maximize resource utilization while minimizing waste aiming to achieve higher quality, lower costs and shorter lead times (Kumar et al., 2022)

Within this philosophy a distinction was made between value added (VA) and non-value added (NVA) activities to help identify where resources create customer value and where inefficiencies exist. Activities that directly transform the production in a way that customers are willing to pay for are classified as value added, while activities that consume resources without increasing customer value are considered nonvalue added and should be reduced or eliminated (Deshmukh et al., 2022). A common method for identifying NVA activities is the TIMWOODS framework, which categorises waste into transportation, inventory, motion, waiting, overproduction, over processing, defects and skills not utilised. By systemically targeting these forms of waste, organisations can increase the proportion of value added work and improve overall manufacturing performance (Wickramasinghe and Illankoon, 2025).

3 Current State Process

3.1 Process Overview

The current state FESTO CP Laboratory process consists of a sequence of automated manufacturing operations through which each component passes before reaching the final output station. Components first enter the process from robot assembly and then move to automated optical inspection. From here they are transferred to the drilling station, where the drilling requirements depend on the type of component being produced. In total 60% of components require two holes to be drilled, while the remaining 40% require four. Once drilling is complete, the components move through top cap dispensing, the hydraulic press and label printing before reaching the final output station.

As well as the main production stages, there are also operator dependent activities that can affect how smoothly the process runs. The top cap dispensing station needs to be refilled after every ten components, while the output station can only hold four completed assemblies before they need to be removed. Both of these tasks are carried out by the same production operative, meaning the operator is shared between two different areas of the process. Components also need to be transferred between each station, so the total time spent in the system is made up of both processing time and movement time. These different processing and transfer times are then used as the input data for the current state simulation.

3.2 Process Data and Parameters

The current state simulation uses the processing and movement data provided for each stage of the FESTO CP Laboratory. As shown in tables 1 – 3, the data has been split into part creation, process times and movement times. Where minimum, average and maximum times give triangular distributions so that the natural variation in processing time can be represented within the model. The movement times between stations are kept as fixed values as only one transfer time is provided for each movement.

As well as the timing data the model also includes the operating conditions from the case study. The product mix is split so that 60% of components require two drilled holes and 40% require four, which creates different processing times at the drilling stage. The top cap dispensing station also needs to be refilled after every ten cycles, while the output station is emptied after every four completed parts. Both of these tasks are carried out by the model. These inputs and operating conditions are then used to build the current state Arena simulation, with the model structure and logic explained in the following sections.

Table 1 - current state part creation times

Part creation time			
Process Function	Min(s)	Average(s)	Max(s)
1.Parts in From Robot Assembly	15	18	21

Table 2 - Current state process times

Process times			
Process Function	Min(s)	Average(s)	Max(s)
2.Automated Optical Inspection	2	2.4	3.4
3.Drilling (2 Holes)	16	18	20
3.Drilling (4 Holes)	30	33	36
4.Top Cap Dispensing	2.7	3	3.5
4.Refill (every 10x cycles)	110	120	135
5.Hydraulic Press	11.7	12.3	12.9
6.Label Printing	6.2	7	8.7
7.Output Station	3.6	4.1	5.1
7.Remove Parts (Every 4x Cycles)	20	26	32

Table 3 - current state movement times

Movement times	
Process Function	Average(s)
Camera to Drilling	8.2
Drill to Dispensing	7.3
Mag Back to Press	7.3
Press to Label	8.2
Label to Output Station	8.2

4 DES Model Development

4.1 Model Structure and Logic

The Arena model was developed to represent the current state FESTO CP laboratory, with each entity representing one component moving through the production process this is shown in figure 1. The model follows the same sequence as the physical system, starting with parts entering from Robot assembly before moving through Automated Optical Inspection, Drilling, Top Cap Dispensing, Hydraulic press, Label printing and finally the Output station. Hold and process modules were used throughout the model to control the movement of parts between each stage, while the movement times between stations were also included.

Additional logic was needed at the drilling and dispensing stages. A Decide module was used to separate components depending on the drilling requirement, with 60% sent to the two hole process and 40% sent to the four hole process before both routes joined back together. At the Top Cap Dispensing stage, a variable was used to keep track of the number of caps remaining. The value was reduced after each cycle and once the refill point was reached, the flow was sent through the refill process before the cap count was reset. This allowed the model to represent the requirement for the dispenser to be refilled after every ten components.

Similar logic was used to the end of the model to represent the limited capacity of the output tray. A variable was used to track the number of available spaces, while a decide module checked when the tray needed to be emptied. Once the removal point was reached, the flow was sent through the Part Removal process before the tray count was reset. An Output Hold was also used to control when parts could enter the final stage of the model. Completed components were then recorded before leaving the system, allowing the overall throughput to be measured.

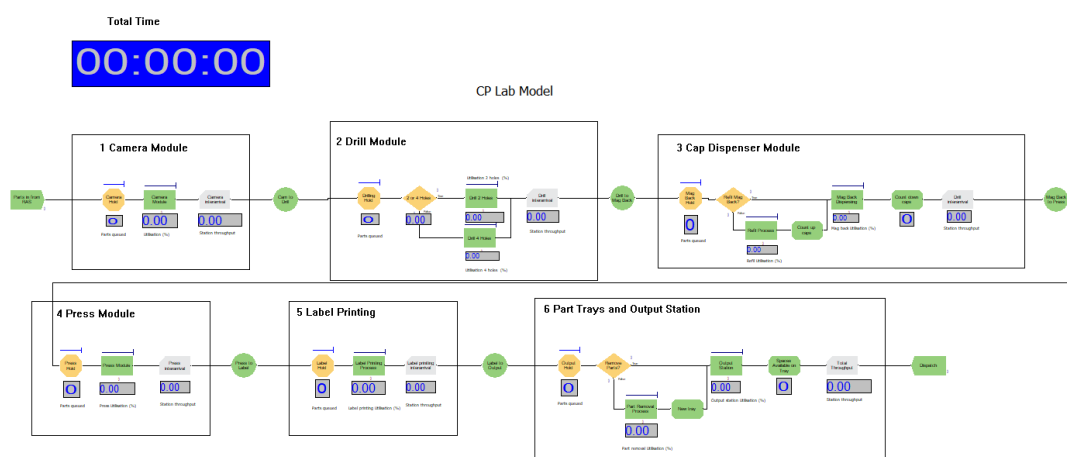


Figure 1 - Arena model

4.2 Model Inputs and Assumptions

The model inputs were taken from the data provided in the FESTO CP laboratory case study. Where minimum, average and maximum processing times were given, triangular distributions were used to include some variation within the model. The movement times between stations were kept as fixed values because only one transfer time was provided for each movement. The model also used the given product mix, with 60% of components requiring two drilled holes and 40% requiring four. The top cap dispensing station was set to be refilled after every ten components, while the output tray was limited to four completed assemblies before it needed to be emptied these simulation settings are shown in table 4.

Some assumptions were also needed where the case study did not provide any further detail. No extra variation was added beyond the processing. The model was also set to start in its normal condition, with the cap dispenser full and the output tray empty and ready for use. These assumptions were kept the same for each simulation run so that the results could be compared fairly.

Table 4 - Simulation setup

Simulation setup	
Setting	Value
Simulation length	8 hours
Replications	10
Base time unit	seconds
Warm up period	0
Production mix	60% 2 hole/ 40% 4 hole
Cap refill frequency	Every 10 components
Output tray capacity	4 components
Production operative	1 shared resource

4.3 Verification and Validation

Verification was carried out throughout the development of the model to check that each stage was working as intended. Parts were followed through the simulation to make sure they travelled through the correct sequence and that the decision logic operated correctly. The 60/40 drilling split was checked, along with the cap and output tray counters. The final model showed that the dispenser was refilled after approximately every ten components and the output tray was emptied after every four completed parts. The processing times and movement times used within Arena were also checked against the original case study to make sure the correct inputs had been used.

Validation was then used to check whether the overall behaviour of the model was reasonable. The simulation was run for eight hours over ten replications to account for the variation caused by the triangular processing times. The results showed a large build-up before the drilling process, which was expected as the average drilling cycle time was longer than the average time between components entering the system. Other queues remained considerably smaller, supporting the identification of drilling as the main restriction within the process. As no real performance data was provided, the model was validated against the process information given in the case study.

5 Simulation Results and Analysis

5.1 Process Performance

The current state model was run for eight hours over 10 replications to account for the variation in the processing times. Across the runs, an average of around 1,191 components were completed, giving a throughput of approximately 149 components per hour. The results also showed that not all of the components entering the system had left by the end of the simulation, meaning that 208 components in the work in progress were building up within the process. The total time that components spent in the system was also much higher than the actual processing time, this suggests that a large amount of the overall cycle time was being caused by waiting and queuing rather than the component being worked on. The queue lengths, waiting times and resources utilisation were therefore looked at in more detail to identify where the biggest delays were occurring and which part of the process was limiting the overall flow.

Table 5 - Current state simulation performance

Current state simulation performance	
Performance measure	Average results
Componets entering system	1,601.10
Components completed	1,190.80
Throughput	148.85 components/hour
Value adding time	72.13s
Waiting time	3653.60s
Transfer time	39.20 s
Total time in system	3,764.93s
Work in progress	208.36 components

5.2 Bottleneck and Resource Analysis

The results shown in table 6 show that the main bottleneck in the process is the drilling stage. Across the ten replications, the Drilling Hold had an average queue of around 199 components with an average waiting time of about 3,572 seconds or 59.5 minutes. This is much higher than the other areas of the process. For comparison the average waiting time at the Mag Back Hold was around 34 seconds, the Press Hold around 29 seconds and the Output Hold around 36 seconds. This shows that most of the build up in the system is happening before drilling. The utilisation results in table 7 show the same pattern. The two hole and four hole drilling processes had average utilisations of around 44.9% and 55.1%, meaning the drilling stage was being used almost constantly across the different product routes. In comparison the camera was used for around 14.5% of the available time, Top Cap Dispensing around 12.7% and the Output Station around 17.6%. The shared production operative had a higher utilisation of around 77.1% as the same operator was used for both refilling the cap dispenser and removing completed parts. Overall, the results show that drilling is the main restriction in the current process and is causing most of the waiting and work in progress in the system.

Table 6 - Queue and Bottleneck results

Queue and bottleneck results			
Queue	Average queue length	Average waiting time (s)	Waiting time (min)
Drilling Hold	199.09	3571.73	59.53
Mag Back Hold	1.43	34.27	0.57
Press Hold	1.21	29.07	0.48
Output Hold	1.49	35.99	0.6

Table 7 - Resource utilisation

Resource Utilisation	
Process	Average Utilisation
Automated optical inspection	14.47%
Drilling - 2 holes	44.90%
Drilling - 4 holes	55.07%
Top Cap Dispensing	12.73%
Hydraulic Press	51.03%
Label Printing	30.24%
Output Station	17.64%
Production operative	77.09%

5.3 Waste and Value Analysis

As shown in Table 5, most of the time a component spends in the system is waiting rather than being processed. The average value-adding time was around 72.1 seconds, while the average waiting time was 3,653.6 seconds, mainly because of the queue building up before the drilling stage. This means only a small amount of the total time is spent working on the component with most of it being lost through delays between processes. From a lean point of view, the biggest waste in the system is waiting, especially before drilling. The large queue also creates work in progress inventory because parts are entering the system faster than they can get through the drilling stage. There is also transportation between each station, although some of this is necessary for the process. Reducing the delays and build-up around drilling would therefore have the biggest effect on the overall flow of the system.

6 Lean Improvement Opportunities

The main improvement opportunity identified from the simulation is the drilling stage, as this is where the largest queue and waiting time were found. One option would be to increase the capacity of the drilling process, either by adding another drilling resource or by looking at ways to reduce the current drilling cycle time. This could help reduce the number of components waiting before drilling and improve the overall flow through the system. Bottleneck identification is recognised as an important part of improving production lines, while simulation can also be used to test whether proposed changes improve overall performance rather than only one individual process (Rocha and Lopes, 2022)

Another area that could be improved is the rate at which parts are released into the process. The current model shows that components are entering the system faster than the drilling stage can process them, which causes work-in-progress to build up. Controlling the release of parts more closely to the capacity of the drilling process could reduce unnecessary WIP and waiting without needing to add extra equipment. Research into WIP control also highlights that reducing buffer sizes and limiting work-in-progress can help maintain a more continuous flow and avoid overloading the process (Kumar et al., 2022)

Any changes would still need to be considered across the full process rather than focusing only on drilling. Rocha and Lopes (2022) found that increasing the rate at which parts enter a production line can increase queues without necessarily improving output when the system is already close to capacity. Improving the drilling stage could therefore move the bottleneck further down the line rather than completely removing it. For this reason, any proposed changes should be assessed against their effect on the whole system as well as factors such as cost, available equipment and resource requirements.

7 Conclusion

The simulation helped show how the FESTO CP Laboratory was performing and where the main problems were within the process. Across the ten replications, the model achieved an average throughput of around 149 components per hour. The main issue was the drilling stage, where a large queue formed and components spent much longer waiting than at any other point in the process.

The results also showed that most of the total time a component spent in the system was made up of waiting rather than actual processing. This created a build up of WIP before drilling and affected how smoothly parts could move through the rest of the process. From the results, the main areas worth looking at would be improving the capacity of the drilling process and controlling how quickly new parts are released into the system.

The model therefore helped identify where the biggest delays and wastes were occurring. Further simulation would be useful before making any changes, as improving drilling could simply cause the bottleneck to move somewhere else in the process.

8 References

- Alsaadi, N. (2022). Assessment and enhancement of the manufacturing productivity through discrete event simulation. *IOP Conference Series: Materials Science and Engineering*, 1222(1), p.012011. doi:10.1088/1757-899x/1222/1/012011.
- Deshmukh, M., Gangele, A., Gope, D.K. and Dewangan, S. (2022). Study and implementation of lean manufacturing strategies: A literature review. *Materials Today: Proceedings*, 62, pp.1489–1495. doi:10.1016/j.matpr.2022.02.155.
- Goyal, A., Yamamoto, Y. and Aslanidou, I. (2026). Adoption of discrete event simulation in manufacturing. *Journal of Simulation*, pp.1–25. doi:10.1080/17477778.2026.2628033.
- Kumar, M., Singh, Dr.K., Kannan, M., Kumar, R. and Rana, N. (2022). Work-in-process (WIP) control by lean and agile manufacturing. *2022 International Conference on Fourth Industrial Revolution Based Technology and Practices (ICFIRTP)*, pp.67–72. doi:10.1109/icfirtp56122.2022.10059427.
- Qiao, D. and Wang, Y. (2021). A review of the application of discrete event simulation in manufacturing. *Journal of Physics: Conference Series*, 1802(2), p.022066. doi:10.1088/1742-6596/1802/2/022066.
- Rocha, E.M. and Lopes, M.J. (2022). Bottleneck prediction and data-driven discrete-event simulation for a balanced manufacturing line. *Procedia Computer Science*, 200, pp.1145–1154. doi:10.1016/j.procs.2022.01.314.
- Wickramasinghe, V. and Illankoon, P. (2025). Service process improvement through VSM of lean six sigma: A case study. *2025 Moratuwa Engineering Research Conference (MERCon)*, pp.25–30. doi:10.1109/mercon67903.2025.11217077.