Proceedings of the 2019 Winter Simulation Conference
N. Mustafee, K.-H.G. Bae, S. Lazarova-Molnar, M. Rabe, C. Szabo, P. Haas, and Y.-J. Son, eds.

SIMULATION MODEL RISK-BASED SCHEDULING TOOL FOR HIGH-MIX AND LOW-VOLUME MANUFACTURING FACILITY WITH SEQUENCE-DEPENDENT SETUP TIMES

Jose E. Linares Blasini
Sonia M. Bartolomei Suarez
Wandaliz Torres-Garcia

University of Puerto Rico Mayaguez
Department of Industrial Engineering
Call Box 9000
Mayaguez, PR 00681, USA

ABSTRACT

The use of deterministic scheduling for high-mix and low-volume manufacturing facility is inefficient and obsolete due to the inherent variability and occurrence of uncertain events in the manufacturing floor. This project develops a robust scheduling tool for a high-mix low-volume manufacturing facility with sequence-dependent setup times taking into consideration some of the inherent variability of the manufacturing floor. This scheduling tool is created using the Simio software package to enable the creation of schedules that adjust to schedulers' needs while incorporating manufacturing constraints. This analytical tool was created to solve an existing problem for a local industry partner and it was investigated further through a case study.

1 INTRODUCTION

Production scheduling in a real-life scenario is very complex, specifically when the process includes changeovers that are time-consuming and sequence-dependent. Manufacturing facilities with a large volume of products from a small mixture of family products (high-volume & low-mix) can handle the scheduling task with more ease as fewer changeovers are needed. Exactly the opposite occurs in the planning process of a high-mix and low-volume manufacturing environment. The complexity in creating a schedule is increased as more and more setups are needed to satisfy demand requirements. A way to tackle the complexity of scheduling is by using a simulation approach. A properly validated simulation model that explains most of the variability in the production environment is used as an input to the optimization of resources and schedules. The variability in the system can be captured when using a simulation model with well-defined random variables such as downtime, repair time, absenteeism, machining time, and changeover time. A schedule that considers variation in the manufacturing floor along with other details can help reduce backorders of certain products with demand. A main decision factor in the scheduling process is the dispatching rule used which we investigate in this work using simulation.

2 METHODOLOGY

To create the scheduling tool, the Simio software package was used. Particularly, the Risk-based Planning and Scheduling (RPS) option which creates a schedule using an embedded simulation model (Kelton 2014). This schedule shows a detailed assignment of orders to resources based on several constraints like the number of machinists, work shifts, machine capabilities, equipment downtime, and repairs. These deterministic schedules are generated using a simulation model. This tool was developed following the typical simulation steps: understand the system, data collection, conceptual design, input analysis, model development, model verification, model validation, schedule creation, risk analysis, and experimentation.

The first challenge encountered to create the simulation model was the lack of robust information collected in a standardized manner. Hence, a data collection process was designed and implemented to characterize the system's variability behaviors which were poorly understood previously. Understanding these uncertainties allowed for a more representative model. Furthermore, there was a need to create customized logic subroutines using Simio Add-on processes functionality to satisfy modeling challenges and have an accurate representation of the system. Some of the modeling challenges are: (1) determining the amount of in-process sampling by part number, (2) triggering inspections, (3) processing failed measurements, (4) equipment repair processing, (5) machinist absenteeism, and (6) preventive maintenance. The simulation model ends up with a backbone of linked tables that feeds all the information necessary for its functioning. These can be edited easily for experimentation purposes of different scheduling scenarios. Two simulation models were created, one with 20 machines that represent a real-life manufacturing facility and the other with 10 machines designed to experiment with dispatching rules and other factors. The demand data generated for the smaller model consisted of 186 orders from 93 unique part numbers to represent a high-mix low-volume manufacturing facility with two different routing sequence-dependent scenarios.

3 RESULTS

The manufacturing floor was simulated taking into consideration real-world information and simulated variability depending on which model was explored. The accuracy of the industry-driven model was verified and validated while the case study model was properly verified and studied. The smaller ten-machine model was used to experiment with seven different dispatching rules (FirstInQueue, EarliestDueDate, Critical Ratio, Shortest ProcessingTime, Least Slack Time, and Longest Processing Time) to create monthly schedules that reduce orders completion time. The dispatching rule that performed the best in regards to the completion time of the orders was Least Setup Time after running the experiment with over 600 replicates to reduce the confidence interval half-width to 1 hour. Additional experimentation was performed to determine the optimal number of machinists needed across the different work shifts to minimize completion time and labor costs using the Least Setup Time dispatching rule. The resource quantity per shift was optimized using 3 to 7 machinists with a labor cost of $25/hr and using the OptQuest add-in. The best scenario for the 1st, 2nd, and 3rd shift consisted of 3, 3, and 2 machinists, respectively.

4 CONCLUSION

Ultimately, this work developed a simulation tool that models inherent variability in a high-mix low-volume manufacturing facility with sequence-dependent setup times and feeds into the generation of risk-based schedules allowing to forecast possible tardiness before it happens and update schedules dynamically as needed. The creation of the simulation model for a real manufacturing facility provided our industry partner with plenty of information to have a better understanding of their system. The data collection process helped identify many inefficiencies in the manufacturing process. For example, the inspection measurement sequence in the manufacturing execution system was not optimal for all parts requiring more time to complete all measurements. These were documented and provided to the supervisor in charge. The models had many detailed restrictions and resulted in a very large model in file size. Due to the complexity of the model, the experimentation of the system and their respective alternatives with different controls required extensive computer power and time. Future work would be focused on making the model computationally efficient, improve the cost function (e.g. add equipment costs, overhead utility costs) and its impact. The simulation tool with resource planning and scheduling capabilities can be used for both long and short time horizons to advance the planning process in high-mix and low-volume systems.

REFERENCES

Kelton, W. D., Smith, J. S., & Sturrock, D. T. 2014. "Simio and Simulation: Modeling, analysis, applications". Sewickley, PA: *Simio Forward Thinking*.