Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

RESOURCE PLANNING FOR ON-TIME DELIVERY IMPROVEMENT USING DISCRETE-EVENT SIMULATION: A CASE STUDY IN THE PACKAGING INK INDUSTRY

Kadek Wahyu Suarta Putra[1], and Niniet Indah Arvitrida[1]

[1]Dept. of Industrial and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, INDONESIA

ABSTRACT

This study presents a case of a packaging ink manufacturer based in Surabaya, Indonesia. The production process involves resources, including bowls, field operators, lab technicians, mixers, quality checking equipment, and a high-stacker. The company faces a persistent problem of low on-time delivery performance, which risks customer loss. To address this issue, a discrete-event simulation approach is employed, considering the system's complexity, process interdependencies, and queuing dynamics. The simulation evaluates several improvement scenarios to identify the best alternative for enhancing on-time delivery while accounting for changes in variable costs. Additionally, analysis for Net Present Value (NPV) is used to assess the financial feasibility of selected solution alternatives. The results indicate that a rearrangement of production resources can significantly improve on-time delivery performance. Although variable costs increase, the selected alternative yields a positive NPV, justifying the investment. This study demonstrates how simulation-based decision-making can support resource planning in complex manufacturing environments.

1 INTRODUCTION

The ink manufacturing process consists of several stages: weighing, mixing, quality checking, canning, and, when necessary, formulation adjustment. The process is highly dynamic and influenced by several production uncertainties. These include variations in order quantity (ranging from 15-900 kg), the number of adjustment iterations required (0-5 times), and lead time requests from customers (1-45 days). Each activity in the process is interdependent. For instance, a batch rejection during quality control can delay the canning process, causing queues for mixers and longer lead times for all work-in-process. Fully occupied lab technicians or field operators can also form queues within the system. Therefore, determining the optimal allocation of resources is crucial for improving on-time delivery performance.

From January to September 2023, the company received an average of 261 orders per month, with the peak recorded in May 2023 with 356 orders. To fulfill these demands, the company utilized 19 weighing bowls (11 large and 8 small), 6 mixers (3 large and 3 small), 1 set of quality control (QC) equipment, and 1 high-stacker for canning. Small bowls are designated for orders between 15–80 kg, while larger orders require large bowls. Similarly, small mixers can only handle orders less than 90 kg. The workforce includes four field operators responsible for weighing, canning, and adjusting the mixture. A lab technician is dedicated to quality control after mixing and reformulating the mixture materials. Despite these resources, the company continues to experience low on-time delivery rates due to bottlenecks in the production flow.

2 METHOD

Considering the variability, interdependence, and dynamic behaviour of the production system, the problem should be addressed using simulation methods. Given the system's nature—characterized by entity flow through sequential operations occurring at distinct moments—a discrete-event simulation (DES) framework is applied.

The modelling process in this study follows the five steps of simulation model development proposed by Robinson (2004). First, a conceptual model is developed as a simplified representation of the system. Next, a computer model is built, and the model is tested to ensure it has been correctly coded according to the conceptual model and produces credible results. After verification and validation, some experiments are conducted. The analysis is carried out to identify the optimal scenario based on the defined objectives.

This simulation study aims to determine the optimal number of field operators, mixers, and lab technicians required to achieve a high on-time delivery rate while accounting for the additional costs associated with resource changes, including overtime cost, inventory holding cost, labour cost, and maintenance cost. After completing the conceptual and computer models, the required number of replications is calculated using the relative error approach used by Kelton (2015). The model is then verified by checking the code, visuals, and output reports, and validated using a Student's t-test to ensure no significant differences exist between the simulation results and real-world performance.

Once the simulation model reflects the actual condition, improvement scenarios are developed to increase on-time delivery performance by varying the number of field operators (1 to 6), small mixers (3 to 5), and lab technicians (1 to 3). Scenario development is carried out in three stages. Initially, only one experimental factor is modified. The best-performing scenario from this stage is then used as a baseline in the second stage, where two factors are modified. For example, if the best scenario in the first stage involves increasing the number of small mixers from 3 to 5, all scenarios in the second stage will use 5 mixers by default, while varying either the number of lab technicians or field operators. In the final stage, all three factors are adjusted based on the results of the previous stages. Ultimately, the recommended scenario is selected from the best-performing scenarios of each stage.

3 RESULTS

The simulation of the existing condition indicates that the average on-time delivery rate is 57.23%. The required number of replications for the simulation is 20. A terminating condition is applied when production reaches 261 completed orders, following a 28-day warm-up period. The simulation results suggest that modifying resource allocation can significantly improve on-time delivery performance at an acceptable cost. The selected scenario recommends adding one lab technician and two small mixers, while reducing the number of field operators by one. This adjustment increases the average on-time delivery rate to 91.78%. The proposed changes would require an initial investment of Rp 526,000,000 and an additional monthly operating cost of Rp 5,730,729. However, these costs are justified by the potential monthly revenue gain of approximately Rp 1,361,925,000. The Net Present Value (NPV) over a 10-year period is calculated at Rp 296,435,117,244. In conclusion, the optimal resource configuration consists of three field operators, five small mixers, and two lab technicians, effectively improving the company's on-time delivery rate while accounting for the associated costs

4 CONCLUSIONS

The packaging ink manufacturer continues to face low on-time delivery performance due to bottlenecks within the production process. To address this issue, a discrete-event simulation (DES) method was employed to identify improvements in system performance. The selected scenario suggests an optimal allocation of resources, including three field operators, two lab technicians, and five small mixers. This configuration significantly improves the on-time delivery rate and is considered feasible based on the Net Present Value (NPV) calculation, which yielded a positive result. This study can serve as a foundation for further research involving systems characterized by variability, interdependence, and dynamic behavior.

REFERENCES

Kelton, W. D. 2015. *Simulation with Arena*. 6th ed. New York: McGraw-Hill Education.

Robinson, S. 2004. *Simulation: The Practice of Model Development and Use.* 1st ed. Sussex: John Wiley & Sons.