Proceedings of the 2020 Winter Simulation Conference
K.-H. Bae, B. Feng, S. Kim, S. Lazarova-Molnar, Z. Zheng, T. Roeder, and R. Thiesing, eds.

HIGH ACCURACY DISCRETE RATE AND RELIABILITY MODELING TO DRIVE IMPROVEMENT OF PLANT OEE AND THROUGHPUT

Lawrence B. Fischel

Clorox Services Company
4900 Johnson Drive
Pleasanton, CA 94588, USA

Thomas J. Lange

Technology, Optimization, and Management
631 Burns Ave
Cincinnati, Oh 45215, USA

ABSTRACT

For Hidden Valley Ranch salad dressing, increased demand required increased production capacity. Rather than obtain additional equipment, improved efficiency was sought using modeling and simulation. Using existing, historical plant data for line event status in JMP Statistical software, failure-mode-specific uptime and downtime distributions were obtained. Using these distributions in an ExtendSim discrete rate and reliability model, the simulation matched the actual data within 1% Overall Equipment Effectiveness (OEE). This high accuracy model enabled prioritization of equipment and procedural improvements and exploration of product selection, run rate, and buffer size changes. Several counterintuitive improvements were identified. Even though increasing the production rate also increases the failure rate, the overall throughput increases. Frequent, short duration stoppages might seem innocuous; however, the integrated cooperativity of the production line magnifies the effects. Visually understanding the impact of their actions on the line stimulated increased vigilance as well as increased agency in the operations staff.

1 INTRODUCTION

Even before the increased consumption in the current Shelter-in-Place conditions, demand for Hidden Valley food products was increasing. Some of the existing production lines had opportunities for Overall Equipment Effectiveness (OEE) improvement when compared to industry benchmark performance. Adding production lines is costly and has long lead times. Modeling and simulation sought to explore the potential to unlock leverage for increasing efficiency in the current production equipment. This paper presents the case study of using modeling and simulation to identify, quantify, and guide throughput improvement in a multiple-product, multiple-process-and-packaging-line food manufacturing plant. The plant already had a rich supply of data on line uptime and downtime events that was sufficient to describe up to 20 individual failure modes for each of over 20 distinct unit operations.

2 RESOURCES

JMP statistical software was selected for the data analysis because of its visualization, library, data analysis tools, flexibility in data transfer, and capabilities for automation by scripting. ExtendSim simulation software was selected because of its ease of use and capability to couple discrete event and reliability block diagram modeling. ExtendSim's reliability capabilities allow for multiple failure modes for each unit operation, for each failure mode to have a specific relationship to time ("reset," "preserve," "ignore"), and for communication to determine the dominant cause of each unit operation ("blocked," "starved," "failed") during a line failure. Furthermore, the data import and export capabilities allow for easy transfer of detailed distribution data and detailed output data between ExtendSim and JMP. Access to and collaboration with the plant operational personnel is crucial not only to get the data or make changes, but also to understand how to map the model to the equipment, and how to best validate and challenge the model. Furthermore, the clear, visual understanding obtained through the model of how their actions impact the process and throughput builds enthusiasm and commitment toward improvement efforts.

3 METHODS

- Data Preparation. The uptimes and downtimes associated with individual failure modes for each unit operation are calculated from the Line Event Data. Defining Availability as the fraction of uptime, plots of Availability over time, product type, packaging type, unit operation, and failure mode were made to identify a data set that was consistent (swings of less than about 5%) over an extended time, multiple years.
- Distribution Estimation. Lognormal, Normal, or Weibull distributions were used to fit the probability of an uptime or a downtime for each failure mode of each product category.
- Model Building. Each unit operation was represented by a Valve (rate control), a Tank (source of material), or a Conveyor (rate control with accumulation). Detailed process equipment data was required: tank volumes, conveyor speeds and lengths, buffer capacities of each conveyor, etc.
- Reliability Inclusion. Reliability block diagrams were associated with each rate-affecting unit operation. These diagrams also scaled the failure rates (constant failure per unit rate) to enable exploration of the impact of line production rate on availability and throughput (the product of rate and availability).
- Model Validation. In short, the ExtendSim Simulation produces the same type of line event data as that obtained from the actual production equipment. Model validation required agreement within 1% for the overall system OEE between a Simulation of 1 year and the actual data, (Actual – Simulated) < 1% OEE. After model validation, equipment, procedure, product mix, rate, and buffer capacity change scenarios could be explored with confidence.
- Scenario Exploration. The availability loss for each unit operation or failure mode was calculated from the source data. The availability gain was achieved by simulation after removing all the failure modes for each unit operation. In a similar way, the losses and gains attributed to procedural aspects, product mix, or of raw material supply were evaluated. The availability impact of changes in production rate was evaluated by scaling the uptime distributions. The availability impact of changes in the surge capacity for each conveyor was also evaluated.

4 RESULTS AND DISCUSSION

Those unit operations or failure modes that result in higher gains than their losses are the best options for attention, as they improve other failure modes that are sensitive to starts and stops. Two unit operations (Case Erector and Palletizer) were found to be impactful enough to warrant redundancy consideration. On the Labeler, at least two specific failure modes with high leverage were identified that could be readily addressed by increased attention from the operations staff. Increasing surge at a specific point in the production line effectively reduces the impact of the lower availability portion (before or after that conveyor) of the line. In many cases, where space is available, increasing the buffer capacity may be less costly than improving the efficiency of equipment. Even though the failure rate increases as the production rate increases, the overall throughput (product of availability and production rate) has an optimum.

5 CONCLUSION

Only through this high accuracy, multiple-failure-mode-per-unit-operation, and multiple-relationships-to-time approach can the specific, actual high leverage opportunities be extracted from the complex interdependencies of the process line. Had an averaged, single-failure-mode-per-unit-operation approach been followed, the gains and losses would be less accurate and essentially identical to each other. This approach enabled analysis of tradeoffs between manpower, capital improvements, and material changes. In cases such as found here, where no single unit operation had distinctly high leverage, the high accuracy enabled many small improvements to be identified to achieve substantial benefit, many points of %OEE.