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USE OF DISCRETE EVENT SIMULATION TO INFORM CAPITAL EXPENDITURES

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ABSTRACT

Schedules provide an invaluable data set for project management - the interconnection of tasks and their durations, forward and reverse path calculations, resource allocation, costs, etc. Schedules begin to suffer when tasks or sub-projects don't have a predecessor or have inherently long durations containing significant free slack with consequences for finishing late or penalties for finishing early. Expanded manufacturing is often tied to a sales forecasts or expecting customer(s), don't deliver on schedule and the loss of customers could be significant. The use of Discrete Event Simulation (DES) techniques to augment schedule data, incorporate task variances and build output distributions allows for a more informed project start date. This case study examines how to structure a DES inputs and outputs to help schedule the major components of expanding manufacturing; equipment and tooling, facility modifications, and initial build.

1 INTRODUCTION

There is no capital expenditure that garners more excitement in operations, management, and engineering communities than building out a new production line. Expanding production signifies a plethora of milestones in the life cycle of a product, the business, and the community overall. This case study examines the timing of bringing online a new production line and the creation of its initial product.

2 SCOPE OF PROJECT

Lead time for the production line was 22 months. Being that there was no significant predecessor to link the schedule to, there was a significant amount of free slack between the completion of the production line and the delivery date of the product off the new line to the customer. Unique to this situation, the Need-By date was fixed with the customer expecting first delivery in 40 months, with little room for negotiation. Project constraints included:

- Significant penalties for late delivery.
- Financial restrictions set by the Leadership Team on the funding profile for the expansion.
- Interest on the capital involved should the expansion finish too early.
- The potential of an extensive overtime expenses should the project start too late.

While construction, installing and setting up tooling and equipment, and training staff are well predicted behaviors, the initial build of product is an unpredictable variable. This particular product build was fraught with test and inspection failure modes which require extensive Markov Chains describing the resolution of the failure modes based upon the product's configuration. Often, the interaction between the product being manufactured and the newly installed equipment can cause issues requiring both rework of the product as well as a modification to the installed equipment. Assuming no failures, the overall manufacturing duration would be 8 months, with the construction and setup of the tooling and equipment an overlapping 22 months.

Making the critical path a total of 29 months. Starting the project at month 11 could drive extensive overtime, or worse yet, late delivery due to rework on failures. Starting now would lead unnecessary interest payments. Given these parameters, leadership questioned, "when should we break ground on the new production line to ensure we (a) deliver the product on-time (b) while minimizing additional expenditures on either overtime or interest on capital".

3 SOLUTION

The first step in identifying the solution is to select the appropriate modeling structure. Traditional embedded Monte Carlo tools offer the ability to adjust task durations using an underlying distribution to create an output-put distribution. While the question posed by leadership could be interpreted as a scheduling challenge, Monte Carlo embedded tools lack the functionality and structure to handle the necessary myriad of feedback loops generated by Markov Chains. When considering meeting a deadline, it is important to have the ability to adjust the manufacturing rate (ideally increasing the capacity) as rework adds duration to the schedule and a single shift may not be sufficient to meet the delivery date. The easiest method for adjusting manufacturing rate is to expand the human factor to work 2nd and 3rd shifts, plus weekend overtime to "make-up" the lost schedule. The ability to change the shifting within a simulated run while being able to adeptly handle the feedback loops generated by Markov Chains, lends itself nicely to the use of Discrete Event Simulation (DES) to explore the solution space. ExtendSim's robust database structure and shifting capability along with its path-selection structure made it the ideal DES tool choice for this project. To simulate this facility, model structure was broken into three major components:

- Finishing out the construction of the building and installing new equipment.
- Supplier delivered material and its historic on-time performance.
- Build-up of the first article on the new production line.

Impacts and delays in each of the three major components affect the other three as well. Construction delays and delays on installation of the new equipment will impact the overall duration of the project. The interaction between material delays and associated out of position plans with increased task durations have been vetted with production and design engineering teams. Lastly and most significant, are the Markov Chain failure models, each with an associated rework model, either to the product, manufacturing equipment, or both.

Three main cases were evaluated for success with nominal operating conditions, in which the Markov Chain failure models for the product build were set based upon established production values. Aggressive failure models where the Markov Chain failure models were selected from early production examples where the manufacturing processes and human factors were still in their infancy and process and manufacturing yields were lower than ideal. The extreme case, which used the aggressive failure model was used in conjunction with beta distributions designed to limit the rework durations to between the 60th and 99th percentiles.

4 CASE STUDY FINDINGS

The approach showed that under all but the extreme cases, starting on the 8th month into the 40 month timeline would ensure on time delivery, with minimal financial impacts. The analysis went further to show that starting on the 5th month, while not financially ideal, would ensure an on time delivery under the most extreme cases.

REFERENCES

WSC BoD (Winter Simulation Conference Board of Directors). 2020. Winter Simulation Conference. http://www.wintersim.org, accessed 15th April 2020.