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THE ROLE OF SIMULATION IN CAPITAL IMPROVEMENTS FOR A PACKAGING SYSTEM

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ABSTRACT

Simulation has many applications throughout the life cycle of a capital project. We discuss a case where simulation played a key role in conceptual design, execution, and startup for a major system upgrade. A discrete-event model was used to determine the accumulation buffer sizes required to support normal operations. Further detail was added to support development of the line controls logic narrative. The base model, with much of the logic removed, was used to debug the control system prior to starting up the physical equipment. The project included a custom schedule optimization tool, which was validated using simulation. In addition to this main model, two additional models were developed. One studied forklift congestion at the end of the lines and the other was used for A/B testing on control logic upgrades on an existing area of the system.

1 INTRODUCTION

Our case study discusses the role of simulation in a project to add automated case packing to an existing production process. The system consists of one main converting asset that distributes product to one of many primary packaging machines. Some pack configurations could be automatically case packed at the end of the line, but an increasing number of complex configurations required running product into bulk totes and manually hand packing offline. Simulation was critical in several phases of the project delivery.

2 CONCEPTUAL PLANNING

A major challenge in system design is understanding the optimal buffer sizing between machine centers. This system included long runs of conveyor from the primary packaging area to a new area of the facility for the automated case packing machines. The new location was primarily driven by space constraints. The long runs provided a good opportunity to add in-line buffers, however, low backpressure accumulation conveyor costs substantially more than belt-style transport conveyor. Several scenarios were simulated to determine the optimal mix of transport and accumulation conveyor. The model did not include detail on specific conveyor sections and device layouts, but it provided enough information to drive the next round of mechanical design.

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3 CONTROL LOGIC DEVELOPMENT AND TESTING

The model helped to define the logic narrative used to develop the line control code. As the mechanical design of the system progressed, we added more detail to the model, such as specific conveyor sections and automation control devices. High-level logic was included to control the conveyors, allowing us to observe system dynamics. For example, we induced faults on the case packers, checked the shutdown sequence for upstream equipment, and refined the recovery procedures to create a good flow of product on restart.

The same model was later used to validate the control system in a virtual environment. The models logic was temporarily disabled and replaced with software communications between control devices in the model and an emulated programmable logic controller (PLC) built for the physical system. This approach to debug improved the startup curves for each new component, since most bugs in the PLC code were corrected in advance. With several distinct startups, this scheme provided significant benefits for system uptime. Another major benefit of the virtual environment was that control logic could be fine-tuned to increase the density of accumulated packs while limiting backpressure.

4 SCHEDULE OPTIMIZATION TOOL VALIDATION

With new automated case packing, the system had many potential outlets that could all produce different package configurations. This drove the need for a new line scheduling tool for the system. With one converting asset feeding several downstream assets, standard ERP systems were unable to schedule the line. The planners had an existing tool for handling the three or four combinations on the system, but the added flexibility introduced by automated case packing presented a more complex problem.

We built a tool using mixed integer linear programming (MILP) to schedule production on each case packer to maximize throughput on the converting asset. Due to a non-linear constraint, the tool did not predict precise end times; these details were calculated in post-processing. Simulation played a role here by allowing us to validate the predictions of the MILP model and refine the run time estimates.

5 FORKLIFT TRAFFIC CONGESTION

A separate model was built to understand forklift traffic at the end of line palletizing. Building pallets is still a manual operation, so the traffic flow needed to quickly remove loads to the finished goods warehouse and also maintain a safe working area. The pallet handling model provided visuals for several concepts allowing stakeholders to make an informed decision to balance throughput and safety. Ultimately a design was chosen to limit traffic to hand-trucks in the manual build area and stage all finished pallets in a specific area for forklifts to move into the warehouse.

6 A/B TESTING FOR CONTROL LOGIC

Distribution of product to the primary packaging machines is controlled by a separate PLC. In the event of downstream faults, product is re-routed to maintain throughput on the converting asset. Operations needed a way to compare proposed logic changes before going live with new code on the system. We built a model that allows for A/B testing with new logic changes. It simulates unplanned stops at machine centers, uses emulated control logic to redistribute product in response to these stops, and records production goals and metrics. Objective comparisons of different control logic provided confidence that updates are actual improvements, not just theoretical ones.

7 CONCLUSION

Discrete-event Simulation can play many roles in the design and execution of packaging line projects. It supports conceptual design decisions and the definition of detailed functions. In some cases one model can be adapted for several purposes, but in others a separate model is more appropriate. Choosing where and how to effectively apply simulation to support project delivery requires artful judgment.