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OPTIMIZING PRODUCTION SYSTEM CONFIGURATIONS ACROSS A BROAD DESIGN SPACE: A CASE STUDY

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ABSTRACT

This paper presents a case study demonstrating the application of LineLab, a mathematical production system modeling tool, to optimize production system configurations and the ramp-up trajectory for novel mass timber building modules. The modeling tool can efficiently co-optimize a large number of variables, such as machine count, work-in-progress (WIP) count, average wait times, and throughput, thus helping to narrow down a broad design space. Sidewalk Labs, a Google company, faced unique challenges related to new product development, high-mix production, and phased ramp-up. This case study highlights the use of this mathematical optimization tool, and its integration with other simulation methodologies, resulting in an optimized digital pipeline for modeling the production scale-up for mass timber buildings. The insights provided contribute to the advancement of production optimization techniques and their applications across various industries.

1 INTRODUCTION

With mass timber emerging as an alternative in construction, Sidewalk Labs, a Google company, sought to leverage mass timber technology and automated, modular production for cost-effective and eco-friendly building construction. The goal was to narrow down production system options for manufacturing large mass timber components in an off-site factory to be shipped and assembled on site. Challenges included uncertainties associated with an innovative production approach and several low-maturity processes, numerous possibilities regarding production rates, production flow routing, and product mix between a diverse range of components, leading to a high-dimensional design space.

A novel production system modeling software that can optimize a conceptual production system configuration with many unknowns (LineLab 2023) was employed in the design phase of the factory to develop a comprehensive model of the conceptual production systems. The tool was used to help with the dimensioning of the factory, finding the needed capacity, exploring different modes of operation, estimating lead time and costs for producing different building components, to validate the business case, and to provide inputs for further modeling and simulation.

2 MODELING

LineLab is a software tool for optimizing production system concepts that has been applied to the aerospace industry, the semiconductor industry, and green tech, and has previously shown high accuracy (error below 0.64%), making it suitable for narrowing down a broad design space and conducting system performance trades with concurrent reoptimization. It uses mathematical models to accurately model the flows and conduct a multivariable optimization on any unknown parameters of the production system, and has numerous trade study features (LineLab 2023).

For the initial production concept, the models were created directly from existing spreadsheet data with execution plan, process time estimates, and resource cost information. The manufacturing team at Sidewalk Labs was in the early stages of planning the new factories; data were available from various suppliers and partners for estimated process cycle times for each product in the BOM. Process flow tables were imported from spreadsheets and automatically converted into production system models by the software.

The system models captured the expected processing times for the different products on each of the pieces of equipment as well as expected natural variability for each process, and part routing. Models included capital costs of equipment and facility, recurring costs of labor, materials, and inventory holding costs. Some models also included costs for scope 1 & 2 carbon emissions.

The ramp-up strategy for the overall system involved deploying equipment in phases, each bringing more automation and novel machinery into the factory, starting with a smaller facility and equipment shared by multiple different components, toward a high-investment permanent facility. The goal was to find the best configuration, possible rates, and approximate costs at each phase. Models were created as "Shared System" files, with specific resources used by multiple, co-produced products. This allowed for varying process times and routes for all the building modules. As some of the process models were further developed to be parametric, the different geometries and features of the products in the system also drove a mix of process times.

For a critical ramp-up phase, analyses included constraining one or more key pieces of equipment to a certain number while the rest of the system was optimized to find the best resource configuration and rate to optimize the utilization of the fixed key equipment.

3 RESULTS & DISCUSSION

The models optimized production resources to maximize performance and minimize costs while optimally buffering against variation. Optimized variables included critical dimensioning outputs such as equipment and tool counts, safety stock sizing, and expected flow behavior including value-add and queueing times, and machine utilization and availability.

The results showed how different end-product building configurations drive throughput and capacity needs when components are co-produced, at each of the different phases of the ramp up. This had direct relevance to the strategy and sales team for timing new projects to match favorable production economics. Moreover, the results revealed that shared workstation usage was only complimentary under certain conditions.

The analysis uncovered a previously unexplored strategy for parallelizing some bottleneck equipment that could improve throughput and costs by 30%.

The results of every iteration also contained sensitivity results for each input, which automatically exposed and ranked cost and performance drivers. When using parametric models, these encompassed all design inputs, which the manufacturing team could forward to the design team. For instance, it quantified how a proposed new fastener would impact the required production system capacity and costs.

The models were used to explore a vast array of different options and concepts as the design process for the buildings and the production system evolved. These parameters for the system dimensioning were then available for the detailed simulation and visualization of the factory.

REFERENCES

"LineLab Production Modeling Software". https://www.linelab.io/ (accessed Aug. 03, 2023).