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MODELING SUPPLY CHAIN RESILIENCY FOR ASSEMBLY FABRICATION USING DISCRETE EVENT SIMULATION

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ABSTRACT

Supply chain resiliency analysis has become a critical focus for organizations striving to navigate disruptions and uncertainties in a complex, global economy. For products requiring a multitude of components and suppliers, the magnitude of the impact of disruptions increases exponentially. Anticipating and addressing these potential disruptions necessitates advanced modeling approaches that provide actionable insights into how supply chain dynamics unfold under both normal and disrupted conditions. Researchers at Pacific Northwest National Laboratory (PNNL) developed a supply chain resiliency model using Process Simulator, a discrete event simulation (DES) software, to model the fabrication of assemblies. This DES evaluates the performance of an assembly's supply chain as a whole and its ability to keep pace with demand given the individual supply chains of each component used in the fabrication of the assemblies.

1 INTRODUCTION

Supply chain resiliency analysis has become a critical focus for organizations striving to navigate disruptions and uncertainties in a complex, global economy. For products requiring a multitude of components and suppliers, the magnitude of the impact of disruptions increases exponentially. Anticipating and addressing these potential disruptions necessitates advanced modeling approaches that provide actionable insights into how supply chain dynamics unfold under both normal and disrupted conditions.
Researchers at Pacific Northwest National Laboratory (PNNL) developed a supply chain resiliency model using Process Simulator, a discrete event simulation (DES) software, to model the fabrication of assemblies. This DES evaluates the performance of an assembly's supply chain as a whole and its ability to keep pace with demand given the individual supply chains of each component used in the fabrication of the assemblies.

2 METHODOLOGY

Each assembly is fabricated using 10 different components. Each component's supply chain is modeled independently, with certain shared raw materials and process steps between components explicitly captured. Building the model required eliciting detailed information from subject matter experts (SMEs) about the supply chain processes for each component. This detailed information included component machining steps, process batch sizes and times, procurement quantities, delivery frequencies, and failure/scrap rates. By modeling individual supply chains in parallel—all of which ultimately converge at the same facility—the team ensured the simulation captured the interdependencies between components and their manufacturing workflows. This granularity enabled the simulation to reflect how disruptions—such as contracting delays or machine downtime—can ripple through interconnected processes. Additionally, a critical, albeit unforeseen, outcome of this effort was the creation of a centralized repository consolidating data from numerous, disparate supply chains. This unified framework provides stakeholders with inventory level insights and process metrics, making it easier to identify gaps and vulnerabilities across each of the supply chains, and the system as a whole.

3 DISCUSSION

Employing DES for supply chain resiliency analysis allows for the injection of disruptions at discrete times throughout the simulation to explore various "what-if" scenarios and assist in identifying critical vulnerabilities in the supply chain. Scenarios like contracting delays for components, unexpected equipment breakdowns, or variability in machining process times can be modeled to evaluate their downstream impacts on production capacity and throughput. This model allows PNNL to help stakeholders answer questions such as: What is the limiting component in the assembly fabrication process? How sensitive is the system to contracting delays or equipment downtime? Which process steps account for the largest bottlenecks in production? And at what point does demand exceed the maximum supply capacity given current constraints?

Ultimately, PNNL's modeling effort provides a robust tool for addressing operational and strategic supply chain challenges. By capturing the procurement, processing, and fabrication phases—and their dependencies—the model empowers stakeholders to evaluate systems in precise detail, and as a whole. This allows organizations to proactively uncover vulnerabilities and optimize workflows before disruptions occur. For example, the model might reveal that a particular machining step creates a bottleneck, disproportionately slowing production relative to other process stages. Alternatively, inventory analysis could show that insufficient raw material procurement frequencies hinder intermediate inventory buffers. With these insights, stakeholders can take targeted actions, like refining machining workflows, improving contracting timelines, or increasing equipment redundancy to mitigate downtime risks.

4 CONCULSIONS

This talk will address the methodology, modeling architecture, and high-level findings of the PNNL supply chain resiliency DES for assembly fabrication.