Digital Supply Chains: the Role of Advanced Optimization Techniques

Ignacio E. Grossmann
Department of Chemical Engineering
Center for Advanced Process Decision-making
Carnegie Mellon University
Pittsburgh, PA 15213

This seminar addresses the need for a more integrated approach to supply chain that considers the relationships between the different flows in the supply network: information, physical, and financial flows. We first focus on the modeling of information flows in the supply chain, as captured in business processes such as the order-to-cash and source-to-pay processes, wherein a request travels through a network of transactions that modify the state of the request until it is fulfilled. Various chemical plant scheduling models from the Process Systems Engineering (PSE) literature are extended to model the flow of customer orders through a business process network, making the analogy that a business process is like a multi-purpose chemical plant and an order is like a batch of product. Of the models extended, the discrete-time State Task Network (STN) is found to perform best in larger problem instances due to its continuous relaxation tightness and its amenability to performance boosts by commercial solvers. A digital twin framework for business processes is then presented, which leverages discrete event simulation (DES) and discrete-time STN models for online scheduling of customer orders in an order-to-cash process network under demand and processing time uncertainty. The use of DES as a tool for uncertainty propagation in disturbance impact forecasting and order fulfillment date estimation is also discussed. Finally, we consider models that integrate the different flows and processes. A model is presented for integrating the order-to-cash process with a make-to-order batch chemical plant model. The model performance is evaluated in an extended version of the digital twin presented, which simulates both transactional and physical processes. The integrated model is then compared against single-focused models that either ignore the transactional network or simplify the physical processes involved. The integrated model shows the benefits of capturing the details of both the material and information flows, as well as the relationships between them, providing schedules that result in higher system profit relative to the single-focused models. In order to extend this model to include more than one supply chain echelon and financial flows, another model based on the STN and RTN modeling approaches is proposed.