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Dynamic scheduling of customer orders in the order-to-cash process of a chemical supply chain

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Abstract

There are two main approaches to supply chain modeling: bottom-up and top-down approach (Shapiro, 1999). The top-down approach is the more traditional approach to supply chain optimization, which focuses on the design, planning, and scheduling of supply chains. On the other hand, the bottom-up approach targets the transactional processes that are present in Enterprise Resource Planning (ERP) systems. In the PSE community, Laínez and Puigjaner (2012) have emphasized the need for a holistic approach to supply chain management, requiring a paradigm shift from operation-based decision support systems to integrated decision frameworks that account for the different areas (e.g. accounting, research and development, sustainability) and flows (material, financial, and information) associated with supply chains. The present work seeks to address this need by merging the two approaches mentioned by Shapiro. As a first step in accomplishing this, a framework is presented to integrate the material flows in a chemical batch plant with the information flows in the order-to-cash (OTC) supply chain process. Previous work by the authors includes the development of scheduling models to optimize the order transactions in the OTC process (Perez et al. 2021a; 2021b). However, these works focused primarily on the information flows in the supply chain and represent the physical processes as nodes in the transactional process network with a lumped process duration. In this work, we provide a more comprehensive approach, which incorporates manufacturing scheduling models in the order fulfillment supply chain model. This approach provides a more complete and accurate view of the supply chain by accounting for both material and information flows. The use of chemical production and material availability models enables an accurate modeling of the processing times in the chemical manufacturing steps, which in turn allows the optimization models to find better solutions when scheduling customer orders. Thus, this work takes a step forward in the development and management of digital supply chains by coupling information flows captured in the ERP system with material flows captured in production processes.

An illustrative example is presented in the context of the order fulfillment business process in the make-to-order batch chemical plant reported in Kondili, et al. (1993). In the plant, three raw materials (A, B, and C) are used to produce two products (P1 and P2), via three intermediates (AB, BC, and E). There are three unit operations in the plant: one heating step (heater), three reaction pathways (small or large reactor), and one distillation step (still). In the illustrative example, orders arrive with stochastic inter-arrival times and are processed by two different transactional agents. A stochastic discrete-event simulation framework is used to dynamically model the system behavior. Optimization events are triggered each time a new order enters the system, at which time a comprehensive State-Task Network model is called to schedule both the order processing steps and the plant operations. Whenever an optimization event is completed, updated order priorities and

queue assignments are passed to the transactional queues in the discrete event simulation, along with the updated production schedule. This closed loop approach allows the system to be optimized without compromising solution quality, as occurs when models focus exclusively on either the transactional system or on the manufacturing system. Purely transactional models can yield suboptimal results because these models do not account for synergies in the manufacturing plant arising from co-production, which allows reducing the order fulfillment lead times. On the other hand, purely physical models can result in schedules that are infeasible. This occurs because the models do not account for bottlenecks in the transactional process, which affect raw material availability at the plant. The integrated approach obtains more profitable solutions than those in the purely transactional approach, and corrects for the infeasibilities in the purely physical approach. These observations are shown in **Fig. 1**.

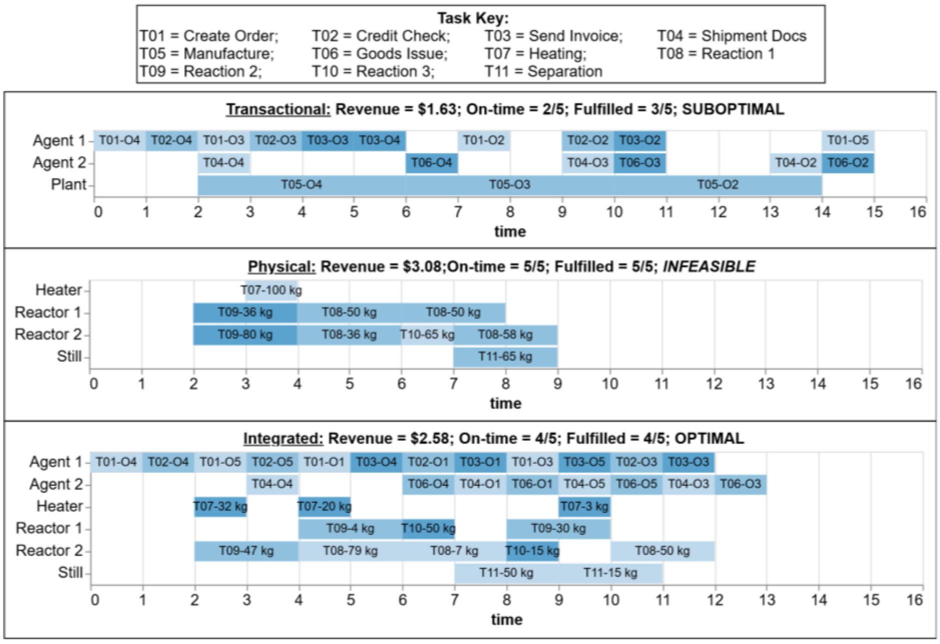

Figure 1. Schedules for each model. Batch sizes and order IDs are indicated in the bars.

Keywords: Scheduling, Business Processes, Supply Chain.

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