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Integrated learning and stochastic optimization for the design of distribution networks under endogenous uncertainty

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This work addresses the design and planning of a two-echelon omnichannel distribution network under endogenous uncertainty. The network consists of suppliers, retail stores, and distribution centers (DC) that serve a dual role i.e., replenishing retail stores and fulfilling direct-to-customer deliveries. We focus on strategic decisions such as the opening and configuration of distribution centers and the allocation of transportation capacity across the network. These decisions are supported by operational decisions related to inventory deployment and replenishment, as well as the assignment of customer orders to fulfillment channels. We formulate a multi-period two-stage stochastic program that maximizes the expected profit while balancing DC deployment costs, operational costs, and service responsiveness. In the first stage, the strategic design decisions are made before demand realization. In the second stage, after demand is revealed, we tackle operational decisions –inventory replenishment and the assignment of customer orders to fulfillment channels. Since the customers' willingness to order online depends on the Order-To-Delivery (OTD) time offered by the retailer, through the location of its DCs, this adds an endogenous uncertainty to the model. We integrate machine learning with stochastic optimization to tackle the model through an iterative learning-and-optimization approach. We predict demand in each iteration based on the current network configuration, reflecting factors such as service offers, OTD time, inventory availability, and responsiveness. These predictions are used to generate demand scenarios over operational periods, which inform the resolution of the two-stage stochastic program. The process repeats until convergence, that is, when the optimized network configuration becomes consistent with the structure used to generate demand scenarios.

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