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Progressive Hedging-based approach for combined forward and reverse logistics in hub-and-spoke e-commerce networks

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A consolidated business model for managing e-commerce logistics involves the combination of forward-and-reverse operations, where the collection of returns is ensured along with the distribution of products, and the use of hub-and-spoke networks, in which both distribution and collection demand from many customers are aggregated into intermediate hubs. In this context, we study a complex variant of the Vehicle Routing Problem with divisible deliveries and pickups, in which each hub may be associated with a mandatory delivery demand and a mandatory return pickup demand, and it may be visited more than once within the same or different routes. Given the large fluctuation of demand within the aggregating hubs, we also assume that an uncertain optional pickup quantity may arise and propose a two-stage Stochastic Programming formulation including ad-hoc recourse actions. The difficulty of solving the resulting model over many scenarios is overcome by the development of a Progressive Hedging-based matheuristic approach exploiting a scenario-wise problem decomposition, an Augmented Lagrangian Relaxation convergence framework, as well as heuristic improvements and refinements. Our method outperforms state-of-the-art solvers in terms of quality of the solution and efficiency over a representative set of realistic instances for the problem at hand and can be easily adapted to other similar settings.

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