

A Metaheuristic for Multimodal Transport in Decentralized Distribution

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This study addresses a mode selection and inventory allocation problem in a decentralized e-commerce distribution network across Europe. The model jointly decides (i) how much storage capacity to reserve in a local distribution center, (ii) how to allocate stock to satisfy SKU-level fill-rate requirements, and (iii) which transport modes and replenishment frequencies to use. The problem is formulated as a bi-objective optimization problem that minimizes total cost and emissions. For small and medium-sized instances, we present a mixed-integer programming formulation. For industrial-scale instances, we develop an NSGA-II algorithm for mode-frequency and capacity decisions, combined with a greedy heuristic for allocating SKUs to transport capacity and simulation for evaluating inventory decisions under stochastic lead times.

A case study based on data from industry partners demonstrates the scalability and applicability of the proposed approach for problem instances with more than 10^5 stock-keeping units (SKUs). The results show that all solutions on the obtained Pareto front dominate the current practice. Depending on the scenario, costs can be reduced by up to 20%, while emissions can be reduced by up to 40%. This is mainly because having local inventory allows the use of efficient transport modes for replenishment. The results further show that the value of reserving local storage capacity depends strongly on demand volume and order sizes, because split-order penalties play an important role in e-commerce fulfillment.