Abstract

An integrated supply chain operational planning system is a tool that is used to jointly optimize several planning decisions by capturing the additional benefits of coordination between sequential activities in the chain. In recent years, many companies have set up an integrated planning system and achieved multi-million cost savings. The key to success is an application that is not only able to produce solutions with minimal costs, but that can also be used in an effective and timely manner. In this study, we present solution algorithms for an integrated operational planning system arising in a typical supply chain network with a production facility and multiple retailers, called the production routing problem (PRP). This problem is a generalization of the inventory routing problem (IRP) where production lot-sizing decisions are incorporated.

Although the PRP and the IRP have received much attention in the past decade, only a few studies have introduced exact algorithms to solve the problems and most studies assume a single vehicle due to its complexity. In our study, we address the multi-vehicle aspect and introduce multi-vehicle PRP and IRP formulations, with and without a vehicle index, to solve the problems under both the maximum level (ML) and order-up-to level (OU) inventory replenishment policies. The vehicle index formulations are further improved by using symmetry breaking constraints, while the non-vehicle index formulations are strengthened by several cuts. Branch-and-cut algorithms are proposed to solve different formulations. We provide extensive computational experiments to compare the two formulation schemes and further explore the performance of the best formulation on parallel computing.

To handle larger instances, we also introduce an efficient heuristic based on the adaptive large neighborhood search (ALNS) procedure. The basic idea of the ALNS is to repeatedly destroy and repair the solution in the hope of achieving an improvement. In our heuristic, binary variables representing setups are handled by an enumeration scheme inspired from local branching and distribution decisions by upper-level ALNS operators, while continuous variables indicating production, inventory and delivery quantity decisions are set by solving a network flow subproblem. This heuristic is adapted to the PRP and IRP with both the ML and OU policies and is used to determine initial solutions for the exact solution algorithms. Extensive computational experiments have been performed on PRP-ML benchmark instances from the literature to evaluate the performance of the algorithm on large instances.
As demand is typically often uncertain in practice, we finally address the PRP under demand uncertainty. The problem is modeled as a two-stage decision process, where the first stage consists of making setup and routing decisions before the realization of demand, and the second stage involves quantity decisions made when the demand becomes known. We evaluate the solution in terms of quality and robustness using different approaches, namely scenario-based two-stage stochastic optimization and two-stage robust optimization. The solutions provided by these two approaches are then compared to the deterministic case under the ML and OU policies.