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The Traveling Salesman Problem with Pickups, Deliveries, and Draft Limits

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Abstract

We introduce a new generalization of the traveling salesman problem with pickup and delivery, that stems from applications in maritime logistics, in which each node represents a port and has a known draft limit. Each customer has a demand, characterized by a weight, and pickups and deliveries are performed by a single ship of given weight capacity. The ship is able to visit a port only if the amount of cargo it carries is compatible with the draft limit of the port. We present an integer linear programming formulation and we show how classical valid inequalities from the literature can be adapted to the considered problem. We introduce heuristic procedures and a branch-and-cut exact algorithm. We examine, through extensive computational experiments, the impact of the various cuts and the performance of the proposed algorithms.

Keywords Traveling salesman; routing; maritime logistics; draft limits; branch-and-cut; constructive heuristics.

1 Introduction

One of the most well known variants of the (asymmetric) *Traveling Salesman Problem* (TSP) is the *TSP with Pickup and Delivery* (TSPPD). The problem is defined on a directed graph $G = (N, A)$ with node set $N = \{0, 1, \ldots, n, n+1, \ldots 2n, 2n+1\}$ and arc set $A = \{(i, j) : i, j \in N\}$. Node 0 is the starting depot and node $2n + 1$ is the ending depot (that can eventually coincide). Each arc $(i, j) \in A$ has a cost $c_{ij} \geqslant 0$, and we assume that the *triangle inequality* ($c_{ij} \leqslant c_{ik} + c_{kj}\ \forall i, j, k \in N$) holds. One has to serve n customers, each of which is associated with a *pickup* node i and a *delivery* node j. We assume, without loss of generality that, for any customer i, the pickup node i is in $\{1, \ldots, n\}$, and the corresponding delivery node j coincides with $n + i$. The objective is to find a Hamiltonian path of minimum total cost that starts at node 0 and terminates at node $2n + 1$, in which the pickup node of every customer is visited before the corresponding delivery node. Although a customer may be origin or destination of a number of different requests, we always associate two distinct nodes to each request.

In the *capacitated* TSPPD (sometimes referred to in the literature as *the* TSPPD),