Time and Capacity Constrained Routing Problem in Railroad Planning

(Extended Abstract)

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Railroads account for 43 percent of America's intercity freight, more than any other mode of transportation. In the railroad industry, three optimization problems address important decisions: (1) the blocking problem, which determines how to aggregate shipments to reduce the impact of reclassification; (2) the train scheduling problem, which determines train origins, destinations, routes, and weekly schedules; and (3) the block-to-train problem, which determines which train should take which block.

Based on the tactical results from the blocking problem, the train scheduling problem and the block-to-train assignment problem, the trip planning problem aims to schedule multiple shipments on different days of a week. This paper considers the time and capacity constrained routing (TCCR) problem to support dynamic trip planning, which assigns multiple shipments to blocks and train-runs to minimize the total transportation cost while the train capacities are not exceeded and the due dates of the shipments are met.

The TCCR problem is defined on a time-space-train-block (TS-TB) network which includes all the information about train routes, time schedules, and blocks. Based on the TS-TB network, two integer programming models are formulated. The first arc-based formulation is a conventional network flow model, which selects arcs in the TS-TB network so as to find a connected path for each shipment from its origin-node to the destination-node while satisfying all side constraints. The second path-based formulation considers a set of feasible paths with respect to the TS-TB network and decides the optimal path for each shipment. The path-based formulation contains much fewer variables and constraints and thus is more manageable in practice.

Due to the large size of TCCR formulations, two heuristic algorithms are proposed to solve the problem more efficiently. The sequential algorithm sends shipments by priority one by one and each shipment is guaranteed to meet its due date and not to violate the existing train capacities. In this approach, Yen's algorithm is used to determine the K shortest train-blocking paths in the train-block network which only contains associated costs, and then the fastest train-run path is determined to meet the due time by only considering the trip which has enough remaining capacity. The sequential algorithm solves the TCCR problem primarily based on a relatively small network, but involves many repetitive operations when solving for a large number of shipments. Therefore, a bump-shipment algorithm is proposed to further improve the computational time. In this algorithm, all shipments are first scheduled together without considering train capacity limits, and then shipments with lower priority are bumped and rearranged so as to satisfy the capacity constraints.

In our numerical study, both sequential and bump-shipment algorithm solve the TCCR problem in a reasonable amount of computational time for representative data with 500,000 shipments provided by a major U.S. railroad. Moreover, the dynamic trip plans solved by our algorithms demonstrate greater flexibility to send shipments and result in better performance for every key cost factor than the static trip plan which is currently used in railroad. On average, the total transportation cost is saved by 12% for shipments which are assigned to a different trip plan than the static plan. To gain more insights of the dynamic trip planning problem, we further analyze the impact of distance factor and capacity limits. It is observed that larger distance factor would reduce travel miles but increase station costs, while larger train capacity lowers both the travel time and total cost.

In summary, the TCCR problem discussed in this paper is formalized using a time-space-train-block network and two optimization models. In addition, two heuristic algorithms are developed to solve large-scale real-life instances effectively and efficiently. Using data from a major U.S. railroad, the algorithms are tested for 500,000 shipments. Computational experiments demonstrate that the proposed algorithms solve the industry sized problems within a few minutes of computational time, and transportation costs are also reduced compared to the currently used trip plans.