Integration of Passenger and Freight Rail Scheduling

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Project Objective

In the United States, the freight railway industry is already running without much excess capacity. Hence, better planning and scheduling tools are needed to effectively manage the scarce resources, to cope with the rapidly increasing demand for railway transportation. The integration of freight train and passenger train scheduling and dispatching is an important railroad management task since in many urban centers they share the same track resources. Leveraging the current railroad trackage to meet the expanding demand in the future is a challenge. The objective of this project is to improve the efficiency of freight trains by reducing their travelling times while maintaining the punctuality of passenger trains.

Problem Statement

Complicating the train scheduling in urban rail networks is both passenger and freight trains share the rail tracks where these two types of trains have different priorities and characteristics. This sharing of the rail network can add significant delay to passenger trains if the freight trains are not effectively scheduled since freight trains travel at much slower speeds and are longer in length averaging between 6000 to 8000 feet, with the lengths expected to become even longer. We present a solution approach involving an integrated routing and scheduling model that can be used to optimize the travel times of the freight trains and tardiness of the passenger trains. The freight train travel time and passenger train tardiness are competing with each other since freight trains and passenger trains share the same track resources.

Research Methodology

We formulate the model as a Mixed Integer Programming (MIP) problem with routing constraints, travel time constraints, deadlock avoidance and safety headway constraints. The problem can be optimized by controlling three kinds of decision variables: routing decisions, arrival/departure time decisions and priority decisions. The algorithm we propose employs a decomposition based hybrid heuristic. First, the train schedules are vertically decomposed into two phases, passenger train scheduling and freight train scheduling. In the passenger train scheduling phase, only the objective related to passenger tardiness is considered, and the problem is optimized using a Genetic Algorithm implementation. In the freight train scheduling phase, the weighted objective is considered and we solve the scheduling of freight trains in an iterative approach. We propose a Backward-Forward Insertion algorithm to effectively solve the subproblem and insert the partial solution to the MIP model. We update the passenger train schedules to reduce the freight train travel time if the weighted objective can be improved.

Results

We test the proposed model and solution framework for a 59 miles long rail track network from Los Angeles to Riverside, CA. The trackage configuration consists of double-track segments and triple-track segments, and it contains eight passenger stations. There are 266 track segments and 88 junctions and the base case schedule is set according to the daily schedule of two passenger rail service providers in this area, Amtrak and Metrolink. In the base case, there are a total of 84 freight trains and 89 passenger trains per day. We refer to the approach which strictly follows our solution approach to get the decision variables, including routing decisions, priority decisions and departure/arrival time decisions as *Complete-Control*. The *Partial-Control* approach deploys the departure/arrival time decisions from our solution model, and uses a greedy based algorithm to construct the routes and assign the priorities as the trains travel along the rail network. The third approach is to randomly determine the freight train departure times and use a greedy algorithm for routing and priority assignment, which is referred as *Random-Departure*. The fourth approach is to assign the freight trains with uniform departure times (equal interval but randomly shift) and uses the greedy algorithm for routing and priority assignment, which is referred as *Uniform-Departure*. In both the *Random-Departure* and *Uniform-Departure* approaches, the departure times of passenger trains from the origin station follow the timetable.

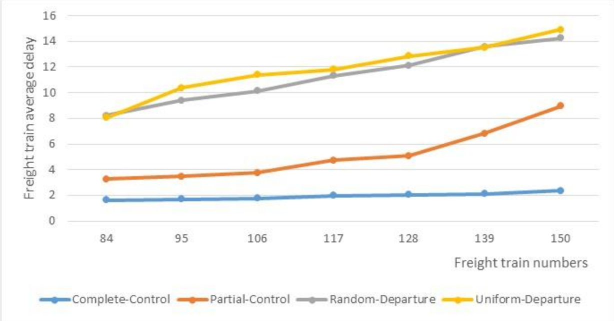

Figure 1. Freight Train Average Delay (min)

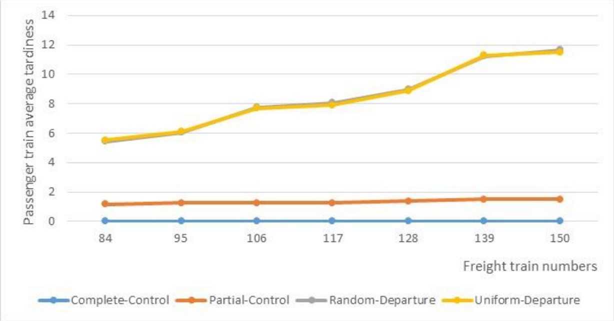

Figure 2. Passenger Train Average Tardiness (min)

A comparison of the four approaches is presented in Figures 1 and 2. Freight train delay is the difference between the actual travel time and the free flow travel time. Passenger train average tardiness is the average tardiness of the trains that arrive tardy to their stations. The figures shows the performance of these two measures as function of the daily number of freight trains. The base case has 84 freight trains and this number is increased by 11 in each scenario. The *Complete-Control* control approach outperforms the other three approaches in reducing the freight train average delay and the passenger train tardiness in each scenario. The *Random-Departure* and *Uniform-Departure* have similar results, since the departure times of the freight trains do not consider the traffic congestion of the network. Thus the delay of the freight trains and tardiness of the passenger trains grows with increasing number of freight trains. Note that the average free flow travel time of freight trains is about 72 minutes in all cases, so when the number of freight trains increases, the delay of the freight trains actually contributes to a larger percentage to their total travel time. These results indicate that to meet the expanded freight train capacity, our proposed solution procedure provides an efficient and high quality solution for the train scheduling and routing problem.