Abstract:

Nothing to do but to look for the next transfer train is the passenger’s plight when taking public transit in many places. To be able to design timetables with good co-ordination between train-lines so that passengers could enjoy “immediate” transfer is a service goal of the Mass Transit Railway Corporation (MTRC), which runs six railway lines with 13 interchange stations in Hong Kong. Whilst important, this problem has not received widespread research attention and there are few papers studying the problem of minimizing the transfer waiting time in a transit network, mostly by heuristic methods.

In this paper, we propose a mixed integer programming (MIP) optimization model for this timetable synchronization problem. The objective is to minimize the sum of all waiting times of all passengers at interchange stations in a railway system. By adjusting the trains’ run-times and station dwell-times during their trips, and their dispatch times, turnaround times and headways at the terminals, we can construct high-quality timetables that optimize the objective of minimizing passenger waiting times. A novelty in our formulation is the use of binary variables to determine the relative sequencing of trains on different lines with passenger transfers, which enables the correct representation of the waiting times for transfers to the “next available” train at interchange stations. Numerical results will be reported, which indicate that our approach improves the synchronization of the current schedule significantly.

With trains departing every few minutes from each terminal, there are a large number of trips to consider, and hence the MIP formulation for the timetable synchronization contains thousands of binary variables and tens of thousands of continuous variables and constraints. We also investigated an optimization-based
heuristic for this problem, where we first solve the LP-relaxation of the MIP formulation. Based on the fractional value of the integer variables, we heuristically “predict” their values, which determine the relative sequencing of the trains on different lines. Once we fix the values of some of the integer variables, we solve the resulting linear programming (relaxation) formulation, which is much smaller than the original MIP, to get the arrival times, dwell times, dispatch times, headways, etc. for all trains in the entire schedule in a very short time. By heuristically searching for the subsets of integer variables to fix, we can get good-quality solutions within a reasonably short time.

We focus our timetable synchronization study on railways only because the run times and dwell times are easier to control. Disturbances (e.g. congestion, traffic accident) in railroad are less then for road-based transport. Synchronized timetables are more easily implemented for railways, and thus resulting benefits are significant. That said, the formulation proposed in this paper is generally applicable to other (possibly multi-modal) transport systems as well. Also in our model, we not only adjust run times and dispatch times of trains but also dwell times, turnaround times and headway of trains, which are not studied in other papers.

In our preliminary study, we consider the train schedule in the MTR system in Hong Kong for both rush-hour and non-rush-hour periods. Using our model formulation, we constructed a schedule that reduce the waiting time for each transferring passenger by over 65% on average, compared to the current schedule. These solutions, whilst not guaranteed optimal, are obtained within a few hours of computation time. These are encouraging results. We also explore the trade-offs among different operational parameters and flexibility and their impact on overall passenger waiting-times.

Mass transit railways are important and growing transportation systems, especially for large metropolitan cities. By 2018, Hong Kong will have 12 railway lines with 26 interchange stations. High quality timetables can conserve time for passengers, generate goodwill, and have other advantages (e.g., reducing the air-conditioning load at stations). There is a need to develop systems to synchronize the schedule of trains.