An Iterative Approach for Integrated Planning in Public Transportation

Philine Gattermann
Institut für Numerische und Angewandte Mathematik
Georg-August-Universität Göttingen, Germany

Alexander Schiewe
Institut für Numerische und Angewandte Mathematik
Georg-August-Universität Göttingen, Germany
Email: a.schiewe@math.uni-goettingen.de

Anita Schöbel
Institut für Numerische und Angewandte Mathematik
Georg-August-Universität Göttingen, Germany

1 Introduction

The planning process in transportation planning consists of many different subproblems, which are usually solved in a specific order (Ceder and Wilson, 1986) with opposing objective functions (e.g. cost oriented and passenger oriented). First, a line plan is created, containing lines that are served in a specified planning period. Afterwards, times for visiting each station are assigned to these lines. A vehicle schedule is calculated for several periods together. This schedule does not need to be periodical. Overviews on these problems can be found in (Schöbel, 2012; Serafini and Ukovich, 1989; Bunte and Kliewer, 2009).

The disadvantage of this sequential process is that the whole solution depends heavily on the quality and structure of the initial line plan and the timetable, without the possibility to adjust them later. In this paper we propose an iterative process for improving a solution, which consists of a line plan, a timetable and a vehicle schedule, by reoptimizing one of the three structures while keeping the other two fixed, see Figure 1.

Thus, we formulate the respective problems and propose algorithms for finding optimal solutions.

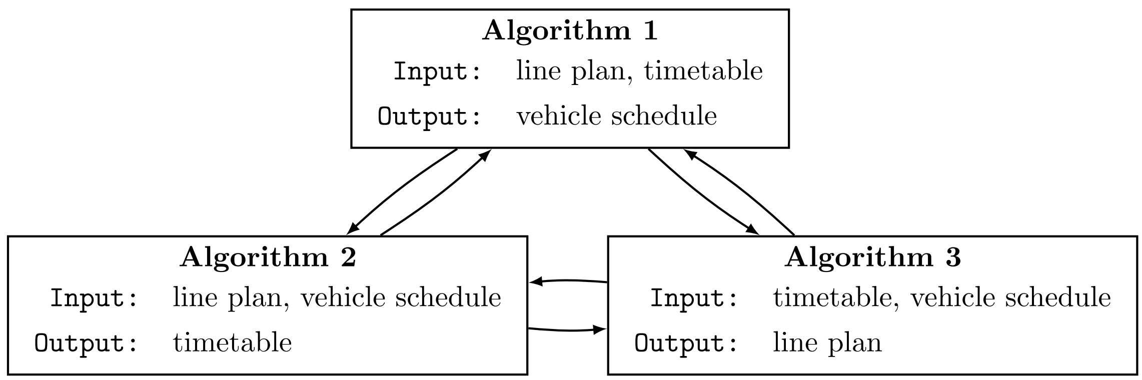

Figure 1: Overview of the algorithms

2 The Subproblems

We need to consider the three different problems as depicked in Figure 1. At first, we fix the line plan and the timetable and reoptimize the vehicle schedule.

Problem 2.1

Given *a line plan and a periodic timetable.*

Find *a vehicle schedule, which adheres the line plan and the timetable.*

This is the well knwon vehicle scheduling problem which arises in the classical sequential process.

A new timetabling problem arises, if we fix the vehicle schedule and the line plan.

Problem 2.2

Given *a line plan and a vehicle schedule.*

Find *a (periodic) timetable, which adheres the line plan, such that the vehicle schedule is still feasible.*

The third problem is a new line planning problem, where a timetable and a vehicle schedule is given, instead of only information regarding the underlying network.

Problem 2.3

Given *a periodic timetable and a vehicle schedule.*

Find *a line plan, such that the periodic timetable and the vehicle schedule are still feasible.*

Note that we consider the line planning problem with binary frequencies, as is done in most publications on timetabling.

These problems can now be solved iteratively in any order until no imprevement is possible any more.

3 Solving the Subproblems

First note, that problem 2.1 is known from the literature (see (Bunte and Kliewer, 2009)), so we will focus on the other two problems. Our goal is to provide models for these new problems and to develop algorithms for finding optimal solutions to these problems.

3.1 Problem 2.2

For problem 2.2, we extend the approach for solving the periodic timetabling problem using a PESP-formulation on a periodic Event-Activity-network (EAN) as follows:

When the vehicle schedule is known, we add *Trip*-activities in the corresponding aperiodic EAN which connect consecutive trips by the same vehicle and define appropriate lower and upper bounds. Since the resulting network is aperiodic, using an algorithm for aperiodic timetabling leads to a solution for the aperiodic timetabling problem. We can derive a periodic timetable for this problem via an IP-model for the aperiodic problem with coupling constraints for the events belonging to the same periodic event.

3.2 Problem 2.3

Now we consider the problem of finding a line plan for a given timetable and corresponding vehicle schedule.

Note that the vehicle schedule is aperiodic, but we want to solve the problem of finding a periodic line plan. For defining a new line in our new line plan, we hence need to ensure that the line is served nonstop by one vehicle in each period of the aperiodic EAN corresponding to the periodic timetable since we may not change the vehicle routes.

Therefore, we determine the set of possible lines by finding all *common label paths* in the aperiodic EAN, i.e., all paths in the aperiodic EAN, that are served nonstop by one vehicle in each period . This can be done by considering the Public Transportation Network (PTN). We introduce labels on the edges, adding one label per period and line covering the edge, stating the id of the serving vehicle in this period and the starting time of the corresponding activity. A common label path now needs to have a compatible label set for each edge in the path. All subpaths of these common label paths are possible lines for our line planning problem. These lines can be found by iterating over all edges in the aperiodic EAN for creating the labels, and afterwards iterating over all edges in the PTN for finding the common paths.

Using all subpaths of the common label paths as a line pool, we can now create a line plan. Note that every drive activity which is not part of a line in the line plan, should be considered as a trip activity and therefore it is not allowed for passengers to travel on this activity. Hence, we need a line planning algorithm that allows the rerouting of passengers, since declaring former drive activities to trip activities may break paths for passengers.

We formulate the problem as an integer program. The formulation is a line planning problem with an integrated multi-commodity-flow problem for routing the passengers, e.g. based on a given OD-matrix.

A way to avoid rerouting of the passengers would be to fix the trip activities and require the coverage on any other activity by a line. For this, the trip activities may not used to label the PTN. This would preserve the passenger capacities of the input solution, but may only find a new solution for very special objective functions (e.g. a cost-model, where the costs of a line does not only depend on the contained edges but also on the overall length of the line).

4 Experiments

Our algorithm is applied to close-to-real-world data and run iteratively. The data used is provided within (LinTim, 2007). The numerical results show the improvements provided by solving the subproblems in every step until convergence to a local optimum is reached. We discuss cases in which the iterative approach gives significant improvement and cases in which the solution by the sequential approach was already good.

References

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