Light Rail, Tram and Bus co-Timetabling Minimising Passenger Travel Time in Practice

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1 Introduction

Timetabling urban transport networks has been the topic of various papers. Different objectives, like transfer synchronisation (Ibarra-Rojas and Rios-Solis, 2012) up to a tradeoff between passenger service and operating costs (Ibarra-Rojas et al., 2014) have been addressed. In this paper, we aim to generate timetables which imply less expected passenger time than the current one in operation. The approach used is derived from earlier work on train timetabling, which is based on a Periodic Event Scheduling Problem (PESP) formulation (Serafini and Ukovich, 1989). This formulation is translated into a Mixed Integer Linear Problem (ILP) model and extended with an objective function that represents the *expected passenger time in practice*. This objective includes passenger ride, dwell and transfer time. Expected primary delays and dependent on these, an estimate for secondary delays are also contained in this measure which then leads to a timetable that is robust against delays. In this paper, the objective now also includes inter-departure and inter-arrival time components.

We have previously shown that cyclic train timetabling for entire countries typically takes some hours of computation. Two hours are needed for solving the Belgian national train model which contains 196 train lines while one hour is needed for solving the Danish one (Sels et al., 2015a,b) with 88 train lines. In this paper, we automatically generate a timetable for a transport network around The Hague, The Netherlands, which consists of 2 light rail lines, 10 tram lines and 8 bus lines, 241 light rail and tram stations and 223 bus stations, some of which overlap.

2 The Transport Network Case Study

The transport network studied is a mixed light rail, trams and bus network as operated by HTM around The Hague, The Netherlands. It has been studied in the literature before by van Oort (2011). The current design of this network is shown in figure 1.

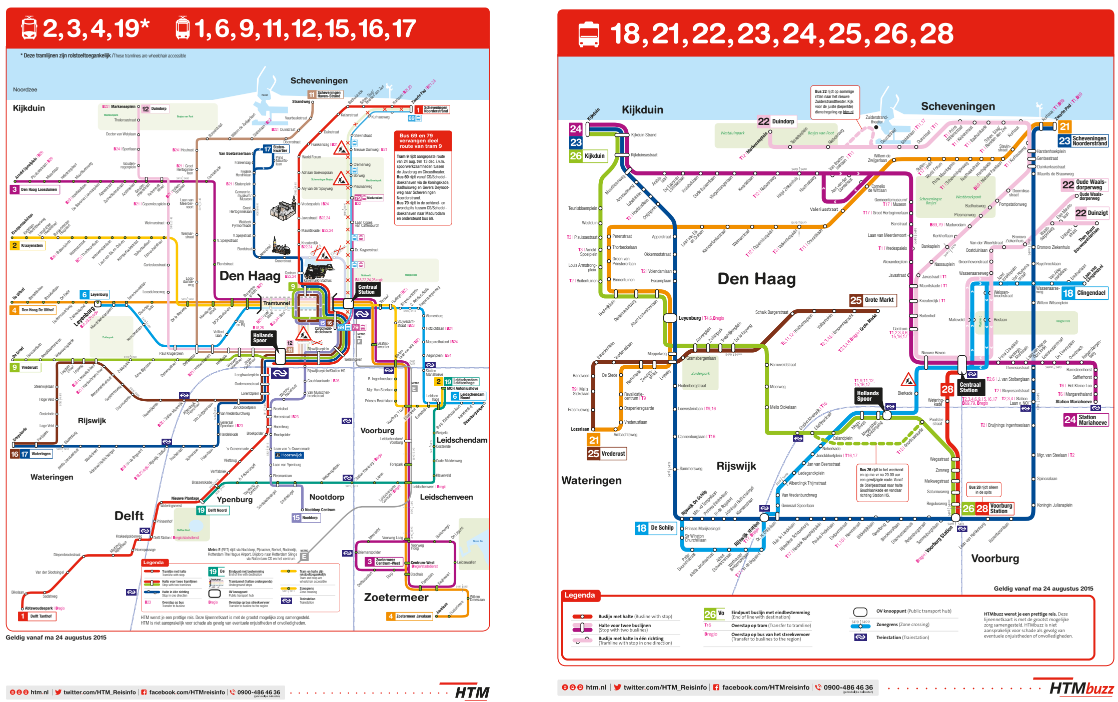

Figure 1: HTM light rail, tram and bus lines around The Hague

3 From a Train to a Tram and Bus Timetabling Model

Apart from the fact that bus and tram frequencies are higher than train frequencies, there are some more differences between train timetabling and bus and tram timetabling. The differences for this case study will be discussed in the next sub-sections.

3.1 More Detailed Origin-Destination Information

In our previous work on train timetabling we derived local passenger numbers starting from ticket sales data and then routing these passengers over the train network. These ticket sales are expressed in station to station resolution. So this data gives no information on train nor route choice yet. In our urban transport network, we have smart card data available from passengers. In buses and trams, check-in and check-out take place in the vehicle, providing also additional information on route choice (van Oort et al., 2015). So in this paper the OD-matrix defines demand from (vehicle, station) to (vehicle, station) rather than from station to station. However, information on numbers of passengers taking transfers are not available yet, so routing of passengers still has to be carried out first to obtain local passenger numbers that can then be used in the actual timetabling.

3.2 Dropping Collision Avoidance Constraints

In train networks, if trains follow each other on the same track, they cannot overtake. This is similar for light rail and tram networks. In bus systems, it is assumed that overtaking is always possible, since roads have multiple lanes or buses arriving in some order at stops can freely depart in any other order. This means that PESP models for trains usually have many headway constraints that dictate that train pairs need to be separated by a number of minutes, usually 3. Bus network models typically do not contain such constraints.

3.3 Keeping Both Arrival and Departing Times

In train timetabling, one considers ride and dwell activities separately. In tram and bus timetables, one only plans the ride activities and dwell activities are generally assumed to be so short that they are not worth planning a separate arrival and departure time for. In train planning, the railway infrastructure manager is responsible for the calculation of minimal run times for each ride activity between subsequent stations. In tram and bus systems, the ride time is dependent on the presence of other traffic. So, basing minimum ride times on a calculated minimum which assumes the absence of other traffic would be less realistic than basing it on averaged realised run times. We used these averages and assumed that the minimum is 10% less than that average (van Oort, 2011). On top of these minima, we try to optimise supplement times as we also do for train timetables. For dwell activities, we assumed a minimum of 20 seconds and added supplement time (sometimes called reserve time for ride activities and buffer time at stops) on top of that. We believe this is more realistic than assuming 0 seconds for the dwell minimum. We also have a more flexible model if we allow dwell supplements to deviate from 0 seconds than if we fix all dwell supplements to 0 seconds. For trains, often a non-zero dwell supplement has to be added to avoid train collisions. As mentioned, for buses, avoidance of collisions needs not be modeled since drivers are assumed to take care of that in real time. However, a non-zero dwell supplement may allow more passengers to come in and transfer from another vehicle. Distinguishing between arrival and departure times and requiring them both for a timetable specification also leads to a more accurate specification of timetables. This could be useful for example in specifying timetables for energy efficient driving.

4 Expected Results

We noted there are some aspects that make urban transport network timetabling models more complex and some aspects that make them simpler. So we wonder how that would affect computation time. We expect that the urban network around The Hague with 20 lines as described in this paper will solve faster than the train networks with 88 and 196 train lines studied before. We expect that similar to our train models, some expected passenger time will be saved and that transfers can be scheduled in a more robust way.

5 Conclusions

We are in the process of generating a timetable for an urban transport network around The Hague containing 20 lines of mixed nature: light rail, tram and bus lines. As was the case in our previous work on train timetabling, we expect that the generated timetables will save passenger time and make transfers more robust compared to the current timetable.

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