Topic Proposal for a thesis:

Can we make it to the end? Combining line planning and timetabling to ensure connections

Scientific head: Prof. Dr. Francesco Corman
Supervision: Viera Klasovitá & Florian Fuchs

Background

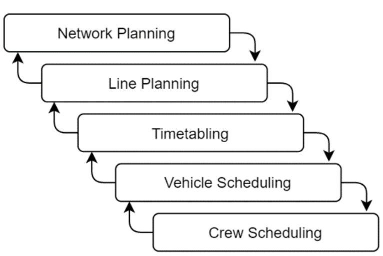
Public transport networks are a crucial transport infrastructure. Their design is the main factor in their potential success. Determining route planning, timetables, and vehicle dispatching is a complex set of interrelated tasks. Development is usually tackled by hand, with multiple objectives requiring time-consuming consideration. Within each task, decisions require multi-criteria optimisation. These planning steps are usually performed sequentially for simplicity (Liebchen and Möhring 2004). However, research has shown that integrated approaches lead to better solutions, but on the other hand, they also increase computational complexity (Schiewe 2020). Thereby, iterative approaches provide a powerful means to trade computation complexity against solution quality.

Problem description

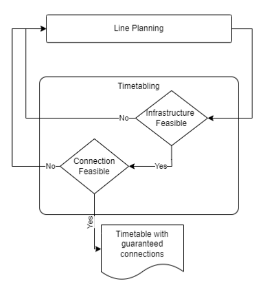
Many iterative approaches allow to the consideration of more than one planning step. For instance, Fuchs and Corman (2019) propose an iterative framework that allows iterating between line planning, timetabling and vehicle scheduling. Alternatively, Pätzold et al. (2017) propose an efficient look-ahead-heuristic, which limits the set of available candidate services in the line planning stage by looking ahead. Schöbel (2017) provides a general approach, the Eigenmodel, to formalise any iterative approach.

However, iterative approaches offer limited interactions between the models. This weakness bears a risk. Essentially, some properties of a solution found in one model might be violated in the subsequent model. For instance, it is conceivable that initially, a line plan promises a connection for an OD relation. However, the subsequent timetable does not yield transfers of the promised quality due to infrastructure limitations. Thus, the iterative approach might lead to an inconsistent result, as the line planning model needs to be made aware of the unacceptable quality of the connection.

This proposal addresses this gap by requiring the student to provide an iterative approach that considers the stages of line planning and timetabling in an iterative approach such that the connections promised in the line plan are also available in the corresponding timetable. They should combine a state-of-the-art line planning model, based on Pätzold et al. (2017), Burggraeve et al. (2017), Fuchs et al. (2022) and periodic timetabling model as Großmann (2011), Gattermann et al. (2016), Fuchs et al. (2022).



(a) Planning stages as sequence (Liebchen and Möhring 2004)



(b) Considered stages and interactions

Figure F1: Workflows

Figure F1b provides an overview on the expected iterative model. The line planning and the timetabling model should interact with each other, such that the line planning model is, on the one hand, aware of infrastructure conflicts as proposed by Fuchs et al. (2022) and, on the other hand, that a subsequent check assures that all connections promised in the line planning model are also provided in the timetable. Consequently, the thesis can be seen as an extension of Fuchs et al. (2022). In essence, this process describes a logic benders decomposition, where the master problem is the line planning problem and the subproblem is the timetabling problem, focusing on feasibility (Hooker and Ottosson 2003).

Approach

As the topic covers two planning stages, the task is challenging. To mitigate the challenge and manage the risks, we offer support in the form of the OpenBusToolBox (Fuchs and Corman 2019). This toolbox provides all essential optimisation models and data structures implemented in Python 3.10.X Thereby, it is not necessary to implement basic requirements since the OpenBusToolBox is usable in a plug-and-play fashion. Furthermore, as additional support, we provide the complete implementation of the approach proposed by Fuchs et al. (2022). If desired, the student may use this code base as a starting ground and then adapt it throughout the thesis. Finally, the resulting approach should be validated and investigated on a case study network. As a baseline, we offer the case study considered in Fuchs et al. (2022), fully implemented and available.

Essentially, we require two tasks to be performed by the student.

A Using the OpenBusToolBox, they should be capable of adapting the existing implementations of the line planning and timetabling problems such that they explicitly incorporate the connections for passengers.

B Once the models are implemented, it is required to implement the iterative process similar to Fuchs et al. (2022), which is provided as a template.

Research Question

While conducting the thesis, the following research questions should be considered and addressed:

- How can an iterative approach combine the tasks of line planning and timetabling planning?
- Which decisions regarding required connection-quality can be taken while planning lines and which must be taken in the timetabling?
- How should the models/stages interact during the iterations such that optimality is maintained?

Note that these questions should serve as a guideline, and the student may choose to adapt and deviate according to their desire. Furthermore, additional (sub) questions may be formulated.

References

S. Burggraeve, S. H. Bull, P. Vansteenwegen, and R. M. Lusby. Integrating robust timetabling in line plan optimization for railway systems. *Transportation Research Part C: Emerging Technologies*, 77:134–160, 2017. ISSN 0968090X.

F. Fuchs and F. Corman. An open toolbox for integrated optimization of public transport. In *2019 6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, pages 1–7, 2019.

F. Fuchs, A. Trivella, and F. Corman. Enhancing the interaction of railway timetabling and line planning with infrastructure awareness. *Transportation Research Part C: Emerging Technologies*, 142:103805, 2022.

P. Gattermann, P. Großmann, K. Nachtigall, and A. Schöbel. Integrating passengers' routes in periodic timetabling: a sat approach. In *16th Workshop on Algorithmic Approaches for Transportation Modelling, Optimization, and Systems (ATMOS 2016)*. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2016.

P. Großmann. Polynomial reduction from pesp to sat. Technical report, Knowledge Representation and Reasoning Group, TU Dresden, 2011.

J. N. Hooker and G. Ottosson. Logic-based benders decomposition. *Mathematical Programming*, 96(1):33–60, 2003.

C. Liebchen and R. H. Möhring. The Modeling Power of the Periodic Event Scheduling Problem: Railway Timetables — and Beyond. In *Computer-aided Systems in Public Transport*, pages 117–150. Springer Berlin Heidelberg, 2004.

J. Pätzold, A. Schiewe, P. Schiewe, and A. Schöbel. Look-ahead approaches for integrated planning in public transportation. *OpenAccess Series in Informatics*, 59(17):1–16, 2017. ISSN 21906807.

P. Schiewe. *Integrated optimization in public transport planning*, volume 160. Springer, 2020. ISBN 9783030462697.

A. Schöbel. An eigenmodel for iterative line planning, timetabling and vehicle scheduling in public transportation. *Transportation Research Part C: Emerging Technologies*, 74:348–365, 2017. ISSN 0968090X.