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Improving the Solvability of Public Transport Problems Using System Routes

”Extended Abstract”

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Abstract The size of realistic public transport networks is often a problem in algorithmic approaches for line planning, timetabling and vehicle scheduling. This paper describes a possibility to use human experience to reduce the instance sizes but still find good solutions for the original network. To this end, we introduce novel network objects called *system routes*. In computational experiments, this does not only decrease the runtime needed to find solutions but increases the solution quality as well.

Keywords System Routes, Instance Reduction, Solvability, Network Design

Mathematics Subject Classification (2000) 90B06

1 Introduction

Finding good public transport supplies, consisting of a line plan, a timetable and a vehicle schedule, requires a set of (sophisticated) mathematical optimization problems, see e.g. Desaulniers and Hickman (2007). While smaller problem instances can be solved efficiently using mathematical models, this is often not possible for real-world instances. Therefore, considering possibilities to reduce the input size for mathematical models is an important research topic.

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In this paper we describe a possibility to reduce the instance size by using the experience of planners. As it was shown in Friedrich et al (2017), adding human experience to the algorithmic planning process in form of a manually created line pool improves the solutions obtained by mathematical approaches drastically. Since this approach is too time consuming for larger instances, we investigate new approaches to incorporate the experience of planners in order to reduce the size of the respective problem instance before algorithmic solution approaches are applied.

We introduce a new concept in public transport planning, called *system routes*. These are an abstraction of a given infrastructure network, uniting multiple edges in the underlying infrastructure network and adding fixed terminals as potential end stations of lines and transfer stations for the passengers. This allows us to transform a given input instance to a new instance with reduced size. The reduced instance is then used as input for off-the-shelf algorithms for public transport planning which compute a public transport supply. After retransforming the obtained solutions of the smaller instance back to the original input instance, we obtain higher quality solutions compared to applying the same algorithms to the original instance. Thus, not only are the computation times of the used algorithms reduced significantly but the solution quality is improved as well. This allows solving larger instances than previously possible.

2 An Aggregated Network based on System Routes

System routes are designed in three steps. First, transport planners choose transfer stations and terminals. Here, transfer stations represent stops at which passengers may transfer between different lines while terminals are transfer stations with an additional property: lines can only start and end at terminals.

Now, we can introduce system routes as additional network objects: a system route connects exactly two stops which belong to the set of terminals and transfer stations. The routes are initialized as shortest paths but can be adjusted manually, e.g., to include additional stops by doing a small detour.

At last, the network is transformed into an aggregated network (called `SR`) using the system routes as new edges. The aggregated network has only terminals, transfer stations and access points as nodes. An access point is an abstraction of all real stops on a system route between two transfer stations. To consider the demand between these stops represented by one access point, we calculate an internal demand for each system route which defines a minimal capacity for each edge when doing line planning.

3 First Computational Experiments

Using system routes for reducing the given network is tested in a grid network. For that, the network used in Friedrich et al (2017) is expanded. Instead of 25 zones and 25 stop points, 100 zones and 341 stop points are used. Due to the modifications, the complexity of finding a good public transport supply with algorithmic approaches is increased.

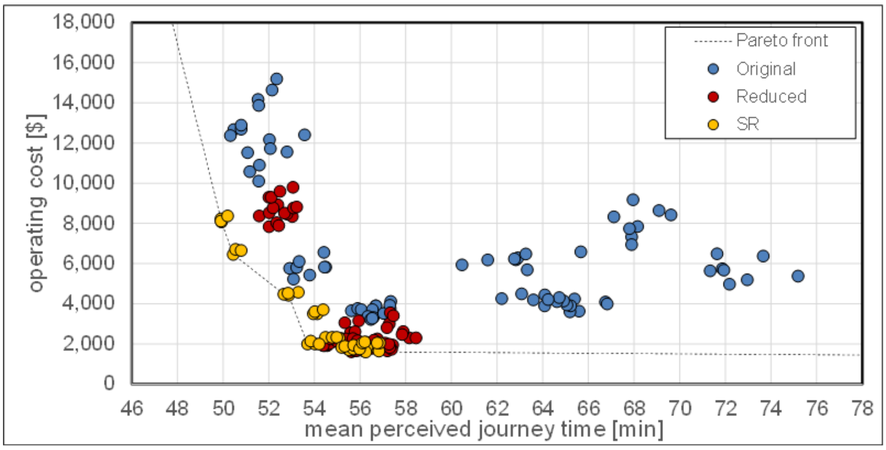

Fig. 1 Different public transport networks evaluated with a multipath assignment

To analyze the effects, we distinguish three approaches which differ in the way the given instance is reduced to a smaller instance:

1. `Original`: The original network
2. `Reduced`: The original network but only with edges covered by system routes. Edges not covered by a system route are eliminated.
3. `SR`: the aggregated network using system routes.

For each instance, several public transport supply plans are created using various parameter sets with the open source software library LinTim, see Schiewe et al (2020a,b). Each public transport supply is afterwards transferred to the original network such that the evaluation of all three instances is comparable.

Note that investigating the transition of `Original` to `Reduced` displays the effects of network reduction based on the experience of a public transport planner while the comparison of `Reduced` and `SR` shows the effects based on further algorithmic network reduction.

For evaluating the quality of a public transport supply in the original network, the *mean perceived journey time* and the *costs* for a fixed time interval are used. The mean perceived journey time is determined by a multipath assignment where walking is penalized as well as transferring from one line to another. The evaluated costs are influenced by the number of required vehicles and by the distance traveled.

These values are displayed in a diagram and the dominating solutions are marked with an approximated Pareto front, see Fig. 1. The approximated Pareto front consists mainly of solutions created for `SR`, i.e., Approach 3 using the aggregated network is the preferable approach.

In average, the mean perceived journey time is reduced by 7% for `Reduced` compared to `Original`, while when comparing `Reduced` to `SR`, the value stays roughly the same. Mainly due to the reduction of the number of lines created, the costs of `Original` are reduced by 44% for `Reduced` and by 54% for `SR` when comparing solutions to the equivalent solutions designed for `Original`. As a further value, the runtimes for creating a public transport supply with LinTim are recorded. The average computing time for the created public transport supply is reduced from 184 seconds for `Original` solutions to 86 seconds for `Reduced` solutions. Using `SR` accelerates the process even more, the average computation time is only 72 seconds here. First investigations on larger infrastructure networks show similar results.

4 Outlook

To further evaluate the approach proposed here, additional computational experiments will be presented. In future work we plan to use Approach 3 described here on large real-world instances, e.g., the city of Stuttgart, Germany.

Furthermore, the system routes proposed here do not permit many possibilities with regard to the network design. Since the system routes imply an internal demand, they all need to be served by the public transport supply created. Additionally, the stop location problem, i.e., which stops should be build, is not considered here yet. First experiments with stop location on the grid network used here show that there are additional optimization possibilities.

References

Desaulniers G, Hickman M (2007) Public transit. Handbooks in operations research and management science 14:69–127

Friedrich M, Hartl M, Schiewe A, Schöbel A (2017) Angebotsplanung im öffentlichen Verkehr - planerische und algorithmische Lösungen. In: Heureka'17

Schiewe A, Albert S, Pätzold J, Schiewe P, Schöbel A (2020a) LinTim - Integrated Optimization in Public Transportation. Homepage. https://lintim.net, URL https://lintim.net

Schiewe A, Albert S, Schiewe P, Schöbel A, Spühler F (2020b) LinTim: An integrated environment for mathematical public transport optimization. Documentation for version 2020.12. Tech. rep., TU Kaiserslautern, URL https://nbn-resolving.org/urn:nbn:de:hbz:386-kluedo-62025