Abstract

Been obliged to act market-oriented instead of the traditional monopolistic approach, public transport companies focus on efficient use of resources, especially vehicles. The vehicle scheduling problem, arising in public transport bus companies, addresses the task of assigning buses to cover a given set of timetabled trips with consideration of additional requirements, such as multiple depots and vehicle types as well as depot capacities. An optimal schedule is characterized by minimal fleet size and minimal operational costs including costs for unloaded trips and idle time, spent outside from depot. Operations research based decision support systems play hereby a crucial role.

Different models and procedures were developed for the optimization of the vehicle usage. In the context of this thesis, we refer to all models that represent connections explicitly as "connection-based" models. As connection-based multi-depot vehicle scheduling models inherently include a very large number of arcs, such models of practical dimensions with thousands of trips and multiple depots often can not be solved with standard optimization software packages. This work proposes a time-space-based network model instead of a connection-based one. This leads to a crucial size reduction of the corresponding mathematical models compared to well-known connection-based network flow or set partitioning models. The proposed modeling approach enables us to solve real-world multi-depot problem instances with thousands of scheduled trips by direct application of standard optimization software.

In order to solve very large practical instances we propose a two-phase method which produces near-optimal solutions. One developed heuristic reduces the model size by fixing a part of the original variables, so that it is possible to solve the reduced problem to optimality. The basic idea of the heuristic is first to solve a number of simplified models, for example a single-depot vehicle scheduling problem for each depot, and then to search for common chains of trips in each of the solutions. If the same sequence of trips is included in each solution, we denote it as a *stable chain* and assume that it may occur in the optimal global solution as well.

Furthermore, various practical requirements, arising in different public transport companies, are taken into account, so that the savings induced by the approach of this work can be realized in practical applications. Thus, we introduce the concept of depot groups for the case that a bus may return in the evening into another depot than it started in the morning. The modeling approach considers depot and vehicle type capacities, bus lines and time windows for the timetabled trips. Several practical side constraints are considered in the postprocessing phase, where we construct an optimal vehicle schedule from the optimal network flow via flow decomposition.

In the context of a co-operation with the software development company PTV AG, we designed and implemented a software component which supports public transport planners in constructing schedules for buses. The presented methods are integrated in commercial systems of the PTV AG and are already used in the planning of the vehicle schedules of several public transport companies.

Keywords:
Vehicle Scheduling, Public Transport, Time-Space Network, Mathematical Optimization, Multi-Commodity Flows