The school bus routing and scheduling problem with mixed loads and transfers

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The school bus routing and scheduling problem deals with the transportation of pupils from home to school in the morning and from school to home in the evening. It is a problem in public transportation and differs from typical vehicle routing problems in several aspects, as for example pointed out in [6]. Variants of this problem are often studied in literature. A comprehensive overview of existing publications can be found in [4], with recent contributions, e.g., in [3, 5, 6].

This work is motivated by a real life problem with about 2400 pupils, 230 bus stations and 22 schools, where the area of operation is mostly rural. We consider the so called morning problem only, i.e., the transportation of the pupils to their respective school before it begins. The process is the same for every day, i.e., no periodic planning is necessary and a feasible solution for a single day can be used during the whole school year. The goal is to generate an efficient transportation plan (according to some objective) so that every pupil arrives at school on time.

Our approach takes into account bus stop selection, bus routing and bus scheduling. Further, we consider multiple schools and pupils of different schools may share a single bus, which is referred to as mixed loads. Pupils can also change the bus during their way to school, which is called transfers. Transfers have not yet been extensively studied in the context of the school bus routing problem [5]. Transfers in the context of goods are for example described in Cortés et al. [1] using a pickup and delivery problem formulation. They have a predefined set of transfer points. In our case, every bus stop can be a transfer point.

The literature distinguishes between the routing problem and the scheduling problem. School bus routing calculates the bus trips which are then scheduled to buses. Hence, a trip is serviced by a single bus but a bus may serve multiple trips. A model for handling routing and scheduling in a single model was proposed by Spada et al. [7].

In this work we handle both aspects of the problem. Our approach is based on the school bus scheduling model of Fügenschuh [2]. They propose a model

for school bus scheduling which allows mixed loads and transfers under the assumption that the bus trips are given.

We propose a school bus routing model, which calculates the bus trips under consideration of pupil's bus changes (transfers) and mixed loads. The model formulation is based on a vehicle routing problem formulation. The solution of the routing model is aggregated and serves as input for the scheduling problem, which then determines the bus schedule.

Real life problem instances are not practically solvable using the proposed model using commercial state of the art solvers like IBM ILOG CPLEX or Gurobi Optimizer. So we propose a heuristic solution concept.

The heuristic solution concept is based on state of the art neighborhood based frameworks and uses exact methods for solving subproblems. At first a feasible set of trips is generated using a generalized savings based construction heuristic. Those trips are then scheduled using the mathematical model of Fügenschuh. Through a feedback loop parts of the routing solution are changed and the scheduling model is solved again. By using such a feedback loop, elements of the solution which have a high influence (positive or negative) on the solution quality can be identified and the design of the bus trips can be changed accordingly and yield an improvement in the overall solution (routing and scheduling).

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