A metaheuristic for solving large instances of the School Bus Routing Problem

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The school bus routing problem discussed in this paper, is similar to the standard vehicle routing problem, but has several interesting additional features. In the standard VRP all stops to visit are given. In our school bus routing problem, we assume that a set of potential stops is given, as well as a set of students that can walk to one or more stops. The school buses used to pick up the students and transport them to their schools have a finite capacity. The goal of this routing problem is to select a subset of stops that will actually be visited by the buses, determine which stop each student should walk to and develop a set of tours that minimize the total distance travelled by all buses.

The focus in this paper lies on understanding the problem in its simple form and on building a powerful meta-heuristic to solve large instances quickly. Our solution method starts with a GRASP-like savings algorithm, after which a Variable Neighbourhood Search algorithm is used to improve the initial solution. A modified version of the well-known transportation problem helps the meta-heuristic to quickly assign students to stops.

Keywords: School Bus Routing, GRASP, VNS, transportation problem

1 Introduction

This research is motivated by a real-life school bus routing problem. In the Flemish region (Belgium), transport of children to their school is organized by the Flemish transportation society. Each pupil that has the right to be transported to its school, also has the right to a bus stop located at a distance of less than 750 metres from its residence. To efficiently design the routes, a set of potential stops is determined, so that each pupil has at least one stop he/she can walk to. Routes are then determined for the school buses so that all students are picked up at a stop they are allowed to use, while making sure that the capacity of the buses is not exceeded. Flemish transportation society are faced with problems where up to 3000 students have to picked up and brought to 7 different schools.

2 Problem Description

The basic School Bus Routing problem as described in [Schittekat et al., 2006] is a generalisation of the basic vehicle routing problem and therefore also NP-hard. In general, the vehicle routing problem defines an optimization problem where allocation of stops to vehicles and the optimal sequence of stops with corresponding demands have to be determined without violating vehicle capacities. Different constraints can be envisaged such as maximum distance constraint and time windows. The total distance covered by all vehicles acts as a criterion which obviously has to be minimized. [Toth and Vigo, 2001]

In contrast with the basic VRP, total demand for each stop is not known beforehand. We only know whether a student is allowed to walk to a stop or not. On the one hand, this gives us the possibility to incur potential savings (e.g. not have to visit a stop), because we can assign students to stops ourselves. On the other hand, introducing these extra assignment decisions makes our problem much more difficult to solve.

As will become clear from the literature review, previous research has focused mainly on building intricate multi-objective models of similar problems. The focus on this paper is on understanding the problem in its simple form and building a powerful meta-heuristic to solve large instances quickly.

3 Literature Review

Contrary to the literature on the ordinary vehicle routing problem and several of its extensions (e.g. time windows), only a limited amount of research has considered the routing of school buses. Moreover, only a very small number of papers consider the simultaneous selection of stops. Most school bus vehicle routing formulations focus on formulating extra constraints and/or objectives to take some student-related factors into account.

4 Solution Method

For VRPs there exist a myriad of solution techniques (exact algorithms, heuristics, metaheuristics). In Schittekat et al. [2006] experimental results on medium-sized instances (10 stops, 50 students) show that for exact methods a large variability in computation time exist ranging from 2 minutes to more than 64 hours. Therefore, for large instances as we encounter in practice probably only metaheuristics such as Tabu Search (TS),
Variable Neighbourhood Search (VNS) could be applied effectively.

Our solution method starts with a GRASP-like savings algorithm (construction phase), after which a Variable Neighbourhood Search algorithm (improvement phase) is used to improve the initial solution. The construction phase begins with a solution where all stops are visited directly. After this initial setup, students are assigned to these stops solving a modified version of the transportation problem. Obviously, if no feasible assignment could be returned, no feasible solution for our school bus routing problem exist. On the opposite, if the algorithm returns a feasible solution then we can proceed with a savings heuristic where step-by-step a new solution is build by combining routes. While normally we would be tempted to choose the move with the largest saving, selection is now randomized in order to diversify the search.

For the VNS improvement phase, several typical neighbourhoods are defined by the following moves:

- Changing stops within a route
- Changing stops between two routes
- Replacing stops from one route to another
- ...

Only when vehicle capacity is violated by a move mentioned above, students are re-assigned to the visited stops of the proposed solution. In addition, a specific move for this problem was implemented which removes one visited stop from a route and adds the best possible unvisited stop back into our solution.

5 Experimental Results

Experimental results indicate that our solution method performs very well on medium-sized instances for which exact algorithms already show variable performance. In contrast, our meta-heuristic approach produces near-optimal solutions within a time span of a couple of seconds. Results on much larger instances will also be reported.

References
