An efficient metaheuristic for the School Bus Routing problem

P. Schittekat[1,2], J. Kinable[3], K. Sörensen[1], M. Sevaux[4], F. Spieksma[3] and J. Springael[1]

[1] ANT/OR, University of Antwerp Operations Research Group, Belgium
[2] SINTEF ICT, Department of Applied Mathematics, Norway
[3] ORSTAT, KULeuven, Belgium
[4] Lab-STICC, Université de Bretagne-Sud, Lorient (France)
marc.sevaux@univ-ubs.fr

Keywords: *school bus routing, stop selection, metaheuristic, lower bound.*

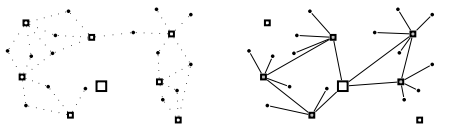
1 Introduction

Existing literature on routing of school buses has focused mainly on building intricate models that attempt to capture as many real-life constraints and objectives as possible. Our work is more concerned with the bus route generation and the bus stop selection. The school bus routing problem (SBRP) is defined as a variant of the vehicle routing problem in which three simultaneous decisions have to be made : (1) determine the set of stops to visit, (2) determine for each student which stop (s)he should walk to, and (3) determine routes that lie along the chosen stops, so that the total traveled distance is minimized. To solve this problem we have developed a GRASP-VND algorithm with no parameters. A part of the subproblem, namely the student allocation subproblem, is solved with an exact method within the metaheuristic.

2 Problem definition

In some countries, students living within a certain distance to school are entitled by law free transportation to and from school. A bus stop should be located at a maximum distance from the home of each student (*e.g.* 750m). Hence a set of potential bus stops is predefined in advance. From a hierarchical point of view, one has to first select the bus stops (and assign the students to the bus stops) and then define the routes for the buses. Of course, solving the problem in this way will lead to sub-optimal solutions. Our goal is to globally solve the problem.

2.1 Example



(a) An instance (b) A possible solution

FIG. 1 – An example of the school bus routing problem

Figure 1(a) shows an example of this *school bus routing problem* (SBRP). In this figure, dots represent students, small squares represent potential stops and a large square represents the school. Dotted lines indicate which stops a student is able to reach. If, for example, the capacity of each bus equals 8, a possible (but not necessarily optimal) solution to this problem is shown in figure 1(b).

2.2 Literature review

In their book on the traveling salesman problem (TSP), [1], mention schoolbus routing as one of the early applications motivating the TSP. However, in their context selecting stops is not part of the problem.

Typically, school bus routing formulations focus on formulating extra constraints and/or objectives to take some student-related factors into account. [3], and [4], add a maximum travel-time constraint for each student and/or a time window for arrival at the school. [2] minimize total travel time of all children. [7] discuss the routing of school buses in rural areas. They develop a system that is able to solve large-scale routing problems with a large number of complex constraints and several objectives. [5] merges clustering (stops positioning) and a routing problem (VRP) in a single and combined new problem.

In their recent survey on the School Bus Routing problem, [6] mention five different subproblems, which are often treated separately in the SBPR literature : data preparation, bus stop selection, bus route generation, school bell time adjustment, and bus scheduling.

3 Proposed methodology

A hybrid exact/metaheuristic procedure is developed to solve large instances of the school bus routing problem. This *hybrid metaheuristic* uses a GRASP construction phase which is based on the Clark and Wright classical savings heuristics. The GRASP is followed by a variable neighborhood descent (VND) improvement phase which has four neighborhoods (*remove-insert within a route or between routes*, *replace* a visited stop by a non-visited stop, and *remove* a stop from a route. These two phases are executed sequentially and the resulting procedure is iterated n_{max} times, after which the best solution is selected as the final solution. As mentioned, the student allocation subproblem is solved by an exact method since we have been able to model the subproblem as a transportation problem.

In addition, based on a MIP formulation, we reformulate the problem by decomposing it in a master and a subproblem where the columns of the master problem are the bus routes. Solving the master problem is still difficult, but a linear relaxation leads to good lower bounds of the problem.

References

[1] D.L. Applegate, R.E. Bixby, V. Chvatal, and W.J. Cook. *The Traveling Salesman Problem : A Computational Study*. Princeton Series in Applied Mathematics. Princeton University Press, Princeton, NJ, 2007.

[2] B. Bennett and D. Gazis. School bus routing by computer. *Transportation Research*, 6 :317–326, 1972.

[3] L. Bodin and L. Berman. Routing and scheduling of school buses by computer. *Transportation Science*, 13 :113–129, 1979.

[4] J. Braca, J. Bramel, B. Posner, and Simchi-Levi D. A computerized approach to the New York City school bus routing problem. *IIE Transactions*, 29 :693–702, 1997.

[5] J.C. Créput and A. Koukam. Transport clustering and routing as a visual meshing process. *Journal of Information and Optimization Sciences*, 28(4) :573–601, 2007.

[6] J. Park and B.I. Kim. The school bus routing problem : A review. *European Journal of operational research*, 202(2) :311–319, 2010.

[7] S.R. Thangiah, B. Wilson, A. Pitluga, and W. Mennell. School bus routing in rural school districts. Working paper, Computer Science Department, Slippery Rock University, Slippery Rock, PA, USA, 2005.