A Case of Study of School Bus Routing Problem

Introduction

The school bus routing problem (SBRP) seeks to plan an efficient schedule for a fleet of school buses that pick up students from various bus stops and deliver them to the school by satisfying various constraints: maximum capacity of the bus, maximum riding time of students, and time window to arrive at school. SBRP has two separate but interrelated routing issues: assigning students to their respective bus stops and routing the buses to the bus stops.

SBRP is a special case of the vehicle routing problem (VRP). In a VRP, a set of n clients (the students) has to be serviced by a fleet of vehicles (the buses). Since the buses have limited capacity, the problem becomes the capacitated vehicle routing problem, which is known to be NP-hard.

Problem description

We are interested in solving a case study of SBRP that is taken from a real-life application, within reasonable computation resources and time. The problem size is 7500 students and 500 teachers for 10 schools in Cancún (México).

A group of spatially distributed students must be provided with public transportation from their residences to and from their schools. The problem is to find a series of school bus routes that ensure the service is provided by the bus company equitably to all students. Additional restrictions are placed on the distance that students can walk from their homes to and from their stops.

The goal is to find optimal school bus routes by mean of reducing:

- The number of buses.
- The number of different routes.
- The total of kilometers accumulated among all routes.
- The duration of the longest route.
- The distance that students have to walk from their homes to and from their stops.

The optimal solution for this SBRP should include the following:

- The number of buses.

  Each selected bus can perform different routes each day. Moreover, all buses have the same capacity.

- The best assignment of students to bus stops.

  The number of student at each bus stop can be larger than the capacity of a single bus. However, all students have to be picked up by all selected buses to have a valid solution.

- The best assignment of bus stops to buses.

  The number of bus stops has to be calculated from a finite set of available bus stops. Each selected bus stop can be visited by more than one selected bus. The number of students on each selected bus must not exceed the bus capacity.

- The bus routes to the schools.

  Each route will be defined as a sequence of bus stops with the number of students (>0) to be picked up and the timetable at each bus stop. Each route begins at the first selected bus stop of that route and arrives at the selected school. The travel time of each selected bus must not exceed the time duration allowed, which is the same for all routes.

Remark: The time and distance between each two bus stops are known. Moreover, the students' addresses are known to be able to assign them the closest and best bus stop. There will be a maximum allowed distance between their homes to the selected bus stops.

Simplified problem description

We can initially assume that the location and number of students assigned to each bus stop is also known. Once this simplified problem is solved, the original problem can be solved by two steps: first, finding the optimal assignment of students to the bus stops, and then using the solution of the simplified problem.

However, the original problem needs to find the optimal assignment of students to each bus stop as well as the optimal bus routes. In most existing approaches in literature, those steps are considered separately and sequentially, although they are highly interrelated. Could it be possible to define a method that look simultaneously for the optimal assignment of student and the bus route?

Remark: An improvement can be performed by assuming that the fleet is not homogeneous –buses with different capacities can be assigned to each bus stop-. This can be modeled by considering a maximum availability of buses for any given capacity, which represent the number of vehicles the company owns for each kind of bus.

Motivation for mathematical modeling

Vehicle routing problem is a well-known problem in operational research area. VRP can be formulated easily; however, it turns to be a relatively difficult problem when the number of inputs increases. Mathematical models and different solution methods have been investigated in the literature to apply them for many cases in daily life.

Most interesting real-world optimization problems are very challenging from a computational point of view. In fact, quite often, finding an optimal or even a near-optimal solution to large-scale optimization problem may require computational resources far beyond what is practically available. Heuristic local research methods, such as tabu search and simulated annealing, are often quite effective at finding near-optimal solutions with high probability.