Chapter 3

School Bus Routing and Student Assignment With Special-Need Student Consideration

Di Zhang  
University of Louisville, USA

Ki-Hwan G. Bae  
University of Louisville, USA

ABSTRACT

This chapter presents a modeling framework that solves a student assignment problem with bus stop selection, and subsequently a school bus routing problem with school time window constraints. The model incorporates the characteristics of special-need and general student population, and provides a school bus service schedule to transport both types of students. The student assignment model selects the number of optimal bus stops from available locations, and measures total student walking distance as part of service quality measure. The routing model includes a multi-objective function regarding service equity and quality that is of interest to decision makers. The authors demonstrate the efficacy of heuristic methods and a column generation technique implemented to solve the problems using real data from a suburban school district of a major U.S. city.

INTRODUCTION

When public school systems provide transportation service to students in an educational district area, it is desirable to work in a timely and efficient manner. Scheduling bus routes requires (i) student information, e.g., residence address, general (Type-1) or handicapped (Type-2), (ii) school information, e.g., school locations, school bell time windows, and number of students, and (iii) bus information, e.g., capacities, number of vehicles, and depot locations. Using these types of input data, the school bus routing problem (SBRP) seeks to attain optimal routes for a fleet of vehicles, while meeting various required constraints. We address in detail the following characteristics of the SBRP.

DOI: 10.4018/978-1-5225-7591-7.ch003
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- **School:** single or multiple schools can be considered in a network of bus transportation systems. When considering a single school, SBRP is similar to the Open VRP (Fu, Eglese, & Li, 2005). One important feature of Open VRP is that it does not require for a vehicle to return to the same home (depot) location upon completion of a route (Li, Golden, & Wasil, 2007). For a multiple-school problem, a model can be more flexible but complex as well. Further, a school can serve as a stop location on the routes, and buses pick up and drop off students at this location on route to another school destination. As such, the number of students traveling along the route may vary.

- **Mixed Loading:** Mixed loading occurs when one bus serves students going to different school destinations at the same route or time. Thus, it is usually taken into account only for a multiple-school problem. While flexibility and cost savings (Braca, Bramel, Posner, & Simchi-Levi, 1997) increases under mixed loading consideration, so does the complexity of a problem. In particular, mixed loading is widely used in a rural area due to a scattered population (demand) distribution.

- **Urban vs. Rural:** For either densely populated urban areas or sparsely populated rural areas, a school bus routing problem is difficult to solve due to a large number of students or long travel distance involved, respectively. The main difference between them is density of students spread throughout a region. In an urban area with high density of students, a bus capacity constraint is likely binding before the maximum riding time limit is reached (Park & Kim, 2010). Conversely, when solving the SBRP in urban areas, maximum riding time constraints are not likely binding. Another difference is that in urban areas, students would have to walk from their home to designated bus stops to wait for a bus, whereas most students in rural areas take a bus at their front doors. Therefore, mixed loading is desirable for the SBRP in rural areas, and the student assignment problem (SAP) becomes trivial.

- **Bus:** Several types of bus vehicles can operate in one school district system, and this leads to two types of bus fleet group: homogeneous and heterogeneous. The heterogeneous fleet indicates that the capacities of buses may not be same since each type has different fixed and traveling costs, whereas the homogeneous fleet has the same capacity and cost for every bus in the group. Another consideration is the type of buses specially equipped to serving Type-2 students and the number of buses that can accommodate them.

- **Student:** Type-2 students require service from a special type of buses with proper equipment and assistance. There are a few differences in routing Type-2 students versus Type-1 students. First, Type-2 students must be picked up and dropped off directly at their home locations. Second, the maximum riding time limit for Type-2 students is typically less than that for Type-1 students. Third, when a Type-2 student’s home location is selected as a bus stop and a mixed loading is allowed, other Type-1 students nearby may walk from their home to this bus stop within the walking distance limit. As a result, by serving more students in the same stop, this adds extra service times to a Type-2 student who has a shorter riding time limit than a Type-1 student. For this reason, modeling fewer Type-2 students per route improves solution tractability.

The SBRP first studied by (Newton & Thomas, 1969) is a variation of the vehicle routing problem (VRP), and we present a summary of the literature related to the SBRP in Table 1.

For a majority of previous works, the solution of bus stop selection was assumed to be given or predetermined, although the solution quality of routing and scheduling is directly subject to the bus stop selections (Spada et al., 2005; Fügenschuh, 2009; Kim et al., 2012; Park et al., 2012). The SBRP of urban areas has been investigated more frequently than in rural areas as the high density of students
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