

Chapter 79

Optimizing School Bus Stop Placement in Howard County, Maryland: A GIS-Based Heuristic Approach

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ABSTRACT

In the current system, school bus stops in Howard County, Maryland are manually placed along the school bus routes based on safety, cost-efficiency, and many other variables. With such liberal placement, bus stops are sometimes placed unnecessarily. This issue is prevalent in many school districts and often results in needlessly close bus stop proximity. In this study, the authors implemented a GIS-based heuristic to assist school officials in optimizing their districts bus stop placement. They also estimated the proportion of county-wide bus stops that could be eliminated by this approach. Following the constraints determined by State and local guidelines, the ArcGIS Network Analyst Extension was used to identify unnecessary bus stops across the study area. The initial output was re-evaluated by school officials in order to determine if those bus stops would be eliminated. The results indicate that approximately 30% of the existing bus stops were marked as “candidates for elimination” by the GIS process. After a review of these candidates, it was determined that at least 15% of the total school bus stops could be eliminated. Statistical estimates lent credence to the benefit of a re-evaluation of these bus stops. The method developed in this study can easily be replicated. Hence, it may inspire other school systems to exercise the same approach. Additionally, the results provide a gateway for future studies in examining more efficient school bus routes with less travel time, as well as investigating how much the carbon footprint of school bus fleets can be reduced.

DOI: 10.4018/978-1-4666-9845-1.ch079

INTRODUCTION

School systems in the United States use different factors and processes when deciding where to place bus stops. Transportation officials heed both local and state policies before considering a potential school bus stop site (National Highway Traffic Safety Administration [NHTSA], 2010). These State and local policies are quite different all over the country. However, local policies usually do not conflict with State policies. Almost all decisions relating to bus stop location and routing are ultimately left to the local school board. In this study, we implement a Geographic Information System (GIS)-based heuristics that combines a mathematical GIS approach with a manual process to identify unnecessary school bus stops. Our purposes are to help school officials minimize effort in optimizing their districts bus stop placement without negatively impacting student safety, and to estimate the proportion of county-wide bus stops that can be eliminated. A reduction in these unnecessary bus stops would help improve school bus routes by minimizing travel time, and potentially reduce school transportation costs. Other school systems that have similar data sets can also replicate this GIS-based heuristics and adapt the parameters to fit their own school districts. Most papers on the routing of school buses have focused on building intricate models with many complex constraints (e.g., Bowerman, Hall, & Calamai, 1995; Braca, Bramel, Posner, & Simchi-Levi, 1997; Thangiah, Wilson, Pitluga, & Mennell, 2005). In this paper, we focus on a basic aspect of this problem, specifically on the bus stop placement parameter.

SCHOOL BUS ROUTING PROBLEM

The School Bus Routing Problem (SBRP) is the objective of a fleet of school buses to efficiently pick up and drop off students to and from school (Li & Fu, 2002). These objectives must abide by specific constraints, such as bus capacity, the number of available buses, school start time, and maximum allowable travel time (Leiva, Muñoz, Giesen, & Larrain, 2010; Spasovic et al., 2001). Several studies have shown that it is almost impossible to efficiently design bus routes that account for all of these desired factors (See Li & Fu, 2002; Spasovic, Chien, Kelnhofer-Feeley, Wang, & Hu, 2001). With the multitude of the SBRP's variables, it is challenging to balance the objective of the school system in reducing costs and the objective in maintaining an acceptable level of equity for the bus riders (Spasovic et al., 2001).

In some specific case studies, SBRP is also related to other parameters, including the Multiple Traveling Salesman Problem, Vehicle Routing Problem, and urban bus routing (Li & Fu, 2002; Park & Kim, 2010; Schittekat et al., 2013). While the Multiple Traveling Salesman Problem is a classic case for a mathematical solution using Operations Research techniques (Spasovic et al., 2001), the SBRP is not easily optimized via mathematical approaches due to the complexity of the problem, the number of constraints, and sometimes conflicting variables to optimize (Li & Fu, 2002; Spasovic et al., 2001). As a result, heuristic approaches are often used to supplement purely automated algorithms (Angel, Caudle, Noonan, & Whinston, 1972). Many school systems even neglect mathematical and GIS solutions completely. For instance, school systems in Hong Kong simply use transportation official's intuition to manually design each route, as well as place each bus stop (Li & Fu, 2002).

The SBRP is made up of a number of different parameters. While some researchers have taken holistic approaches to address all of the aspects at once (Desrosiers, Sauvé, & Soumis, 1988), others have attempted to address them somewhat independently (Newton & Thomas, 1969; Park and Kim, 2010), even

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