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A methodology for rearranging transit stops for enhancing transit users generalized travel time

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HIGHLIGHTS

- A model for consolidating transit stops to maximize users generalized travel time savings.
- Several hypothetical scenarios were tested with variations in six different factors.
- Distance between stops, passenger activity, and demand change are most influential factors.
- Testing the model resulted in considerable savings with minimal effect on passenger demand.

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ABSTRACT

This study develops a methodology to consolidate transit stops. It develops a mathematical model and a program which takes stop consolidation decision(s) according to users generalized travel time savings and desired accessibility. The model iterates until the users generalized travel time savings are maximized. The study tests this mathematical model in different hypothetical scenarios. Six factors (distance between stops, passenger activity, average cruising speed, maximum walking distance, service frequency, and percentage of decreased passengers) with multiple levels were set to build the scenarios. Three responses (percentage of consolidated stops, percentages of travel time and operating time savings) were observed. The findings showed that the distance between the stops the passenger activity, and the probable demand change (or the percentage of decreased passengers) are the most influential factors. The frequency of service was found to be influential as well. The average cruising speed has very little influence on the response variables. Finally, the model is tested on two routes (route 900 and 930) of Al Ain City public bus service. It shows that 22 and 32 out of 98 and 126 stops can be consolidated in route 900 and 930 respectively. This can save considerable amounts of users travel and operating times. In monetary values, the savings are about $329,827 and $491,094 per year for routes 900 and 930, respectively.

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1. Introduction

Public transportation is gaining its share in many cities due to the growing congestion, rise in the fuel price and the better awareness of the transport-related environmental impacts. To cope with the continuous demand, traffic growth and competition, transit systems need to be efficient. One of the important efficiency indicators of transit performance is the trip travel time. A number of strategies have been developed and advocated in the literature to reduce the transit trip timing; stop rearranging is one of them. In transit planning, stop rearranging refers to "stop consolidation" which involves removing or merging or relocating stops. It is an effective strategy to reduce the service headways and fleet size, and consequently, saves the agency's operating cost. It also increases the reliability of service, enhances schedule adherence and decreases the riding time of the through passengers. However, at the same time, it may reduce accessibility and may also increase the walking time of the passengers. Some of these factors (e.g. reliability, accessibility, walking time and riding time, cost savings) are addressed sufficiently in different research studies, while some other factors (such as frequency of service, travel speed, passengers travel time savings) are not addressed adequately. The aim of this study is to investigate the major factors of stop consolidation thoroughly.

Stop consolidation has the most direct effect on travel time. This is due to the fact that each stop is characterized by individual delay elements such as deceleration and acceleration time, dwell time, time taken in the open and close doors and re-entering traffic delay. Thus, consolidation can decrease the travel time by saving these delay times. This can reduce the operating cost (Furth et al., 2007; Furth and Rahbee, 2000; Levinson, 1983; Li and Bartini, 2008) and even reduce the fleet size (Ibeas et al., 2010; Saka, 2001). Removing bus stops also reduce variations in travel times because there are fewer opportunities for delay. Stop consolidation can improve reliability by reducing the number of late trips. More proficient scheduling with less recovery time can be achieved with an improved reliability (El-Geneidy et al., 2011; Furth and Muller, 2007; Zhao and Chien, 2014). Reliable schedule reduces passenger waiting time and frustration (Furth and Muller, 2006). The "bunching effect" can also be decreased with improved reliability.

Stop consolidation increases walking distance of some users. Moreover, it may reduce the catchment area of the stops and thus reduces accessibility, which may reduce ridership. Nonetheless, a smart consolidation approach may show no adverse impact on ridership (El-Geneidy et al., 2006; Kehoe, 2004). Rather, it may increase the ridership by improving the reliability and travel time (Abkowitz and Tozzi, 1987; Kehoe, 2004; Vuchic, 2005). As a result, user satisfaction can also be increased (El-Geneidy and Surprenant-Legault, 2010; Hensher et al., 2003).

Vuchic and Newell (1968) are the pioneer researchers who presented an analytical method to determine stop spacing. They assumed a uniform population distribution along the line to find out the optimum spacing by minimizing the total passenger travel time. Wirasinghe and Ghoneim (1981) defined optimal spacing as a problem to minimize costs. These costs include the users' cost coming from the access, egress, and in-vehicle time cost. Cost also includes transit operating cost and the cost of building and maintaining stops. They presented a heuristic approach using continuum approximation and calculus to optimize stop spacing by minimizing passengers' travel time.

Saka (2001) extended this line of research further by developing a mathematical model based on the fundamental relationships among velocity, uniform acceleration or deceleration, and displacement, with the average bus operating speed, headway, required fleet size and potential system capacity. Furth and Rahbee (2000) used a discrete model combining Geographic Information System (GIS) and dynamic programming to minimize passengers' time costs and the operating expenses of the route. Chien and Qin (2004) proposed a mathematical model to determine the optimum number of stops and location by minimizing total cost. A realistic demand distribution based on a general street configuration was considered. Ibeas et al. (2010) proposed an optimal bus stop location and spacing model to minimize the social cost of all the transport system. Li and Bertini (2008) estimated the average stop spacing by their model using the Bus Dispatch System (BDS) data. The aim of their design is to minimize the operating cost while maintaining a high degree of transit accessibility. Oliveira et al. (2008) developed a model comprising non-linear programming and heuristics to optimize bus stop spacing by minimizing users' average travel time. Alonso et al. (2011) proposed a bi-level optimization model, which includes a modal split function at a lower level and a social cost minimization function on the upper level.

In the literature, the distance between stops is considered as the most important factor of stop consolidation. Many transport agencies have their own standards of distance between stops, which usually vary, depending on transit modes, population density, etc (El-Geneidy et al., 2006; Furth and Rahbee, 2000; KFH Group, 2009; Saka, 2001). Accessibility, another important factor of consolidation, often assessed by users' willingness to walk (Biba et al., 2010; Lam and Morrall, 1982; Murray and Wu, 2003; O'Sullivan and Morall, 1996; Zhao et al., 2003) or tolerance of walking, which varies with the physical environment of the walking path (El-Geneidy and Surprenant-Legault, 2010; Gruen, 1964; Wibowo and Olszewski, 2005; Zhao et al., 2003), different transit systems and places (El-Geneidy and Suprenant-Legault, 2010; O'Sullivan and Morrall, 1996). In the literature, transit demand after consolidation is mostly assumed to be unchanged or slight change. Alonso et al. (2011) admit that demand may change and addressed this issue by considering modal split after stop consolidation. Researchers also pointed out the importance of reliability in the travel/arrival time (Chen et al., 2007; Lin and Bertini, 2004; Zhao and Chien, 2014).

This study, formulate a mathematical model which computes the direct effect of consolidation (generalized travel time savings) on each single stop. The model uses a combinatorial procedure to determine the group of stops for consolidation that maximizes users generalized travel time savings. The numbers of consolidation stops are optimized by using the iterative method. The use of the combinatorial and