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A quality control framework for bus schedule reliability

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Abstract

This paper develops and demonstrates a quality control framework for bus schedule reliability. Automatic vehicle location (AVL) devices provide necessary data; data envelopment analysis (DEA) yields a valid summary measure from partial reliability indicators; and panel data analysis provides statistical confidence boundaries for each route-direction's DEA scores. If a route-direction's most recent DEA score is below its lower boundary, it is identified as in need of immediate attention. The framework is applied to 29 weeks of AVL data from 24 Chicago Transit Authority bus routes (and therefore 48 route-directions), thereby demonstrating that it can provide quick and accurate quality control.
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Keywords: Schedule adherence; Data envelopment analysis (DEA); Panel data analysis (PDA); Confidence interval; Automatic vehicle location (AVL)

1. Introduction

The importance of reliable bus service to customers is well known, with "arriving when planned" being the most important desire of transit riders (Nakanishi, 1997; Transportation Research Board, 2002). Not surprisingly, consistency of service is one of the key sets of bus performance indicators that are monitored by most transit systems (Benn, 1995). Public transit agencies have developed multiple indicators to measure consistency of service, with indicators of on-time performance and headway adherence being almost universal, and a third common measure being running time adherence (Nakanishi, 1997; Benn, 1995; Vuchic, 2004; Transportation Research Board, 2003).

Unfortunately, the value of these service reliability indicators has been diminished by three problems. The first problem has been their infrequent collection. In order to make the best use of these indicators, it is necessary to frequently collect samples from each bus route, and to quickly make them available for analysis.

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In the past, for this activity to occur would have resulted in unacceptably high expenses because the data had to be collected and recorded manually (Nakanishi, 1997).

The second problem has been the absence of a single, over-all performance indicator that validly aggregates partial measures such as those identified above. One comprehensive service reliability indicator would make it much easier to quickly and validly identify those routes most in need of intervention. With multiple indicators, it may be difficult to determine which routes have the overall worst performance because routes doing well on some measures may be doing poorly on others. This problem is exacerbated when quick decisions should be made.

The third problem is determining whether a route's declining service is caused by systematic new problems, or simply due to random chance. If management is to address problems of routes that are truly in difficulty, it should avoid wasting time on routes whose reported declines are simply random variations.

The purpose of this paper is to present a framework for mitigating these three problems, thereby enabling management to more quickly and accurately identify those routes most in need of assistance. The framework involves use of (1) automatic vehicle location (AVL) data to obtain frequent and quickly-available samples, (2) data envelopment analysis (DEA) to aggregate the various service reliability measures into one comprehensive indicator, and (3) panel data analysis (PDA) to develop quality control charts for the performance of each individual route, which will alert management to routes performing worse than normal random variation explains.

The paper unfolds as follows. In the rest of this introductory section, background information on AVL, DEA and PDA is presented. Then, application of the framework is illustrated through a case study using archived AVL data provided by the Chicago Transit Authority (CTA). The CTA's bus route schedule adherence performance measures are defined in Section 2. The assessment framework is presented in Section 3. The case study results are reported in Section 4, including discussion on the DEA scores and their confidence intervals as quality controls for bus schedule adherence performance. Finally, the study contributions, limitations of the study and future research needs are summarized in Section 5.

1.1. Availability of automatic vehicle location data

With automatic vehicle location (AVL) devices becoming available on many buses in recent years, the quantity and quality of data have greatly improved and can be made quickly available to transit agencies. According to the US Department of Transportation, two thirds of the 19 largest American transit agencies had their fleet fully equipped with AVL technology by 2004; the Chicago Transit Authority (CTA) is among those 100% AVL equipped agencies (US Department of Transportation, 2007). Therefore, AVL has become widespread and will likely be available at even more transit agencies in the future.

1.2. Data envelopment analysis

DEA is widely used in economic analysis for identifying technically efficient operations (Cooper et al., 2004; Färe et al., 1994; Färe and Grosskopf, 2004; Gattoufi et al., 2004). It is a linear programming method that combines partial efficiency measures into a single comprehensive indicator that provides objective evaluation and consistent comparisons of technical efficiency among decision making units (DMUs), i.e., base analysis units in DEA.

Use of DEA to compare the efficiencies of urban transit systems has become increasingly popular in recent years, particularly since 2000. De Borger et al. (2002) and Brons et al. (2005) have given comprehensive reviews of transit DEA studies. Among the articles published since 2000, some analyze the efficiency of public transit in terms of services delivered (Graham, 2008; Karlaftis, 2003, 2004; Pina and Torres, 2001; Novaes, 2001); some measure the efficiency in terms of productivity (Odeck and Alkadi, 2001; Odeck, 2006); others compare technical and social efficiency of transit agencies (Boilé, 2001; Boame, 2004; Nolan et al., 2001, 2002). One recent study uses panel data analysis to make statistical inferences about estimated technical efficiencies of Canadian paratransit systems (Barnum et al., forthcoming-a). Most recently, DEA has been applied to compare subunits within a single transit agency. Sheth et al. (2007)