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The demand for reliable transit service: New evidence using stop level data from the Los Angeles Metro bus system

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ABSTRACT

This study explores the role of service reliability in determining bus transit ridership. Using stop level service supply, demand, and performance data from the Los Angeles Metro bus system, I investigate whether reliability of a directional line serving a stop influences the number of passengers boarding the line at that stop, controlling for various other established factors affecting demand. This cross-sectional analysis of the variation in line boardings across about 1300 sample schedule time point bus stops served by about 300 directional bus lines over a six-month period uses a historical archive of real-time geo-referenced vehicle location data, and focuses on five different time periods, peaks and off-peaks, of a typical weekday. By evaluating two measures that capture different dimensions of bus service reliability, and by estimating a series of regression models, I find systematic evidence that higher average service punctuality (or schedule adherence) and lower variation in schedule deviation over time are associated with greater ridership, all else equal, particularly during the peak periods. This study also provides first empirical evidence that the effect of reliability on peak-period ridership is moderated by headway. The demand for reliability seems to be higher for lines with relatively longer headways. The findings indicate that service reliability influences transit mode choice and/or line/route selection, and suggest that system-wide ridership gains can be expected from reliability improvements. From an urban planning perspective, this study provides more evidence that good service quality can effectively compliment transformations in the urban fabric brought about by coordinated land use — transit plans to promote transit use.

1. Introduction

Over the past several decades, U.S. planning authorities, local governments, and public transit agencies have collectively worked towards coordinating innovative land use policies with unprecedented transit service improvements for promoting transit use, and consequently reducing various negative externalities associated with extreme automobile dependence. Governments have steadily increased funding for transit, and communities have embraced increased tax burdens for giving transit the opportunity of fulfilling its agenda (e.g. Measure R in Los Angeles County). Data from the Federal Transit Administration's National Transit Database (or NTD; see www.ntdprogram.gov, accessed on 5/31/2015) shows that between 1991 and 2012, total annual government (federal, state and local combined) funding support for transit has increased from $22 billion to $58.5 billion at an inflation-adjusted annual growth rate of about 5%.

Unfortunately, however, transit's share in the U.S. travel market continues to be relatively small. Between 1990 and 2009, transit has consistently maintained an estimated mode share of less than 2% of all trips made in the US (Santos et al., 2011). Moreover, productivity of public transit systems continues to decline across the nation. NTD data shows that the number of unlinked passenger trips per revenue vehicle hour (a standard measure of "service effectiveness") has declined from 46.5 to 39.4, and fare box recovery ratio has dropped from 36.4 to 33.1 between 1991 and 2012. Consequently, the search for magic planning-policy bullets to generate greater enthusiasm around transit continues.

Experts argue that key to increasing transit's market share is to invest in those dimensions of service quality that travelers value most (e.g. Giuliano, 2011). In this paper, I explore whether service reliability, an element of service quality (or performance), can increase the demand for transit travel. Although the importance of service reliability is evident from numerous analyses of transit passenger surveys, empirical investigation of the effect of reliability on ridership has not been performed in the past. Consequently, it is still unclear whether reliability can be used as an effective tool for promoting transit use. My research aims at providing new information to transit managers using new data and methods, and consequently facilitating formulation of future policies that can potentially rejuvenate the U.S. public transit industry.

In this paper, I use Los Angeles Metro (transit service operated by the Los Angeles County Metropolitan Transportation Authority) bus system

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data, collected as part of the ADMS[1] research project. I perform a cross-sectional analysis of the variation in average line boardings across around 1300 schedule time point stops (i.e. those stops along transit lines for which trip schedules — arrival and/or departure times — are available; typically, drivers must adhere to planned arrival and/or departure times at these stops only) of about 300 directional bus lines over five time periods (peaks and off-peaks) of a typical weekday. The analysis helps determine the marginal impact of line service reliability at a stop on the number of passengers who board the line at the stop.

I employ different measures of service reliability (including the industry's standard schedule adherence measure — "on-time performance" or OTP, and a new schedule deviation measure derived using a historical archive of Metro's real-time GPS-based vehicle location data feeds) and different modeling approaches (e.g. negative binomial regression and two-stage least squares regression) to provide information to both practitioners and scholars. To foreshadow briefly, I find evidence that reliability drives in part the demand for transit.

The rest of the paper is organized as follows: Section 2 outlines the research context and reviews relevant literature; Section 3 explains the research design; Section 4 describes variables and their summary statistics; Section 5 presents various analyses, results of regression models, and discussions on findings; Section 6 summarizes the broad takeaways and highlights limitations; and Section 7 concludes the paper with policy implications.

2. Research context

2.1. Significance of transit service reliability

Theory (refer to Fosgerau & Engelson, 2011) and evidence from studies mainly involving the automobile mode (e.g. Small, 1982; Noland et al., 1998; Lam & Small, 2001; Liu et al., 2004; Small et al., 2005; Asensio & Matas, 2008; Tilahun & Levinson, 2010) have long suggested that risk-averse travelers (motorists) tend to minimize the unpredictability of travel, and that the demand for reliability can, under certain circumstances, be stronger than the demand for travel time savings.

Till date, considerable research effort has gone into exploring the significance of transit service reliability. Passengers are found to consistently rank unreliability among the top inconvenience costs associated with transit travel (e.g. studies by Wachs, 1976; Glascock, 1997; Eboli & Mazzulla, 2007; Tyrinopoulos & Antoniou, 2008; Cantwell et al., 2009; dell'Olio et al., 2010; Iseki & Taylor, 2010; and Nurul Habib et al., 2011 are illustrative). And outputs from theoretical and simulation models demonstrate how service unreliability negatively affects passengers' wait times (e.g. Turnquist, 1978; Bowman & Turnquist, 1981; Chen & Chen, 2009), departure time choice and travel cost (Benezech & Coulombel, 2013), and overall transit network performance (e.g. Turnquist & Bowman, 1980). In sum, past studies indicate that service reliability must matter to travelers and hence to operators.

Researchers have proposed many innovative methods of measuring transit service reliability (e.g. Polus, 1978; Nakanishi, 1997; Camus et al., 2005; Lin et al., 2008; Chen et al., 2009) using available or state-of-the-art technologies. Some have analyzed factors that cause unreliability (e.g. Sterman & Schofer, 1976; Abkowitz & Engelstein, 1983; Strathman & Hopper, 1993; Strathman et al., 1999; Chen et al., 2009; Yetiskul & Senbil, 2012). Others such as Abkowitz and Engelstein (1984), El-Geneidy et al. (2006), El-Geneidy et al. (2009), El-Geneidy et al. (2011), and Xuan et al. (2011) have explored and recommended strategies to improve reliability. We now know that efficient network design, better system maintenance and human resource management, improved system resilience, advanced system operations and management, coordinated multi-modal traffic management, and real-time decision making and information sharing can enhance reliability.

While there is a large volume of literature exploring various determinants of transit ridership (e.g. Taylor et al., 2009; Cervero et al., 2010; Gutiérrez et al., 2011; Dill et al., 2013), empirical investigation of the influence of service reliability on ridership has been missing, particularly due to unavailability of historical archived real-time system performance data. A recent paper (Chakrabarti & Giuliano, 2015) has provided evidence on how on-time performance can explain in part the variation in patronage across transit lines. The current study extends that research and addresses a critical gap in public transit planning-policy literature by conducting analysis at highly disaggregate spatial/temporal scales and testing multiple reliability measures that are relevant to both system managers and users.

2.2. Measuring transit service reliability in practice

Although many original approaches to measuring transit service reliability have been proposed, none have been tested beyond small corridors (specific routes/lines or segments thereof), and data acquisition–management–processing–analysis constraints have led to limited adoption within the U.S. transit industry. Also, different measures capture different dimensions of service reliability; there is no consensus regarding a best or most comprehensive measure.

The U.S. Federal Transit Administration (FTA) recognizes reliability as a key dimension of transit service quality (refer to Kittelson et al., 2013, "Transit Capacity and Quality of Service Manual"; the third edition, last accessed on 5/31/15, is available online at http://www.trb.org/main/blurbs/169437.aspx). FTA proposes several measures based on the source of unreliability, magnitude of impact, and purpose of measurement. For example, service disruptions are captured through measures such as: a) percent of scheduled trips that were canceled, b) percent of scheduled time operations were down, or c) average distance traveled between mechanical breakdowns. Note that a), b), and c) can be measured for a given line or system-wide, averaged over a given time period (e.g. month), and aggregated across different times of the day (e.g. peak and of-peak) and days of the week (weekdays and weekends). Variants of these measures are periodically reported to government funding/regulatory agencies (refer to the NTD). More direct measures of system unreliability affecting regular user-experience are captured through: a) on-time performance (or OTP; most commonly the fraction of total trips that serve intermediate schedule time point stops/stations between 1 min early and 5 min late with respect to schedule), b) headway adherence (or some metric of evenness of intervals between vehicle arrivals at designated stops/stations), and c) excess wait time (or average schedule delay in departure from designated stops/stations). Note that a), b), and c) can be measured for a given line, or for a given line at a given stop/station, or system-wide, averaged over a given time period (e.g. month), and aggregated across different times of the day (e.g. peak and of-peak) and days of the week (weekdays and weekends). These measures are comparatively difficult to derive. For accurate and exhaustive data, GPS-based automatic vehicle location (AVL) systems need to be installed in transit vehicles.

Currently, OTP, with some variation in definition, is most widely used as the reliability indicator within the U.S. public transit industry. Despite its limitations (e.g. inability to capture the average or variance of schedule deviation in minutes), it is a conceptually simple and practically useful measure for transit planners. A low average OTP implies that a transit line is mostly unable to adhere to schedules, and hence indicates associated problems such as frequent (that may or may not be systematic) early or late arrivals/departures from stops/stations and uneven headways (and consequently bunched vehicles) that may cause

[1] ADMS refers to Archived Data Management System. The ADMS project (2010-), a collaborative effort of the METRANS Transportation Center and the Integrated Media Systems Center at the University of Southern California, has been funded by the Los Angeles County Metropolitan Transportation Authority (Metro). The research has two objectives: 1) develop an historical archive of real-time data from RIITS (Regional Integration of Intelligent Transportation Systems) and other sources, and 2) demonstrate how the archive can be used for transportation planning, operations, and management.