Transportation Research Part A 100 (2017) 162–169

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

What explains rapid transit use? Evidence from 97 urbanized areas

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1. Introduction

Glaeser's 2011 book, *Triumph of the City*, includes a chapter with the provocative title "Is There Anything Greener than Blacktop?" Glaeser answers his own question in the negative, explaining that there is a strong negative empirical association between various measures of energy use and population density (see also Glaeser and Kahn, 2010). One of many reasons for the alleged greenness of cities is that many city-dwellers choose to commute by rapid transit (i.e. subway, metro, elevated train, etc.) rather than by automobile. This is especially so in the largest and densest cities, where it has proven easier for policy-makers to justify investments in an especially costly type of transportation infrastructure. Simply put, a large number of potential users within walking distance from a new station implies a low fixed cost per station user. A higher (residential or daytime) population density around a station also provides a larger pool from which to find passengers, thereby creating a viable flow for the station.

Most studies of transit use and modal choice have considered a single city or at most different cities in the same country, most often the United States. But modern rapid transit networks now exist on all continents, offering researchers the opportunity to compare outcomes in a much greater variety of combinations of land use patterns and policy choices than is possible in even the largest of countries. In this study, we make use of all 97 (out of 157)[1] urbanized areas with both a mass rapid transit (MRT) and/or a light rapid transit (LRT) system as well as a complete set of observations of relevant transportation and socioeconomic variables (Table A.1 lists the 97 included cities).

We define LRT as any form of rapid transit with multiple cars per train, including medium-capacity rapid transit and monorail, but excluding bus rapid transit (BRT) and personal rapid transit (PRT), which often contain less than two cars per set; MRT refers to all rapid transit lines with higher capacity than LRT lines. There is no clear and universally agreed upon definition that clearly separates MRT from LRT. Usually, LRT have smaller or fewer cars per train than MRT lines. However, the main distinction between LRT and MRT is the technology-related construction cost, not capacity. For example, one medium-capacity LRT in Taipei (Taiwan) carries more passengers per day than both MRT lines in Kaohsiung (Taiwan). Also, it is generally the case that passengers pay the same fare for using both systems, in those cities that have both. It is therefore unnecessary, in our view, to separate LRT from MRT in our analysis.

From a public policy perspective, questions of MRT/LRT use is of much greater importance than bus use, and we have thus not attempted to analyze overall public transportation use. This is not only because of partially missing data. Investments in MRT/LRT systems tend to be very costly and are largely irreversible, and—because of their reliance on spatially inflexible routes—the operators tends to be monopolies. The routing, expansions and contractions of bus routes are much easier to

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[1] An extensive search involving numerous databases and websites preceded the analysis presented here. Sixty metropolitan areas were excluded because of incomplete and/or unreliable data. Most of the excluded cities are in non-OECD countries (e.g. Caracas), have an isolated short-distance line (e.g. Detroit), and/or had been operational for a very short time at the time of the study (e.g. Suzhou). Five cities, in addition to the 97 used in the main analysis, had complete sets of observations, but one or more of the variables had atypical definitions, delimitations, or magnitudes. The results with 102 observations are presented in Table A.2 in the Appendix. The five additional cities are Bangalore, Birmingham, Haifa, Jaipur, and Manchester.

http://dx.doi.org/10.1016/j.tra.2017.04.019
0965-8564/

reverse, are easier to change, and are much less costly, which leaves room for a lot of trial-and-error experimentation, and bus services can (and have been) provided with one, a few, or numerous operators in the same area, which can be either public or private. Moreover, Andersson and Andersson (2008) show that it is those infrastructural variables that change at an extraordinarily slow pace that are the main determinants of long-term regional competitiveness. This would include the roads that buses and automobiles use, but not the buses and automobiles themselves. In contrast, rail transportation and train or MRT/LRT cars are much more closely linked; they are almost perfect complements, unlike buses and roads.

Bus rapid transit (BRT) is often found in Latin America, China, India and Indonesia as a substitute for its more expensive counterpart, rail rapid transit. BRT often operates separately from the rail transit network. Transfers from BRT to MRT/LRT systems are usually not possible within inter-modal stations, making the two modes less integrated than, for example, MRT and intercity trains. As a result, patronage data for most rapid transit systems do not include BRT ridership. BRT represents an intermediate case between MRT/LRT and traditional bus transit networks in terms of investment cost and investment reversibility.

While most of the included urbanized areas have more than one million residents, there is still considerable variability, ranging from less than 150,000 people in the smallest city (Lausanne) to more than 30 million in the largest (Tokyo). Densities are also very different, with the densest city (Manila) being more than 45 times denser than the most sprawling one (Brisbane).

Perhaps the most surprising heterogeneity concerns ticket pricing. Urban economists have long argued that ticket prices should equal or approximate marginal cost, with either land-value increment taxes or rental income from properties near stations covering fixed costs (Foldvary, 1994). An MRT/LRT car is an example of a territorial public good. This means that if there is no congestion, the marginal cost of an additional passenger is zero, which implies a price of zero if we disregard marginal maintenance costs. If there is congestion, so that some passengers are forced to take a later train, then the marginal cost will equal the opportunity cost of the waiting time, which can be expected to differ among passengers. Thus price becomes a more efficient rationing mechanism than queuing.

The marginal-cost approach to MRT/LRT pricing is however uncommon in the real world, with average fares for a ten-kilometer trip ranging from US$0.07 in Kolkata to US$9.97 in Lausanne. Obviously, both transportation workers' labor costs and transit users' incomes are much higher in Switzerland than they are in India. But affordability varies a lot too. In Stockholm, it takes almost a quarter of an hour for a worker with median earnings to earn enough to pay for a ride. In Beijing it takes less than 40 s.

There are a number of hypotheses that have been advanced regarding which factors are most likely to stimulate demand for rapid transit. It is to some of these hypotheses that we turn next.

2. What are the factors that influence rapid transit use?

Taylor et al. (2009) is one of the most ambitious studies that addresses this question. It consists of a cross-sectional analysis of transit use in 265 urbanized areas in the United States, and includes dozens of potential explanatory variables. These variables cover demographic, socioeconomic, transit, as well as highway attributes. Using a two-stage simultaneous equation regression technique, the authors contend that most of the factors that influence transit use are beyond the control of politicians and transport planners in the short run. Examples of significant factors include population size, density, average household income, education, political party preference, and the size and scope of each region's highway system. However, there are two policy choices that do have substantial impacts on demand for transit services: higher frequencies attract passengers, while higher fares drive them away. Indeed, these two variables accounted for 26 percent of the variability in per capita transit patronage (Taylor et al., 2009).

Bresson et al. (2004) offers the most comprehensive European study of general transit use, focusing on 62 urban areas in France from 1975 to 1995. It makes use of fixed-effect panel as well as Bayesian models to derive city-specific factor elasticities. Throughout the period, public transport was clearly an "inferior good," with negative income elasticities. Increased automobile use explained most of this effect. However, the shift from public to private modes of transportation has now run its course in an advanced economy such as France, and by the end of the study period the size of the network and ticket prices became increasingly important in their effects on transit use.

While the two studies above analyze general transit use, including MRT, LRT, and bus transit, other recent multi-city studies have tended to focus on bus services, which are a cheaper and more flexible alternative to rail-based networks in small and medium-sized cities. Hensher (2007) is a prominent example of recent advocacy of "bus rapid transit" (BRT). This no doubt reflects the rise in popularity of BRT in numerous cities, particularly in Europe and South America. Hensher (ibid.) contends that BRT is more affordable, offers greater visibility, and additionally offers levels of service delivery and flexibility that are unusually competitive with the private car.

In a similar vein, Currie and Wallis (2008) offer an overview of bus improvement schemes in Europe, North America, and Australasia. They attempt to synthesize the results of a number of more detailed studies, and focus on the positive impacts on transit use of policy instruments such as network size, bus priority lanes, pricing, and ticketing systems. Similarly, Currie and Rose (2008) review the empirical evidence and conclude that the main policy variables that affect transit use are service reliability, service levels (frequency), and fares. Examples of local case studies that supply some of this empirical evidence on transit use include Badami and Haider (2007), Rye and Scotney (2004), and Estupinan and Rodriguez (2008).