Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions

Technical Background Document

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October 8, 2013

Policy Brief: http://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_brief.pdf

Technical Background Document:
http://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_bkgd.pdf

California Environmental Protection Agency
Air Resources Board

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Study Selection

Many studies have documented the effects of transit service strategies on transit ridership, measured as total ridership or ridership per capita. Three types of service strategies are most often studied: service and frequency increases, system expansion or optimization, and fare reductions. No studies were identified that directly test the effect of transit service strategies on vehicle miles traveled (VMT) or greenhouse gas (GHG) emissions.

The primary criterion for including studies in the research brief was measurement of ridership from before to after the implementation of the strategy. Additional considerations included the timing of the study (with preference given to more recent studies), U.S. location for the data (though studies in other developed countries were also considered), and control for other factors that influence transit ridership.

Several comprehensive reviews of such studies are available. The Transportation Cooperative Research Program (TCRP) Report Number 95, specifically Chapters 9, 10, 11, and 12 (see Evans, 2004; Pratt & Evans, 2004; and McCollom & Pratt, 2004), reports average elasticities from mostly U.S. studies. Paulley et al. (2006) conducted a meta-analysis of elasticities from studies of transit service improvements mostly in the United Kingdom. This review was included in the brief because of its relatively recent publication date, and because development patterns and auto use there are closer to the U.S. than in most European countries. In addition, this review provides estimates of the effect of transit service improvements on car use (measured as share of trips by car). Finally, Taylor et al. (2009), though a cross-sectional study, was included because of its use of relatively recent data for a large sample of U.S. cities, and because it controls for external factors and accounts for the reciprocal relationship between transit supply and demand. Two other recent studies, each focusing on a particular city, were not included in the summary table: Hickey (2005) analyzed changes in ridership in response to fare increases in New York City, a very different context than California; Currie & Loader (2009) examined the impact of evening and weekend service expansion in Melbourne, Australia.

Table 1: Measures Used and Sources of Effect Sizes

Study	Study Location	Transit-Service Measure	Ridership Effect Size and Source
Evans (2004)	Average across multiple studies	Service frequency – bus	Elasticity between bus ridership and service frequency is +0.5 (see pg. 9-5 in cited report). Elasticity estimate based on average of reviewed studies. Reported elasticities cluster around +0.3 and +1.0.
Pratt and Evans (2004)	Average across multiple studies		Elasticity estimates based on average of reviewed studies.
		Service hours or miles – bus	Elasticity between bus ridership and service hours or miles is +0.7 to +0.8 (see pg. 10-8 in cited report).
		Service frequency – bus	Elasticity between bus ridership and service frequency is +0.5 (see pg. 10-8 in cited report).
	Santa Clara County	Service hours – bus	Elasticity between bus ridership and service hours is +1.42 and between bus ridership per capita and service hours is +1.02, for the period 1977 to 1997 (see pg. 10-11 in cited report). Sources for reported elasticities are agency reports.
	Orange County	Service miles – bus	Elasticity between bus ridership and service hours is +0.68 for the period 1974 to 1989 (see pg. 10-11 in cited report). Source for reported elasticity is Ferguson, 1991. Estimated elasticity based on econometric modeling that controls for employment growth.
McCollom and Pratt (2004)	Average across multiple studies		Elasticity estimates based on average of reviewed studies.
		Fares – bus	Elasticity between bus ridership and fares is -0.4 (see pg. 12-6 in cited report).
		Fares – rail	Elasticity between rail ridership and fares is -0.17 to -0.18 (see pg. 12-6 in cited report).

Study	Study Location	Transit-Service Measure	Effect Size and Source
Paulley et al. (2006)	Meta-analysis of 104 studies in Britain and elsewhere		Fare elasticities based on regression model estimated with 902 fare elasticities from 104 studies in Britain between 1951 and 2002.
		Bus fares	Elasticity between bus ridership and fares is -0.4 in the short-run, -0.55 in the medium-run, and -1.0 in the long-run (see Section 2.11 in the cited paper).
		Metro fares	Elasticity between Metro ridership and fares is -0.3 in the short-run, -0.6 in the long-run (see Section 2.11 in the cited paper).
		Fares- bus or rail *Effect is on car share*	Elasticity between share of trips by car and bus fares is +0.057 (see Table 6 in cited paper). Elasticity between share of trips by car and rail fares is +0.054 (see Table 6 in cited paper). Elasticity estimates based on results from two cited studies.
			Estimated elasticities based on results from prior studies; studies not specified.
		Vehicle kilometers of service – bus	Elasticity between bus ridership and vehicle kilometers of service is +0.38 in the short-run and +0.66 in the long-run (see Table 4 in the cited paper).
		Vehicle kilometers of service – rail	Elasticity between rail ridership and vehicle kilometers of service is +0.75 in the short-run (see Table 4 in the cited paper).
			Estimated elasticities based on results from prior studies; studies not specified.
		Increase in time spent on vehicle – bus	Elasticity between bus ridership and in-vehicle travel time range from -0.4 to -0.6 (see Section 3.4 in cited paper). Note: elasticities are reversed in the Brief (increase in ridership given decrease in time).
		Increase in time spent on vehicle – rail	Elasticity between rail ridership and in-vehicle travel time range from -0.4 to -0.9 (see Section 3.4 in cited paper). Note: elasticities are reversed in the Brief (increase in ridership given decrease in time).

Taylor et al. (2009)	265 urbanized areas in U.S.		Estimated elasticities based on cross-sectional analysis of transit use in 265 urbanized areas, using a 2-stage least-squares regression that accounts for the interrelationship of supply and demand.
		Fares – all transit	Elasticity between total ridership and fare is -0.43 and between per capita ridership and fare is -0.51 (see Tables 7 and 9, respectively, in cited paper).
		Vehicle hours – all transit	Elasticity between total ridership and vehicle hours is +1.1 and between per capita ridership and vehicle hours is +1.2 (see Tables 7 and 9, respectively, in cited paper).
		Service frequency – all transit	Elasticity between total ridership and service frequency is +0.5 and between per capita ridership and vehicle hours is +0.48 (see Tables 7 and 9, respectively, in cited paper).

Effect Size, Methodology and Applicability Issues

In most cases, the measured outcome of transit-service strategies is change in ridership. Ridership is typically expressed as either total ridership or as ridership per capita. The advantage of using a per capita measure is that it controls for population growth. The results suggest that a 1 percent increase in service frequency will lead to a ridership increase of approximately 0.5 percent (elasticity of 0.5), that a 1 percent increase in service hours or miles could lead to a higher increase of around 0.7 percent (elasticity of 0.7), and that a 1 percent decrease in fares will lead to about a 0.4 percent increase in transit ridership (elasticity of -0.4). However, researchers are careful to stress that “no single transit elasticity value applies in all situations” (Litman, 2004, pg. 52). Currie & Loader (2009), for example, found higher elasticity for increases in service in the evenings and on weekends, while Hickey (2005) found a much lower elasticity for fare increases in New York City (-0.10) than reported in other studies.

Evidence is slim for other strategies, such as transit information, promotional programs, service reliability, vehicle characteristics, and other elements of service quality. Most published studies of the effects of transit information and promotion focus on the reach of the promotional message or awareness of information sources. They rarely report the ridership effects of these strategies or control for other factors (Turnbull & Pratt, 2003). The effects of service reliability, vehicle characteristics, and other elements of service quality have often been studied by asking people how such strategies would change their behavior rather than by observing actual changes in behavior (Paulley et al., 2006).

The limited evidence available suggests that these other strategies do increase ridership, at least temporarily. Mass market promotions, such as free rides and giveaways, have generated 4 to 35 percent increases in ridership during and immediately after the promotion. Targeted promotions have had effects of around 10 percent in the short-run. However, ongoing customer information services have had no discernible effects in most studies, and evidence on the effects of real-time transit information is insufficient to draw conclusions. Strategies that reduce out-of-vehicle time (e.g. by reducing headways or coordinating transfers) seem to have more impact than strategies that reduce in-vehicle time (Evans, 2004).

Evidence is also slim for Bus Rapid Transit (BRT) systems. BRT is relatively new in the U.S. and thus has not yet been extensively studied here. The two studies cited in the policy brief for the example of LACMTA's bus rapid transit service provide evidence of the promise of this strategy. Levinson (2003) examined transit use and mode switching using on-board surveys before and after the opening of the new service in 2000. Callaghan and Vincent (2007) used ridership and travel time data from LACMTA in addition to surveys of riders of the Orange Line. The survey included a question on previous mode of travel that enabled an analysis of the extent to which the line attracted riders who switched from driving rather than conventional bus service. A study of the EmX BRT line in Eugene, OR also used a survey to assess whether riders switched from driving (Thole et al., 2009). Diaz and Hinebaugh (2009) provide additional U.S. examples.

Limited evidence is available as to which features of BRT have the most effect on ridership. Currie and Delbosc (2011) used a cross-sectional regression model to examine features associated with higher ridership on bus systems in Australia including both conventional and BRT systems. They found higher ridership per vehicle-kilometer on systems with: greater frequency (that is, the rate of ridership per unit of supply increases at high frequency); lower speeds (that is, slower lines have more riders, attributed to reverse causality, as found in other studies); more segregated right-of-way (even after controlling for average speed); more disabled-accessible buses (attributed to appeal of newer vehicles and branding); and not in Sydney (attributed to shortcomings particular to that system). Notably, they found no significant boost for buses in Adelaide despite enhanced BRT features such as high-quality grade separation and enhanced stations. This result suggests that the effects of BRT on ridership derive from higher speed, segregated right of way, and service levels (variables included in the model), rather than from grade-separation or enhanced stations (features specific to the Adelaide system).

Increases in transit ridership do not directly translate into decreases in driving, since not all new transit trips replace driving trips. Studies suggest that substitution of car trips occurs for between 10 and 50 percent of the new transit rides attributable to fare decreases or service increases (McCollom & Pratt, 2004; Litman, 2006); more recent studies show a similar range for BRT (Callaghan & Vincent, 2007; Diaz & Hinebaugh, 2009; Thole et al., 2009). Between 10 and 20 percent of transit trips may be entirely new – trips that would not have occurred at all without the service or fare changes (Evans, 2004). In addition, the low market share for transit means that even significant increases in transit ridership may translate into a small decrease in total driving. Paulley et al. (2006) estimate that a 1 percent decrease in bus fare leads to a 0.054 percent decrease in the share of trips by automobile (cross elasticity of 0.054), and a 1 percent decrease in rail fare leads to a 0.057 percent decrease in car trips (cross elasticity of

0.057 - see Table 2). As this study notes, "… public transport use is remarkably sensitive to car costs, but car use is much less dependent on public transport costs" (pg. 303). We did not identify any studies that measured change in GHG emissions in response to improvements in transit service, but two international studies document reductions in GHG emissions for BRT systems outside of the US (Hook et al., 2010; Vincent et al., 2012).

In applying the estimated effects, several methodological limitations should be considered. First, the reviews, while comprehensive, include studies that are now quite old and may be of questionable quality. For example, the reviewed studies typically do not control for other factors by comparing changes in ridership for the communities in which the service improvement is made to changes in ridership for similar communities without service improvements.

Second, the reviews report simple averages of the elasticities from the studies they review, with the one exception of the elasticity between total ridership and fares reported in Paulley et al. (2006), which was based on a regression analysis of the elasticities from the reviewed studies.

Third, while Taylor et al. (2009) use relatively recent data from a large sample of U.S. cities, the cross-sectional approach means that the analysis establishes associations between service quality and ridership, but does not directly show that an *improvement* in quality leads to an *increase* in ridership.

Fourth, transit-service strategies are often adopted in combination. For example, fare decreases may be paired with increases in service frequency. Such strategies are often combined with other strategies for which little evidence is available, such as promotional programs. Separating the effects of different strategies is challenging, and it is possible that the total effect of a combined set of strategies is greater than the sum of the separate effects of the individual strategies.

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Acknowledgments

This document was produced through an interagency agreement with the California Air Resources Board with additional funding provided by the University of California Institute of Transportation Studies MultiCampus Research Program on Sustainable Transportation and the William and Flora Hewlett Foundation.