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

Policy Brief

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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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Policy Description

Many different transit service-related strategies can be used to increase transit ridership. As summarized in Table 1, strategies fall into three general categories, with many variations within each category. These include service and frequency increases, system expansion or optimization, and fare reductions. Other categories, not listed because of the lack of evidence of their effects, include transit facility improvements (for example, vehicle and station enhancements or intermodal connections) and information and marketing promotions.

Bus Rapid Transit (BRT) systems combine many of these strategies to provide service that is closer to that of rail systems than bus systems, usually with higher fares than the latter. Ideally, BRT systems have separated lanes or rights-of-way, stations rather than stops, more rail-like vehicles, and other amenities not typical of bus systems, though there is no consensus on what qualifies as “true” BRT, and each BRT system is unique (Wirasinghe et al., 2013). There are several different BRT and BRT-like systems in the U.S. (Diaz and Hinebaugh, 2009).

Table 1. Types of Transit Service Strategies

Type	Strategies
Service and Frequency Increases – Existing System	
Frequency increases	Increased number of scheduled vehicle trips
Service hours increases	Lengthened service day Added days of service
Frequency increase with fare reductions	Increased frequency with decreased fares
Combined service frequencies	General service combined with targeted service, e.g. express service and local service on same street
Regularized schedules	Easy-to-remember departure times Service timed to match regularly scheduled activities Improved coordination at transfer points
Reliability changes	Reduced deviations from schedule Reduced missed trips
System Expansion – New or Reconfigured Routes	
New bus transit systems	Implementation of entire new bus system where no transit service previously existed

Type	Strategies
Comprehensive service expansion	Major system-wide extension and addition of bus routes with substantial enlargement of system coverage
Service restructuring	Reworking of existing bus network to rationalize or simplify service, accommodate new travel patterns, reduce circuitous routes, ease or eliminate transfers, otherwise reconfigure
Changed urban coverage	Extending or adding bus routes to provide transit service for new developments or other previously unserved areas
Changed suburban coverage	Implementation of outlying radial services (in traditional or reverse commute direction)
Circulator/distributor routes	Use of shuttle services to provide enhanced connectivity within downtowns or other activity centers, or between activity nodes in close proximity; may be multipurpose or targeted to specific purposes
Feeder routes	Use of shuttles to provide local coverage to link residential areas and employment areas to express or rail services; may also serve as neighborhood circulators
Disadvantaged neighborhoods to jobs routes	Implementation of special purpose routes to connect disadvantaged neighborhoods to jobs, usually in suburban areas not otherwise easily served by transit
Other special routes	Implementation of other special purpose routes to serve specific, inadequately serviced, existing or potential users
Fare Reductions	
Reductions in general fare level	Decreases in adult fares accompanied by corresponding changes in other fare categories, with percent changes kept generally the same
Changes in pricing relationships	Decreases that deliberately modify the relationship between fare categories, e.g. implementation of deep discount fares for multiple-ride tickets
Changes in fare categories	Introduction of new fare purchase methods, such as multiple-ride tickets or unlimited-ride passes, or new fare category, such as school fares or express bus fares
Changes in fare structure basis	Change in basis on which fares are calculated, e.g. flat fare for entire system, zonal fare with additional fare increments for each zone boundary crossed, or distanced-based fare
Free transit	Eliminate charge to transit riders all together; usually applied to selected periods, services, or geographic areas

Source: Adapted from TCRP 95, Chapters 9, 10, and 12

Impacts of Transit Service Strategies

Many studies have documented the effects of transit service strategies on transit ridership, though few have examined effects on vehicle miles traveled (VMT). Thorough summaries of studies of these impacts are provided in 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). This brief presents average effects from this report, as well as results from two newer studies (Paulley et al., 2006; Taylor et al., 2009).

Effect Size

Transit-service strategies are usually quantified in one of three ways:

- percentage change in fares
- percentage increase in frequency (or reduction in headway)
- percentage change in vehicle miles of service, whether from service increases or system expansions

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. All but one of the studies included here measure changes in ridership from before to after implementation of the strategy for one or more systems. In contrast, Taylor et al. (2009) analyzes the relationship between transit service and ridership at one point in time for a large sample of transit systems. One study (Paulley et al., 2006) examines the effect of a fare increase on car use. These studies distinguish between impacts of bus service versus rail service. While not examined in these studies, bus rapid transit (BRT) that functions more like rail is likely to have impacts more similar to rail service, and BRT that functions more like a conventional bus is likely to have impacts more similar to bus service.

Table 2: Transit Service Strategies' Impact on Ridership

Study	**Study Location**	**Study Year(s)**	**Results**		
			Transit Service Strategy Variable	*Ridership Variable*	*Increase in Ridership for 1% increase in Service Strategy Variable*
Evans (2004)	Average across multiple studies	1970s to 2000s	Service frequency	Bus ridership	+0.5%
Pratt and Evans (2004)	Average across multiple studies	1970s to 2000s	Service hours or miles	Bus ridership	+0.7% to +0.8%
			Service frequency	Bus ridership	+0.5%
	e.g. Santa Clara County	1977 to 1997	Service hours	Bus ridership	+1.42%
				Bus ridership per capita	+1.02%
	e.g. Orange County	1974 to 1989	Service miles	Bus ridership	+0.68%

Study	Study Location	Study Year(s)	Results		
			Transit Service Strategy Variable	*Ridership Variable*	*Increase in Ridership for 1% increase in Service Strategy Variable*
McCollom and Pratt (2004)	Average across multiple studies	1970s to 2000s	Fare decrease*	Bus ridership	+0.40%
				Rail ridership	+0.17% to +0.18%
Paulley et al. (2006)	Meta-analysis of 104 studies in Britain and elsewhere	1951-2002	Fare decrease*	Bus ridership – short-run	+0.40%
				Bus ridership – medium-run	+0.55%
				Bus ridership – long-run	+1.0%
				Metro ridership - short-run	+0.3%
				Metro ridership - long-run	+0.6%
			Bus fare decrease*	*Car share*	-0.057%
			Rail fare decrease*	*Car share*	-0.054%
			Vehicle kilometers of service	Bus ridership – short-run	+0.38%
				Bus ridership – long-run	+0.66%
				Rail ridership – Short-run	+0.75%
			Decrease in time spent on vehicle*	Bus	+0.4% to +0.6%
				Rail	+0.4% to +0.9%

Study	Study Location	Study Year(s)	Results		
			Transit Service Strategy Variable	*Ridership Variable*	*Increase in Ridership for 1% increase in Service Strategy Variable*
Taylor et al. (2009)	265 urbanized areas in U.S.	2000	Fare decrease*	Total ridership	+0.43%
				Per capita ridership	+0.51%
			Vehicle hours	Total ridership	+1.1%
				Per capita ridership	+1.2%
			Service frequency	Total ridership	+0.50%
				Per capita ridership	+0.48%

*Studies report effect on ridership for *increase* in fare or time spent on vehicle.

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). Conditions leading to higher and lower effect sizes are summarized in Table 3 and are evident in the results presented in Table 2. The physical, operating and economic environments all moderate the effect of increased service or decreased fares on ridership (Evans, 2004). In general, ridership is likely to increase the most where existing service is infrequent, for riders who are not dependent on transit, and for discretionary trips.

Table 3. Factors Influencing Effect Size

Category	Higher effect size	Lower effect size
User type	Transit "choice" riders Higher income	Transit dependent riders Lower income
Trip type	Non-commute Off-peak hour	Commute Peak hour
Geography	Small cities Suburbs	Larger cities
Transit type	Bus or rail, depending	Bus or rail, depending
Time of day	Evening Weekend days	Day time Weekdays
Time period	Long-run	Short-run
Direction of price change	Fare increase	Fare decrease

Source: Adapted from Litman, 2004; Currie & Loader, 2009.

Evidence is slim for the effects of other strategies, such as transit information, promotional programs, service reliability, vehicle characteristics, and other elements of service quality. The limited evidence available suggests that these strategies do increase ridership, at least temporarily (Evans, 2004; Turnbull & Pratt, 2003; Paulley et al., 2006). Evidence on the cumulative impact of service improvements, station upgrades, and branding that comprise bus rapid transit (BRT) is also limited. While new BRT systems report increases in ridership after opening (Diaz & Hinebaugh, 2009), it is unclear which aspects of the new service matter.

Increases in transit ridership do not directly translate into decreases in driving, since not all new transit trips replace driving trips (McCollom & Pratt, 2004; Litman, 2006). 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).

In general, transit service has a greater potential for reducing miles driven if it attracts riders who would otherwise drive versus attracting riders who would otherwise walk or use some other type of transit for a particular trip. BRT may have more potential to attract riders from cars than conventional bus service, but this potential likely depends on the specific context. Estimates of the percent of new BRT ridership drawn from private vehicles on U.S. systems vary greatly. The estimate for one line in Boston was 2 percent of riders, while for another line in Boston it was 50 percent of riders (Diaz & Hinebaugh, 2009). A study of a BRT line in Eugene, OR found that 16 percent of riders previously drove or were driven (Thole et al., 2009).

Evidence Quality

The strength of the studies on the effect of transit strategies is that most employ a longitudinal approach that compares ridership before to after the implementation of the strategy. However, few of these studies control for other factors that may also influence ridership over the same period of time, such as population growth, economic changes, and changes in the automobile system. Studies that measure the effect on ridership per capita, rather than total ridership, account for population growth but not other factors. Although no studies use a “control group”, which in this case would be a similar transit system that does not implement the strategy (difficult if not impossible to find in most cases), some control for other factors statistically.

The studies included in Table 2 have both strengths and weaknesses. In contrast to other studies, Taylor et al. (2009) is a cross-sectional study that compares ridership for different systems with their service characteristics and fare levels. Cross-sectional studies are considered less conclusive than longitudinal studies, but Taylor, et al. use a large sample of U.S. transit systems and employ sophisticated statistical techniques to control for other factors. As noted above, the TCRP reports provide a thorough summary of individual studies, but with little screening for study quality. As a result, the cited studies are often not peer-reviewed and many of them are 20 to 40 years old. The reports in TCRP 95 summarize the results from the reviewed studies using simple averages. In contrast, Paulley et al. (2006) conducted a meta-analysis of a large number of studies that statistically accounts for the characteristics of the different transit systems. However, most of the studies are from Britain rather than the U.S. Despite these differences, the estimated effects are relatively consistent across these three sources.

Caveats

It is important to note the significant variability in estimated effects for studies of individual transit systems. As shown in Pratt and Evans (2004), the estimated ridership increases resulting from a 1 percent increase in service ranged from 0.41 percent to 1.34 percent across a sample of U.S. cities in the 1970s. As noted earlier, many different factors influence the effect size, and these should be considered in deciding on an appropriate effect size for a particular transit system. Another consideration is the length of time it may take before the full effect of the strategy is realized, or, conversely, whether the effect of the strategy will wear off over time. In addition, evidence suggests that multi-faceted strategies have a synergistic effect, with the total effect greater than the sum of the effects of the individual strategies on their own.

GHG Emissions

The effects of transit strategies on greenhouse gas (GHG) emissions are unknown. As noted above, increases in transit ridership do not translate directly into decreases in driving. In addition, strategies that increase the amount of transit service (through increased frequencies, extended service hours, or new or longer routes) increase the amount of fuel consumed by transit vehicles. The increased transit fuel consumption may largely or completely offset automobile energy saved (Evans, 2004). The overall impact on GHG emissions will therefore depend on the context. One study found large differences in the estimated impact of a major new BRT system on overall GHG emissions in three international cities (Bogota, Mexico City, and Jakarta); estimates of CO_2 emissions reductions per passenger ranged from 357 to 12,636 kilograms per passenger per year (Hook et al., 2010). Another study reports that the TransMilenio BRT system in Bogota achieved reductions in CO_2 emissions of 1.7 percent of city-wide transport emissions (Vincent et al., 2012).

All else equal, more efficient transit vehicles consume less fuel. In the U.S., many BRT systems employ lower-emitting vehicles, and for that reason have the potential to generate fewer emissions than older, conventional bus service (Diaz & Hinebaugh, 2009). In addition, the manner in which a bus is driven may also affect fuel consumption and emissions, with frequent stops and starts in congested traffic consuming more fuel. Systems with bus-only lanes or separated rights-of-way may thus generate lower GHG emissions than conventional service.

A net reduction in energy use, and thus GHG emissions, is more likely if transit ridership increases are achieved through a combination of decreased fares and expanded service (Evans, 2004). Apart from those particular considerations, one would generally expect GHG reduction to be similar to VMT reduction if vehicle fleet composition and driving patterns are unchanged. While the pattern of such changes in response to transit service strategies has not been documented, it is reasonable to expect that policies that reduce VMT will also lead to reductions in GHG emissions.

Co-benefits

Expansions of transit service and improvements to service quality enhance transportation equity for those unable to drive. Decreases in driving that result from transit strategies help to reduce congestion, noise, air pollution, and other negative effects. To the degree that improved transit service results in increased transit use and particularly increased walking to and from transit stations, it can increase levels of physical activity and yield significant health benefits (Besser & Dannenberg, 2005). Rail service and BRT can also generate additional benefits over the long-term by attracting higher density, mixed-use development around stations (Wirasinghe et al., 2013) that in turn encourages a shift from driving to physically active travel.

Examples

The Los Angeles County Metropolitan Transportation Authority (LACMTA) commenced operation of one of the most extensive systems of rapid transit buses in the United States in 2000. This system includes two bus rapid transit (BRT) routes operating on dedicated busways (Orange and Silver lines) and a network of bus routes with BRT features that run on city streets (Metro Rapid).

Metro Rapid offers many features of true BRT, including signal prioritization, level boarding and alighting on flat-floor buses, fewer stops, headway-based schedules, and active management of service operation. Stops are located on the far side of intersections rather than the near side. Real-time information on the arrival of the next bus is provided, and some stops feature station-like amenities, such as canopies. Headways during peak hours are 7 minutes in the Ventura corridor and 2.5 minutes on the Wilshire/Whittier corridor. Two years after opening, ridership was up 26 percent in the former and 33 percent in the latter (Levinson, 2003). Of this increase, Metro estimated that one-third were new riders, which equated to nearly 11 percent of the total on Metro Rapid. By 2006, ridership had increased a total of 45 and 47 percent for the two corridors respectively (Callaghan & Vincent, 2007).

The 14-mile Orange Line, which opened in 2005, runs entirely on a dedicated busway, with traffic control priority where it crosses surface streets and 5-minute headways during peak hours. The Silver Line, opened in 2009, is 26-miles long and operates on both busways and city streets. A preliminary evaluation of the Orange Line showed that seven months after opening, initial monthly ridership projections were exceeded by a factor of approximately three, and data collected from a survey in January 2006 indicated that 17 percent of Orange Line riders were new to Metro, while 18 percent previously used private cars to make the surveyed journey, either as a driver or passenger (Callaghan & Vincent, 2007). GHG emissions are likely to have declined for the passengers who switched to transit from driving.

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Acknowledgements

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.