COMPARATIVE PERFORMANCE OF

LOS ANGELES' TRANSIT MODES

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Presented at the
11th Joint Light Rail Conference
Los Angeles, April 20, 2009

ABSTRACT

New ways of using bus transit have evolved in the United States over that past decade. Los Angeles' Metro is unique in that it now operates all fixed-route urban bus and rail transit modes. This allows us, for the first time, to compare how these modes perform without the differences in labor costs, operating practices, and other externalities that can easily confuse modal comparisons.

The on-going building of Los Angeles' Metro rail and busway system has greatly increased the speed, capacity, and productivity of transit services within critical travel corridors. The continuing addition of enhanced bus (Rapid Bus) services has increased bus speeds and productivity in many more corridors. Together, although accounting for a small fraction of Metro's overall transit mileage, these few rail lines and bus routes carry over half its passenger-miles of travel.

The analysis confirms that Rapid Bus routes are faster and more cost-efficient than local bus routes and that busways are better yet. L.A.'s rail lines are at least 36% faster than any bus mode and have already shown they can carry well over twice the probable capacity of the busways. The analysis also indicates that unit operating costs and subsidies drop as one moves from local bus services to full rapid transit. Capital costs, of course, rise in the same direction.

One conclusion from this analysis is that bus and rail transit speed improvements benefit the public and the agency by decreasing travel times, operating costs, and operating subsidies. They should be implemented in all cities. Another conclusion is that bus transit provides a range of service options if high speeds and capacities are not needed, but only rail provides truly high speeds and capacities. Busways are not equivalent to light rail. A good transit system uses the strengths of all modes working together.

PURPOSE

Over the past 25 years Los Angeles' Metro transit network has evolved from an all-bus system to a network of many transit services and modes. As of Spring 2008, this network included a rapid transit line, three light rail lines, three busways, 19 enhanced bus routes, and 95 local bus routes. Twelve other transit operators run municipal bus services and Metrolink operates the region's commuter rail system. This paper deals only with services operated directly by Metro, by far the dominant service provider. With Metro, we have the unique opportunity to compare a variety of transit modes all operated by the same agency within the same urbanized area. This eliminates external factors which cloud modal comparisons, such as differences: in labor costs between urban areas, in operating and management practices, in efficiencies of scale, and in time and methods of data collection.

The purpose of this paper is to compare the travel speeds, trip lengths, capacities, operating costs, and capital costs of four bus modes and two rail modes all operated by one American transit agency. These measurements were selected because they are straight-forward to obtain and are central to any debate comparing transit modes.

Past Studies

Past studies comparing transit modes generally fall into two categories. The first compares modes which are being planned or hypothesized, that is, not in operation. These types of studies are needed, of course, when doing major planning work, but they must use projections of ridership and costs rather than actual ridership and costs. The alignments and operational assumptions made for each alternative may have to be different or may not, in the end, be possible. For example, Sislak (*1*) compared a busway and light rail alternative, each having a different alignment, for a planned Cleveland corridor. Stutsman (*2*) in another busway vs. light rail comparison study for the Exposition corridor in Los Angeles, acknowledge that the assumption of full signal pre-emption for the busway mode was problematic.

The second category of studies compares operating modes among two or more cities. Until fairly recently, the only bus mode in the United States that could be compared with light rail was the busway within a freeway. Recent studies have had more bus services with which to compare. Two studies are worth noting in this regard. In 2002, A study by Kühn (*3*) compared various enhanced bus services with light rail using existing operations culled from cities worldwide. Although Kühn lumps the various bus services under the catch-all term Bus Rapid Transit (BRT), he does recognize the useful range of bus modes that are available. It is a good study with useful conclusions, but each system included operates in a different cultural, economic, and operational context. Moreover, how well do transit systems serving diverse cities around the world translate to America? Helping to fill that gap is a 2005 study by Hess, Taylor and Yoh (*4*) that looks at various bus modes within U.S. cities and compares them with light rail. Part of this study's value is in separating the term BRT into its three main components: enhanced bus services on arterial streets, busways within freeways, and at-grade busways within their own rights-of-way. The study's weakness - though no fault of its own - is that most of the projects cited were still in the planning and construction when its data were collected. The study does note the difficulty of comparing projects in different cities each using their own ways of cost estimating and operating.

What is needed is a study of transit modes based on actual operating experience, preferable one in which as many externalities as possible are removed. Los Angeles provides a unique opportunity to do just that.

OVERVIEW

In early 2008 Metro operated the following fixed-route services:

- **Red/Purple Line –** A rapid transit line in subway, the first segment of which opened in 1992, its last extension in 2000. It includes a 17-mile Red Line service and a 5-mile Purple Line service. Peak-period headways in each branch are ten minutes with a combined frequency of five minutes in the common four-mile downtown L.A. segment.
- **Green Line –** A fully grade-separated light rail line opened in 1994 in the median of a freeway. Because of this and long station spacing, its average speed is the highest of all Metro transit lines. It operates with peak period headways of 7-1/2 minutes.
- **Blue Line –** A light rail line opened in 1990 with 75% of its length in an exclusive and/or grade-separated right-of-way. It operates peak period headways averaging 5-1/2 minutes.
- **Gold Line** – A light rail line opened in 2002 with 100% of its length within an exclusive and/or grade-separated right-of-way. It operates peak period headways of 7-1/2 minutes.
- **Orange Line Transitway** – A busway opened in 2004 with 90% of its length in an exclusive right-of-way. It has the same one-mile station spacing as the light rail lines. It is served by one bus route which is given signal priority, uses high-capacity buses, and has peak-period headways averaging 4-1/4 minutes.
- **El Monte Transitway –** A busway opened in 1972 on an exclusive roadway within a freeway right-of-way. For many years this facility was used only by buses, the busway is now shared with 3+ person carpools. Buses leave the busway to distribute passengers in downtown L.A. on surface streets in mixed traffic. Five MTA and seven Foothill Transit routes use this busway, coming together in the 11.5-mile freeway segment. Each bus route has its own frequency.
- **Harbor Transitway –** Opened in 1996, this is special busway/HOV facility on a separate roadway within a freeway right-of-way. It was designed for joint use by buses and car pools (3+ occupants) and has two lanes in each direction. Eight MTA bus routes (along with seven other bus routes) use the busway, coming together in the 12-mile freeway segment. Buses distribute passengers within downtown Los Angeles on surface streets in mixed traffic. Each bus route has its own frequency.
- **Wilshire Rapid Express** A mainly peak-period express bus service with very limited stops, signal priority, and articulated buses. It has a peak-period headway of 15 minutes. This type of service is now just on Wilshire Blvd.
- **Metro Rapid Bus –** Rapid Bus routes operate in mixed traffic on existing streets. Almost all Rapid Bus services operate on the same route as the still-operating local bus route, but have fewer stops, signal priority, usually a truncated length, and no late evening service. There are 19 Rapid Bus routes.
- **Local Bus –**The 95 MTA bus routes not in the above categories. Included are conventional bus routes, some shuttle bus routes and a few peak hour, limited-stop bus routes.

Metro's Bus Rapid Transit Lines

Metro operates three types of bus services that fall under the Federal Transit Administration's broad definition of Bus Rapid Transit (BRT)(*5*). This paper will not use the term BRT because it is too general. It will use the term Rapid Bus for Metro's Rapid Bus routes and the Wilshire Rapid Express. It will use the term Busway for the El Monte and Harbor Freeway bus/HOV transit services. The Orange Line, which operates quite differently from the other two busways, will be referred to by its name. All three services use articulated buses with a distinctive red color scheme. Metro has clearly tried to brand them as different from its local bus fleet, which is painted orange.

CHARACTERSITICS OF MODES WITHIN THE METRO SYSTEM

In this section travel times, trip lengths, capacities, and operating costs of the Metro transit modes are compared. Unless otherwise noted, the data used in calculating the values shown in the figures came either from Metro's unpublished Third Quarter FY2008 (January-March, 2008) bus operating statistics or from Metro's unpublished April, 2008 rail operating statistics.

Distribution of Transit Use by Mode

Metro operates a total of about 5,200 miles of transit routes. The four rail lines account for 1.3% of that mileage, rapid bus routes and busways another 11%. As Figure 1 shows, local bus routes comprise the vast majority of Metro route miles. However, the rail system carries almost one-fifth of the system's ridership, rapid buses and busways slightly less. The importance of the higher-speed, higher-capacity modes becomes even more pronounced when considering passenger-miles carried. The four rail lines already carry over a quarter of Metro's total passenger-miles of travel, rapid buses and busway buses another quarter. In short, one-eighth of Metro's transit miles carries over one-half of its total passenger-miles of travel!

Average Peak Period Speed

Metro keeps annual revenue service miles and hours for each route, and from them it calculates the route's annual revenue speed. This information combines off-peak, peak and weekend speeds and includes layover and rest times. It does not reflect what passengers experience during the important peak periods. For this analysis, average peak-period travel speeds were estimated using travel times in Metro's printed timetables and route distances measured with tools in Google Earth.

Ideally, average peak period travel speeds would be calculated for each trip in each peak period in both peak-period directions, and these dozens of speeds averaged to obtain the peak-period speed for each route. This was not practical. Instead, at least four randomly selected peak-period travel times for each route were used to derive the average speed of that route. The average speed shown for each *mode* is the combined speeds of all routes within that service type. (Checks using 16 data points per route resulted in average peak hour speeds per mode that were at most a fraction of a mile-per-hour different than an average derived from four data.)

The average scheduled speed for the 95 local bus routes came from the calculated average speeds of a random selection of 19 local routes (every fifth route). Peak-period speeds were calculated the same way for each rail line and bus route.

FIGURE 1: TRANSIT DISTRIBUTION BY MODE

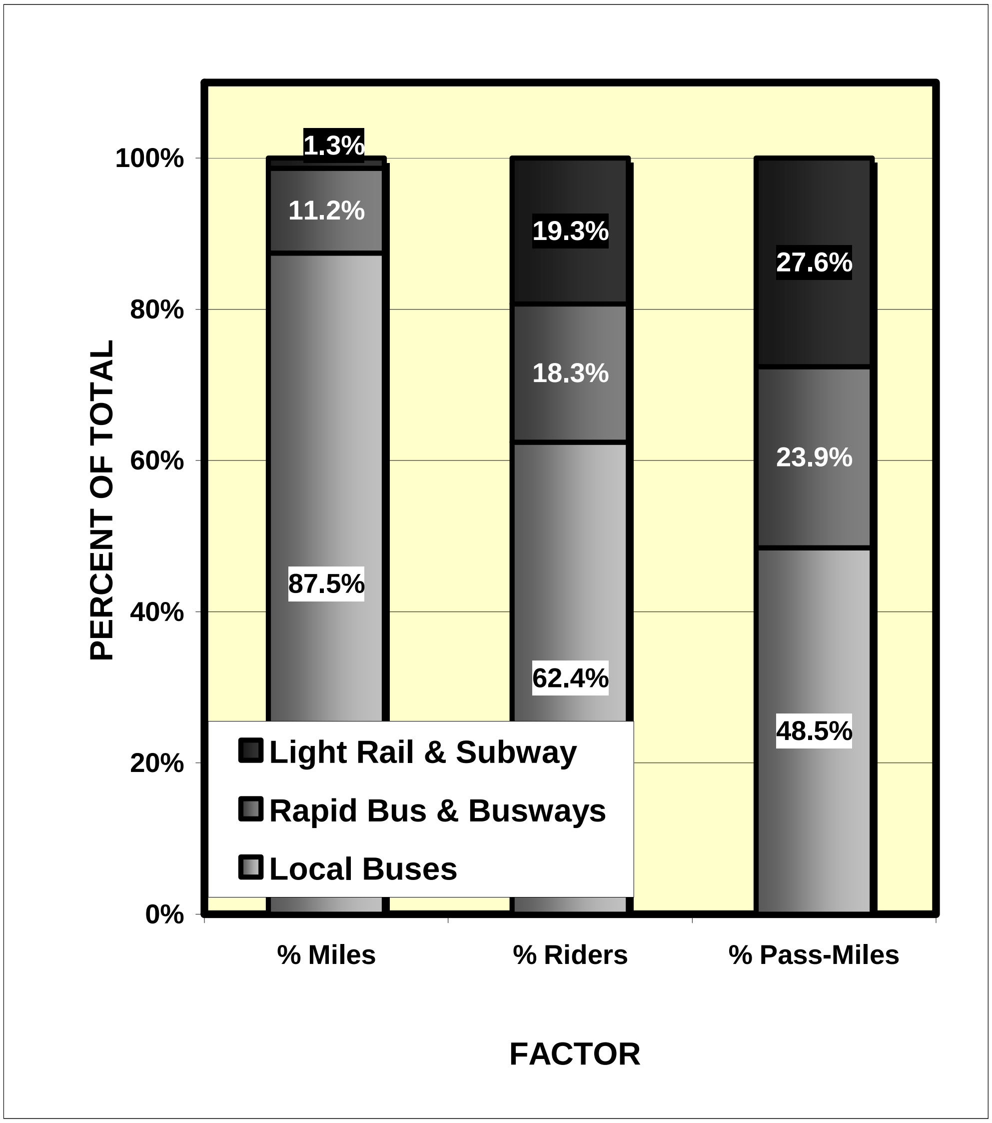
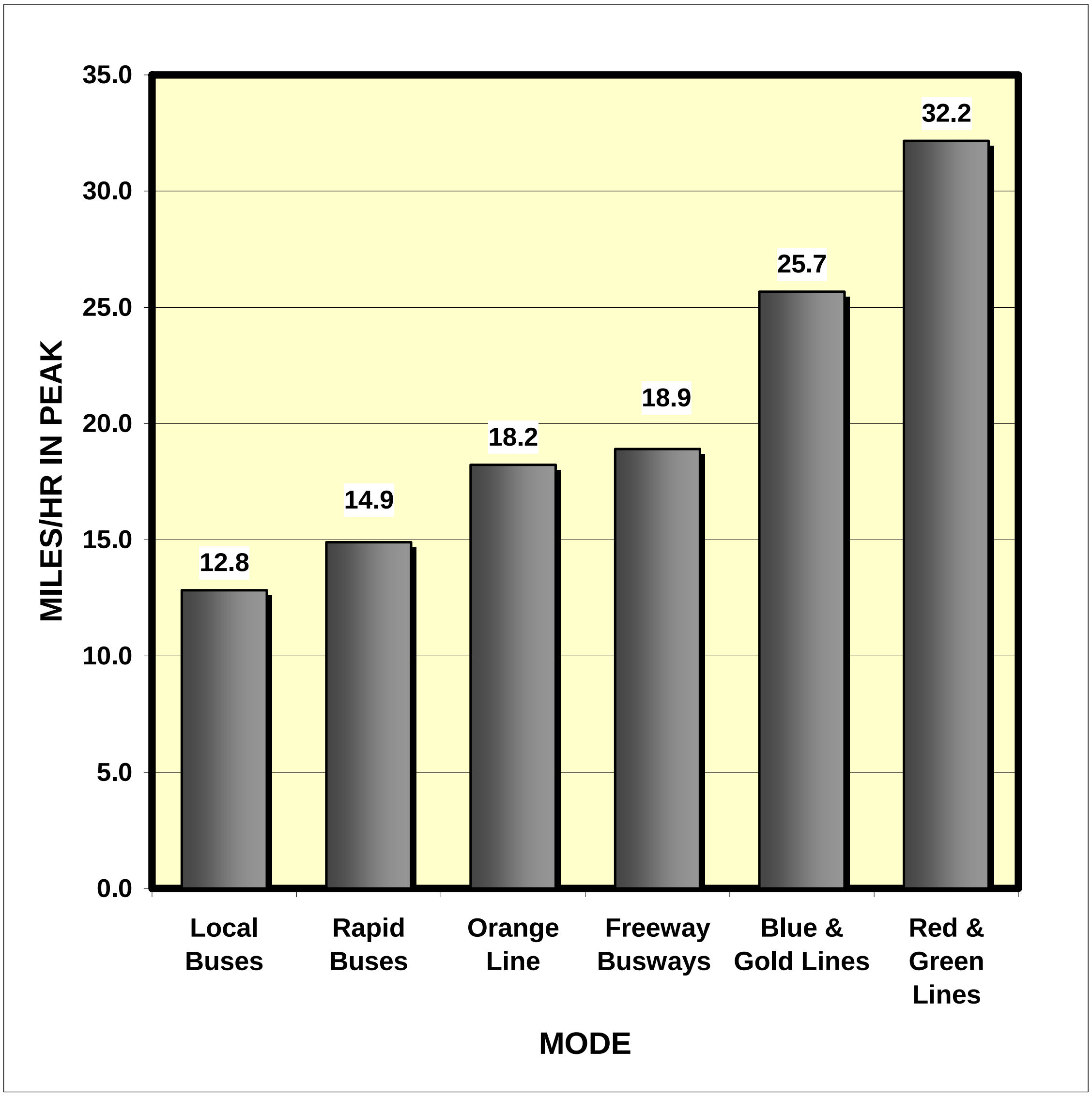


Figure 2 shows the resulting average peak-period speeds of the various modes operated by Metro. The Green Line in combined with the Red Line for this figure only because both these lines are fully grade-separated. All other figures include the Green Line statistics with the other two light rail lines.

Rapid Bus Routes

To speed up service on its more important bus routes, Metro has implemented Rapid Bus service on 19 routes and is adding more. The major difference between this type of service and local bus services on the same streets is the longer stop spacing. Secondarily, Rapid Buses get signal priority within the City of Los Angeles and some other jurisdictions.

FIGURE 2: AVERAGE PEAK HOUR SPEEDS BY MODE

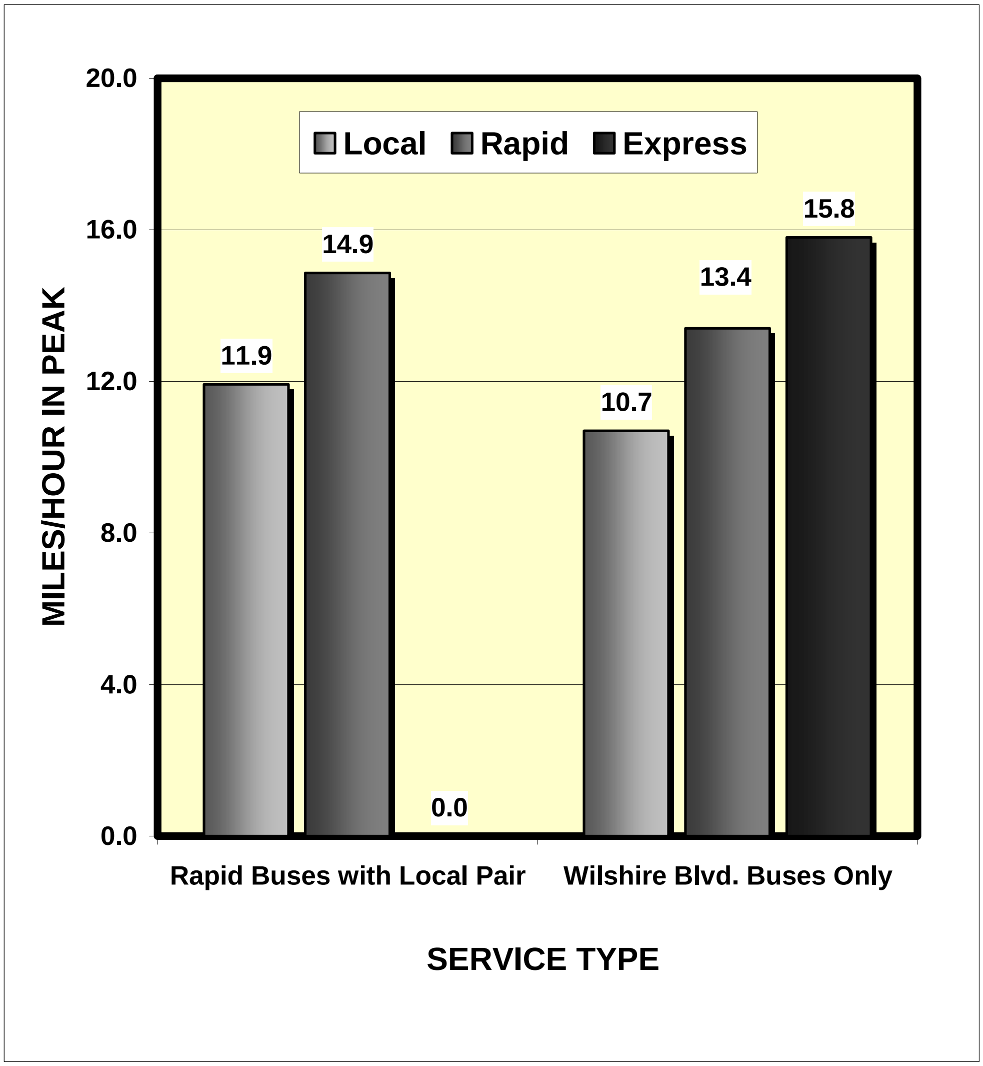


The average peak-period speed for the Rapid Bus routes is 16% faster than the average local bus route. However, as shown Figure 3, Rapid Bus routes are 25% faster than local buses on the same routes. This chart also shows the average speeds of the three Wilshire Boulevard bus services – local route #20, Rapid Bus route #720, and Express route #920 – in their common, eight-mile segment (between Westwood Boulevard and Western Avenue).

Orange Line and Busways

The Orange Line, with its exclusive right-of-way, one-mile station spacing, and off-vehicle fare collection, could be expected to achieve a speed comparable to a light rail line in the same alignment. However, its buses slow at each crossing to make sure the crossing is "safe" (any

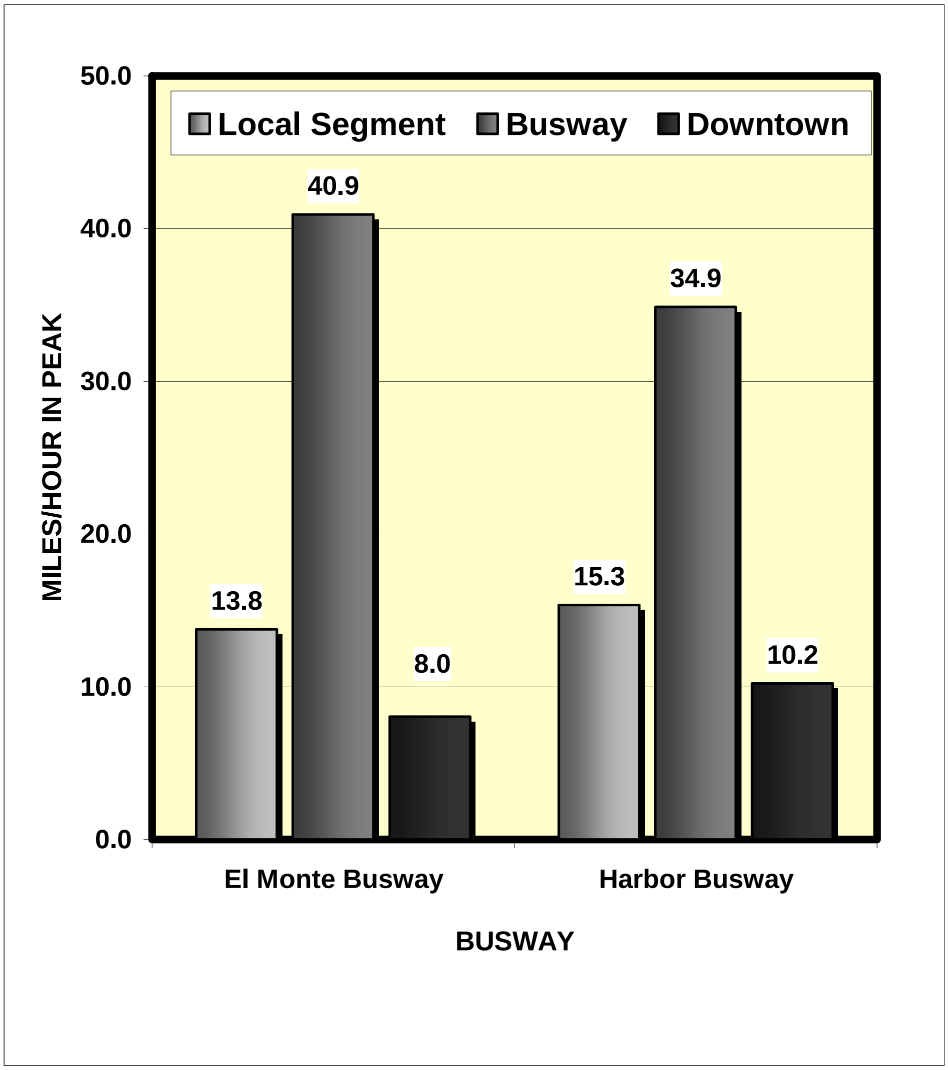
FIGURE 3: AVERAGE SPEEDS OF 19 RAPID BUS AND LOCAL BUS PAIRS



collision at higher speeds is far more serious for bus riders than light rail riders). It has limited signal priority and it is very doubtful that its buses will ever get full signal pre-emption because as more buses are added to meet growing demand they would pre-empt more and more of the available green time and unacceptably disrupt vehicle flows across the busway (*6*).

Figure 4 shows speeds by route segment in the two busways within freeway rights-of-way: the El Monte and Harbor Busways. The bus routes on these two facilities have an average speed of 21.3 mph on the Harbor Transitway and 16.6 mph on the El Monte Transitway, for a combined average of 18.9 mph. As the figure shows, however, the high speed achieved on the busway section is reduced substantially in the street segments at both ends of the routes, which include congested downtown Los Angeles streets.

FIGURE 4: AVERAGE BUSWAY SPEEDS BY SEGMENT



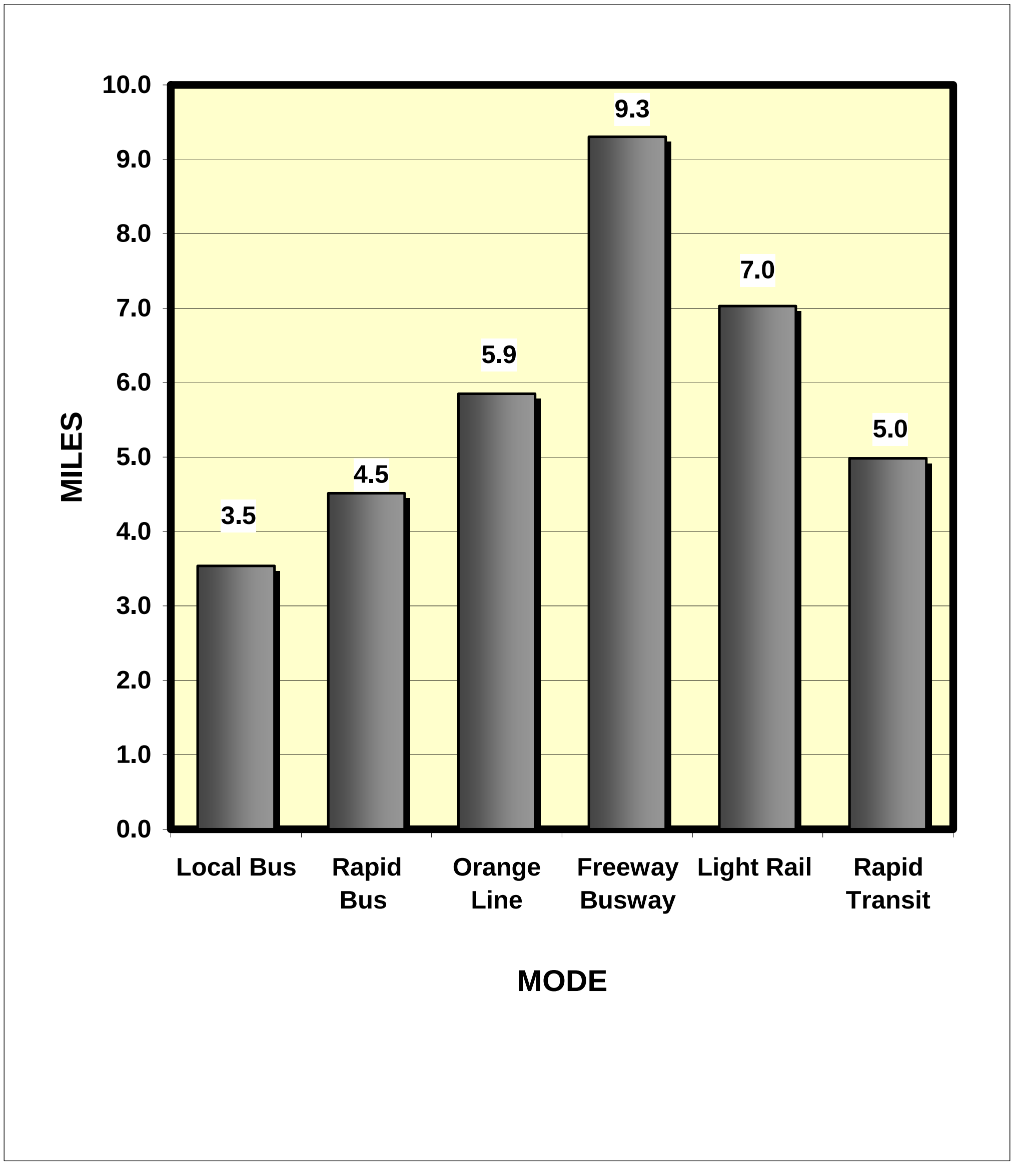
Light Rail and Rapid Transit

The Blue and Gold Line's travel speeds reflect their predominantly exclusive rights-of-way and full signal pre-emption. The Blue and Gold Line's average travel speed is 40% greater than the Orange Line's speed, 36% greater than the busway speeds. The Red and Green lines, with their full grade-separation, achieve a 25% higher speed than the Blue and Gold light rail lines, and a 70% higher speed than that of the busways.

Average Trip Length

Figure 5 shows the average (unlinked) passenger trip lengths for each mode. It shows that trip length generally increases with the faster modes. The average trips on freeway busway routes are the longest, probably because they are predominantly made by commuters. The average trip length on the Red Line is relatively short. This reflects what has become one of it major

FIGURE 5: AVERAGE TRIP LENGTH BY MODE

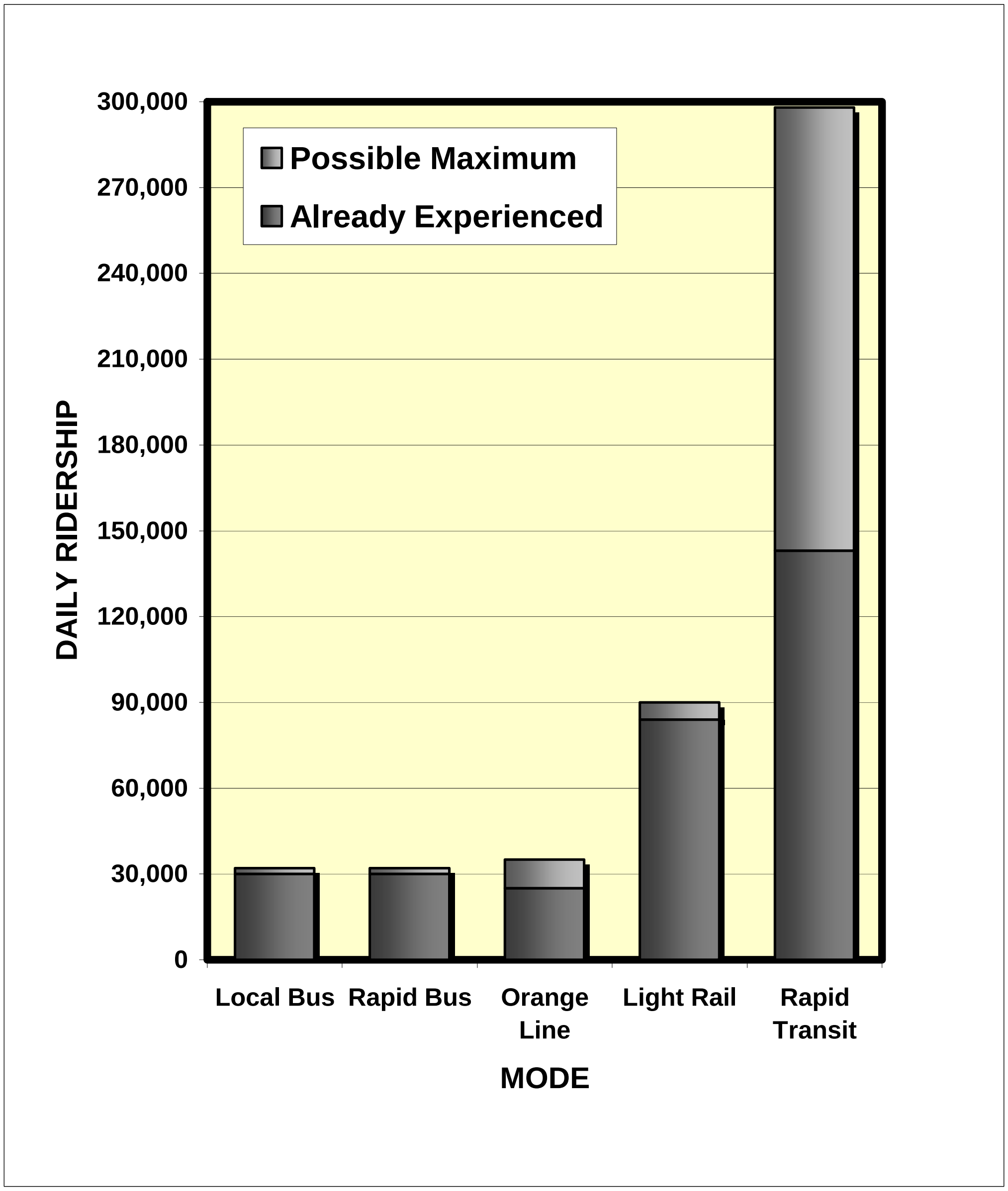


functions: to distribute Metrolink, Blue Line, and Gold Line riders (among other services) through downtown Los Angeles.

Capacity

There are innumerable discussions of the capacities of various transit modes in the literature (*7*). Theoretical capacities can be high, but may not be achievable. This section will compare the possible capacities of Metro's various modes based on its own operating experience. The results are shown in Figure 6.

FIGURE 6: DAILY RIDERSHIP BY MODE



Local and Rapid Bus Routes

Several Metro local bus routes carry almost 30,000 passengers per day, but only one surpasses that number (#204 Vermont Avenue at 30,385). This route is fairly long with high turnover (2.5 miles average trip length) and steady all-day demand. Only one Rapid Bus route carries more than 30,000 daily riders (#720 Santa Monica-Commerce). However, this route is really two routes interlined through downtown, and neither half carries 30,000 riders. Only four Rapid Bus routes together with their local bus route pairs have daily ridership levels above 30,000. However, the combined 54,000 daily riders on the Vermont Avenue routes approach twice the daily "capacity" shown for each mode in Figure 6.

Orange Line

The Orange Line has carried an average of 25,400 weekday daily riders (April, 2008) on crowded 60-ft articulated buses, and there is still limited unused capacity. The probable maximum ridership of the Orange Line Transitway is 35,000 riders per day. This is because the Orange Line traverses east-west across at least 20 heavily traveled north-south arterials. As a result, the LADOT does not give Orange Line buses signal pre-emption and their headways are limited to a minimum of about 4 minutes. Using double-articulated buses or operating existing buses in platoons may add another 25% in capacity, which might allow the service to carry 35,000 riders per day.

Light Rail and Rapid Transit

The Blue Line has already carried 84,000 daily riders, albeit under very crowded conditions, and it is unlikely that it can carry many more daily riders than that under present conditions (three-car trains and five-minute headways). For this reason, the possible maximum daily ridership for Metro's three light rail lines is 90,000. With its capability to run longer trains and its full grade separation, the Red Line has carried 143,000 average daily riders (April 2008) and should be able to carry 300,000 daily riders.

Operating Cost

Figure 7 depicts the operating cost/passenger-mile by mode. Passenger-miles are used because trip length varies by mode. Comparing the operating cost per trip between modes providing service for different length trips is inconclusive.

Rapid Bus Routes and Busways

The operating cost per passenger-mile of these bus services is lower than local bus services because their speeds are faster and because Rapid Bus routes often serve higher demand corridors. Also, local bus routes are at a relative disadvantage, having to operate during low-demand, late evening periods. The cost per passenger-mile of buses in the El Monte and Harbor Transitway is even lower than for rapid buses, as they are primarily tailored to peak-hour commuters with less or no midday and evening services.

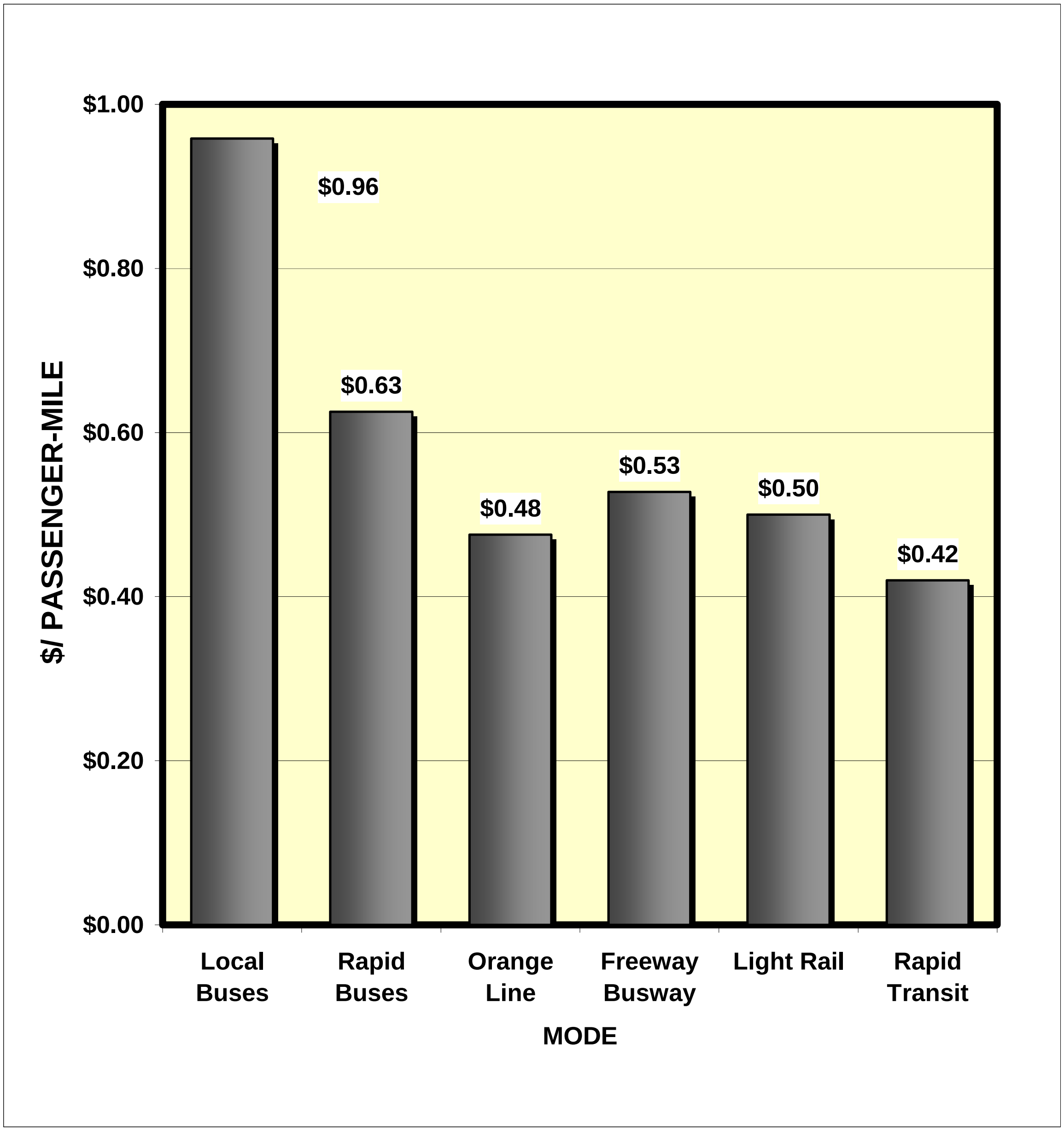
Orange Line

This is the most efficient of Metro's bus services because of its high ridership throughout the day. This is quite significant considering that the Orange Line's cost per revenue hour is almost double that of Metro's other busway services ($222/RevHr vs. $121/RevHr) due to the maintenance expenses associated with the guideway.

Light Rail and Rapid Transit

The three light rail lines achieve a low average cost per passenger-mile. This reflects the faster speed and the higher capacity of LRT trains. The LRT lines are more expensive to run, given the need to maintain the track, signals, traction power equipment and vehicles. But these greater costs are spread over a larger ridership. The Red Line has the lowest cost per passenger-mile of all modes despite the high maintenance of its subway. This can be attributed in part to its high speed, its secondary distribution function, and its resulting high ridership.

FIGURE 7: OPERATING COST PER PASSENGER-MILE BY MODE

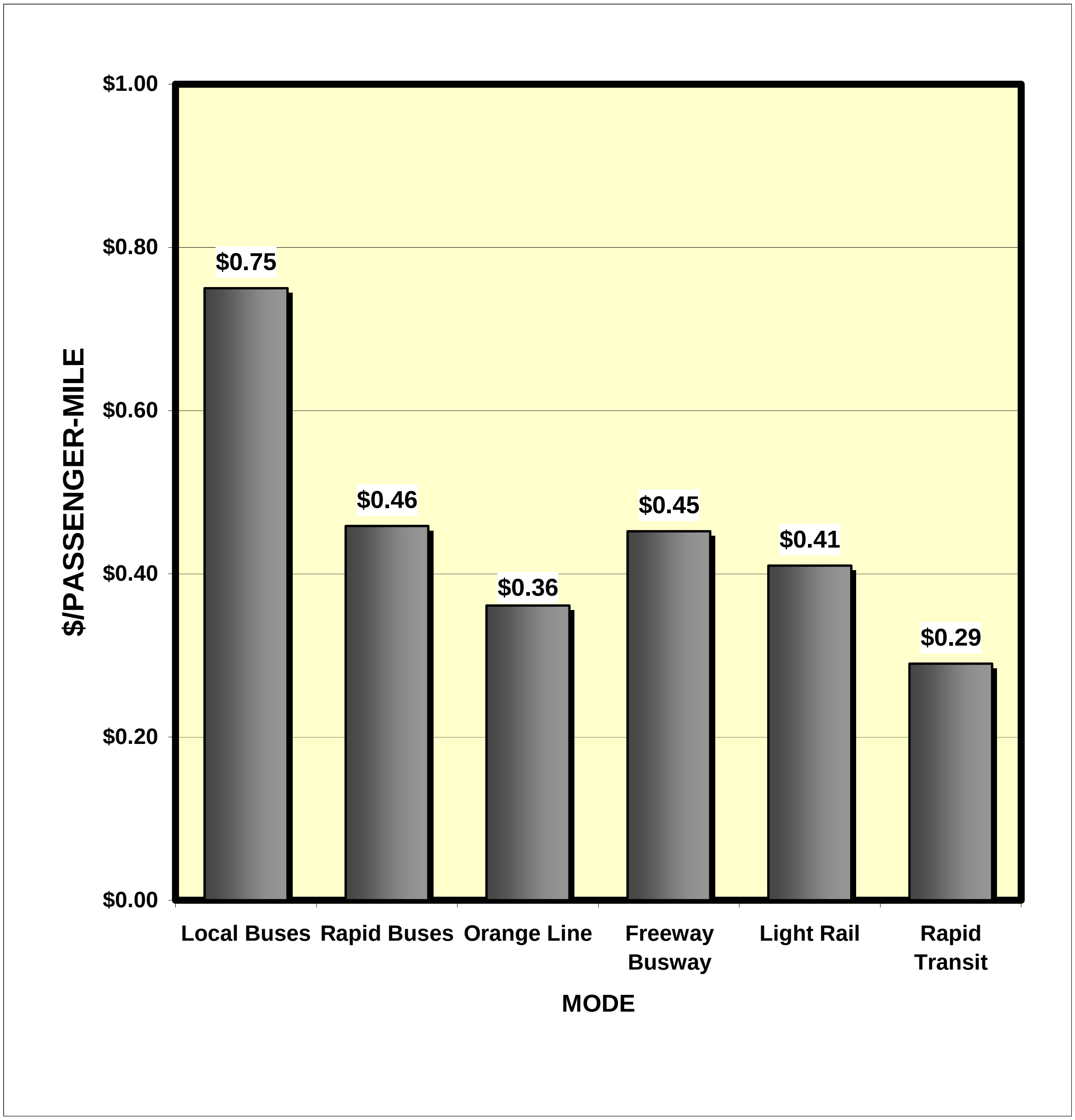


Operating Subsidy

Average trip length must again be taken into account to compare levels of subsidy needed by mode. In early 2008 the average fare for the Metro system was $0.67. Metro estimates fare revenues by mode by multiplying this average fare by the number of boarding passengers. The resulting revenues are subtracted from the corresponding operating costs to determine the subsidy.

Figure 8 shows the average subsidy per passenger-mile by mode. The pattern follows the same pattern as cost per passenger-mile above: highest for local buses and lowest for rapid transit. However, if taken as a percentage of the operating cost, the range is less, from a high of 86% (busways) to 69% (rapid transit).

FIGURE 8: SUBSIDY PER PASSENGER-MILE BY MODE



Capital Costs

Even within one urbanized area, capital costs reflect the construction climate during the years the project was constructed. It is even questionable trying to compare construction costs of the Blue Line built between 1985 and 1990 with the costs of the Gold Line built between 1999 and 2003. However, Metro completed several projects in 2000 and 2005 and this may allow a useful comparison of the relative costs of constructing each mode under similar conditions. It should be noted that the Red Line's MOS-3 segment has only three stations in its 6.3-mile length, and therefore its cost/mile should be considered relatively low.

Table 1 arrays the cost-per-mile for four Metro projects. The capital costs came from Metro statistics or from the sources noted in the table. Obviously, capital costs escalate rapidly as bus and rail projects are increasingly separated from urban traffic. Tellingly, the increase in cost by mode generally mirrors the increases in speed shown in Figure 2 and the increases in capacity shown in Figure 6.

TABLE 1: CAPITAL COST OF SELECT METRO PROJECTS

Project	Mode	Year Opened	Length (miles)	Cost (millions)	Cost/Mile (millions)
Wilshire Rapid Bus	Rapid Bus	2000	16.7	$3.25	$0.195 (*4*)
Orange Line	At-Grade Busway	2005	14.2	$390 (*6*)	$27.5
Gold Line	Light Rail	2003	13.7	$859	$63
Red Line, MOS-3	Rapid Transit	2000	6.3	$1,313 (*8*)	$208

CONCLUSIONS

The above analysis shows that Metro has derived clear benefits in improved performance, capacity, and efficiency by investing in faster, higher-capacity bus and rail modes. Below are conclusions that may be derived from Metro's experience.

Find Ways to Increase Bus Speeds

Faster bus travel times generally mean lower operating costs and subsidies. The instant success Metro experienced with its first Rapid Bus line on Wilshire Boulevard dramatically demonstrated that the public was ready for a new type of bus service with higher speed through longer stop spacing and signal priority. Wisely, Metro continues to expand its Rapid Bus program.

Transit operators need to re-examine policies that were established long ago and may be obsolete today, such as a bus stop every block or two. In most cities, such policies may belong to a different era. Faster travel may well lead to more gains in riders than losses. Some operators, while adding limited-stop services, have retained nominal local bus service to serve destinations between longer-spaced stops. This may be desirable as long as the schedule of the parallel local bus service does not overlap the limited-stop bus service. In addition, the limited-stop bus service should not be compromised by allowing passengers to disembark at any requested local stop. Transit agencies should also work closely and aggressively with local traffic engineers to achieve signal priority for important bus routes.

Understand the Limitations of Busways

Busways like the Orange Line Transitway (and the South Miami Busway) are inherently far slower than light rail transit. Their buses do not have signal pre-emption and, even with limited signal priority, they catch some red lights. Their buses are also required to slow at all grade-crossings to avoid high-speed accidents. They are not much faster than Rapid Buses.

At-grade busways also have significantly less capacity than light rail. That may not be a factor for most cities in the United States, but it matters significantly in our largest cities. For these reasons, the planning and design of at-grade busways need to be closely coordinated with the city's traffic engineers to assure that realistic assumptions are made in the planning phases of project development. Assuming too high a speed for buses raises projected ridership and makes the busway appear as attractive as light rail, when in reality a Rapid Bus route might well serve the future requirements.

Design and Build to Emphasize Rail's Strengths

Light rail is too costly to build to allow its speed and capacity to be compromised, yet too often they are. Its exclusive rights-of-way must be used whenever available and protected from encroachment, its full signal pre-emption must be a prerequisite for construction, its curves must be as few and as gradual as possible to assure high operating speeds, and its stations should be adequately spaced.

New light rail and subways also too often operate with excessive headways given the high capital investment they represent. It would be far better to run even one-car trains at closer headways. The addition cost of a few more operators is minor compared with the system's overall operating cost, and would yield great benefits to the users.

Build What Works For The Given Requirements

The best hope for better transit in general is to improve bus service through longer stop spacing, signal priority, and special bus lanes. Most transit riders will continue to use buses on existing roadways. Although the speed of buses in streets cannot match that of rail, in most corridors enhanced, Rapid Bus services will most benefit the public. Given the extreme sprawl in many cities in the U.S., it is unlikely that these urban areas could ever afford or be well served by higher-speed rail lines or even busways.

Acknowledgements

I would like to thank Manuel Padron who reviewed the draft of this paper and provided valuable comments, and Carolyn Flowers of Metro and her staff for helping with data collection.

References

(1) Sislak, K.G., Bus Rapid Transit as a Substitute for Light Rail Transit: A Tale of Two Cities. CD-ROM. Presented at the 8th Joint Conference on Light Rail Transit, Dallas, TX 2000.

(2) Stutsman, J., Bus Rapid Transit or Light Rail Transit – How to Decide? Los Angeles Case Study. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1973,* Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 55-61.

(3) Kühn, F., Urban Mobility for All – La Mobilité Urbane pour Tous, Godard & Fatorzoun (eds), ©2002, Swets & Zeitlinger, Lisse, pp 357-365.

(4) Hess, D., Taylor, B., and Yoh, A., Light Rail Lite or Cost-Effective Improvements to Bus Service? Evaluating Costs of Implementing Bus Rapid Transit. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1927*, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 22-30.

(5) Booz-Allen and Hamilton, *Proceedings: Bus Rapid Transit Deployment Strategy Workshop,* Federal Transit Administration, U.S. Department of Transportation, 2001.

(6) Stanger, R., An Evaluation of Los Angeles' Orange Line Busway. In *Journal of Public Transportation, Volume 10, No.1*, 2007, National Center for Transit Research, Tamps Fl., pp. 103-119.

(7) For example, Vuchic, V., Table 2.4: Maximum offered line capacities of transit modes. In *Urban Transit: Operations, Planning, and Economics*, John Wiley & Sons, 2005, p.94.

(8) *Predicted and Actual Impacts of New Start Projects*, Federal Transit Administration, U.S. Department of Transportation, 2003. pp. 103-108. www.fta.dot.gov/documents/CPAR_Final_Report_-_2007.pdf. Accessed January 27, 2009.