LOS ANGELES, CALIFORNIA

BUSWAYS AND BRT

Table of Contents

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SUMMARY

Los Angeles County has several roadways that have many aspects of bus rapid transit (BRT). The 12-mile San Bernadino (I-10 El Monte) Busway, built at a cost of $57 million, carries more than 18,000 bus riders each day at speeds of over 40 mph [65 kph]. It also carries an additional 25,000 high-occupancy vehicle (HOV) users. The 11-mile [18-km] Harbor Transitway serves over 9,500 riders each day at speeds of over 30 mph [48 kph].

In addition, the Los Angeles County Metropolitan Transportation Authority (LACMTA) initiated its demonstration Metro Rapid service on the 26-mile [42-km] Line 720 Wilshire/Whittier Boulevard and the 14-mile [23-km] Ventura Boulevard line. Implementation coincided with the extension of the Metro Red Line subway to the San Fernando Valley. BRT elements included simple route layout, frequent service, headway-based schedules, less frequent stops, level boarding and alighting, color-coded buses and stations, and bus signal priorities. (Stations with "next bus" displays were completed in 2001.) Implementation costs were about $31 million, including previously ordered buses diverted to the project.

The Metro Rapid Demonstration program has successfully met the program's objectives to reduce passenger travel times, increase ridership, attract new riders, increase service reliability, improve felt facility appearance, improve service effectiveness, and build positive relations with communities.

- The Metro Rapid program introduced several attributes specifically to reduce passenger travel times, including bus signal priority; level boarding/alighting with low-floor buses; headway-, rather than timetable-based schedules; fewer stops; far-side intersection location of stations; and joint active management of service operation from the Transit Operations Supervisors (TOS) in the field and the Metropolitan Transit Authority (MTA) Bus Operations Control Center (BOCC). Since the initial date of service, Metro Rapid operation has achieved the following improvements:
    - Wilshire/Whittier Corridor – operating speeds increased by 29%, and ridership increased by 33%; and
    - Ventura Corridor – operating speeds increased by 23%, and ridership increased by 26%.
- The increase in ridership came from three principal sources: one third of the increase was from riders totally new to transit (riders from households making over $50,000 per year rose to over 13% of total line ridership); one third was current riders riding more often (a higher percentage now ride 5 or more days a week); and one third was current MTA riders who changed routes (diversion).
- Metro Rapid was designed to improve service reliability by addressing bus bunching and vehicle overcrowding. Service reliability has been excellent on the Ventura Metro Rapid, outperforming the time-point-based local service in terms of achieving lower bus bunching and improved reliability. Service reliability was initially mixed on the

Wilshire/Whittier Metro Rapid, largely because of heavily loaded trips during much of the day. Scheduled service was increased to match service levels with demand. Service reliability improved with the increase in service and with the introduction of a new module in the City of Los Angeles Department of Transportation's (LADOT's) bus signal priority system that helps maintain headway intervals.

- Fleet and facility appearance has been excellent. Buses are new, easily identifiable, and well maintained. New stations have been installed.
- Service effectiveness (passengers per revenue hour) has been mixed. The Wilshire/Whittier corridor had an 8% to 10% improvement with a 7% drop in the subsidy per passenger. There was a 33% ridership gain with a 20% increase in service hours. The Ventura corridor initially showed a decline of 28% to 36% in service effectiveness as a result of large increases in local service concurrent with the initiation of Metro Rapid (the local service was operating twice as often as Metro Rapid in peak periods). This increase in local service did not generate a significant change in ridership, and the effectiveness of the Ventura corridor will likely improve with better matching of local service levels with local service demand.
- Planned next steps call for completing the Phase I attributes, including the bus signal priority system outside the City of Los Angeles, and upgrading of Metro Rapid bollard gate stations to canopy gate stations where feasible. Phase II will implement remaining attributes, including multiple door boarding and alighting with off-vehicle fare collection, exclusive lanes/bypass lanes, high-capacity vehicles, and a feeder bus network.
- The BRT network will be expanded to encompass a grid of BRT routes and two BRT lines on exclusive rights-of-way (e.g., Chandler Way and Exposition Boulevard).

CITY CONTEXT

Los Angeles is the second largest region in the United States, and it continues to grow rapidly. The urbanized area has a population of about 15 million people: about 9.6 million live in Los Angeles County, and 3.7 million live within the city. The county population is expected to increase to over 12 million by 2001. Employment in the 2.0-square-mile Los Angeles central business district (CBD) is over 200,000. The peak day time accumulation (1980) was reported at 160,000, of which about 40% arrived by public transport.

TRANSIT OVERVIEW

The Los Angeles region is served by an extensive freeway system; commuter railroads; rail and light rail transit; and local, express and BRT bus service. Fixed route transit service in Los Angeles County is provided by 43 different public agencies, ranging in size from the Metropolitan Transportation Authority (MTA), with nearly 2,000 peak vehicles, to the City of Baldwin Park with 4 peak vehicles. These agencies collectively operate over 2,800 vehicles and nearly 9 million hours annually and carry 470 million passengers. Rail transit service is provided by MTA and the Southern California Regional Rail Authority (SCRRA or Metrolink). Annually, 67 million passengers ride rail service in Los Angeles [(1).] MTA operates almost 380,000 revenue train hours of service on three different rail lines. The Metro Blue Line provides service to 22 stations along a 22-mile [35-km] route from downtown Los Angeles to downtown Long Beach.

The Metro Green Line delivers service to 14 stations along the 20-mile route between the cities of Norwalk and Redondo Beach in the median of the I-105/Glenn Anderson Freeway. The Metro Red Line subway currently includes 17.4 miles [28 km] of underground heavy rail service and consists of 16 stations between downtown Los Angeles and North Hollywood. Weekday ridership approximates 100,000 on the Red Line, 60,000 on the Blue Line, and 15,000 on the Green Line.

Metrolink is a five-county, joint-operating authority overseeing the commuter rail operations for the entire region. It provides service to Ventura County, the Antelope Valley, San Bernardino County, Riverside County, and Orange County. With 126 daily trains providing service to 47 stations along six different lines, Metrolink operates over 158,000 revenue train hours a year and transports over 8 million patrons annually. Weekday ridership is approximately 31,000. There are over 350,000 bus boardings per day on some 200 bus routes. Express bus service operates on the El Monte and Harbor Freeways. Bus rapid transit (BRT) service operates on Wilshire/Whittier and Ventura Boulevards (Figure 1).

Planning Responsibilities

Transportation planning for Los Angeles County at the regional level is the responsibility of the Southern California Association of Governments (SCAG), which is the designated Metropolitan Planning Organization for a six-county region, including Imperial, Orange, Riverside, San Bernardino, Ventura, and Los Angeles counties. Under federal law, SCAG must prepare a Regional Transportation Plan (RTP). The RTP demonstrates how the region will meet federal mandates, particularly air quality requirements, and must be approved by federal agencies in order to continue receiving federal transportation funds. Only projects and programs included in the RTP are eligible for federal funding. The MTA, as the state-designated planning and programming agency for Los Angeles County, submits recommended projects and programs to SCAG for inclusion in the RTP. The MTA proactively identifies the transportation needs and challenges that Los Angeles County will face over the next 25 years through the development of its Long Range Transportation Plan (LRTP).

Transitways

Transitways along the San Bernadino and Harbor Freeways provide rapid travel for express bus users. Access to the San Bernadino Transitway is provided via contra-flow bus lanes along Spring Street in downtown Los Angeles. Table 1 gives lengths, bus running times, bus trips, and riderships on the three facilities. The high daily ridership in the Spring Street contra-flow lane reflects both local and express routes.

San Bernardino (El Monte) Busway

The San Bernardino (El Monte) Busway is a 12-mile [19-km] exclusive roadway for buses and high-occupancy vehicles. It extends eastward from downtown Los Angeles to El Monte (Figure 2). One-way lanes built on the median strip or alongside the freeway are separated from general traffic lanes by concrete barriers or a buffer lane with traffic posts. Development costs were $57 million.

A 1-mile extension into downtown Los Angeles was opened in 1986. This $18-million extension provides direct access into the downtown street system. The 11 miles [18 km] from El Monte to Los Angeles opened in 1976. Downtown distribution is provided via Spring Street and Broadway inbound and the Spring Street contra-flow lane outbound.

Planning Background

The transitway was developed in conjunction with the widening of the San Bernadino Freeway. It was jointly developed by the Southern California Rapid Transit District (SCRTD) and the California Department of Transportation (Caltrans). When built, it was the most complete busway in the United States with on-line stations, park-and-ride facilities, and feeder bus lanes. Following an SCRTD bus strike in 1975 that affected approximately 5,000 bus commuters, the facility was opened to authorized carpools of three or more occupants from 6 a.m. to 10 a.m. and 3 p.m. to 7 p.m. After the strike ended, the use by carpools continued.

In 1999, the state legislature revised the vehicle code to provide for an 18-month experiment that allowed two-person carpools. The reduction was in effect from January 1, 2000, to June 30, 2001. After June 30, 2001, carpools were returned to a minimum of three occupants per vehicle.

Design Features

The general plan of the busway and illustrative cross sections are shown in Figure 3. The 6.6-mile [11-km] section between El Monte and the Long Beach Freeway is located in the freeway median. A 20-foot [6-meter] railroad opening is maintained in the median and flanked by a median wall, a 17-foot [5-meter] busway, a 3-foot [1-meter] flexible post every 50 feet [15 meters], a 10-foot [3 m] common shoulder, and then four freeway lanes.

A 3.8-mile [6-km] section adjacent to the freeway between Mission Road and the Long Beach Freeway consists of a 54-foot [16.5-meter] two-way busway with 12-foot lanes [3.6-meters], an 8-foot [2.5-meter] right shoulder, and a 4-foot [1.2-meter] left shoulder in each direction separated by a barrier.

Contra-flow operation exists west of the California State University to the Santa Ana/San Bernardino Freeway interchange. The transposed operations facilitate access to and from the busway (Figure 4).

A circular island platform at the El Monte Station provides for easy transfer between express and feeder bus lines. There is a large park-and-ride lot (over 100 spaces) at this location as well as an island station on one side.

Ridership

The San Bernardino (I-10) Freeway Transitway was initially restricted to buses-only when it opened in 1973. The number of buses using the lanes and the ridership increased significantly during the first few years of operation and then grew slowly. Ridership increased from 1,000 to 14,500 passengers during the initial bus-only operating period; between 50% and 70% of the riders during this period previously drove alone [1]. The average daily bus ridership was 18,000 in 1994 and 19,400 in 1996. MTA indicates a daily ridership of 18,000 (2001). The park-and-

ride facility at the El Monte terminal was filled to capacity in the first few years and appears to have inhibited ridership growth.

During the peak hour, about 70 MTA buses carry about 2,750 passengers. Buses save about 17 minutes of travel time over general-purpose lanes when car pools are required to have three or more persons. In 1988, Foothill Transit began operating bus service in the San Gabriel Valley Transportation Zone that had previously been provided by the Los Angeles County Metropolitan Transit Authority (LACMTA). Foothill Transit operates two express bus services from the suburbs into downtown Los Angeles via the San Bernardino Transitway. Route 498, the first, provides 12 morning and 12 afternoon peak-period trips into and out of the downtown area. Annual ridership on Route 498 has grown from 438,308 in 1992 to 650,274 in 1998. (2) Route 480/481, the second bus service, operates on the local streets and then enters the San Bernardino Freeway and the Transitway. Service is provided throughout the day with 10-minute peak, 15-minute off-peak, and hourly late evening/early morning headways. Approximately 1.7 million passengers were carried in 1992 and 2.8 million passengers in 1998.

Table 2 summarizes salient characteristics of express bus riders associated with initial busway operations. The main reason for using the busway was cost savings, the main trip purpose was shopping, and the main access modes were automobile drivers (commuters) and bus passengers (reverse commuter and midday).

Impacts of Two-Person Car Pools

For nearly 30 years, the El Monte Busway afforded residents of the San Gabriel Valley a significant incentive to use public transportation or carpool for trips within the San Bernardino Freeway Corridor. Until January 2000, when the carpool eligibility requirement was lowered from three persons to two, Busway users enjoyed a significant speed advantage over travelers using the adjacent mixed-flow freeway lanes. Carpoolers and vanpoolers averaged 60 mph [96 kph], and bus passengers averaged 43.5 mph [70 kph] as compared with mixed-flow traffic traveling at 15 mph [24 kph] during peak periods. Consequently, a 12-mile [19-km] peak period trip (the length of the Busway facility) that required an average of 48 minutes within the mixed-flow lanes of the freeway could be completed in 12 to17 minutes by a three-person carpool or bus trip [(3)].

With the advent of the two-person minimum eligibility requirement, initial observations by Caltrans and transit operators found that enough vehicles shifted from mixed-flow to HOV travel to roughly equalize the travel speeds on both. As a result, bus riders and three-person carpoolers on the Busway experienced significant reductions in their average speed while traffic in the mixed-flow lanes of the freeway improved, and the peak period throughput of the freeway (passenger miles per hour) increased. Bus delays were estimated at 2 minutes in the a.m. peak and 5 minutes in the p.m. peak for MTA buses.

Foothill Transit staff reported consistent travel delay impacts of 10 to 20 minutes during peak periods for Busway services. Travel time checks conducted by LACMTA staff on January 28, 2000, and February 24, 2000, found that a.m. peak westbound travel time increased by an average of 1.8 minutes (for a scheduled 16-minute trip on the Busway), and p.m. peak eastbound travel time increased by an average of 4.9 minutes (for a scheduled 17-minute trip). As LACMTA's observations were limited to Busway running time only, Foothill's observations

likely incorporate the impact of other factors such as delays incurred by merging back onto the freeway.

The maximum average observed MTA delays were the equivalent of a reduction in average bus speeds from 43.5 mph [70 kph] to 34 mph [55 kph]. Additional delays, particularly during the afternoon peak period, were incurred by buses merging back into the mixed-flow freeway lanes at the eastern end of the Busway. Off-peak travel times did not appear to have been materially affected by the change in HOV facility eligibility.

Foothill Transit operators also noted a 10-fold increase in the number of reported incidents of unsafe operation at merge points as automobile drivers sought to gain an advantage over other vehicles waiting to merge back into the mixed-flow lanes of the freeway at the eastern end of the Busway. Observed behavior included automobiles encroaching into the bus-only lane, and sudden braking from automobiles merging into the line of waiting vehicles. The California Highway Patrol also observed this behavior and intervened only in extreme cases because of the lack of adequate space to pull vehicles aside.

BRT Perspective

The Busway has several important BRT elements: an exclusive guideway, stations, and a park-and-ride bus operation. However, it lacks clear identification of vehicles and stations, high-capacity multi-door buses, and above all, "marketing of the bus service." Carpools, while adding to the throughput (in person-miles per hour), do not enhance the "BRT image."

HARBOR FREEWAY TRANSITWAY

Carpool and transit lanes were installed in a separate roadway as part of rebuilding Interstate 110. The lanes extend about 11 miles [18 km], and seven bus stations are provided at key intersecting roads. Two HOV lanes are provided each way from Martin Luther King Boulevard to California I-105, and single lanes are provided from that point to Cal 91 (Figure 5).

The bus running times total 19 minutes – resulting in an average speed of 35 mph [55 kph]. Five MTA routes use the Transitway, with a daily ridership of 9,600. The relatively low bus ridership is a result of several factors: (1) the freeway is located between two major population concentrations, (2) stations are relatively inaccessible to pedestrians or transferring patrons, (3) the "bus rapid transit" aspects of the services provided have not been marketed, and (4) there is competition from the Blue light rail transit (LRT) line to the east.

SPRING STREET CONTRA-FLOW BUS LANES

Downtown access to the San Bernardino (El Monte) Busway is provided via the Spring Street contra-flow bus lane. The contra-flow lane was placed in service on May 16, 1978, between about Ninth Street and the freeway (Figure 6).

Design Features

The contra-flow lane is separated from general traffic flow by striping and stanchions (Figure 3). North of First Street, dual contra-flow lanes are provided to accommodate the heavy bus volumes in this section. Traffic signals are generally set for southbound traffic.

Performance

Some 70,000 daily bus riders on all routes use all or part of the facility. During the peak hour, bus volumes range from 40 to 60 south of First Street to about 100 to the north. A study of bus-lane operations reported peak-hour dwell times of 18 to 45 seconds at stops and average bus speeds of 6 to 7.6 mph [4].

METRO RAPID PROGRAM

PLANNING BACKGROUND

The bus rapid transit lines on Wilshire/Whittier and Ventura Boulevards are an outgrowth of coordinated efforts by the City of Los Angeles and the Los Angeles County Metropolitan Transportation Agency to improve bus transit. For many years, emphasis had been placed on building rapid transit and light rail transit lines.

The long delays and cost overruns associated with building the Red Line subway led to public and agency concerns, which ultimately led to a county referendum in 1998. Voters approved by a two-to-one margin a ballot measure outlawing any future underground construction.

Accordingly, both the city and county turned their attention to improving the bus system and establishing bus rapid transit. Several reasons underlie the focus on BRT: (1) the public was dissatisfied with slow bus service, (2) MTA average bus speeds had declined by 12% since the mid-1980s, and (3) LADOT found that a bus was stopped 50% of the time that it was in service.

Faced with a county population of 12 million by 2020, the city and the county focused on BRT. A brochure highlighting the features and advantages of BRT reported the following costs per mile of busways and rail transit [5]:

Subway	$300 million
Monorail or Elevated Rail	$125 million
Light Rail	$75 million
Busway	$10-20 million

These estimates included purchasing new vehicles; replacing streets on rights-of-way; adding landscaping, construction stations, and maintenance yards; and building replacement parking facilities.

The Metro Rapid program was initiated in March 1999 by the MTA's Board of Directors following an initial feasibility study. Staff was directed by the Board to conduct the administration's feasibility study in response to a visit to Curitiba, Brazil, by MTA and City of Los Angeles officials. The Curitiba urban design and public transportation model has been widely praised internationally for its success and has been a major force in the Federal Transit Administration's (FTA) creation of a national bus rapid transit (BRT) initiative.

The feasibility study recommended that MTA, in partnership with the City of Los Angeles, conduct a demonstration along two to three major arterials that had strong ridership and conducive characteristics for BRT development. The operating experience would provide a basis for further BRT development.

Twelve key attributes were associated with the Curitiba System (Table 3). Six of these, along with bus signal priority, were included in the Phase I Demonstration. The remaining six attributes (e.g., special lanes and high-capacity buses) would be deployed in the Phase II System Expansion).

The main purpose of the Metro Rapid Bus Demonstration program was to offer rail-type frequent and high-quality transit services connecting the terminus of the Red Line to major destinations in the outlying areas.

DEMONSTRATION PROGRAM DESCRIPTION- PHASE I

Phase I implementation planning was initiated in the summer of 1999 with a spring 2000 goal for start-up of Metro Rapid. Two lines were selected for the demonstration [2] (See Figure 7). These were Line 720 – Wilshire/Whittier (very high passenger demand urban corridor) connecting through the Los Angeles Central Business District (LACBD) and Line 750 – Ventura (high passenger demand suburban corridor serving the Metro Red Line).

The two Metro Rapid lines began service on June 24, 2000, coinciding with the opening of the extension of the Metro Red Line to the San Fernando Valley. All seven of the Phase I attributes were fully operational at start-up except for the Metro Rapid stations where temporary stops were utilized. The "next bus" displays were installed at selected stations in 2001.

Buses operate in mixed traffic, usually in the curb lanes wherever they are available. This permits curbside passenger boarding and alighting (Figure 8).

BRT Services

The BRT service is complemented by local bus service on both Ventura and Wilshire Boulevards.

The Ventura Boulevard Line - Runs from Warner Center to the University City Red Line station. There are 15 stations on the 16-mile [26-km] route. Service was initially provided every 10 minutes during peak periods and at 12-minute intervals during off-peak and weekend hours. As a result of increased ridership, peak headways were reduced to 7 minutes.

The Wilshire-Whittier Rapid - Runs from Santa Monica to East Los Angeles. There are 30 stations on the 26-mile [42-km] route. Service was initially provided at 3-minute intervals during the peak hour and at 10-minute intervals off-peak and on weekends. As ridership increased, the westbound peak headway was reduced to 2-1/2 minutes.

Local bus service is generally alternated with the BRT routes. This results in about 20 buses per hour in the peak hours on Ventura one way and about 50 buses per hour on Wilshire, exclusive of overlapping bus routes.

Vehicles

Low-floor, 40-passenger, North American Bus Industries (NABI), compressed natural gas (CNG) buses with a unique red and white livery are used on each route. The buses have a special exterior paint scheme that is easy to distinguish from other buses and is coordinated with

station design (Figure 9). The buses also have a special interior image. They are equipped with bus signal priority transponders, automatic vehicle location, and automatic passenger counters.

Stations

Exclusive Metro Rapid bus stops are located on the "far" corner of intersections. Local stops are provided "near-side." There are some 30 stations on the Wilshire/Whittier Metro Rapid Line and 15 on Ventura Boulevard. Several types of passenger stations and stops have been installed, depending on passenger boardings and sidewalk space. At major stations, a "double canopy" provides overhead protection without blocking sidewalks or interfering with adjacent properties (Figure 10). A "next bus" display indicates when the next bus will arrive (Figure 11). A single canopy shelter and a bollard gate design are provided at other locations (Figure 12). Landscaping, station art, and seats remain to be provided. Stations and buses share visual cues including color and graphics.

Transit Priority Signal System (TPS)

A bus priority system along the portions of the two BRT routes in the City of Los Angles gives late buses additional green time. Buses are given preference at most signalized intersections; the signal green time along the bus routes may be advanced or extended up to 10% of the signal cycle whenever a bus approaches. (Cycle lengths range from about 70 to 90 seconds, with longer cycles in a few locations.) At important intersections, the green light can be extended only in every other cycle. To prevent drivers from speeding up to extend the green time, early buses are not given priority.

The system is based on communications between antennae loops embedded in the pavement and transmitters mounted on buses. The automatic bus detection using loops and transponders was designed to reduce bus delay, maintain bus spacing, and simultaneously minimize impact on cross traffic.

A key objective was to maintain uniform headways between successive buses. The Transit Priority System (TPS) was designed and implemented by the City of Los Angeles Department of Transportation (LADOT). This program has gained nationwide attention since its debut on June 24, 2000, and has significantly improved the quality of transit operations along the two Metro Rapid corridors.

The Transit Priority System, developed to provide traffic signal priority to buses operating on heavily used transit corridors, is an enhancement to the City's Automated Traffic Surveillance and Control (ATSAC) System. This concept was embraced by the MTA and became an integral part of its Metro Rapid program. The system has been deployed at more than 211 intersections along the two Metro Rapid corridors in Los Angeles: Ventura Boulevard and Wilshire/Whittier Boulevards.

The project also includes control of dynamic passenger information signs at selected bus shelters along the Metro Rapid routes. These highly visible Light Emitting Diode (LED) signs inform passengers of the estimated arrival time of the "next" Metro Rapid bus. The arrival time information is computed by the system based on the actual speed of the bus and is accurate to within 1 minute. This information is communicated to the respective stations using "cell-phone-

like" technologies. The sophisticated algorithm, which calculates the arrival time, was completely developed by LADOT staff.

Automatic Traffic Surveillance and Control

Each signalized intersection in the project is equipped with loop detectors that serve as Automatic Vehicle Identification (AVI) sensors. These sensors, embedded in the pavement, receive a radio-frequency code from a small transponder installed on the underside of a vehicle. Buses equipped with unique transponders are detected when traveling over the loop detectors. These loops are connected to a sensor unit within the traffic signal controller at each intersection, which transmits the bus identification number to the Transit Priority Manager (TPM) computer in the city's Automated Traffic Surveillance and Control (ATSAC) Center at City Hall East for tracking and schedule comparison.

Once the bus identification and location are received by the TPM, the computer determines the need for traffic signal priority. If the bus is early or ahead of the scheduled headway, no traffic signal priority treatment is provided. However, if the bus is late or beyond the scheduled headway, then the downstream traffic signal controller will provide signal priority to help the bus catch up with the scheduled headway. In addition, real-time data links from the MTA dispatch center to the ATSAC center are used to obtain the daily bus assignment for schedule comparison.

Individual Intersection Operation

Traffic signal control at each intersection is provided by a Model 2070 controller that is equipped with a state-of-the-art software program developed by the City of Los Angeles specifically for this project. Once the Model 2070 traffic signal controller receives a request from the Transit Priority manager, it implements one of four types of traffic signal priority actions depending upon the point in time when the signal controller receives the commands, relative to the background cycle. The four types of traffic signal priority actions are the following:

- "Early Green" priority is granted when a bus is approaching a red signal. The red signal is shortened to provide a green signal sooner than normal.
- "Green Extend" priority is granted when a bus is approaching a green signal that is about to change. The green signal is extended until the bus passes through the intersection.
- "Free Hold" priority is used to hold a signal green until the bus passes through the intersection during non-coordinated (free) operation.
- "Phase Call" brings up a selected transit phase that may not normally be activated. This option is typically used for queue jumper operation or a priority left turn phase.

Operations and Maintenance

Bus schedules for BRT service use vehicle spacing (i.e., headway) rather than time points. Lane supervisors monitor service. Maintenance policies (in development) include new enhanced daily cleaning of vehicles, zero tolerance of vehicle defacement (e.g., seat inserts) and enhanced station maintenance and cleaning. A satellite operation control center, developed specifically for the Metro Rapid program, provides a graphic display of bus operations for management.

Marketing Plan

The marketing and communications plan (under development) is designed to reach both existing and new riders. It will position Metro Rapid Bus as an extension of Red Line rail service. It will involve before and after interviews and surveys to identify impacts and the levels of service.

PROGRAM RESULTS: PHASE I

The Metro Rapid Demonstration program had seven basic objectives:

1. Reduce Passenger Travel Times,
2. Increase Service Reliability,
3. Increase Corridor Ridership,
4. Attract New Riders,
5. Improve Fleet and Station Appearance,
6. Improve Service Effectiveness, and
7. Build Positive Community Relations.

The program has been successful in achieving these objectives even without the completed stations. Operating speed, service quality, ridership, and customer response have all exceeded expectations, with very little or no negative impact on the rest of the system and general traffic.

OPERATING SPEED AND SERVICE QUALITY

The Metro Rapid program introduced several attributes specifically designed to improve service operating speeds. These included bus signal priority, level boarding/alighting with low-floor buses, headway- rather than timetable-based schedules, fewer stops, far-side intersection location of stations, and joint active management of the service operation from the Transit Operations Supervisors (TOS) in the field and the MTA Bus Operations Control Center (BOCC). Since the initial date of service, the Metro Rapid operation has achieved several major improvements in operating speeds. Travel time savings of about 25% were recorded in each corridor (see Table 4). Overall bus travel speeds increased from 11 to 14 mph [18 to 23 kph] on Wilshire Boulevard, and increased from about 15 to 19 mph [24 to 31 kph] on Ventura Boulevard. The impacts to cross-street traffic were minimal, typically averaging about 1 second of delay per vehicle per cycle.

The City of Los Angeles conducted independent research regarding the attributes that contributed to the speed improvement and found that the bus signal priority system accounted for approximately one third of the improvement and the other elements (wider stop spacing) accounted for the remaining two thirds of the benefit. The segments with bus signal priority operate faster than the adjacent segments, especially when ridership loads are considered. To further increase bus speeds along the Wilshire/Whittier corridor, bus signal priority should be extended to the segments in Beverly Hills, East Los Angeles, Montebello, and Santa Monica.

Tables 5 and 6 give the detailed results from the LADOT studies for Ventura and Wilshire/Whittier BRT bus routes, respectively. Delays were reduced from 1.8 to 0.9 minutes

per mile on Ventura Boulevard and from 2.4 to 0.9 minutes per mile on Wilshire/Whittier Boulevards.

Studies conducted by LADOT in 1998 found that about 20% of the total bus running time was spent waiting at traffic signals, and another 25% of the time was spent at bus stops. After the bus priority at signals and the reduction in passenger stops, the total delay time was reduced to about 25%. The key elements of service quality that were considered important were reduction in bus bunching (headway ratios), average passenger wait times, and passenger standing loads. The two demonstration lines have differing degrees of success, largely depending upon the nature of passenger demand. Line 750 Ventura is showing excellent improvements in service quality, whereas Line 720 Wilshire/Whittier is still trying to manage the massive increase in ridership created by riders attracted to the new service.

Line 720 Wilshire/Whittier headway ratios show considerable bus bunching, especially during peak periods when the buses are very frequent. Average passenger wait times are typically less than 5 minutes except during p.m. peak periods, especially westbound, when wait times can exceed the typical headway. High daily ridership results in high average loads for much of the day. The passenger-perceived average loads were even higher due to the variability induced by the high headway ratios (bus bunching). On September 10, 2000, an additional 23 trips were added during peak periods with a resulting 10% increase in ridership within just 3 days, indicating strong latent demand still remaining. The heavy p.m. peak rail-to-bus transfer to already full buses at Western Avenue results in long dwell times and contributes to the bunching.

Line 750 Ventura headway ratios, with almost no bus bunching, are excellent, significantly better than the time-point-based local service. Average passenger wait times are in the 4- to 6-minute range, which is excellent for service operating every 10 to 12 minutes. Average loads are below maximum-seated levels, but are expected to increase concurrently with ridership growth.

The companion local services on Wilshire/Whittier and Ventura have shown improved service quality and performance due largely to the reduced local ridership loads, which make the service operate faster than previously. On Wilshire/Whittier, local service levels initially operated at the same levels as Metro Rapid, whereas on Ventura, local service ran twice as often during peak periods and as often as Metro Rapid during the remainder of the service day. As local service levels are adjusted to reflect actual local ridership, service performance should return more closely to normal.

Metro Rapid operated faster in mixed arterial traffic than the Curitiba Express lines in exclusive lanes. This is attributed to Curitiba's closer station spacing and externally controlled vehicle speed governors. Depending on the time of day and direction, Metro Rapid speeds average between 14 and 30 mph [23 and 48 kph] compared to Curitiba's average speed of 13.8 mph [22 kph].

Several segments on both BRT lines operated significantly more slowly because of other factors:

1. Traffic congestion caused major delays for Line 720 through downtown Los Angeles and for Line 750 along Ventura Boulevard between Balboa and Van Nuys (I-405 back-ups) and between Vineland and the Universal City Station.

2. Very high ridership loads result in extended dwell times and slower operations between downtown Los Angeles and Western Avenue on Line 720. The higher-capacity buses and multiple door boarding in Phase II will reduce dwell times significantly, further improving operating speeds.

RIDERSHIP

MTA has estimated the ridership on the two Metro Rapid corridors using both point-check data and data from automated passenger counters. Although the two methods return somewhat different results, there is agreement that ridership has increased dramatically on both corridors by approximately 25% to 33% (See Table 7).

The increase in the Wilshire/Whittier corridor appears to result from major growth in both Metro Rapid and local ridership, with the percentage of riders using Metro Rapid dropping slightly from the historic limited-stop service. This is possibly due to (a) the wider stop spacing for Metro Rapid, (b) the old limited-stop service was only limited-stop for a portion of the route and operated in local service for long segments, and (c) some people transfer between the Metro Rapid and local buses along the corridor. The Wilshire/Whittier Metro Rapid appeared capacity-constrained in the morning peak period, and an additional 23 trips were introduced on September 10, 2000, to alleviate the problem. This resulted resulting in an immediate increase in ridership for the overall Metro Rapid line.

Passenger surveys indicated that one third of the overall increase was from new riders (patrons who never rode transit before), one third was from current riders riding more often, and one third was from riders of other MTA transit switching to service in these corridors.

1. *Passenger Trip Length*. Changes in passenger trip lengths are shown in Table 8. Trip lengths of Metro Rapid riders (7 to 8 miles) [11 to 13 km] are similar to those for the prior limited-stop service; they are about double the trip length of riders on the local bus routes (3 to 4 miles) [5 to 6.5 km].
2. *Passenger Boardings and Alightings*. The passenger boardings and alightings and the boarding density (boardings per mile) are shown in Table 9. As expected, there are significant differences between the two BRT lines.

Ventura boardings are heavily influenced by the Metro Red Line station at Universal City, with relatively even boardings elsewhere along the line. Service for both the BRT line and local service is timed to the arrivals and departures of trains for Hollywood and downtown Los Angeles. Passenger surveys indicate that over 24% of all trips on Line 750 involve the Metro Rail as compared with 8% to 14% of local bus trips. Thus, in many aspects the line is a "feeder" BRT. The 1-in-4 trip ratio linking Metro Rapid with Metro Rail is expected to grow as new riders enter the system.

The Wilshire/Whittier Metro Rapid line is influenced by the Metro Red Line although the segment from Western to Vermont has the highest ridership generation of the line. Downtown Los Angeles is not a major ridership generator although heavy loads are carried through the LACBD. Other above average ridership generating segments include Vermont to Alvarado (Westlake), Alameda to Soto (Boyle Heights), Downey to Atlantic (East Los Angeles),

Ocean/Pico to Fourteenth (Santa Monica), and Soto to Downey (Boyle Heights/East Los Angeles).

The Wilshire/Whittier Metro Rapid line was expected to provide an important service link between the east and west sides through downtown Los Angeles. Analysis of both the Automated Passenger Counter (APC) ridership data and passenger survey data indicates that significant numbers of riders make these trips using Metro Rapid. One half or more of the on-board riders entering downtown continue between the east and west sides during peak periods. Passenger survey responses indicated that approximately 41% of the Eastside riders travel to the Westside or Santa Monica and that 24% have a downtown destination.

Metro Rapid has exceeded ridership expectations in terms of overall increased passenger use on both Metro Rapid and local buses, penetration of previous non-user markets, use by longer distance travelers, meeting the needs of persons traveling between the east and west sides of Los Angeles County, and serving as an extension of the Metro Red Line in the San Fernando Valley. Ridership continues to grow, especially on the Wilshire/Whittier line, which appears to be capacity constrained during at least the peak periods. Growth will be further fostered by the completion of the Metro Rapid stations along both corridors and the second phase of the marketing campaign. This will make it essential to provide significantly more capacity along the Wilshire/Whittier corridor in a cost-effective fashion.

A September 2001 ride check on the Wilshire/Whittier BRT line indicates about 10,000 daily boardings. The maximum all-day segment is between Crenshaw and Western Boulevards, where more than 17,000 riders were observed. The peak-hour ridership buses and load factors were as follows:

- Eastbound – between 4:35 and 5:35 p.m., between Crenshaw and Western: 23 trips, 930 seats, 1,280 on board, 139.1% load factor.
- Westbound – between 6:50 and 7:50 a.m., between La Brea and Fairfax: 30 trips, 1,200 seats, 1,503 on board, and 133.6% load factor.

CUSTOMER PERCEPTIONS AND BEHAVIOR

On-board questionnaires were distributed to bus riders "before" Metro Rapid in early June 2000 and "after" in September 2000 (prior to the strike) to assess rider perceptions, behavior, and profiles. The surveys asked riders to evaluate various elements of service as well as overall satisfaction, with the purpose of determining changes in customer perceptions of bus service after the introduction of Metro Rapid. Specific questions focused on rider behavior, including trip origins and destinations and frequency of bus use. Questions also obtained information on the ability to recognize Metro Rapid and perceptions of service quality. Finally, demographic questions provided a basis to assess changes in the demographic profile of Metro Rapid and local riders compared with the previous ridership. Findings are shown graphically for BRT and local service in Figure 13.

Major findings include the following:

- Customer ratings of all service attributes show that Metro Rapid riders perceive a quantum leap in service performance and quality. Changes of this magnitude in performance ratings are rare, particularly over a relatively short time frame (90 days). Thus, MTA has essentially raised the standard significantly in terms of service quality for its riders through the Metro Rapid Demonstration program.
- Ratings for Metro Rapid service are also higher for all attributes as compared with the prior limited-stop service ratings. These improvements are statistically significant for all service attributes. The overall rating of MTA service increased by 0.35, from 3.48 among previous limited riders to 3.83, among Metro Rapid riders.
- Ratings for Metro Rapid service are higher for all attributes compared with the "after" local service ratings, and all differences are statistically significant. The largest differentials are for cleanliness, travel time on the bus, and frequency of buses.
- Ratings have also increased on local bus service for most attributes, but many of the increases are not statistically significant.
- A surprising number of riders came from neighborhoods that were usually seen as low transit ridership areas, especially south of Ventura Boulevard on Route 750.
- Metro Rapid service is drawing new, non-traditional riders. Whereas most Metro Rapid passengers were existing transit users, 17% either did not make this trip previously or used a non-transit mode (most likely the automobile). Most Metro Rapid and local bus riders report income levels below $15,000 annually. However, over 13% of Metro Rapid riders have incomes above $50,000 versus just 6% for local buses. Metro Rapid also has a higher percentage of male riders compared with the local buses and former limited lines.
- Nearly 14% of Metro Rapid riders began using MTA services within the last 3 months. By comparison, only 9% of local riders began using MTA services in this same timeframe.
- Automobile availability is surprisingly similar for Metro Rapid and local bus riders. Approximately one quarter of riders in both groups are from households with at least two automobiles.
- Approximately one quarter of Line 750 Ventura riders connected to the Metro Red Line to complete their journey, indicating that the Metro Rapid is serving as an extension of the rail system in the San Fernando Valley.
- A large percentage of riders originating from the Eastside, on Route 740 (Wilshire/Whittier) traveled through downtown to the Westside on the morning trips. This supported findings in previous studies that suggested a relatively large east-to-west demand in the peak hours.

In summary, the Metro Rapid program has demonstrated two critical elements: (1) customers perceive Metro Rapid as clearly superior to MTA's existing bus services, and (2) Metro Rapid has been able to increase transit's market share among discretionary travelers.

SERVICE EFFECTIVENESS AND EFFICIENCY

The original operating concept for the demonstration was to provide existing and potential customers with equal amounts of local and Metro Rapid service and allow them to choose the service that best met their needs. This operating plan was implemented in June 2000. From the initial week of operations, it was clear that many customers were choosing the Metro Rapid service. This led to overloading on both Metro Rapid lines initially (only the Wilshire/Whittier line continues to have problems) and continuing underutilization on two of the three local services (i.e., Lines 20/21 and 150/240).

Although overall performance (service effectiveness and efficiency) has improved on the Wilshire/Whittier corridor with the introduction of Metro Rapid, performance on the Ventura corridor declined significantly despite the 25% percent increase in riders. This is mainly due to the very large increase in Ventura local service compounded with an overall 50% rider switch from the local to Metro Rapid service. However, once services on Wilshire, Whittier, and Ventura Boulevards are adjusted to reflect actual ridership, overall and individual corridor performance should improve drastically.

The changes in weekday corridor ridership and services are shown in Table 10. Overall, bus ridership increased 32%, peak vehicles increased 21%, revenue hours increased 36% and revenue miles increased 34%. The changes in weekday corridor performances are shown in Table 11. Overall passengers per revenue bus hour decreased 4%, the passengers per revenue mile decreased 2%, and the subsidy per passenger increased 11.7%. The net new subsidy per new passenger was $1.26. Difference in performance between the two Metro Rapid lines reflected differences in ridership density.

The net subsidy per new passenger (net revenue minus net operating cost per new passenger) is very attractive for the Wilshire/Whittier Metro Rapid service at just under $0.60, competing very effectively with the various rail options. At a subsidy of over $6.00 per new passenger, the Ventura Metro Rapid has been less cost-effective. However, if local service is adjusted at approximately the same ratio as has been done on the Wilshire/Whittier corridor, then the next subsidy per new passenger drops by nearly half, to under $3.50.

OPERATING AND CAPITAL COSTS

A principal advantage of Metro Rapid service is that its operating and capital costs are considerably lower than those for rail.

Capital costs are summarized in Table 12. The overall demonstration cost for stations and bus signal priority was $8.3 million, or slightly less than $200,000 per route mile. The Metro Rapid capital program involved three areas: station development, bus signal priority, and vehicle acquisition. The station program was designed, fabricated, and installed at a cost of approximately $100,000 per mile. The bus signal priority system cost was approximately $20,000 per intersection. NABI, 40-foot, CNG, low-floor buses from current fleet procurement orders were used to operate the Metro Rapid routes.

Operating costs are shown in Table 13. The overall annualized (12-month) marginal operating cost of Metro Rapid Demonstration service approximates $12.7 million – slightly under

$300,000 per route mile. It is likely that $2 million to $3 million of this increase will be eliminated through further refinement of Metro Rapid and local bus schedules.

The cost savings of the Transit Priority System were estimated at $3.3 million in annual operating costs (exclusive of passenger travel time savings). When compared with an average intersection cost of $3 million to install the Transit Priority System along Ventura Boulevard and Wilshire/Whittier Boulevards and life cycle of 10 years, the benefit-to-cost ratio is more than 11 to 1.

DESIRED IMPROVEMENTS

The Phase I Demonstration program has proven successful in increasing speeds, improving reliability, and attracting riders. However, several areas emerged where additional refinements are desirable. Accordingly, MTA believes that the Phase II Demonstration program should

1. Continue to improve bus operating speeds by completing the bus signal priority installation outside of the City of Los Angeles (in Beverly Hills and Santa Monica) and on Line 720 Wilshire/Whittier and establishing a standard requiring that future Metro Rapid service will be fully covered with bus signal priority. Also, introduce exclusive bus lanes where feasible and give priority to arterial segments with chronic, debilitating, traffic congestion delay.
2. Provide more passenger capacity along Wilshire/Whittier Boulevards by introducing larger vehicles during peak periods rather than increasing service frequency. The westbound morning peak frequency on Wilshire/Whittier is approaching 2 minutes, which allows for little traffic signal recovery between bus priority overrides and increases the likelihood that individual Metro Rapid buses will not receive signal priority. LADOT indicates that 5-minute intervals are a good balance between service frequency and maximum bus signal priority availability, with 3 minutes on the lower end of desirability.
3. Reduce station dwell times by testing and introducing off-vehicle fare collection systems such as "proof of payment" and introducing high-capacity buses to manage standees within standards and avoid gross aisle congestion delays. As an interim measure, it may be desirable for agents to manually collect fares off-vehicle to allow rear-door loading.

METRO RAPID PROGRAM, PHASE II

The Phase II Expansion Program (in advanced planning) will (1) introduce the remaining Curitiba model attributes, and (2) expand the Metro Rapid network.

INTRODUCE REMAINING BRT ATTRIBUTES

The Phase II program will introduce exclusive bus lanes, higher-capacity buses, multiple door boarding and alighting, off-vehicle fare payment, a feeder bus network, and land use planning.

Exclusive Bus Lane: Bus-only lanes will be introduced in two ways: (a) in short segments where warranted by congestion and delay and (b) as full-length exclusive lanes or transitways either on arterials or on exclusive rights-of-way.

Higher-Capacity Buses*:* Options being considered include the following:

- 45-foot vehicles (8 to12 more seats than the standard bus),
- 60-foot articulated vehicles (18 to20 additional seats), and
- 80-foot bi-articulated vehicles (36 to 40 additional seats).

Multiple Door Boarding and Fare Prepayment*:* Multiple door boarding requires off-vehicle fare collection through either controlled access or use of a barrier-free, proof-of-payment system. The benefits have been long established for light and heavy rail operations; they are clearly applicable to high-volume Metro Rapid service (the Wilshire/Whittier Metro Rapid line is Los Angeles County's third heaviest transit line after the Metro Red and Blue Lines and ahead of the Metro Green Line). MTA has adopted a barrier-free system with random inspections for the rail lines. Metro Rapid has very similar needs and will likely require a similar approach, especially given the limited space along the arterial rights-of-way for Curitiba-type stations.

Feeder Bus Network**:** MTA's basic grid of regional and local bus routes provide feeder services. In Phase II, new community-based transit services and some local network restructuring will be appropriate, especially where the prevailing local network is not grid-based.

COORDINATED LAND-USE

One reason for the success of both the Wilshire/Whittier and Ventura Metro Rapid lines is their operation in corridors where land use is coordinated with transit. Streetscapes and densities are not unlike the "structural corridors" that were developed in Curitiba for bi-articulated red express lines. The City of Los Angeles has a project underway to identify transit impacts that could become part of its redevelopment warrants (i.e., coordinated land use around Metro Rapid stations).

EXPANDING THE METRO RAPID NETWORK

The success of the demonstration lines has provided clear indications that the Metro Rapid program as currently implemented has met with customer approval. Together with the introduction of the additional Curitiba model attributes, expansion of the Metro Rapid network is appropriate.

Collectively, the proposed Metro Rapid network will provide an integrated grid serving the high-demand central portion of Los Angeles County. A multi-level selection process was developed for identifying the Phase II Metro Rapid arterial lines.

The first step is based on three "Tier One" criteria and includes lines that meet the following minimum requirements:

- Serve major regional corridors,
- Provide key network connections for longer distance travel, and
- Have high passenger use

The second step prioritized the bus lines meeting the Tier I requirements based on the following secondary criteria:

- Weekday unlinked passengers,
- Average passenger trip length,
- Revenue operating speed,
- Annual passengers per route mile,
- Weekday seat utilization,
- Weekday riders retained on weekends,
- Weekday passengers per bus hour, and
- Operating ratio.

The resulting candidate lines were then checked for current frequency levels (ability to support Metro Rapid frequencies), whether the corridor currently has multiple levels of regional service (e.g., express, limited-stop, local, and community), and whether it duplicates any other comparable rapid transit (generally a 1-mile spacing between continuous lines). Based on these findings, lines were confirmed as Metro Rapid candidates and prioritized in three sub-phases: IIA, IIB, and IIC. The proposed Metro Rapid candidate lines for Phase II are show in Table 14.

Priority BRT improvements include providing bus lanes along Wilshire Boulevard and developing BRT along several exclusive rights-of-way. These include Exposition Boulevard and a San Fernando Valley line, largely along former Pacific Electric Railway rights-of-way on Burbank Boulevard, Chandler Way, and Sherman Way.

Wilshire Boulevard Exclusive Bus Lanes – This corridor is currently the heaviest traveled surface transit route in Southern California with more than 100,000 daily boardings. Dedicated bus lanes at strategic locations between the Wilshire/Western Metro Red Line Station and the City of Santa Monica would further increase bus speeds. Additional bus transit improvements would include larger capacity buses, multiple door boarding and alighting, and pre-payment of fares in station areas.

San Fernando Valley Bus Rapid Transit – This project, scheduled for completion in the year 2004, calls for implementation of bus rapid transit (BRT) service on an exclusive 14-mile, at-grade busway from the Metro Red Line North Hollywood station to Warner Center via the Burbank/Chandler right-of-way. The full busway project will consist of a 26-foot-wide busway, a bikeway, and a landscaped buffer on the typically 60- to 100-foot-wide exclusive right-of-way. It would parallel several major streets including Chandler Boulevard, Oxnard Street, Victory Boulevard, and Topham Street and would have 13 stations spaced approximately 1 mile apart. In North Hollywood, Oxnard Street is being considered as a route alignment alternative to Chandler Boulevard. Total travel time for the full length of the corridor will be approximately 30 minutes. Park-and-ride facilities at five stations will provide approximately 3,250 parking spaces to the already existing parking at the North Hollywood Metro Red Line Station.

EXPOSITION BOULEVARD

Bus rapid transit is among the options being considered in this corridor along railroad rights-of-way. The potential project length from downtown Los Angeles is about 15 miles. This project is tentatively scheduled for after 2005.

ASSESSMENT

Los Angeles County has shifted its emphasis from rail to bus transit in recent years. Existing and planned Metro Rapid bus lines reflect this redirected emphasis.

The express buses using the San Bernardino and Harbor Transitway along with carpools and the Metro Rapid limited-stop bus service operating on Wilshire/Whittier and Ventura Boulevards incorporate many BRT elements. These include easily identifiable low-floor buses and stations, frequent all-day services, wide spacing between stops, and traffic signal preference at intersections.

All facilities have improved bus speeds. Bus speeds on the San Bernardino and Harbor Transitways range from 30 to 40 mph. Those on the Metro Rapid routes range from about 15 to 20 mph. These speeds are comparable with and sometimes faster than those on many light rail and rapid transit lines.

The combination of improved speed, reliability, frequency, and identity on the two Metro Rapid routes has increased ridership about 25% to 30% as compared with a 23% to 29% increase in operating speeds.

Further increases in Metro Rapid speeds might be achieved by introducing bus-only lanes at congested locations, using large vehicles with more doors, and implementing off-vehicle fare collection practices.

LESSONS LEARNED

Several lessons emerge from existing and proposed express bus and Metro Rapid operations:

1. Express buses and carpools can co-exist in transitways, provided that the carpools do not reduce bus speeds or detract from BRT identity. The San Bernardino experiment with two-person carpools resulted in a 30% loss in express bus speeds.
2. The presence of an exclusive right-of-way is not in itself sufficient to ensure BRT – especially where the right-of-way is removed from major markets and the stations are relatively inaccessible to transferring bus riders or pedestrians.
3. It is essential to serve demonstrated markets. The 33% ridership gain along Wilshire Boulevard – perhaps the busiest bus corridor in Los Angeles – indicates the desirability of penetrating (rather than skirting) major catchment areas.
4. A combination of BRT elements – distinctive buses and stations, wide spacing between stops (e.g., a mile or more), frequent service, and modest traffic signal priorities can achieve a 25% to 30% reduction in bus travel times and a corresponding gain in ridership.
5. Ideally, a BRT line should separate "feeder" services to a rail transit terminal from through service. The Wilshire/Whittier BRT Line has experienced long dwell times at Wilshire and Western because Metro Rail passengers have difficulty boarding full buses through a single front door. If such a service must be provided, passengers should be able to board buses from several doors.

6. Suitable high-capacity easily accessible buses are essential for BRT routes that serve large numbers of people. Articulated low-floor buses with three sets of double doors have the advantage of increasing passenger capacity and allowing faster boardings and alightings.
7. Where BRT buses extend or advance the green intersection at signalized intersections, headways should not be less than 2.5 to 3.0 minutes to enable cross-street traffic to "recover" from the time lost. Far-side stops are essential.
8. A modest signal advance or extension (e.g., less than 7 to 10 seconds per cycle) can reduce bus delays with negligible impacts on cross-street traffic.
9. Headway-based schedules work where buses operate at close intervals.
10. Bus lanes are desirable, especially in congested areas, to improve speed and reliability. However, in providing these lanes, it is essential to reflect the needs of motorists, delivery vehicles, pedestrians, and turning and cross traffic. These concerns are especially important where plans for median busways are developed.
11. Various public agencies *can* work together to provide bus rapid transit. The METRO bus, for example, was a cooperative effort between the MTA (transit) and LADOT (traffic)

APPLICATION ELSEWHERE

The Los Angeles Metro Rapid concept – specially designated buses, frequent service, wide stop spacing, and signal preference along major arterials with heavy bus ridership – has wide applicability. However, implicit is the commitment to dedicate BRT vehicles to the specific BRT routes. Transitway development, while desirable, depends upon the availability of rights-of-way and their relation to markets. Hence, their application may be more selective.

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Table 1: Characteristics of Three Transitways

Facility	Length of Facility (miles)	One-Way Bus Running Time (minutes)	Number of Routes	Weekday Trips	Daily Ridership at Station	Total Line Ridership
El Monte Busway (MTA Service)	12	17	7	200	2,300	18,000
Harbor Transitway	11	19	5	125	2,500	9,600
Spring Street Contra-Flow Lane	1.2	4	11	420	6,500	69,000

Source: Los Angeles County Metropolitan Transportation Authority

Table 2: Characteristics of Express Bus Riders on San Bernardino Transitway (1974/5)
%

ITEM	Bus Only Commuter	Reverse Commuter	Off-Peak Riders
1. Reasons for Using Busway			
Cheaper than Driving	64	45	51
Saves Time	27	20	18
Time to do other things	36	19	25
No Car	N/A	N/A	N/A
Other	3	16	6
2. Trip Purpose			
Work	82	49	49
School	2	38	20
Shopping	--	1	6
Personal Business (including medical/dental)	4	1	7
Other	2	11	18
3. Access Mode			
Walk	23	18	28
Bus	5	63	33
Auto driver	54	9	24
Carpool	17	10	13
Dropped Off	--	--	--
Other	8	--	2

Source: Richard H. Pratt “Draft Busways and Express Bus Service, 2001”

Table 3: Demonstration Program Elements

Curitiba Key Attributes	Metro Rapid	
	Phase I Demonstration	Phase II Expanded System
Simple Route Layout	Yes	Yes
Frequent Service	Yes	Yes
Headway-based Schedules	Yes	Yes
Less Frequent Stops	Yes	Yes
Level Boarding and Alighting	Yes	Yes
Color-coded Buses and Stations	Yes	Yes
BUS-SIGNAL PRIORITIES		
Exclusive Lanes	No	Yes
Higher Capacity Buses	No	Yes
Multiple Door Boarding and Alighting	No	Yes
Off-Vehicle Fare Payment	No	Yes
Feeder Network	No	Yes
Coordinate Land Use Planning	No	Yes

Source: Crain & Associates, Summary San Bernardino Freeway, Express Busway Evaluation of Mixed Mode Operations, July 1978

Table 4: Improvements in Bus Operating Speeds

Operating Speeds	Wilshire/Whittier (Line 720)	Ventura (Line 750)
Overall Improvement	29%	23%
Eastbound (Range)	31% (18-40%)	20% (11-29%)
Westbound (Range)	28% (21-32%)	27% (16%-34%)

Source: Crain & Associates, Summary San Bernardino Freeway, Express Busway Evaluation of Mixed Mode Operations, July 1978

Table 5: Ventura Boulevard Travel Delay Analysis
14-Mile Route

Length	Time (minutes)	Minutes Per Mile	Before
CONDITIONS BEFORE PROJECT—NO PRIORITY LOCAL BUSES			
Base running time	56	4.0	No priority local buses
Bus stop delay	14	1.0	25% of base running time
Traffic signal delay	11	0.5	20% of base running time
Actual travel time	31	2.2	27 mph running speed
PRIORITY BUSES			
New running time	43	3.1	77% of base running time
New bus stop delay	5	0.4	9% of base running time
New traffic signal delay	7	0.5	13% of base running time
Bus stop delay reduction	9	0.6	64% of base bus stop delay
SAVINGS DUE TO PROJECT			
Rapid bus	9	0.6	16% of base running time
Signal priority	4	0.3	7% of base running time
Total Savings	***13***	***0.9***	***23% of base running time***

Source: 2001 Long Range Transportation Plan for Los Angeles County, Draft, February 2001.

Table 6: Wilshire/Whittier Boulevard Travel Delay Analysis

Length	Time (minutes)	Minutes Per Mile	Before
CONDITIONS BEFORE PROJECT—NO PRIORITY LOCAL BUSES			
Base running time	76	5.4	No priority local buses
Bus stop delay	19	1.3	25% of base running time
Traffic signal delay	15	1.1	20% of base running time
Actual travel time	42	3.0	27 mph running speed
PRIORITY BUSES			
New running time	55	3.9	72% of base running time
New bus stop delay	3	0.2	4% of base running time
New traffic signal delay	10	0.8	13% of base running time
Bus stop delay reduction	16	1.1	84% of base bus stop delay
Signal delay reduction	5	0.4	33% of base signal daily
SAVINGS DUE TO PROJECT			
Rapid bus	16	1.1	21% of base running time
Signal priority	5	0.4	7% of base running time
Total Savings	***21***	***1.5***	***28% of base running time***

Source: Crain & Associates, Summary San Bernardino Freeway, Express Busway Evaluation of Mixed Mode Operations, July 1978

Table 7: Ridership Changes (Due to Project Implementation)

Total Unlinked Ridership	Wilshire/Whittier Corridor		Ventura Corridor	
	Before	After	Before	After
Local	39,708	55,946	10,800	4,650
Limited	23,785	---	---	---
Metro Rapid	---	28,207	---	9,000
Total Ridership	**63,493**	**84,153**	**10,800**	**13,650**
% Corridor Ridership				
Local	63%	66%	---	34.1%
Limited/Metro Rapid	37%	34%	---	65.9%
Net Increase	---	20,666	---	2,850
% Increase	---	32.6%	---	26.4%

Source: Crain & Associates, Summary San Bernardino Freeway, Express Busway Evaluation of Mixed Mode Operations, July 1978

Table 8: Average Passenger Trip Lengths

Wilshire/Whittier Corridor Routes	BEFORE		AFTER	
	Eastbound (miles)	Westbound (miles)	Eastbound (miles)	Westbound (miles)
Local line 18	1.8	3.1	2.6	2.6
Local line 20/21	3.2	4.4	3.3	4.2
Limited-stop line 320	5.2	7.9		
Metro Rapid line			7.0	7.3

Ventura Corridor Routes	BEFORE		AFTER	
	Eastbound (miles)	Westbound (miles)	Eastbound (miles)	Westbound (miles)
Express line 424/522	10.6	7.8		
Express line 425	25.2	N/A		
Local line 150/240			N/A	N/A
Metro Rapid			8.4	7.5

Source: Crain & Associates, Summary San Bernardino Freeway, Express Busway Evaluation of Mixed Mode Operations, July 1978

Table 9: Passenger Boardings and Alightings

		Average Per Trip			
Line 750 Ventura		**Boardings**	**Alightings**	**% Boardings of Total**	**Boardings Per Mile**
Universal City Station	Ventura Vineland	11.1	3.9	32.5	17.6
Ventura Vineland	Ventura Laurel Cyn	2.3	2.0	6.9	1.5
Ventura Laurel Cyn	Ventura Van Nuys	3.5	4.1	10.3	1.1
Ventura Van Nuys	Ventura Balboa	5.3	5.2	15.5	1.7
Ventura Balboa	Ventura Reseda	3.9	3.4	11.3	1.8
Ventura Reseda	Ventura Winnetka	1.8	1.4	5.2	0.9
Ventura Winnetka	Ventura Tpga Cyn	2.6	2.2	7.7	1.3
Ventura Tpga Cyn	Owensmouth Oxnard	3.6	1.6	10.5	1.8
Total		34.2	23.8	99.9%	2.0

		Average Per Trip			
Line 720 Wilshire/Whittier		**Boardings**	**Alightings**	**% Boardings of Total**	**Boardings Per Mile**
Ocean Pico	Wilshire 14th St	8.3	9.1	8.4	4.4
Wilshire 14th St	Wilshire Sawtelle	5.6	5.4	5.7	2.0
Wilshire Sawtelle	Wilshire Westwood	2.2	1.9	2.2	3.0
Wilshire Westwood	Wilshire Beverly	6.7	7.4	6.8	2.4
Wilshire Beverly	Sanvicn Wilshire	3.8	4.8	3.9	2.4
Sanvicn Wilshire	Wilshire Fairfax	2.2	2.1	2.3	3.7
Wilshire Fairfax	Wilshire La Brea	1.8	3.8	1.9	1.8
Wilshire La Brea	Wilshire Western	7.4	6.8	7.6	3.7
Wilshire Western	Wilshire Vermont	12.9	9.5	13.1	12.9
Wilshire Vermont	Wilshire Alvarado	6.5	5.6	6.6	6.6
Wilshire Alvarado	6th St Alameda	8.5	14.7	8.7	3.0
6th St Alameda	Whittier Soto St	8.0	7.0	8.2	5.8
Whittier Soto St	Whittier Downey	8.4	7.2	8.6	3.8
Whittier Downey	Whittier Atlantic	7.0	6.0	7.2	5.2
Whittier Atlantic	Whittier Garfield	5.9	6.4	6.0	3.7
Whittier Garfield	Montobello Metrolink	2.6	2.1	2.6	2.7
Total		**97.8**	**99.8**	**99.8%**	**3.9**

Table 10: Weekday Corridor Service

	Ridership			Peak Vehicles			Revenue Hours			Revenue Miles		
Corridor	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**
WILSHIRE - WHITTIER												
Lines 18/318	32,082			45			517			5,472		
Lines 20/21/22/320/322	31,405			77			727			7,767		
Line 18		27,066			34			400			3,949	
Lines 20/21		28,880			44			503			4,057	
Metro Rapid 720		28,207			64			619			7,877	
Combined Corridor	**63,487**	**84,153**	**32.6%**	**122**	**142**	**16.4%**	**1,244**	**1,522**	**22.4%**	**13,239**	**15,883**	**20.0%**
VENTURA												
Lines 424/425/522	10,800			37			285			4,339		
Lines 150/240		4,650			31			353			4,486	
Metro Rapid 750		9,000			20			211			3,138	
Combined	**10,800**	**13,650**	**26.4%**	**37**	**51**	**37.8%**	**285**	**564**	**98.1%**	**4,339**	**7,624**	**75.7%**
Total Demonstration	**74,287**	**97,603**	**31.7%**	**159**	**193**	**21.4%**	**1,528**	**2,086**	**36.5%**	**17,578**	**23,508**	**33.7%**

Table 11: Weekday Corridor Performance

	PASSENGERS PER REVENUE HOUR			PASSENGERS PER REVENUE MILE			NET SUBSIDY PER PASSENGER			NET NEW SUBSIDY PER PASSENGER		
Corridor	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**	**Pre-Rapid**	**Post-Rapid**	**% Change**
WILSHIRE - WHITTIER												
Lines 18/318	62.0			5.86			($0.52)					
Lines 20/21/22/320/322	43.2			4.04			($1.08)					
Line 18		67.7			6.85			($0.41)				
Lines 20/21		57.4			7.12			($0.54)				
Metro Rapid 720		45.5			3.58			($1.16)				
Combined Corridor	**52.6**	**56.9**	**7.6%**	**4.95**	**5.85**	**15.4%**	**($ 0.80)**	**($ 0.70)**	**-14.0%**		**($0.57)**	
VENTURA												
Lines 424/425/522	47.4			3.11			($1.16)					
Lines 150/240		22.8			1.79			($4.38)				
Metro Rapid 750		42.6			2.87			($1.11)				
Combined	**47.4**	**32.7**	**-36.2%**	**3.11**	**2.33**	**-28.1%**	**($1.16)**	**($2.75)**	**91.1%**		**($6.23)**	
Total Demonstration	**5034**	**48.5**	**-3.7%**	**4.38**	**4.30**	**-1.7%**	**($0.85)**	**($0.95)**	**11.7%**		**($1.26)**	

Table 12: Capital Cost Summary

Capital Element	Wilshire-Whittier		Ventura	
	Units/Miles	Cost	Units/Miles	Cost
Stations	25.7 miles	$2,441,000	16.7 miles	$1,590,300
Bus Signal Priority	25.7 miles	$2,569,000	1637 miles	$1,674,000
TOTAL DEMONSTRATION	---	$5,010,000		$3,264,300

Capital Element	Total		Cost Per Mile
	Units/Miles	Cost	
Stations	42.4 miles	$4,031,300	$95,000
Bus Signal Priority	42.4 miles	$4,243,000	$100,000
TOTAL DEMONSTRATION	---	$8,274,300	$195,000

Table 13: Operating Cost Summary

Corridor	Wilshire-Whittier		Ventura	
	Pre-Rapid	Post-Rapid	Net Change	% Change
WILSHIRE - WHITTIER				
Lines 18/318	$10,563,000	---		
Lines 20/21/22/320/322	$14,964,000	---		
Line 18	---	$8,312,000	-$2,251,000	-21.3%
Lines 20/21	---	$10,216,000	-$4,703,000	-31.4%
Metro Rapid 720	---	$14,137,000	$14,137,000	N/A
Combined Corridor	$25,527,000	$32,665,000	$7,183,000	28.1%
VENTURA				
Lines 424/425/522	$6,954,000			
Lines 150/240		$7,662,000	$708,000	10.2%
Metro Rapid 750		$4,831,000	$4,831,000	N/A
Combined	$6,954,000	$12,493,000	$5,539,000	79.7%
TOTAL DEMONSTRATION	$32,481,000	$45,158,000	$12,722,000	39.2%

Table 14: Proposed Phase II Routes

Metro Rapid Phase II		
Phase II A	**Phase II B**	**Phase II C**
Avalon	Hawthorne	Alvarado
Crenshaw/Rossmore	Hollywood/Pasadena	Atlantic
Florence	Long Beach	Century
Van Nuys	San Fernando	Garvey
Venice/Pico/E 1st	Santa Monica	Hollywood/Fairfax
Vermont	Sepulveda	Lincoln
	Soto	Roscoe
	Western	Vernon/La Cienega
		West Third

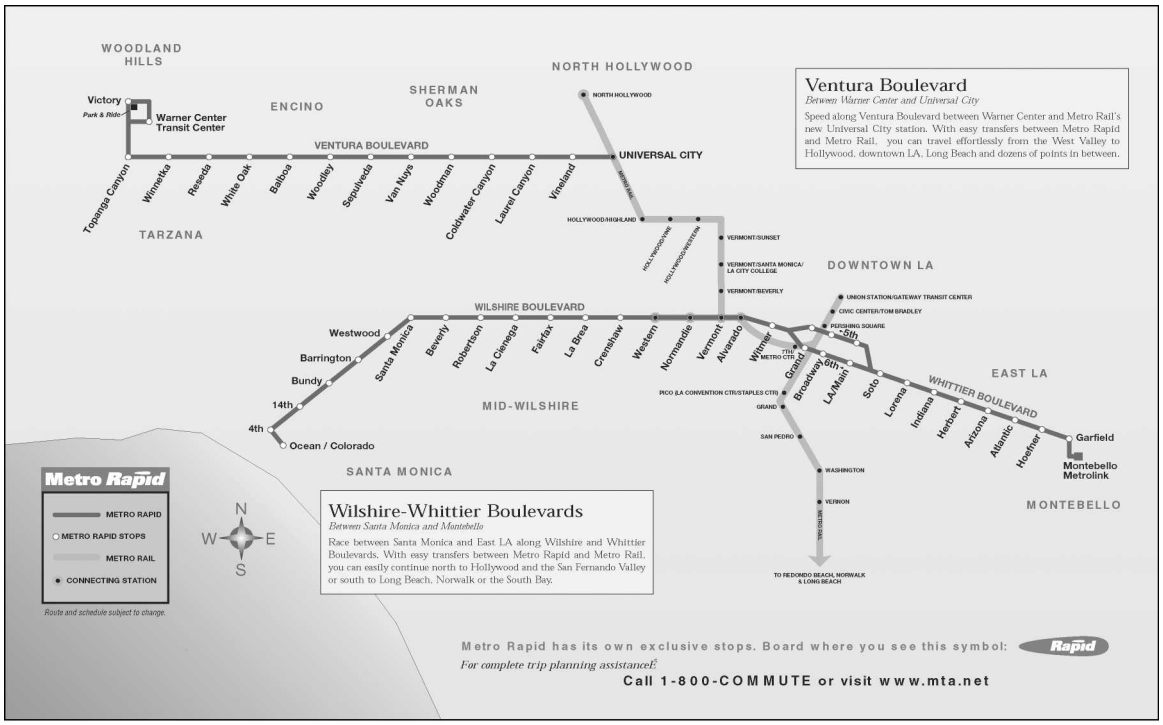

Figure 1: Map of Busways and BRT Facilities

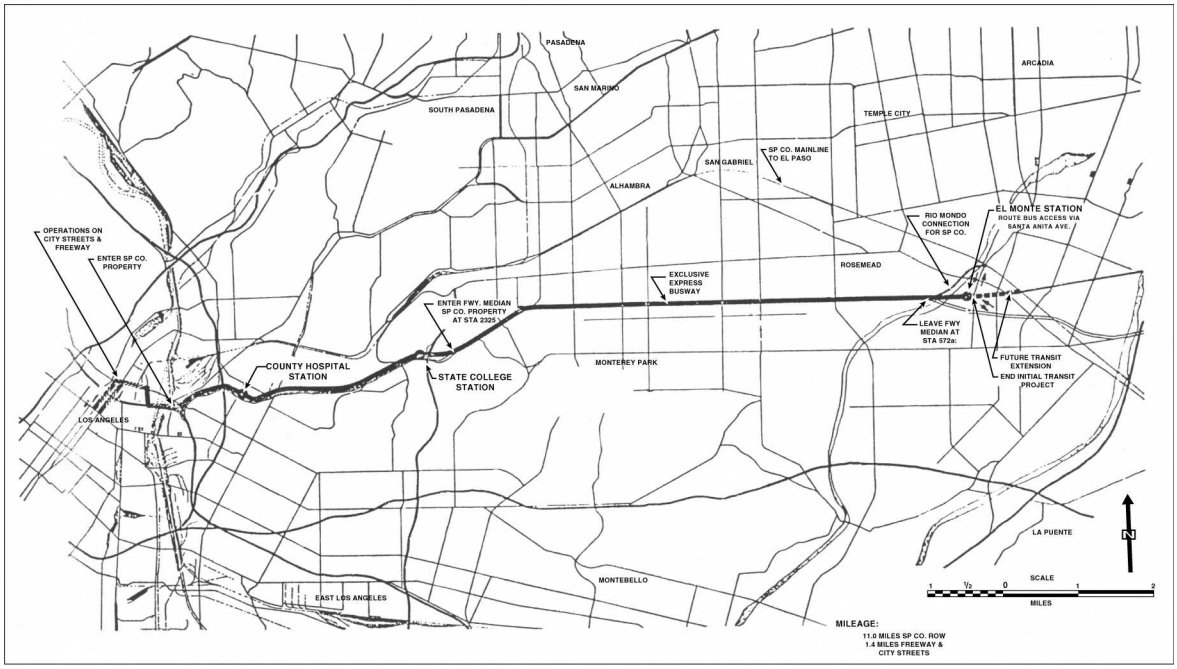

Figure 2: Map of El Monte Busway

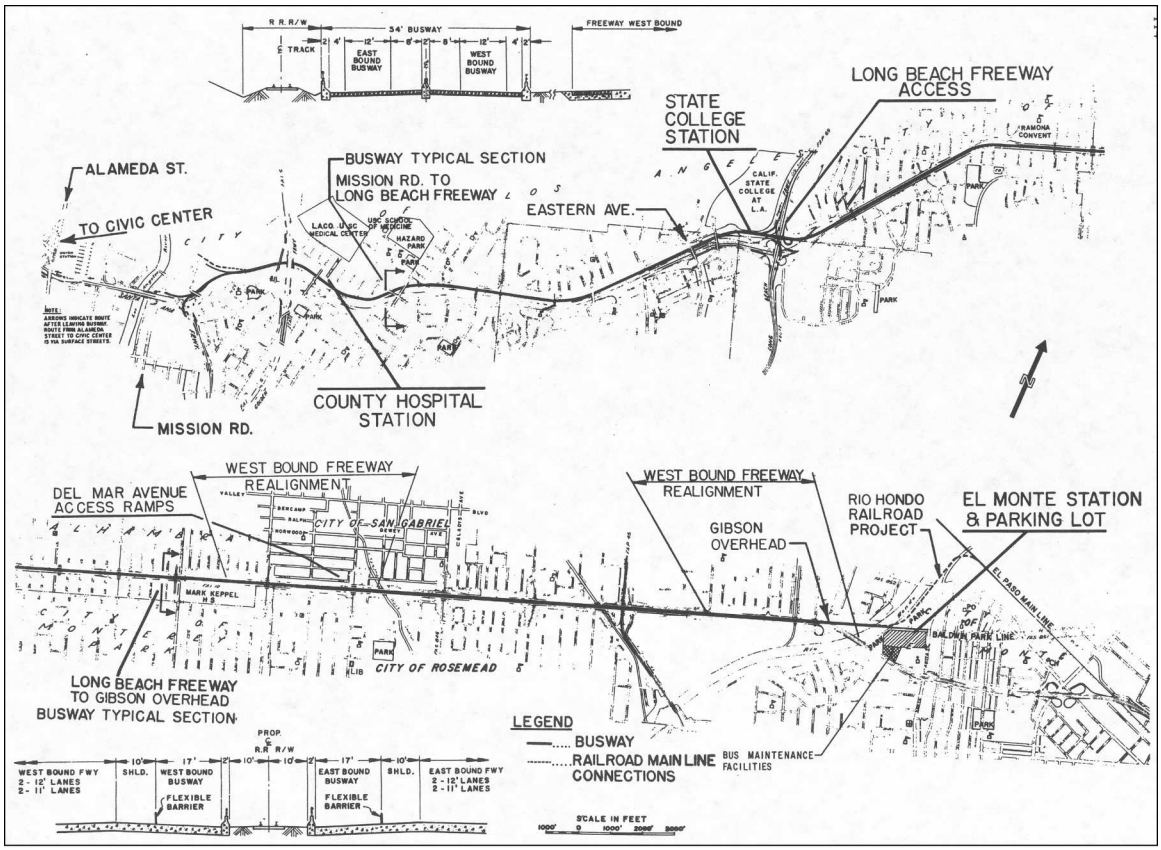

Figure 3: General Plan and Typical Cross Sections of El Monte Busway

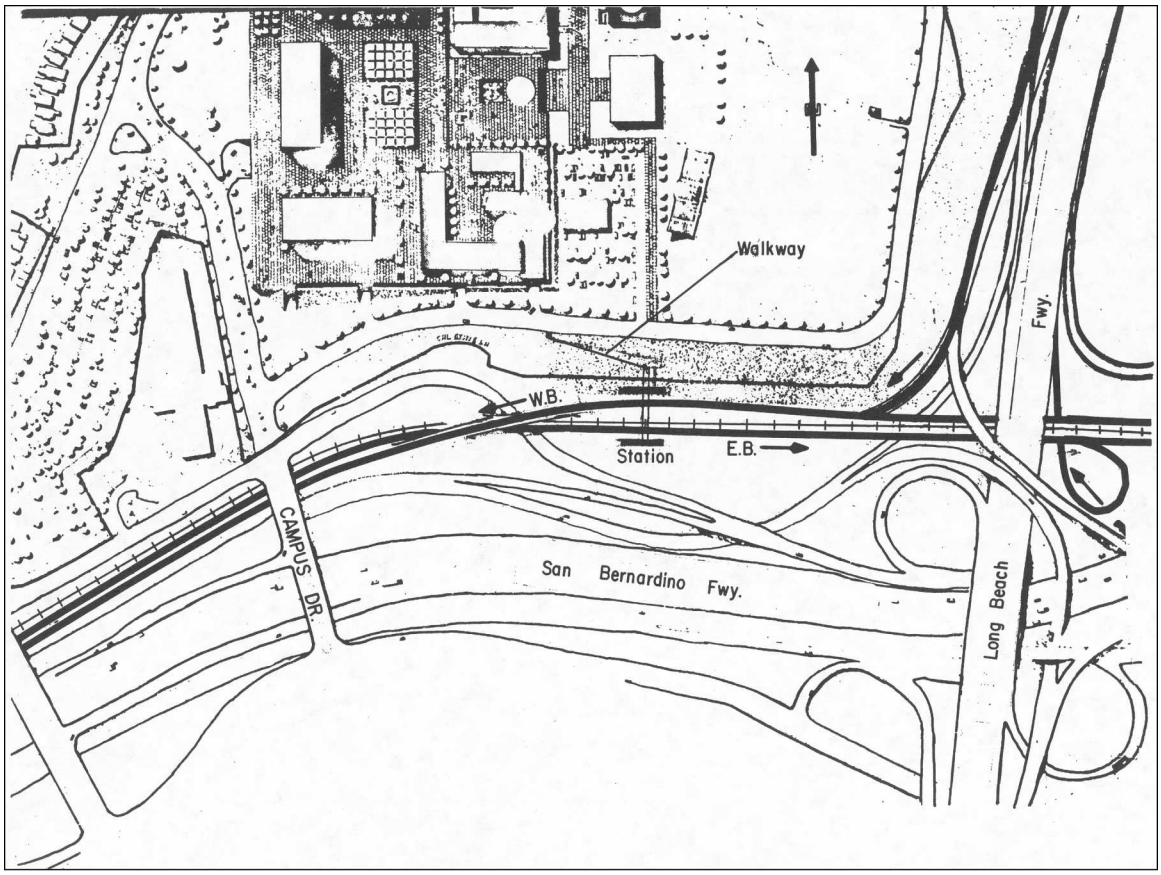

Figure 4: Busway Access at California State University Station

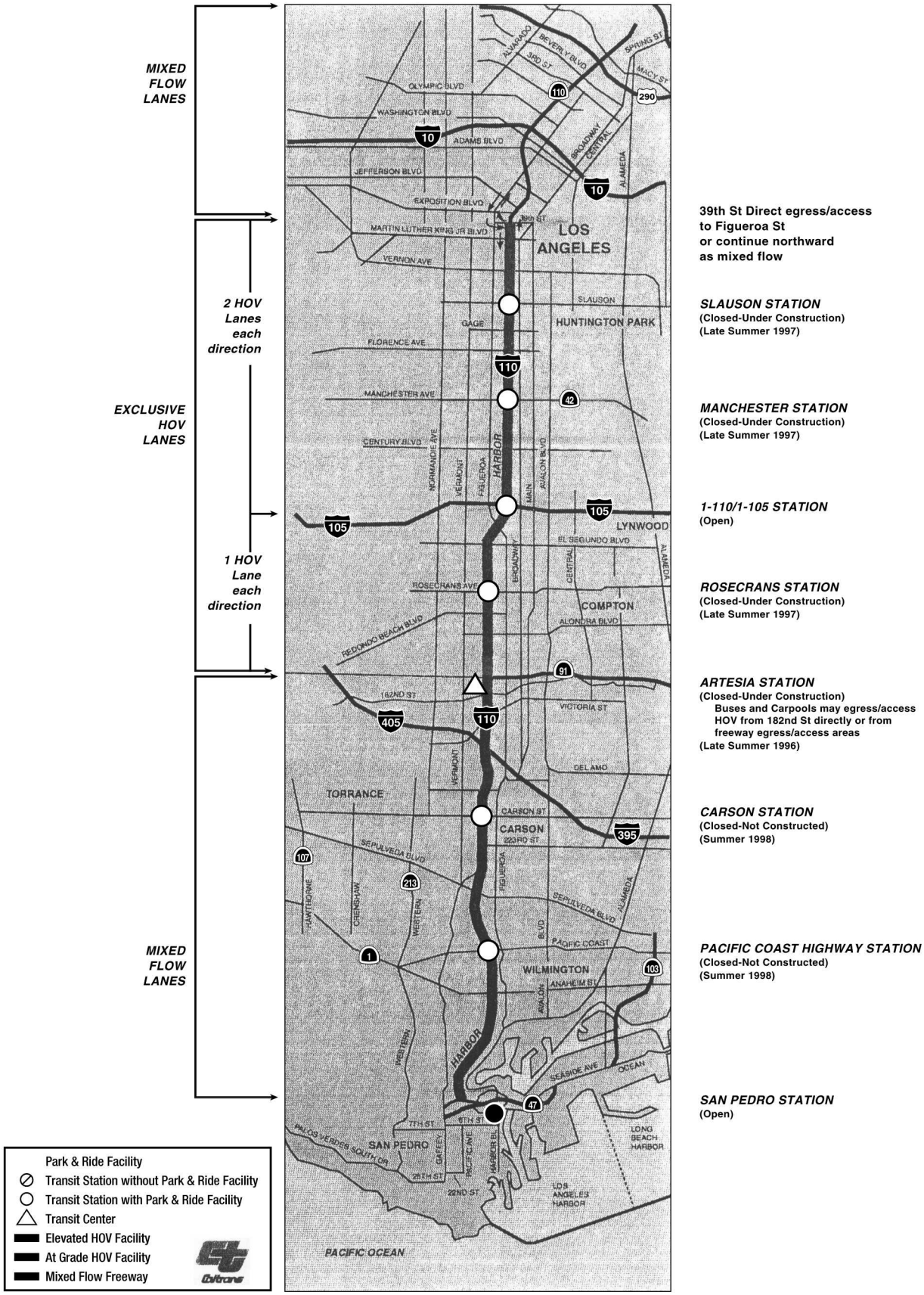

Figure 5: Harbor Freeway

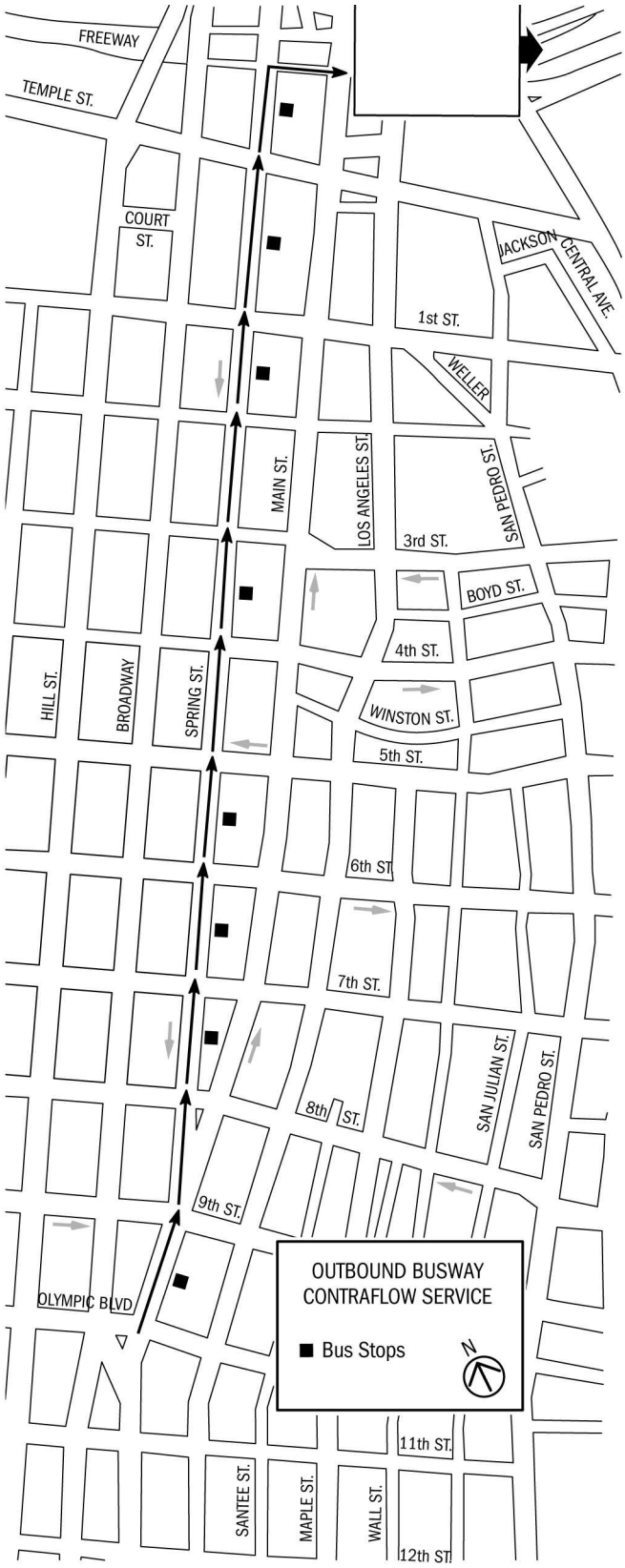

Figure 6: Spring Street Contra-Flow Lane

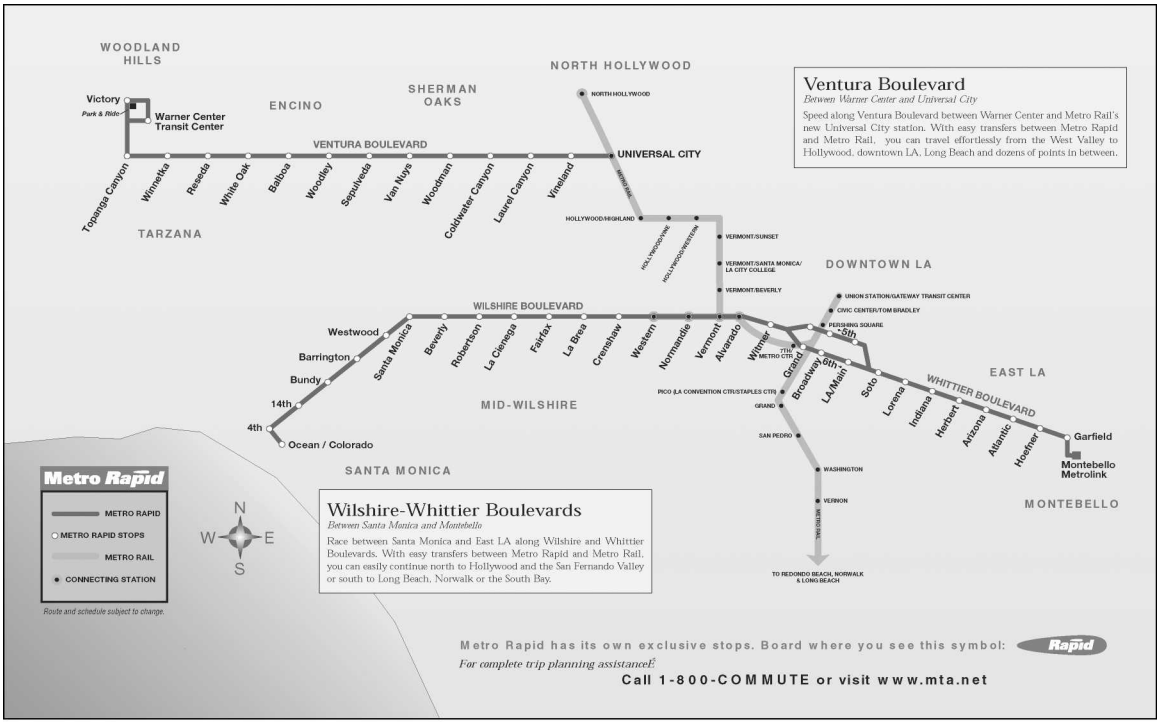

Figure 7: Map of Metro Rapid Routes

Figure 8: Passengers Boarding and Alighting

Figure 9: Metro Rapid Vehicle

Figure 10: Double Canopy Station

Figure 11: Next Bus Message Sign

Figure 12: Single Canopy Station

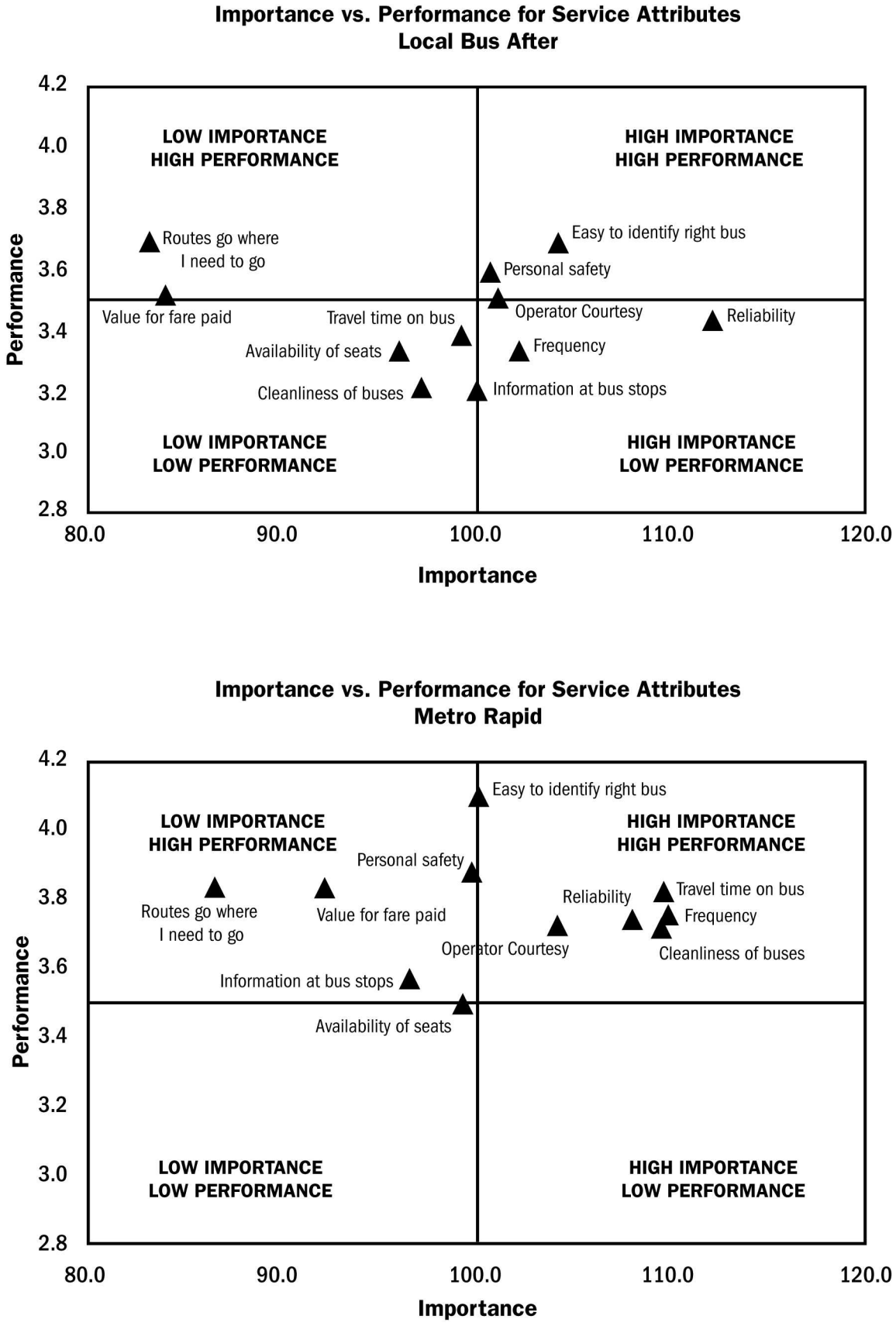

Figure 13: Customer Perceptions of Local Bus Versus BRT