Creating a Light Rail Transitway Within Existing Arterial Street Right-of-Way

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The downtown Los Angeles portion of the recently opened Metro Blue Line runs south, through a short subway, then continues at grade in reserved trackways on Flower Street and Washington Boulevard to the Mid-Corridor private right-of-way and eventually to Long Beach. The light rail trackways on Flower Street and Washington Boulevard were created as part of the Blue Line project; prior to Blue Line construction, sidewalks and traffic lanes occupied the entire public right-of-way. Building the Blue Line required a series of planning and engineering decisions about how best to mix light rail, automobile, and pedestrian traffic on the streets and how to relocate utilities.

The 22-mi-long Metro Blue Line, originally designated the Long Beach–Los Angeles rail transit project, was the first rail project undertaken by the Los Angeles County Transportation Commission (LACTC). The 20-mi segment from Pico Station to Anaheim Station, including the street-running sections on Flower Street and Washington Boulevard, opened for revenue service in July 1990. The Long Beach Loop opened in September 1990, and the Seventh and Flower Station opened in February 1991 (Figure 1).

For much of its length, the Blue Line operates in right-of-way formerly used by the interurban Pacific Electric Railroad (PE). The Pacific Electric's Long Beach line, which ceased passenger service in 1961, operated from the PE station at Sixth and Main streets in downtown Los Angeles. The line ran east on a three-block-long steel elevated structure to San Pedro Street, then south and east for 2 mi in mixed traffic on city streets to Olympic Boulevard and Long Beach Avenue, where it entered private right-of-way.

One of the Blue Line conceptual design phase challenges was to find an alignment to connect the private right-of-way to downtown Los Angeles. The former PE alignment was not appropriate for several reasons. The elevated structure had been demolished and the right-of-way redeveloped; the San Pedro Street and Olympic Boulevard rights-of-way are too narrow for reserved trackways; and, perhaps most importantly, the center of downtown retail and commercial activity had moved steadily west since the PE station on Main Street was built at the turn of the century.

ALIGNMENT AND RIGHTS-OF-WAY

The Metro Blue Line begins in subway under Flower Street just south of Sixth Street in the central business district (CBD) of Los Angeles. The initial station at Seventh and Flower is a two-level underground joint station with the heavy rail Red Line. (The Red Line center platform is under Seventh Street on the lowest level; the Blue Line side platforms are under Flower Street at the Red Line mezzanine level.) The Blue Line continues south from the station in a short subway, crossing under the intersections of Flower Street and 8th Street, 9th Street, Olympic Boulevard, and 11th Street. The subway portal and trackway ramp to the surface are located on the east side of Flower Street between 11th and 12th streets.

The Blue Line crosses 12th Street at grade and proceeds south on the east side of Flower Street past Pico Station to Washington Boulevard. At Washington Boulevard the tracks swing east and proceed in the median of Washington Boulevard east past Grand Station and San Pedro Station to Long Beach Avenue. At Long Beach Avenue the Blue Line swings south into the Mid-Corridor segment private right-of-way.

Los Angeles transit planners operate under the shadow of the Pacific Electric, the transit system that "got away." At its peak, the PE Red Cars operated over more than 1,000 mi of standard gauge electrified track in the Los Angeles basin. Although the outlying sections were frequently on private rights-of-way, the PE made extensive use of street trackage in downtown Los Angeles and Hollywood. By the 1950s, street congestion had seriously compromised the PE's reliability as a rush-hour passenger carrier.

When light rail transit (LRT) shares street right-of-way with automobiles, the potential alignment classifications include the following:

- Exclusive trackway—Open tie and ballast construction,
- Exclusive trackway—Embedded track construction,
- Semiexclusive trackway—Left turn lanes on tracks, and
- Nonexclusive trackway—Mixed traffic.

One of the early Blue Line policy decisions was that the LRT system would operate in exclusive transit lanes when sharing street rights-of-way. The LACTC was not going to spend hundreds of millions of dollars to build an unreliable system, and the PE had already demonstrated the unreliability of mixed LRT/automobile lanes in Los Angeles.

On Flower Street and Washington Boulevard, the Blue Line operates in exclusive trackways with embedded tracks separated from automobile roadways by curbs. The Blue Line tracks were embedded in asphalt at the request of the city of Los Angeles so that emergency vehicles could cross or, if necessary, drive on the trackway to reach the scene of an emergency. Separate signalized left turn lanes outside of the

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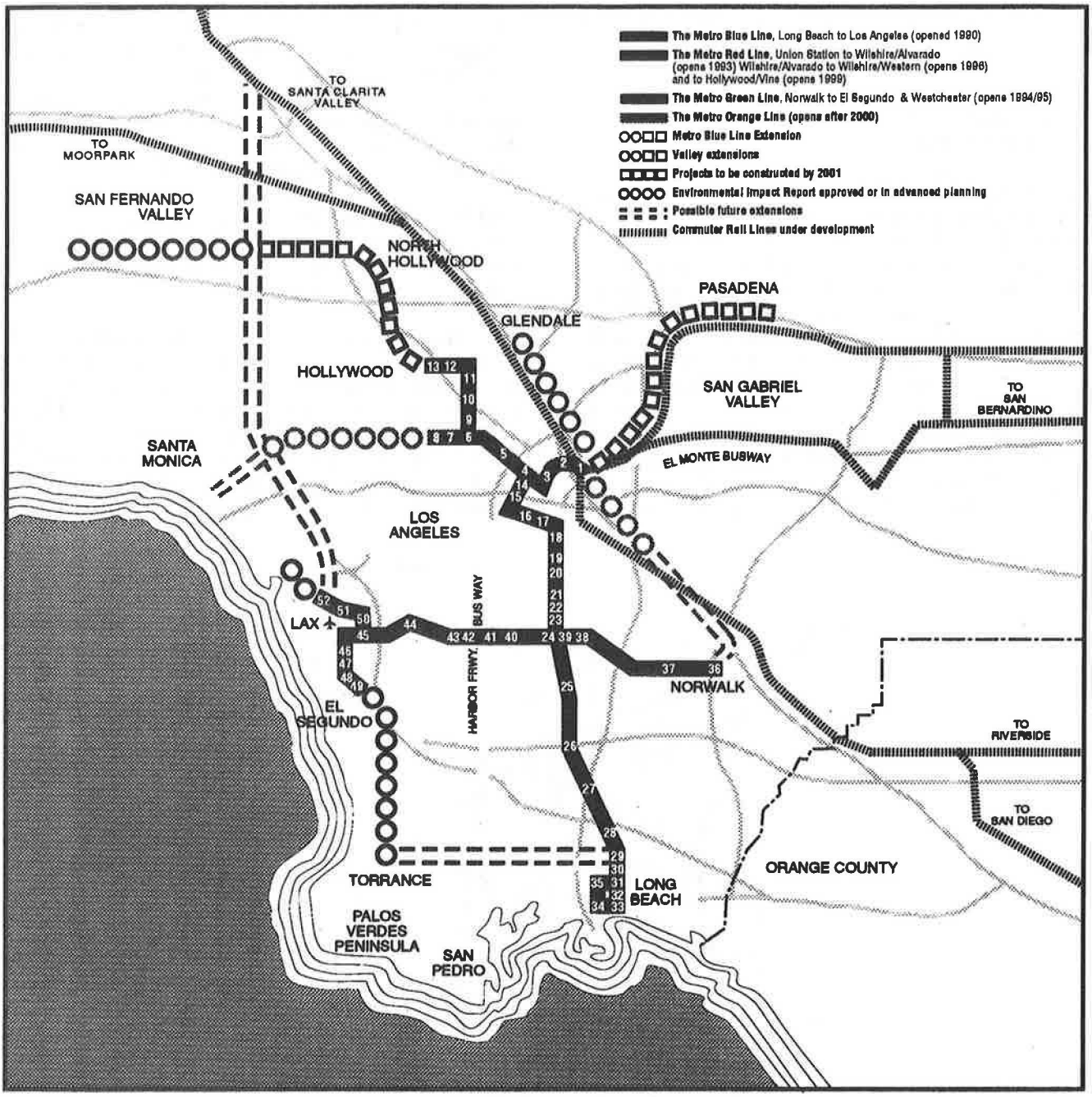

STATION LOCATIONS

***Metro Red Line**-Union Station to Hollywood/Vine*

1. Union Station
2. 1st St./Hill St. (Civic Center)
3. 5th St./Hill St.
4. 7th St./Flower St.
5. Wilshire Blvd./Alvarado St.
6. Wilshire Blvd./Vermont Ave.
7. Wilshire Blvd./Normandie Ave.
8. Wilshire Blvd./Western Ave.
9. Vermont Ave./Beverly Blvd.
10. Vermont Ave./Santa Monica Blvd.
11. Vermont Ave./Sunset Blvd.
12. Hollywood Blvd./Western Ave.
13. Hollywood Blvd./Vine St.

***Metro Blue Line**-Long Beach to Los Angeles*

14. 7th St./Flower St.
15. Pico Blvd./Flower St.
16. Grand Ave./Washington Blvd.
17. San Pedro St./Washington Blvd.
18. Washington Blvd./Long Beach Ave.
19. Vernon Ave./Long Beach Ave.
20. Slauson Ave./Long Beach Ave.
21. Florence Ave./Graham Ave.
22. Firestone Blvd./Graham Ave.
23. 103rd St./Graham Ave.
24. Imperial Hwy./Wilmington Ave.
25. Compton Blvd./Willowbrook Ave.
26. Artesia Blvd./Acacia Ave.
27. Del Amo Blvd./Santa Fe Ave.
28. Wardlow Rd./Pacific Ave.
29. Willow St./Long Beach Blvd.
30. Pacific Coast Hwy./Long Beach Blvd.
31. Anaheim St./Long Beach Blvd.
32. 5th St./Long Beach Blvd.
33. 1st St./Long Beach Blvd.
34. 1st St./Pine Ave.
35. 5th St./Pacific Ave.

***Metro Green Line**-Norwalk to El Segundo*

36. Studebaker Rd./605 Fwy.
37. Lakewood Blvd./Imperial Hwy.
38. Long Beach Blvd./Imperial Hwy.
39. Imperial Hwy./Wilmington Ave.
40. Avalon Blvd./117th St.
41. 110 Fwy./117th St.
42. Vermont Blvd./117th St.
43. Crenshaw Blvd./119th St.
44. Hawthorne Blvd./111th St.
45. Aviation Blvd./Imperial Hwy.
46. Mariposa Ave./Nash St.
47. El Segundo Ave./Nash St.
48. Douglas St.
49. Freeman Ave.
50. Century Blvd.
51. LAX Lot C
52. Westchester Pkwy.

FIGURE 1 Los Angeles Metro Rail plan.

reserved transitway are provided at all intersections where left turns are legal.

CONCEPTUAL DESIGN AND ENVIRONMENTAL DOCUMENTATION

The goal of the conceptual design and environmental documentation phase was to reach agency and public consensus on Metro Blue Line alignment.

Early in the conceptual design, the LACTC established an interagency working group to propose and screen Los Angeles CBD segment alternative alignments. The working group consisted of staff from the interested agencies, including the LACTC; the Los Angeles City Departments of Transportation (LA DOT), Public Works (DPW), Planning, and the Community Redevelopment Agency; Los Angeles County; and the California Department of Transportation (Caltrans).

In a series of workshops held in 1982 and 1983, the working group identified more than a dozen possible alignments from the Mid-Corridor right-of-way to downtown Los Angeles. The possible alignments included both alternative street routings and alternative guideway profiles (at-grade, subway, and aerial). The working group screened the list of possible alignments and recommended three alignments for conceptual design and environmental clearance. The LACTC adopted the three recommended Los Angeles CBD segment alternatives for further study in May 1983 (Figure 2):

- LA-1—Broadway/Spring Couplet, at-grade,
- LA-2—Flower Street Subway (including at-grade trackways on Flower Street and Washington Boulevard), and
- LA-3—Olympic/Ninth Aerial.

Because the Blue Line would be locally funded through the 0.5 percent county sales tax approved by the voters in 1980, no federal environmental documentation was required. A draft environmental impact report (draft EIR), as required by the California Environmental Quality Act (CEQA), was prepared for the entire 22-mi Blue Line project. The draft EIR, which was issued for public review and comment in May 1984, documented the three Los Angeles CBD alternatives. The

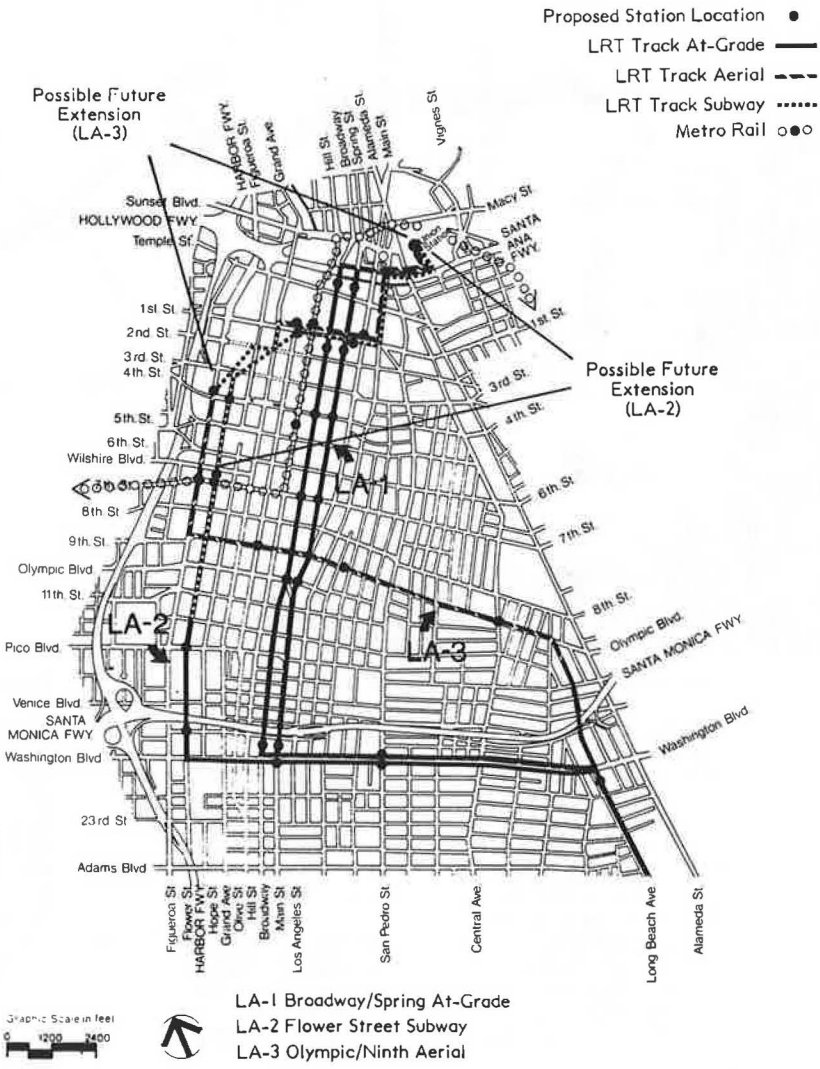

FIGURE 2 Downtown Los Angeles alignment alternatives.

LA-2 alternative was subsequently endorsed by the Los Angeles City Council and adopted by LACTC, in large part because of the transit efficiency of the joint Blue Line/Red Line station at Seventh and Flower.

PRELIMINARY ENGINEERING DESIGN

The goal of the preliminary engineering design phase was to reach agreement on how the Flower Street and Washington Boulevard public right-of-way would be shared between the roadway and the Blue Line trackway.

Flower Street: Side Running and One-Way Street Operation

The conceptual design focused on fitting the Blue Line transitway into the existing downtown Los Angeles street system. At the time both Flower Street and Washington Boulevard were operated as two-way arterial streets. With the endorsement of the LA-2 alignment by the city council, LA DOT proposed changes to the downtown street system, including conversion of Flower Street to one-way southbound operation, to improve operations for both motorists and LRT.

A limited number of one-way street couplets had been implemented in downtown Los Angeles during freeway construction in the 1950s. LA DOT had been attempting to expand the one-way street system to include additional north-south couplets for several years, but merchant opposition had stalled the conversion. The Blue Line project gave LA DOT the opportunity to reopen the issue and successfully implement two of the three proposed additional couplets.

In many respects the conversion of Flower Street to one-way operation was timely and helpful. The Blue Line was requesting that a significant fraction of the 90-ft-wide Flower Street right-of-way be dedicated to LRT operations, particularly at passenger stations. The more efficient traffic operation of a one-way street compared to a two-way street helped the city agree to that request. Another advantage was at the subway portal. With two-way street operation, northbound motorists would be driving toward the portal and might accidentally either drive into the end of the portal retaining wall or attempt to drive down the portal ramp. The conversion to one-way southbound operation diverted the automobile traffic that otherwise would be driving toward the south-facing portal.

The disadvantage of the conversion to one-way street operation was that roadways (northbound and southbound) were no longer between the transitway and the adjacent sidewalk and private property. (A median trackway between roadways operating in the same direction was judged to be unsafe because of turning movement conflicts—signs would not prevent motorists from turning across the trackway when they found themselves on the wrong roadway for their destination).

The conversion of Flower Street to one-way operation essentially forced the Blue Line to a side running alignment, placing trackway between private property and the public street. The existing driveways had to either remain in service (with motorists crossing the trackway) or LACTC would have to compensate the owners for the loss of driveway access to their property.

If the driveways were allowed to remain, a motorist turning left to enter a driveway might not see a light rail vehicle (LRV) approaching from the motorist's rear. This conflict between automobiles turning into driveways and overtaking LRVs was judged to be a significant safety problem. Automobiles exiting from a driveway cross the tracks at a right angle, then turn onto the roadway. Because the track crossing would be at a right angle, the exiting driver has a better opportunity to look both ways before crossing the trackway. The conflict between automobiles exiting driveways and LRVs was judged to be less of a problem.

Where driveway traffic was projected to be heavy, the LACTC purchased the property owner's vehicle access rights and closed the driveway. For all driveways that remained, the project installed internally illuminated No Left Turn signs facing the entering motorist (Figure 3). The normally dark No Left Turn signs are activated (illuminated) by an LRV approaching from either direction on either track. Driveway exit movements are controlled by LRV warning signs. Between driveways, handrails separate the trackway from pedestrians on the sidewalk.

As was anticipated by the designers, the one-way southbound Flower Street operates with less congestion than the two-way street experienced prior to Blue Line construction. Congestion has not increased noticeably on the adjacent one-way northbound or two-way streets. The LRV-activated No Left Turn signs at driveways are operating as planned. No LRT-related accidents on Flower Street have been reported to the city.

Washington Boulevard: Typical Section and Roadway Capacity

Washington Boulevard is an important east-west arterial street immediately south of downtown and the Santa Monica Freeway. Prior to Blue Line construction, Washington Boulevard consisted of a 70-ft- or 80-ft-wide roadway (a center continuous left turn lane plus three through lanes for each direction for a total of seven traffic lanes) and two 15-ft- or 10-ft-wide sidewalks in 100-ft-wide right-of-way. The Washington Boulevard curb lanes were signed to permit parking middays and nights, but not during rush hours. The adjacent streets are discontinuous, essentially prohibiting a one-way couplet scheme.

The conceptual design typical sections indicated that the LRT would replace traffic lanes on Flower Street and Washington Boulevard within the existing roadway—the existing curbs, gutters, and sidewalks would not be reconstructed. LA DOT commented during the environmental document review period that this would have an unacceptable traffic impact on Washington Boulevard. LACTC responded by committing to provide two through lanes plus a left turn lane for each direction of travel as mitigation.

The first preliminary engineering attempt to define a new Washington Boulevard typical section was a failure—the width of the 24-ft median trackway plus two 34-ft roadways (13-ft curb lane for buses, 11-ft through lane, and 10-ft left turn lane) plus two 10-ft sidewalks exceeded the 100-ft right-of-way by 12 feet. LACTC and LA DOT then examined various schemes to fit the roadway and transitway into the existing right-of-way, including an asymmetric design that eliminated

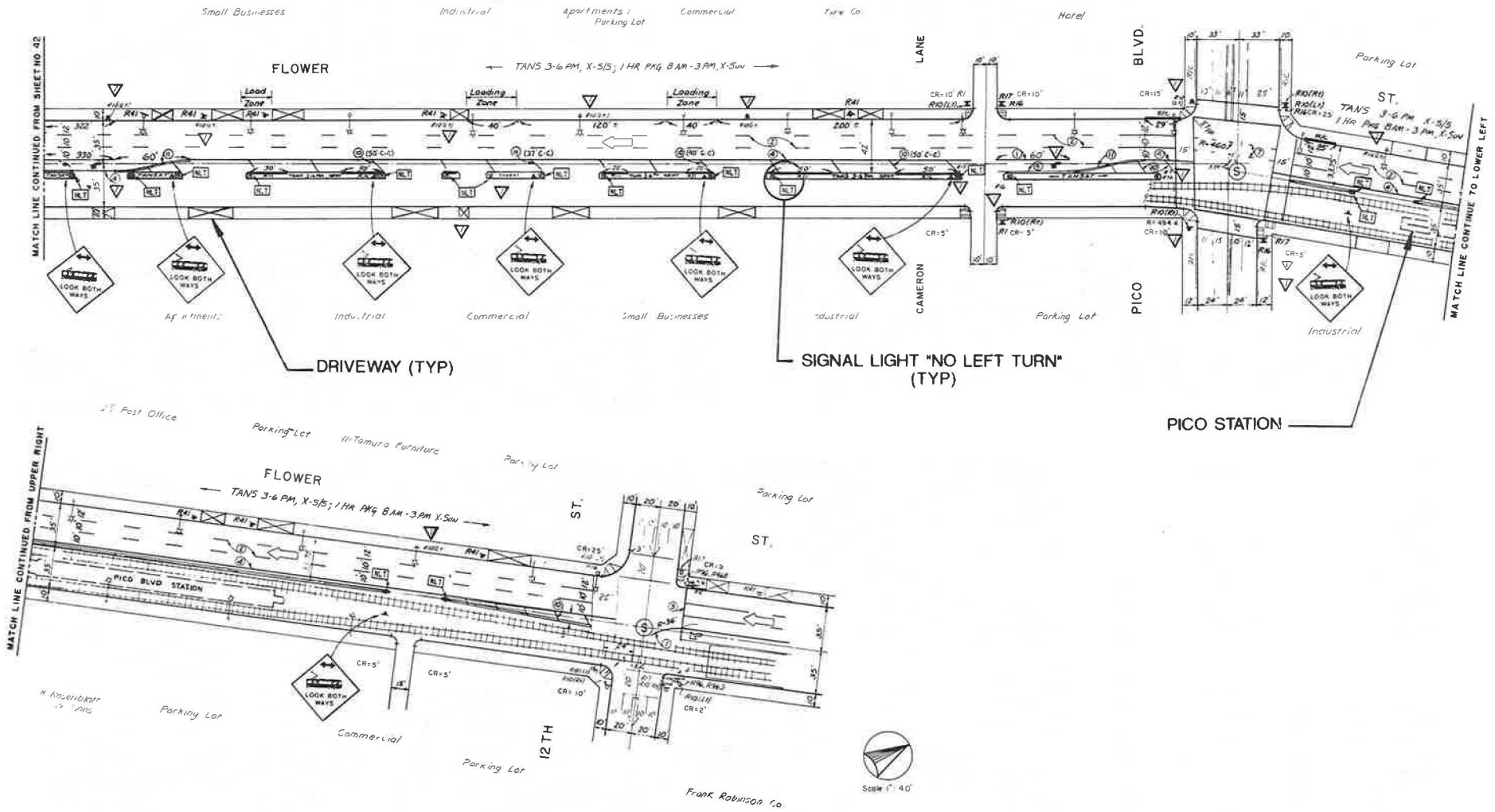

FIGURE 3 Driveways, No Left Turn signals, and warning signs on a typical block of Flower Street.

the westbound left turn lane and westbound-to-southbound (away from downtown) movement.

Eventually a "share the misery" program of a 22-ft median trackway, two 31-ft roadways (12-ft curb lane, 10-ft through lane, and 9-ft turn lane), and two 8-ft sidewalks was accepted with reservations by all parties (Figure 4). The agreement on a Washington Boulevard typical section was the most important decision to come out of the Los Angeles CBD approach segment preliminary engineering.

The Blue Line reduced the Washington Boulevard rush hour roadway from six through lanes to four through lanes. LA DOT took two actions to help mitigate the reduction in traffic capacity. First, all driveways and all but one of the intersections with side streets (defined as intersections that did not have an existing traffic signal) were closed to left turns. Automobiles could turn right into a side street or driveway, or could turn right from a side street or driveway onto Washington Boulevard. But automobiles could no longer turn left into or from side streets or driveways or use side streets to cross Washington Boulevard. Railings were installed between the Blue Line tracks at the closed intersections to discourage pedestrians from crossing as well.

Second, LACTC extended LA DOT's Automatic Traffic Surveillance And Control (ATSAC) system to include the traffic signals along the Blue Line portion of Washington Boulevard. The ATSAC system is used to monitor and reprogram traffic signals in real time and had proven itself in the Coliseum area during the 1984 Olympic Games. Bringing the narrowed portion of Washington Boulevard into the system gives LA DOT the ability to monitor traffic volumes and adjust signal timing from City Hall.

Somewhat to the surprise of the designers, the narrowed Washington Boulevard is now operating more smoothly than the wider street did before Blue Line construction. This is in large measure because of the reduced number of heavy trucks on the street. The trucks apparently found alternative routes during construction and have not returned to the narrower roadway. (The house movers, who also occasionally used Washington Boulevard late at night, have also had to find alternative routes.) Congestion has not noticeably increased on the adjacent arterial streets.

Three LRT-related accidents occurred on Washington Boulevard in the 6 months immediately after the start of revenue operations, but no significant LRT-related accidents occurred in the subsequent 12 months.

Passenger Stations

The 1984 Blue Line conceptual design called for low-platform passenger stations. In early 1985 during the general project review associated with the environmental clearance process, LACTC determined that high-platform passenger stations would provide better service to patrons than low-platform stations. High-platform stations allow for quicker boarding and exiting, thus reducing station dwell and total trip time. The increased convenience and reduced dwell time resulting from high-platform stations are important elements in LACTC's campaign to encourage the use of public transit rather than private automobiles. The high-platform stations have the additional benefit of making every car in a light rail train handicapped accessible.

LA DOT supported LACTC passenger station program by finding locations where left turns could be prohibited and the typical section left turn lane width used to widen the track centers around a center platform and access ramp. (Side platforms were considered and rejected for two reasons. First, a center platform could be wider than either of a pair of side platforms. Second, although any high platform in the middle of the roadway is a potentially hazardous fixed object, a center platform would be separated from the through traffic lanes by the width of the trackway. A side platform, on the other hand, would be immediately adjacent to the through traffic lanes.)

Left turns were prohibited from southbound Flower Street into Pico Boulevard, thus providing room north of the intersection for Pico Station. Station access is from the Flower Street east sidewalk. Left turns from eastbound Washington Boulevard into Grand Avenue were also prohibited, providing room west of the intersection for Grand Station. Station access is from the west intersection crosswalk. At San Pedro Street, LA DOT could not justify eliminating any of the left turn movements. The San Pedro Station was instead located 300 ft east of the intersection, east of the westbound left turn pocket. Station access is via signal-protected midblock pedestrian crosswalks from the Washington Boulevard north and south sidewalks. (The crosswalks have separate traffic signals, so that a pedestrian request to cross to the south sidewalk will not cause automobiles in the north roadway to stop.)

The Blue Line inbound and outbound tracks flare from the typical 11-ft-2-in.-track centers to 23-ft-2-in.-track centers at the passenger stations. The tracks are tangent from 50 ft before to 50 ft after the station platform to avoid any vehicle middle overhang clearance problems. All track transition curves start and end with 31-ft-long spiral curves.

Utility Relocations and Coordination with City Projects

Extensive utility conflicts were identified during preliminary engineering. Many of these conflicts were the result of narrowing the sidewalks to provide additional room between the curbs for both a roadway and a trackway.

The major utility under the trackway was a 45-in. brick sewer built at the turn of the century 10 to 11 ft under the centerline of Washington Boulevard. After reviewing videotapes of the sewer, the DPW Bureau of Engineering agreed that the sewer could remain in place. However, all of the sewer manholes had to be reconstructed as offset manholes to permit emergency maintenance access to the sewer without interfering with LRT operations.

The construction of the offset manholes required the relocation of existing utility lines that were otherwise clear of the trackway. The new structures were expensive and, because of the offset, do not allow truck-mounted maintenance equipment to be positioned over the sewer. Because the adjacent properties are already developed, few new sewer connections are anticipated. Any new connections that are made, however, will have to be mined under the LRT track slab. In hindsight, the authors feel we might have been "penny wise and pound foolish" to have worked around the existing sewers under the trackway. We might have been better off replacing

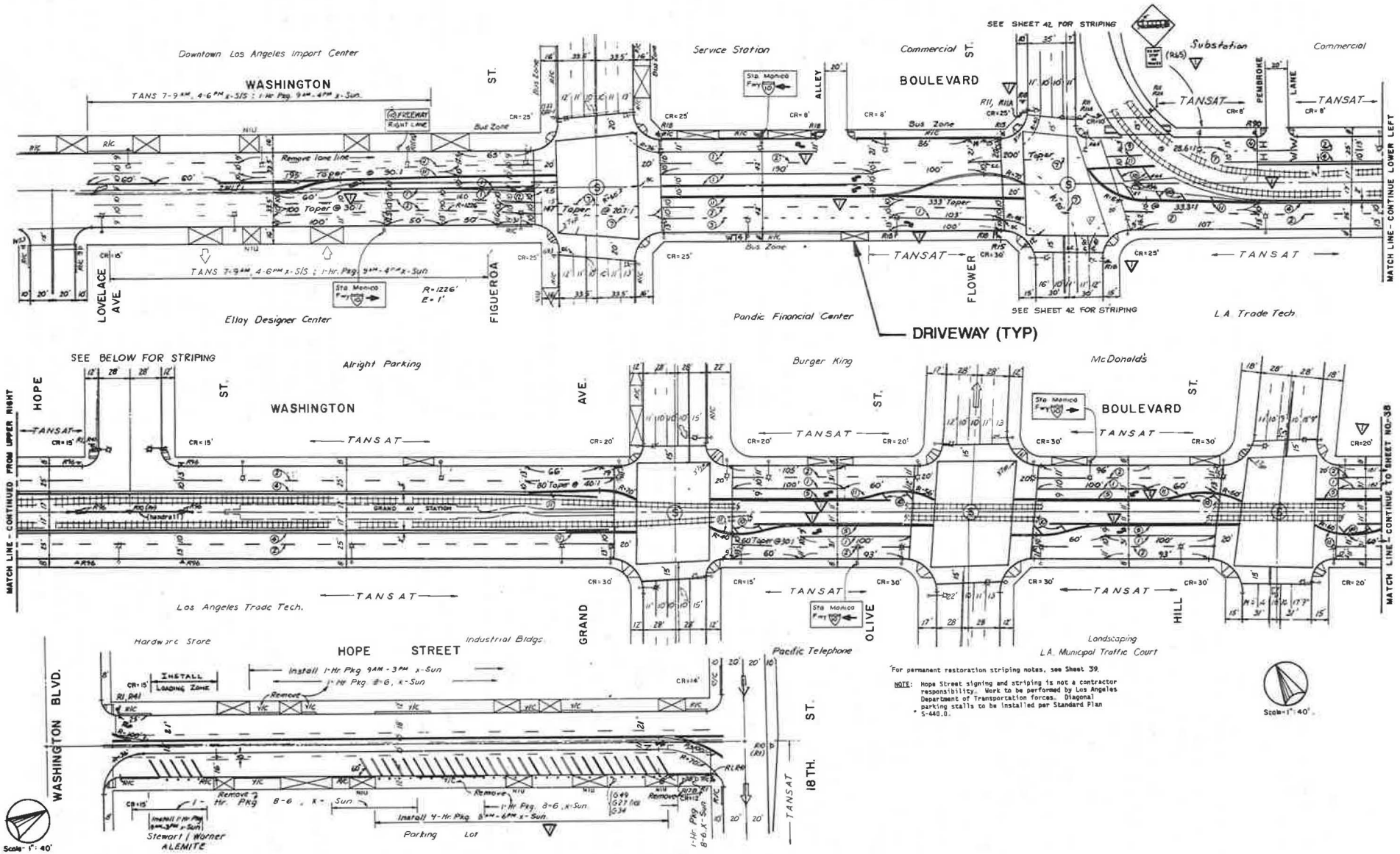

FIGURE 4 Roadway lane layout and trackway on the short blocks typical of the western portion of Washington Boulevard.

the centerline sewers with new pipes on either side of the trackway and solving the sewer problem once and for all.

The major utility conflict outside of the trackway was with a Department of Water and Power (DWP) 34.5 kV distribution line mounted on wood poles on the south side of Washington Boulevard. The existing poles would be in conflict with the widened roadway, and DWP felt that the new 8-ft sidewalk would be too narrow for a relocated pole line. LACTC built a replacement duct bank system under the street and DWP furnished and installed the new conductors as part of DWP's overhead line undergrounding program.

The DPW Bureau of Engineering had a street reconstruction project scheduled for Flower Street between Eighth Street and Olympic Boulevard. The DPW Bureau of Street Lighting had a street lighting reconstruction contract for Washington Boulevard advertised and bid. Both of these capital improvement program projects were canceled and the work assigned to the Blue Line project by task order under the master agreement between the LACTC and the city.

One conflict could not be relocated and required a special waiver from the California Public Utilities Commission (CPUC). CPUC requires that contact wire installed over public streets have a minimum clearance of 19 ft above the roadway. The Interstate 10 Santa Monica Freeway crosses over Flower Street and over an eastbound freeway on-ramp with only 16 ft of clearance. After much analysis CPUC granted a waiver to permit the Blue Line contact wires to pass under the freeway and over the on-ramp entrance. The waiver was conditioned on installation of special signs and an overheight load warning system.

Right-of-Way Acquisitions

The preliminary engineering design confirmed that the existing street right-of-way was generally adequate for the Blue Line Los Angeles CBD approach segment. Additional right-of-way was required for the curves from Flower Street to Washington Boulevard and from Washington Boulevard to the Mid-Corridor private right-of-way, and for two traction power substations. One substation was to have been located at a former service station site that turned out to have petroleum-contaminated soil; the substation was relocated to another site. Right-of-way action also was required to close several driveways on Flower Street and to remove two building canopies on Washington Boulevard that would overhang the street after the sidewalk was narrowed.

FINAL DESIGN

The goal of the final design phase was to prepare construction plans and specifications. The construction documents were subject to review and sign-off by the city to confirm that they correctly implemented the shared right-of-way strategies developed in earlier phases.

Construction documents were prepared for three Los Angeles CBD approach facilities construction contracts: an advance utilities relocation contract; a street reconstruction, station foundation, and embedded track contract; and a station finishes contract. The Blue Line systemwide traction power substation, overhead contact system, and communication/signaling contractors also worked in the segment.

Final Alignment

The Los Angeles CBD approach design speed is generally 35 mph. The design speed is reduced to 8 to 10 mph at the 90 degree turns from Flower Street into Washington Boulevard and from Washington Boulevard into the Mid-Corridor private right-of-way (between the two roadways of Long Beach Avenue). At both of these locations, additional right-of-way outside of the intersection was required to widen track centers (to permit opposing trains to pass) and to permit 120-ft to 150-ft radius curves.

At one intersection on Flower Street and two intersections on Washington Boulevard, the existing street alignment abruptly changes bearing by up to 20 degrees. The change in bearing on Flower Street at Pico Boulevard was easily accommodated in the transition from the Pico Station wide track spacing to the typical narrow track spacing. On Washington Boulevard at Central Avenue, the already narrow sidewalks on the inside of the curve were narrowed up to 6 in. more to maintain roadway width while allowing larger radius track curve. At the tighter Compton Avenue curve, LA DOT omitted the typical section left turn lanes, permitting wider track centers and larger radius curves. The Los Angeles CBD approach track curves are not superelevated, but do have spiral transition curves in advance of all circular curves of less than 10,000-ft radius.

Street Reconstruction

On both Flower Street and Washington Boulevard, the existing sidewalks had to be replaced with narrower sidewalks before trackway construction could begin. The narrower sidewalk and new curb locations forced the relocation of all of the utilities that sit immediately behind the curb, including curb outlets from roof drains; catch basins; water meters and fire hydrants; telephone splice boxes; power poles; street lighting poles; and traffic signal poles. The new foundations for the relocated street light poles and the overhead contact system support poles forced the relocation of additional utilities (such as gas distribution lines) that had been safely under the old sidewalk. All of the existing mature street trees had to be removed and replaced with young trees. Utility relocation and street reconstruction on Flower Street and Washington Boulevard cost approximately twice as much per mile ($9 million versus $4.5 million) as the sum of the right-of-way purchase and railroad relocation costs in the adjacent private right-of-way segment.

LACTC attempted to reach an agreement with the DPW Bureau of Street Lighting (BSL) for the joint use of poles on Flower Street and Washington Boulevard but failed. BSL felt there would be an unacceptable risk to BSL maintenance personnel if street lights were mounted on poles supporting the overhead contact system. (The city of Long Beach, on the other hand, insisted on joint use poles as a condition of using public right-of-way.) BSL redesigned the Flower Street and Washington Boulevard lighting systems using 50-ft tall

electroliers, thus minimizing the number of street lighting poles. With the addition of contact wire support poles, however, the total number of poles per block increased.

The combination of removing mature street trees and adding contact system wires and support poles did not improve the appearance of either street. The Long Beach solution—joint-use street light and contact system support poles placed in the median between the Blue Line tracks—is a better solution where right-of-way width and utility policies permit.

As a result of the street widening, all of the traffic signals on Flower Street and Washington Boulevard were replaced. The replacement traffic signals are fitted with additional loop detectors between the rails and additional signal heads for the detection and control of LRVs. LACTC funded preparation of modified traffic signal controller software to support additional signal phases and variable levels of priority for LRVs. The new LRT phase software was installed in all traffic signal controllers along the Los Angeles CBD approach segment prior to revenue operations. The LRT priority software is still under development and is now scheduled to be installed in December 1992.

Trackway Structure and Drainage

The Los Angeles CBD approach tracks are supported by a reinforced concrete track slab. Fire trucks or maintenance vehicles driving on the trackway between intersections are supported by asphalt pavement placed between the rails on top of the track slab. At intersections, motorists crossing the trackway are supported by a second pour of portland cement concrete placed on top of the track slab.

Ballasted track needs to be maintained periodically (track realigned and the ballast rejuvenated) to maintain good ride quality. The Blue Line design criteria recognize that ballasted track is more likely to shift out of position than track supported by a concrete slab. The criteria therefore require a larger spacing (greater allowance for track shift) between parallel ballast-supported tracks than between parallel slab-supported tracks.

Embedded ballasted track is difficult to maintain because the embedding material must be removed to retamp the ballast. The Blue Line embedded track may well have been supported by a track slab even if the trackway were 24 ft wide as originally planned, just to reduce the maintenance requirements. With the "share the misery" 22-ft trackway width, the LA CBD approach trackway had to be supported by a track slab to comply with the design criteria. The 22-ft trackway is too narrow for two Blue Line tracks supported by ballast but is adequate for two tracks supported by a track slab.

The trackway is not crowned. At any longitudinal location, all four running rails have the same elevation. The trackway is separated from the adjacent roadways by a curb. Rainfall collecting on the asphalt embedment would form a large, shallow pond if some form of positive drainage were not provided.

Flower Street has sufficient longitudinal gradient so that drainage is not a problem. Water drains to the low end of any block, where it is intercepted by trackway catch basins. Washington Boulevard has very little longitudinal slope. The Washington Boulevard top-of-rail elevations match the roadway elevation at all intersections. Between intersections, the top of rail profile rises to a high point in the middle of the block, then falls to match the roadway at the next intersection. This false grading provides longitudinal slope to drain runoff to catch basins typically located in the trackway on either side of intersections.

CONCLUSIONS

The Los Angeles County Transportation Commission and Los Angeles (City) Department of Transportation were able to reach an agreement to dedicate a portion of the existing public street right-of-way to exclusive transit use. This agreement resulted in a permanent reduction in street capacity that could only be partially mitigated by transportation system management measures. That this happened in Los Angeles, arguably one of the more automobile-oriented cities in North America, should give inspiration to transit planners everywhere.

The side-running alignment on Flower Street and the median alignment on Washington Boulevard are successful. For various reasons automobile congestion on Flower Street and Washington Boulevard has decreased since Blue Line construction. No significant LRT-related accidents were reported on Flower Street or Washington Boulevard in 1991.

The construction resulting from the agreement was expensive—in the order of $20 million per mile for civil works alone. To optimize use of the public right-of-way for both LRT and automobiles, it was necessary to relocate most utilities and completely reconstruct the roadway and sidewalks. If a transit private right-of-way (not shared with an existing roadway or major utilities) is potentially available, planners should look hard at purchasing the private right-of-way. The Blue Line private right-of-way acquisition and railroad relocation costs per mile were approximately half the cost per mile of utility relocation and street reconstruction on Flower Street and Washington Boulevard.

If a transit agency plans to use street right-of-way for an LRT project, it is imperative that the traffic agency be brought into the planning process at an early phase. The traffic agency must accept the concept of reducing automobile capacity to increase the total number of riders or trips on all modes. Both the transit agency and the traffic agency will want to reduce conflicting movements to improve safety and operating speed. This common interest should be the basis for the many compromises that will be required to implement the project successfully.

Because of the removal of mature street trees and the addition of contact system wires and poles, LRT projects have the potential to diminish the appearance of the street. The transit agency and all participants in the transit project should make a commitment to aesthetic design.