Planning and Design of On-Street Light Rail Transit Stations

MARK C. WALKER

Planning for contemporary light rail transit (LRT) systems often presents the challenge of integrating modern stations into an on-street setting. In this context the planning and design of the station has consequences not only for the alignment and operation of the light rail line, but also for pedestrian movement, traffic flow, and safety. The planning and design of on-street LRT stations is divided into two general areas. First are the specific features of the stations and intersections, including platform size, high or low platforms, facilities for the disabled, fare collection arrangements, and other station features plus such roadway features as turn lanes and crosswalks. The second aspect is the configuration of the station tracks and platforms on or adjacent to the street.

Unlike commuter and rapid rail stations that are usually located off-street and streetcar stops that provide minimal facilities for the passenger, today's light rail transit (LRT) systems often present the challenge of integrating a station with multiple design features into an on-street setting. In this context the planning and design of the station has consequences not only for the alignment and operation of the light rail line but also for pedestrian access to the station, operation of the roadway or intersection, utilities, and safety. For purposes of this study, "on-street" includes stations that are on the side of a street as well as stations in the center of a street.

Early streetcar lines normally operated on tracks down the middle of a street in mixed traffic (with horses and carriages at first, then automobiles). Frequently no platform was provided—passengers had to contend with other traffic (and horse "exhaust") when boarding and alighting the vehicles. As streetcar and interurban services became more sophisticated, simple platforms were provided, but these often lacked shelters, seats, travel information, or other amenities for the passenger. Platforms were small, particularly in on-street settings. On the new generation of LRT systems, developed since 1980, more elaborate stations are standard, even where LRT is operating within a street right-of-way. New stations are normally at least 10 ft wide, 300 ft long, and often include shelters, seating, fare machines, transit information, facilities for the disabled, and high platforms. As older systems are refurbished, some of their stations are upgraded to contemporary LRT standards, as in Pittsburgh and San Francisco. Modern stations improve the quality of the transit passenger's trip, making LRT more competitive with car travel, but increase costs and problems, particularly in an on-street setting where space is often limited.

Parsons Brinckerhoff Quade and Douglas, Inc., One Penn Plaza, New York, N.Y. 10119.

The planning and design of on-street LRT stations can be divided into two general areas. First are the specific features of the stations and intersections. These include platform size, high platforms versus low platforms, facilities for the disabled, fare collection arrangements, safety provisions, and other station features plus such roadway features as turn lanes and crosswalks.

The second aspect is the configuration of the station tracks and platforms on or adjacent to the street. Examples include a center platform station in the center of the roadway, side platforms in the center of the roadway, a station to one side of the street, a "near and far" platform station where light rail vehicles (LRVs) stop on opposite sides of an intersecting street, and many other variations.

PLANNING ON-STREET STATIONS

The station planning and design process has two phases that overlap and interact. In the first phase, specifications and criteria that apply to all stations on a line or section of a line are determined. Such specifications and criteria include design features of the vehicles to be used that, once fixed, are quite inflexible. For example, if LRVs are obtained that allow only low-level or only high-level boarding, then all stations must conform. The third option, high and low platform boarding, gives the most flexibility but may not be justified in many cases. Another example is access for the disabled. Normally a single method of providing for disabled access to vehicles is established for an entire system or line. Other standards such as platform length and width, minimum curvature in stations (if any), and architectural design may be set for an entire line or system but may be flexible where conditions warrant.

The second phase of station planning addresses the requirements of each individual station. Planning and design of each station responds to its particular setting and system standards may be modified where required. For on-street stations, variations may include configuration of the platforms, tracks, roadway, turn lanes, traffic and pedestrian access patterns, platform width, arrangement of walkways and crosswalks, and station amenities such as shelters, benches, vending machines, ramps, and landscaping.

Station Planning Issues

A number of issues may affect the configuration and design features of a particular station or all stations on a line. These

include physical and alignment geometry constraints at a particular location, utilities present, anticipated patronage, climate, and the design of LRVs to be used. Other less tangible factors such as personal safety, environmental concerns, political considerations, and community input may also affect station planning and design. Although many issues are common to all stations, including on-street stations, other issues or their effects are unique to on-street stations.

Accessibility for the disabled is an increasing concern as a result of the Americans with Disabilities Act of 1990. The act requires that key stations in existing rail transit systems and all new stations be made accessible to the disabled.

Pedestrian Access

Because all passengers will, for some time, be pedestrians at the beginning and end of their trip by light rail and most will reach their destination on foot at one end of the trip (rather than transfer to car or bus), pedestrian access to stations is an important consideration in the overall quality of the transit trip. Pedestrian access to on-street station platforms is affected both by the layout of platforms, tracks, and roadways and by barriers to pedestrian movement that may be incorporated into the design of the station. At the broad scale, pedestrian access means locating a station as close as possible to passenger destinations, particularly dense concentrations such as office buildings, shopping, or entertainment centers. Likewise a station may be located so that new development can be clustered around it. The distance to destinations, which must be measured in terms of actual walking distance (not necessarily a straight line), becomes increasingly critical as Americans and others become increasingly accustomed to the "park in front of the door" convenience of the automobile. With on-street stations, station location and distance to destinations must be balanced with alignment constraints, roadway design, and other factors. The LRT planner must bear in mind that the ultimate purpose of the LRT system is not to merely operate trains but to deliver passengers most conveniently to their destination.

Layout of the station and its on-street setting is the second aspect of providing convenient pedestrian access to the station platforms. The fact that the station is on or adjacent to a street itself places a constraint on easy pedestrian access, depending on the volume and speed of traffic and the width of the roadway. If crosswalks to the platform are located only at one end of the platform, then passengers approaching the station from the opposite end will have a significantly longer walk to reach the appropriate position on the platform—or they may jaywalk, a safety problem. In cases where traffic on an adjacent roadway is extremely heavy or fast, a pedestrian bridge or tunnel may be used. Other design elements may limit pedestrian access and circulation deliberately or unintentionally. Normally, pedestrians can cross LRT tracks because there is no third rail. At some locations, however, this may be undesirable or impractical. Elements that may restrict pedestrian circulation include barriers to crossing tracks, high platforms, restrictive signage, or other barriers. Naturally a balance must be struck between pedestrian safety and free pedestrian circulation but excessive concern for safety may unnecessarily limit circulation.

Transit Operation

Providing fast, reliable, and safe operation of the LRT line is a central consideration in planning on-street stations. Any location where cars or pedestrians may cross tracks creates a potential constraint on LRV operation. Where vehicles may be "caught" on tracks or pedestrians cross in large numbers, safety may be compromised and operation must be slowed to compensate. This issue also pertains to the placement of platforms at a signaled intersection. Whereas bus stops may be most effectively located on the far side of an intersection when buses are in heavy mixed traffic, LRT platforms are often best located on the near side of the intersection if the LRV is on an exclusive trackway and no signal preemption is provided. Other things being equal, the speed of LRV operation is enhanced if a station is placed near a location where the LRV would have to slow or stop anyway (such as a tight curve or signaled intersection) instead of a location where open running is possible (such as the middle of a long straight run). In all cases, however, the final measure of LRT operation is in service to the passenger, not in the operation of trains.

Traffic Flow

Layout of an on-street LRT station may significantly affect the movement of traffic by the provision or exclusion of left or right turn lanes, conflict with pedestrians approaching the station, and buses or cars stopping in traffic lanes to pick up or drop LRT passengers. Both the volume of traffic on the street and the volume of "conflicting" movements by buses, LRVs, pedestrians, and turning cars are factors in determining what steps should be taken to maintain traffic flow.

Transfers to Bus

Convenient transfer between buses and light rail is an issue at many on-street LRT stations. The transfer itself is an integral and important part of the overall transit trip. Locating bus stops close to station platforms and making the transfer connection as convenient and visible as possible are key. Depending on station layout, a number of bus stop locations may be possible, including along a parallel road, cross street, along the outside of the LRT platform, or with buses sharing the LRV travel lane to stop at the same platform. In each case, space for buses to stop, their effect on local traffic, and space for bus stop elements and queues must be considered. An additional arrangement involves joint operation of LRVs and buses on the same transitway allowing both to use the same platforms. This may occur along a stretch of the LRT line or may occur only at certain stations. In this case, the effect of shared right-of-way on LRT and bus operations must also be considered.

Safety

Safety is a critical issue throughout any transit system. However, nowhere are safety issues more visible than around an on-street LRT station. Four potential safety concerns are found here. First is the conflict between pedestrians and street traffic.

Whether station platforms are located in the median or along the side of a roadway, pedestrians will cross the road to the station. Passengers trying to catch an approaching train may pay little attention to traffic. The second conflict occurs between LRVs and pedestrians who are usually allowed to cross the tracks near stations. Because an LRV may approach relatively rapidly and silently, passengers disembarking an LRV may fail to see a train approaching from the opposite direction, or other pedestrians may fail to look both ways before crossing tracks. The third safety conflict is between LRVs and traffic. Although this issue is not directly related to the station, on-street stations are often located at intersections where roadways cross tracks, so the overall layout of the station and intersection is integral to safe LRT operation. Depending on the frequency of LRVs and the volumes of traffic and pedestrians, these first three conflicts can be mitigated by visible crosswalks, clear roadway markings, physical barriers, signs, and signals for vehicles, trains, and pedestrians. In the most severe cases, grade separations may be used.

Personal security of passengers is the fourth safety issue at on-street stations. The on-street location of these stations provides more visibility and natural surveillance from the community than most off-street locations. However, in some cases, increased visibility, enhanced lighting, or emergency call boxes are suggested. If a station is even *perceived* to be unsafe, patronage will suffer.

Access for the Disabled

Accessibility for the disabled is an increasing concern. In the United States this concern resulted in the Americans with Disabilities Act of 1990. The act requires that key stations in existing rail transit systems and all new stations be made accessible to the disabled. The act requires that at least one vehicle per train be accessible by July 26, 1995. Key stations on existing systems should be accessible by July 26 although extensions may be granted. All stations constructed or remodeled after January 26, 1992, must be accessible. In addition to the accessibility issues at all light rail stations, on-street stations often require that handicapped persons cross the street to reach the station.

The act distinguishes between two types of right-of-way and requirements for accessibility. "Vehicles intended to be operated solely in light rail systems confined to a dedicated right-of-way, and for which all stations or stops are designed and constructed for revenue service after January 26, 1993, shall provide level boarding. Vehicles designed for and operated on pedestrian malls, city streets, or other areas where level boarding is not feasible shall provide wayside or car-borne lifts, mini-high platforms, or other means of access." For level boarding or high blocks, the U.S. Department of Transportation stipulates that the horizontal gap between platform and vehicle floor be no greater than 3 in. and that the height of the vehicle floor be no more than 5/8 in. above or below the platform.

Fare Collection System

The fare collection system in use on a line or at a particular station may have a direct bearing on the design of a station. Two basic methods of fare collection may be used in light rail systems, on-board or in-station. With an on-board fare collection system, tickets are validated or fares collected by an on-board validation machine or the operator. With an in-station fare collection system, tickets, tokens, or fares are collected as the rider enters a controlled area of the station. Where fares are collected on-board, ticket vending machines may be located in stations, if desired, but no barriers, turnstiles, or other fare collection devices need be located in a station and access to the platform can be from any direction. An in-station fare collection system places greater demands on station space and design, but improves system operation at a busy station. In-station fare collection requires space for ticket vending machines, turnstiles, and barriers to segregate the paid fare zone. In addition, access and egress from the station are limited to certain locations, potentially increasing walking distances and congestion. Self-service proof-of-payment (or "honor") systems, in which passengers validate their own tickets or carry passes and inspectors make random inspections, display characteristics of both on-board and in-station fare collection and provide the smoothest operation and fewest demands on station space.

Patronage at Station

The pattern of passenger usage at a particular station may be important in the layout of the station. The volume, primary direction, and frequency of use on each platform may be considered in sizing platforms and walkways, providing amenities, and determining operating practice at the station if these differ from the norm for the system. The direction of travel is particularly important in determining whether passengers will be primarily boarding or alighting at a particular platform, or both. Passengers who are boarding typically wait on the platform, thus requiring such amenities as benches and shelters whereas passengers alighting will depart the platform quickly. Thus two platforms at the same station may be appointed differently. In situations where patronage is very low and intermittent, shorter than standard platforms and on-call or "flag stop" service may be provided. A station where excessive volumes are periodically generated, such as at a sport stadium or fair grounds, may have longer platforms to load more than one train simultaneously or a siding to hold waiting trains.

The patronage at a station may have a direct impact on the size of platforms required. Generally a minimum platform width and length is specified for a system to accommodate the maximum train length and provide a space deemed adequate or comfortable. If patronage at a particular station would exceed the reasonable capacity of the minimum platform size, then a wider platform may be needed. The size requirements of inbound and outbound platforms may differ because passengers may dwell longer on one platform (usually inbound) than on the other. The same platform may also require more features such as shelters, ticket vending machines, and other vending machines.

In-Street Utilities

When an LRT line and stations are incorporated into an established urban setting, extensive utilities are almost always

found under streets. To maintain underground utilities, surface access must remain possible, often by relocating utilities away from the LRT trackbed. Where the cost of reconfiguring the utilities or providing alternate access is prohibitive, the layout of tracks and station may be modified.

Design of LRVs Used

In the early stages of planning, the features of the LRVs to be used may interact with planning for stations. However, once the design of LRVs is fixed, station design must conform, whether or not the station is in an on-street location. This is particularly relevant to the placement and loading height of doors, including left- versus right-side boarding, width of cars, and maximum length of trains.

Station Design Elements

To address the issues just discussed, a number of specific features of the station and roadway design are considered. For on-street stations the design of the station is integral to the design of the street or intersection. Thus design elements relevant to on-street stations include elements of the street, such as traffic lanes, turn lanes, crosswalks, and traffic signals, in addition to elements directly related to the light rail line. In determining the design of the station, conflicting issues must be resolved or balanced, and design features must respond to each other and the physical constraints of the site.

Platform Level and Access for the Disabled

Platform level and the provision of access for the disabled to trains are interrelated, so these features can be addressed together. Four basic combinations of features are possible. To some extent, more than one of these combinations can be used at different stations within a system.

High Platform High platforms are approximately 39 in. above rail and street level. A ramp approximately 44 ft in length, including one landing, is required for wheelchairs to reach platform height from street level. Other access may be provided by stairs and additional ramps. Advantages and disadvantages of high platforms include the following:

- Provides fastest easiest loading for all passengers,
- Controls and limits movement of people around the station,
- Provides easiest loading for people who would not use a wheelchair lift but who have difficulty climbing steps, including people with baby carriages and passengers carrying packages,
- Requires no maintenance and does not suffer from potential unreliability (unlike mechanical devices),
- Allows boarding by disabled with no delay to operations (unlike mechanical devices),
- Requires a ramp to reach platform and additional space that may further affect on-street setting,
- Has higher construction cost than low platform, and
- Requires that all stations on a line use high platforms, unless LRVs are equipped to load from both high and low levels.

Low Platform with Mini-High Platform A mini-high platform (or "high block") is a small raised platform at vehicle floor level normally located at the front end of the full platform. The mini-high platform, approximately 39 in. above rail level, is normally reached by a ramp approximately 44 ft in length, although a lift can be used to reach the mini-high platform. Even the smallest mini-high platform may be difficult to accommodate in a tight setting, but larger and more elaborate mini-high platforms can be used where space permits. Trains may stop regularly with the front door by the operator's cab on the mini-high platform so that anyone who wishes can use the level entrance, or LRVs may stop short of the mini-high platform except when a disabled person wishes to board or alight at the mini-high platform. When the vehicle's stairwell creates a gap between the mini-high platform and the vehicle floor, a movable bridge is placed by the operator to cross the gap. Advantages and disadvantages of low platforms with mini-high platforms include the following:

- Depending on operating procedure, the platform may be used by others who have difficulty climbing steps, including the elderly, passengers with baby carriages, and passengers carrying packages.
- Unlike mechanical devices, the platform requires little maintenance and does not suffer from potential unreliability.
- Unlike mechanical devices, the platform allows the disabled to board without causing delay to operations.
- Mini-high platforms require more space than mechanical devices, especially because of ramps. They can be difficult to accommodate in a tight station space, such as in a street median or on a narrow sidewalk. Required placement (usually at the front of the train) may limit circulation onto the platform in some station configurations.
- A lift may be used with a mini-high platform to save space and loading time (the LRV does not have to wait for lift to be operated), but this introduces a maintenance cost and the potential unreliability of a mechanical device.
- Most passengers must climb steps into the vehicle, which makes loading slower than from a high platform.
- Low platform can be approached from any direction and passengers can cross tracks directly if desired (no stair or ramp is required to reach the platform). However, placement of the mini-high platform can limit circulation, particularly in a tight setting.
- Mini-high platforms may introduce operational constraints where the splitting or combining of trains is desired to serve multiple branches of an LRT line.

Low Platform with Mechanical Lift Mechanical lifts come in a variety of designs and may be located at stations or may be built into LRVs. In-station lifts take much less space than a mini-high platform with ramps. However, a mechanical lift that accesses the vehicle directly must be operated while the LRV waits in the station, delaying all of the passengers, whereas

a lift to a mini-high platform can be operated by the user before the train arrives. Advantages and disadvantages of low platforms with mechanical lifts include the following:

- They require less space than mini-high platforms.
- They require maintenance and may suffer from potential reliability problems.
- Because lifts must be operated then locked away while the LRV sits in the station, they cause a delay to all passengers.
- Most passengers must climb steps into the vehicle, which makes loading slower than from a high platform.
- Because of the inconvenience of using lifts, only wheelchair passengers will generally use them. Others who may have difficulty climbing into the vehicle will climb nonetheless (or use other transportation).
- Lifts are normally installed at stations (wayside lifts) or on LRVs (on-board lifts).
- A low platform can be approached from any direction and passengers can cross tracks directly, if desired (no stair or ramp is required to reach the platform).
- Fixed position wayside lifts may introduce operational constraints where the splitting or combining of trains is desired to serve multiple branches of an LRT line.

Low Platform with Low-Floor Vehicles A relatively recent development in LRV design, low-floor vehicles have a floor height approximately 12 in. above rail or street level as compared to approximately 39 in. for standard LRVs. Thus a platform raised only slightly above street level (say 6 to 12 in.) and a simple ramp on the vehicle provide easy access for wheelchair passengers. Boarding for all passengers is essentially level. Low-floor LRVs have been introduced in a number of European cities. Advantages and disadvantages of low-floor vehicles include the following:

- They provide fast, easy loading when all doors are at low level.
- They offer easiest loading for the elderly and disabled who would not use a wheelchair lift, people with baby carriages, and passengers carrying packages.
- No mechanical devices require maintenance or suffer from potential unreliability.
- Unlike with mechanical devices, boarding by the disabled causes no delay to operations.
- A low platform can be approached from any direction and passengers can cross tracks directly, if desired (no stair or ramp is required to reach the platform).
- Replacement of existing vehicles may not be practical in some locations.
- Low-floor vehicles increase constraints to vertical curvature of tracks and may cause undervehicle clearance concerns, particularly in snowy conditions.

Left and Right Turn Lanes

For on-street stations located at or near intersections, the provision of left or right turn lanes is integral to the overall design of the station and intersection. Left or right turn lanes may compete with station platforms for limited space. At the same time provision of turn lanes may be made more important by the presence of the LRT line. If the LRVs and parallel traffic are signaled to proceed at the same time, then turning vehicles that would cross the tracks must wait. If no turn lane is provided, waiting vehicles will block one of the through lanes, significantly reducing intersection capacity. Although left turn lanes are most common, right turn lanes may be required where an LRT line parallels one or both sides of a street and may compete with station platforms for limited space. Where there is sufficient space, turn lanes can be located adjacent to a station platform. Where space is more constrained or where better roadway geometry is desired, locating platforms on the far side of the intersection in line with turn lanes reduces right-of-way requirements. When parking is provided along a street with an LRT line, parking can be eliminated at intersections to provide space for a turn lane or station platform. Locating a station in midblock also frees space at intersections for turn lanes but raises other issues such as pedestrian access.

Pedestrian Access to Station Platforms

Access to station platforms is provided by walkways, crosswalks, stairs, or ramps and is limited by pedestrian barriers, signs, and by changes in height as with high platforms. Passengers may be able to reach platforms from any direction, including across tracks, or access may be limited to only one or two points. Provision of more access points shortens walking distances but may adversely affect safety and train operations. At the same time, because many passengers will take the shortest route when possible, omitting a walkway or attempting to restrict movement through signage may simply inconvenience the passenger without really enhancing safety or operations.

LRV Lane Shared with Traffic and Exclusive Right-of-Way

The LRT right-of-way at a station may be independent of all other traffic, may be shared with general traffic, or may be shared only with buses. Use of a shared lane reduces overall space requirements but inhibits LRT operations and vehicular traffic when an LRV is stopped in the station. Where LRVs run in mixed traffic along most of a roadway, an exclusive lane for LRVs may be provided approaching a station at an intersection where traffic queues could block passage of the LRV. This arrangement allows LRVs to stop without blocking any traffic and to pass a line of cars waiting at the signal.

Size of Platforms

Platform size is determined by minimum design standards, patronage, and amenities to be located on platforms, such as benches, shelters, ticket machines, and vending machines. Where vehicular traffic is very light and slow, little or no platform may be provided—passengers can board through traffic lanes as was common with streetcars. Where a platform

is required because of traffic conditions or minimum design standards, platforms may be as narrow as 3 ft. However, contemporary standards for new station construction, including ADA provisions, typically call for platforms at least 10 ft in width for side platforms and 15 ft for center platforms. More space may be provided where high boarding volumes warrant or simply where space and budget are available.

Associated Bus Stops

Where transfer between LRT and bus routes occurs, the location of associated bus stops is an integral part of overall station and intersection design. Placement of bus stops affects the distance that transferring passengers must walk and the traffic they must cross (if any). If no bus pull-out is provided, stopped buses also block traffic on the street, suggesting placement of the bus stop on the less traveled road where possible. On-street stations provide opportunities to directly relate bus stops to station platforms without diverting buses from their routes. Depending on station configuration, potential bus stop locations include a cross street, a parallel roadway, directly across from the LRT on the same platform, or buses may share the LRT lane and load at the same platform.

ALTERNATIVE STATION CONFIGURATIONS

Potential configurations of on-street station elements, including platforms, tracks, roadways, and pedestrian facilities, are nearly unlimited. Moreover, each configuration has consequences for transit, traffic, pedestrians, and adjacent land uses. The many possible configurations can be represented by a more limited number of basic configurations. These configurations are presented in this section under three categories: stations at intersections, midblock stations, and stations on transit malls. As indicated in the introduction, on-street stations may be either in the center of a roadway, on both sides, or to one side of the roadway.

For purposes of presenting alternative station configurations in a uniform manner, certain dimensions that vary in practice are held constant on the accompanying figures. Most of the layouts shown include left turn lanes. However, a narrower cross section can be achieved if left turn lanes are omitted.

Stations at Intersections

Center Platform Station in Street Median

Figure 1 shows a center platform station located in the street median with LRT tracks on exclusive right-of-way. Access to platforms in this arrangement, like most median stations, is normally limited to one or both ends of the station. Care must be taken that pedestrians waiting on the median to cross do not block the tracks. If sufficient right-of-way is available, curbside parking can be located along the sides of the street at the station or parking can begin beyond the station as tracks and roadways converge. Operation of LRVs on an exclusive right-of-way at the station limits the impact on traffic and LRT operation, particularly if left turn lanes are provided.

A similar layout with LRVs in mixed traffic at the station is also feasible. Left turn lanes are not practical with this layout. Operation of LRVs in mixed traffic at the station has a significant impact on traffic and LRV operation—LRVs may have to wait for cars waiting at the signal to move before stopping at the station and cars, particularly those turning left, must wait for an LRV to leave. Therefore such a layout is most useful where traffic is light and available right-of-way is minimal.

Side Platform Station in Street Median

Figure 2 shows a side platform station located in the street median with LRT tracks on exclusive right-of-way. Access to platforms may be limited to one or both ends of the station or, if traffic is light and low platforms are used, crosswalks to adjacent sidewalks can be located along the length of the station. If sufficient right-of-way is available, curbside parking can be located along the sides of the street at the station or parking can begin beyond the station as tracks and roadways converge. Operation of LRVs on an exclusive right-of-way at the station limits the impact on traffic and LRT operation, particularly if left turn lanes are provided.

Near and Far Platform Station in Street Median

Figures 3 and 4 show "near and far" platform stations located in the street median with LRT tracks on exclusive right-of-way. Figure 3 shows the layout with a straight track alignment and left turn lanes, whereas Figure 4 shows the layout with an S-curve but without left turn lanes. The primary advantage of these schemes is their minimal right-of-way requirements. "Near and far" platform arrangements offer the narrowest right-of-way requirements. A layout in which the outside track on each side of the intersection is in mixed traffic is also possible. Access to platforms may be limited to one or both ends of the station or, if traffic is light and low platforms are used, crosswalks to adjacent sidewalks can be located along the length of the station. If sufficient right-of-way is available, curbside parking can be located along the sides of the street at the station or parking can begin beyond the station. Operation of LRVs on an exclusive right-of-way at the station limits the impact on traffic and LRT operation, particularly if left turn lanes are provided.

Sidewalk Platform Station with LRT on Both Sides of Street

Figure 5 presents a sidewalk platform station with LRT tracks along both sides of the street. This layout may be applied either with the LRT on an exclusive right-of-way (as shown) or in mixed traffic. Platforms may be fully integrated with sidewalks or may be separate, particularly if high platforms are used. The layout of the street and turn lanes is flexible with this arrangement but curbside parking is not possible with either layout. Operation of LRVs on an exclusive right-

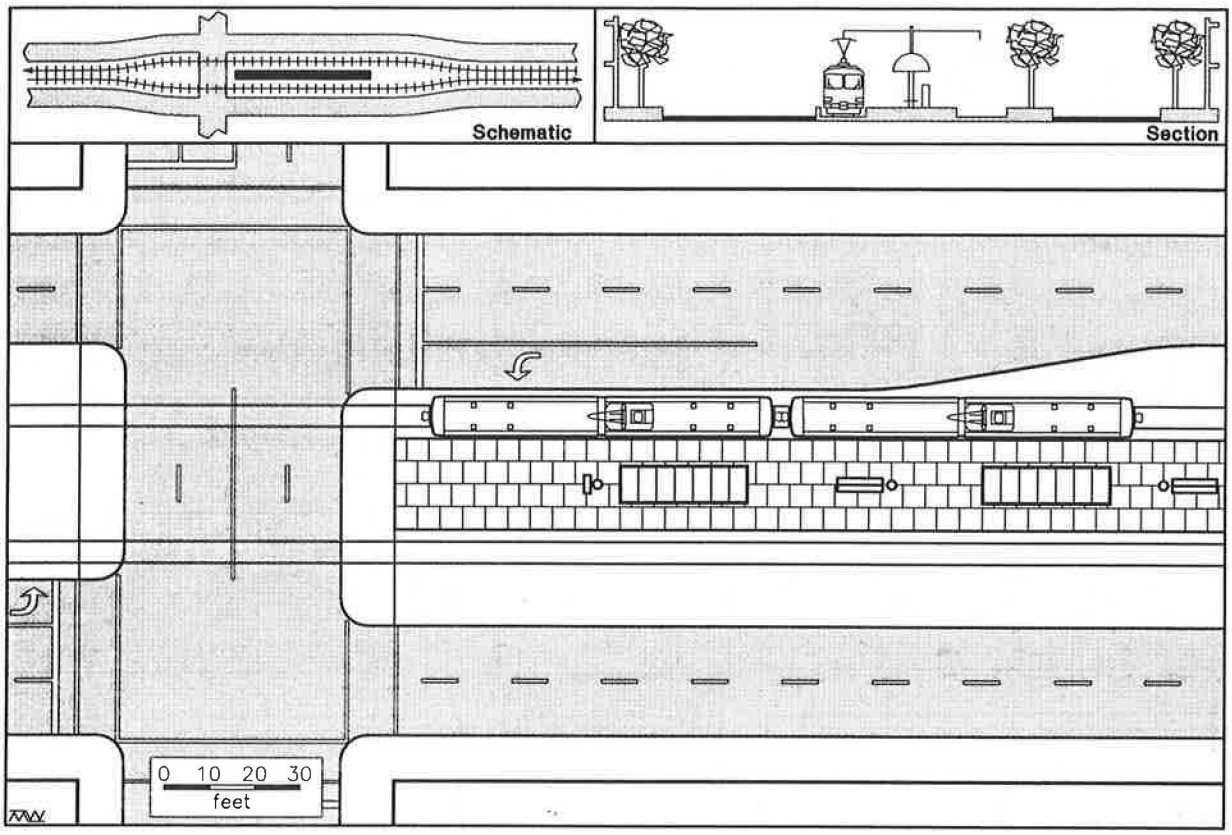

FIGURE 1 Center platform station in street median.

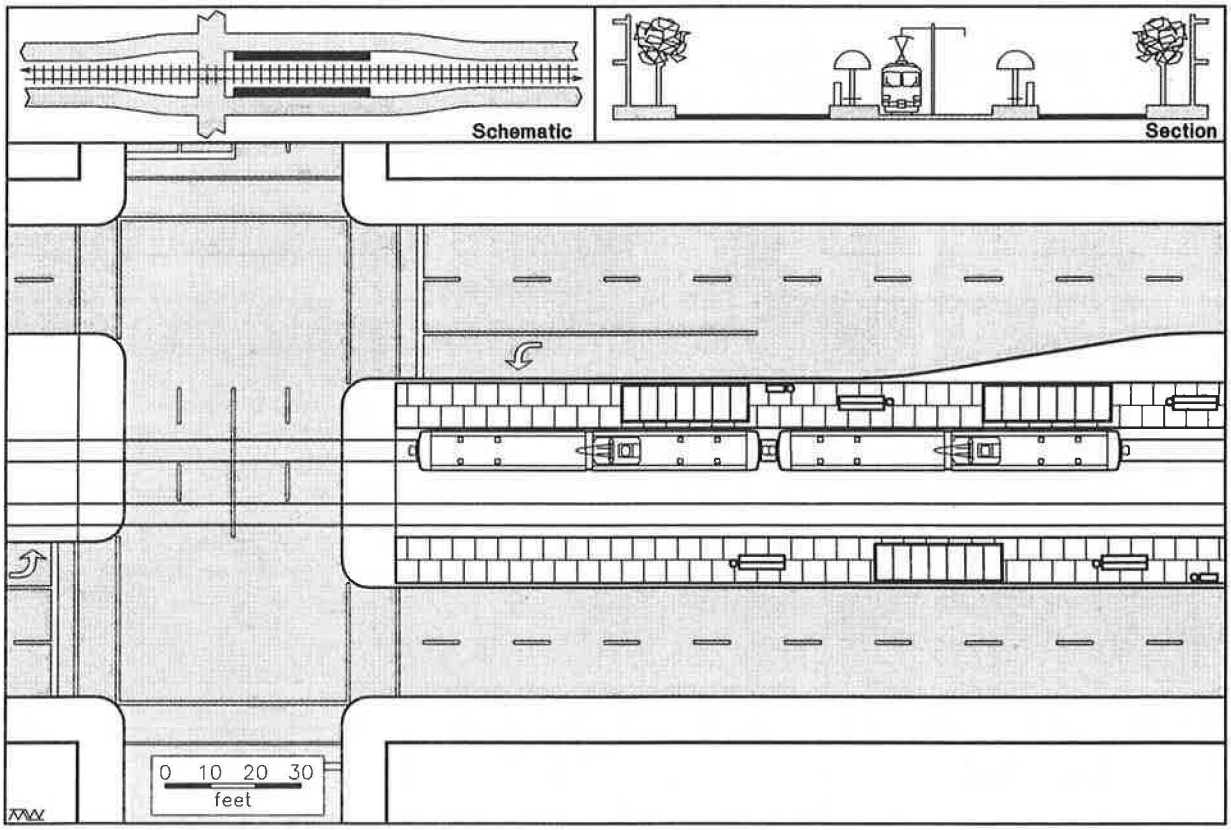

FIGURE 2 Side platform station in street median.

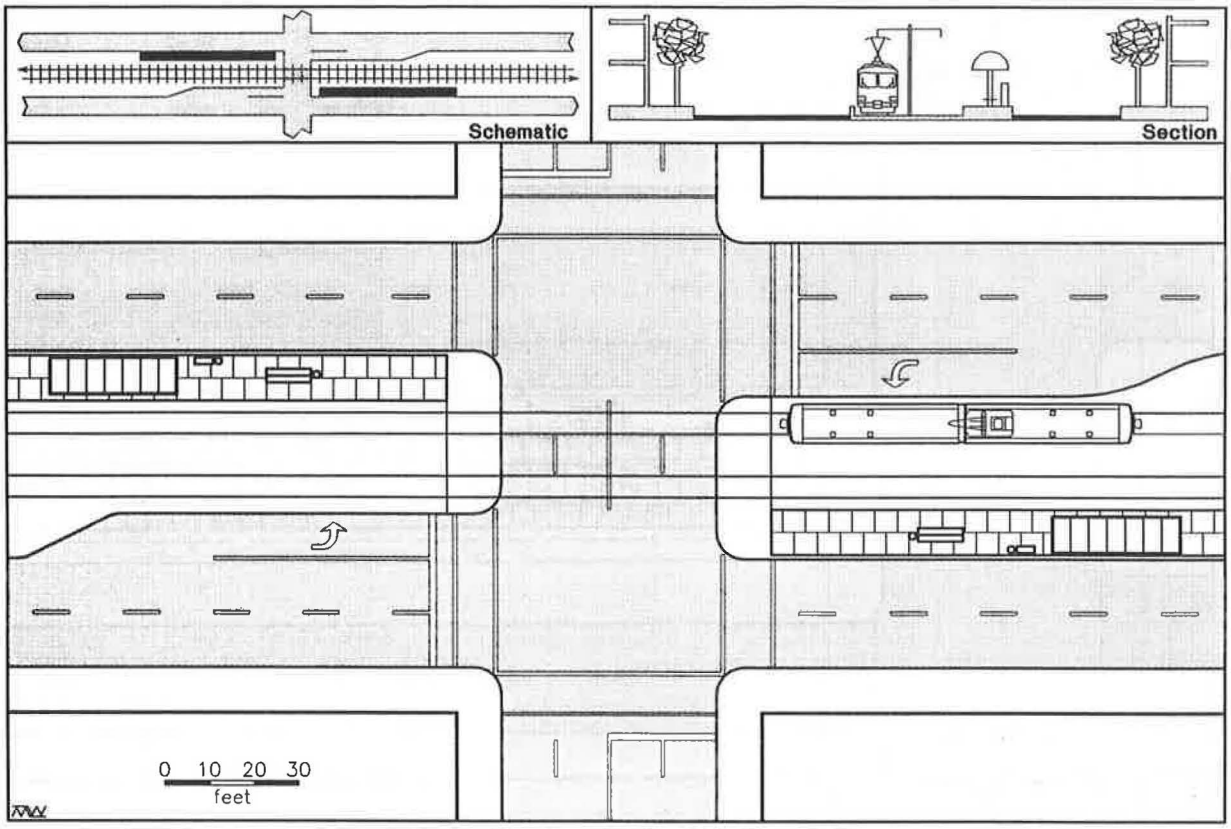

FIGURE 3 Near and far platform station with left turn lanes.

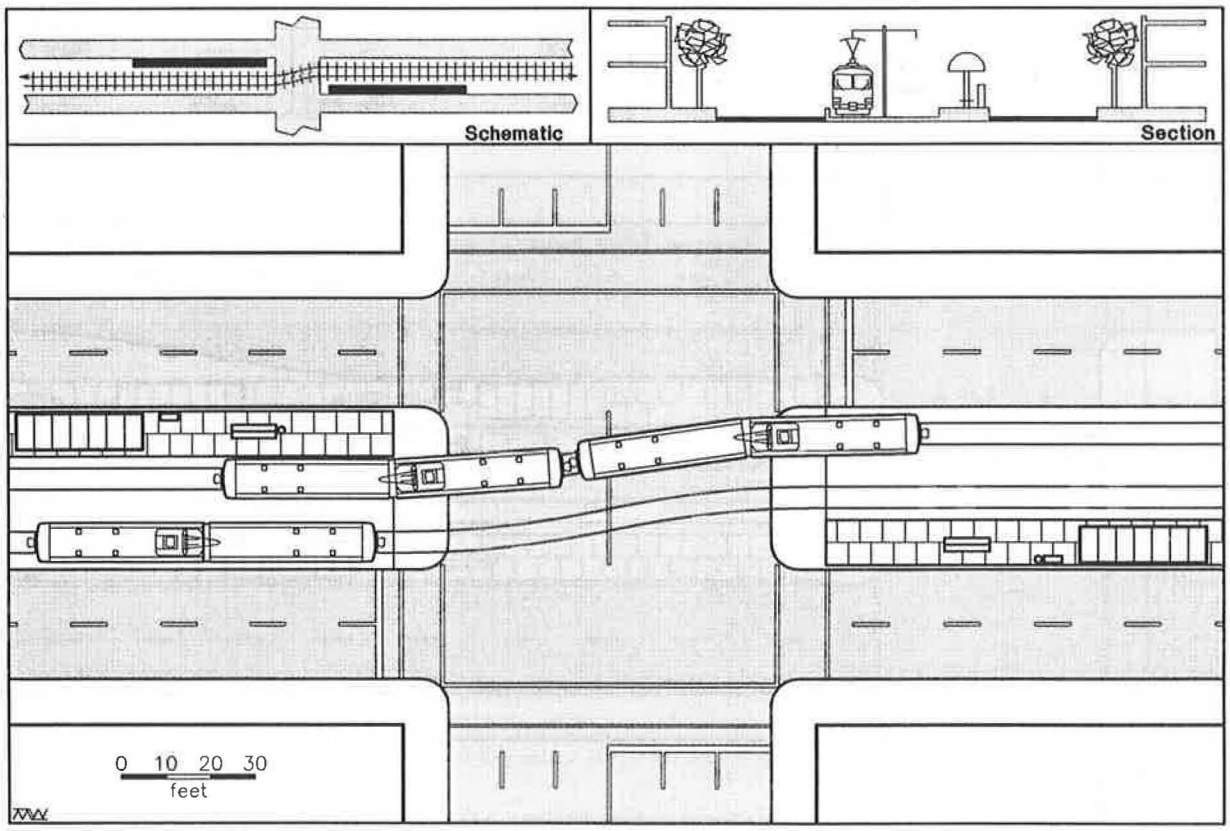

FIGURE 4 Near and far platform station in minimum right-of-way.

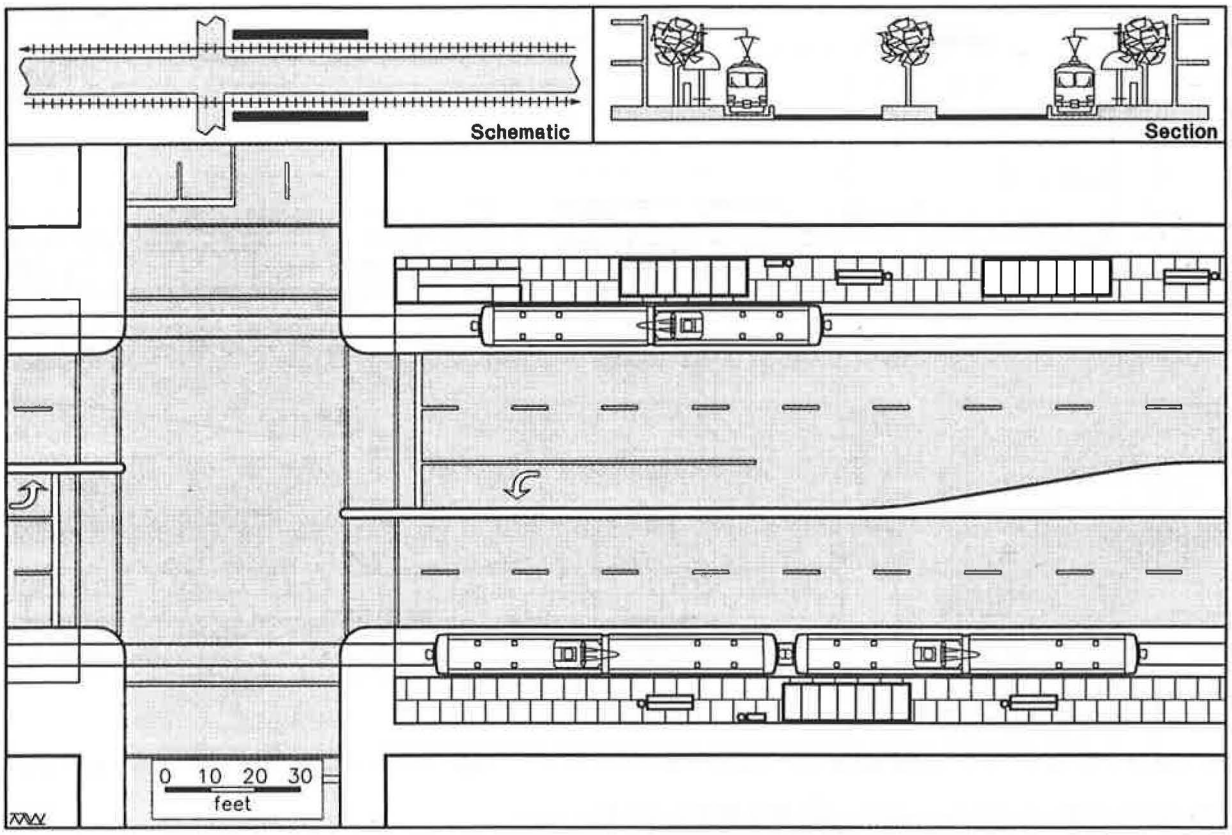

FIGURE 5 Sidewalk platform station with LRT along both sides of the street.

of-way limits the impact on traffic, whereas mixed traffic operation in curbside lanes affects traffic and invites standing or disabled vehicles to block LRVs. In either case buses can stop at the platform, providing a direct LRT-to-bus transfer.

Sidewalk Platform Station with LRT Running "Outboard" on Both Sides of Street

Figure 6 presents a sidewalk platform station with LRT tracks located "outboard" on both sides of the street. In this layout station platforms and sidewalks are between the street and the LRT tracks. The layout of the street and turn lanes is flexible with this arrangement and operation of LRVs on an exclusive right-of-way limits the effect on traffic and LRT operation. Unlike the arrangement presented in Figure 5 the "outboard" configuration does not affect parking in the curb lane and buses can stop adjacent to station platforms, making for a direct transfer between LRT and bus. However, direct access to properties along the right-of-way is limited unless a parallel walkway is provided. Therefore this alignment is most useful where properties do not front directly on the street.

Center Platform Station on One Side of Street

Figure 7 presents a center platform station where both tracks are located in exclusive right-of-way on one side of the street. Access to the platform is limited to one or both ends of the station. Care must be taken that pedestrians waiting at the end of the station to cross the street are aware of trains and do not block tracks. Because one track is adjacent to the street, cars cannot park along the curb, and direct bus loading is not possible. Direct access to properties along the right-of-way is limited, making this arrangement most useful where properties do not front directly on the street. The layout of the street and turn lanes is flexible with this arrangement and operation of LRVs on an exclusive right-of-way limits the impact on traffic and LRT operation.

Side Platform Station on One Side of Street

Figure 8 presents a side platform station where both tracks are located to one side of the street. Care must be taken that pedestrians waiting at the end of the station to cross the street are aware of trains and do not block tracks. With side platforms and a continuous sidewalk between the roadway and adjacent tracks, curb parking can be located along the side of the street at the station or buses can stop adjacent to station platforms, making for a direct transfer between LRT and bus. Access to adjacent properties is not limited by this arrangement, and the layout of the street and turn lanes is flexible.

Midblock Stations

Most of the arrangements presented for stations at intersections may also be applied at midblock locations.

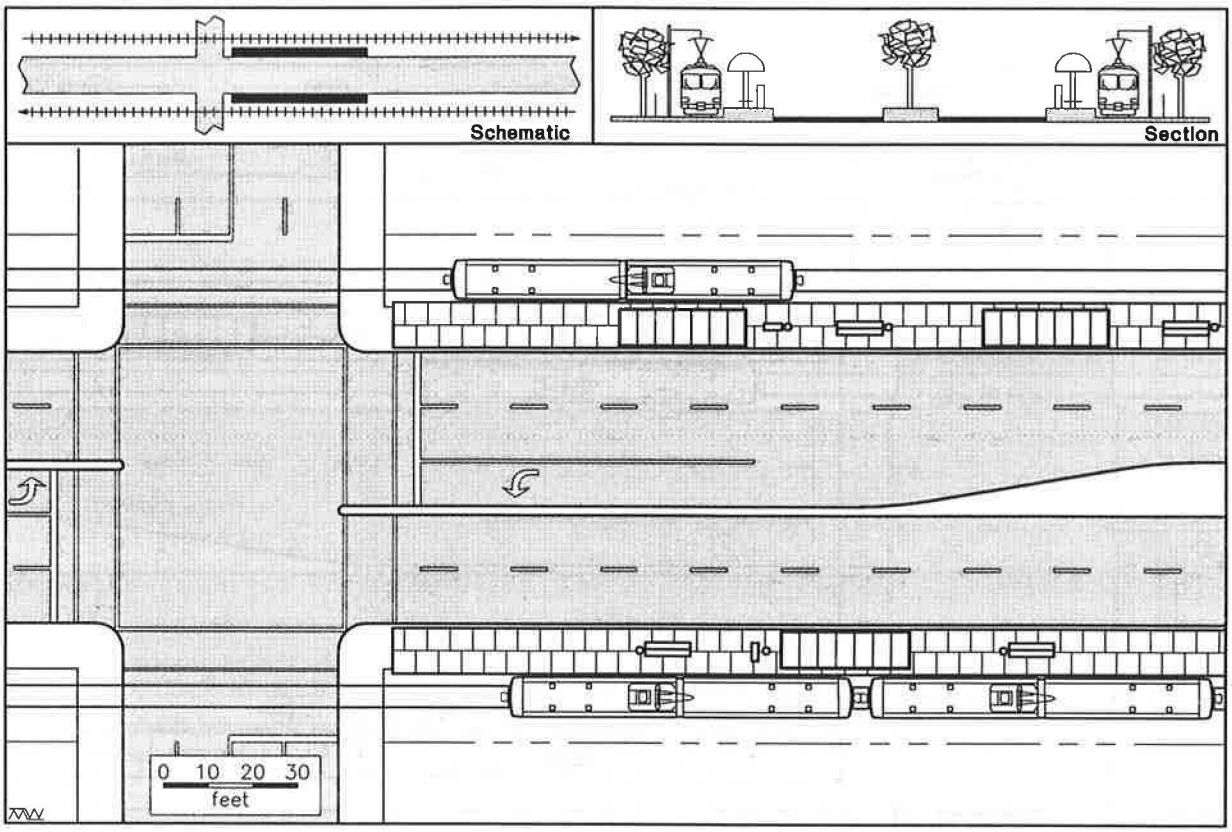

FIGURE 6 Sidewalk platform station with LRT on the outside.

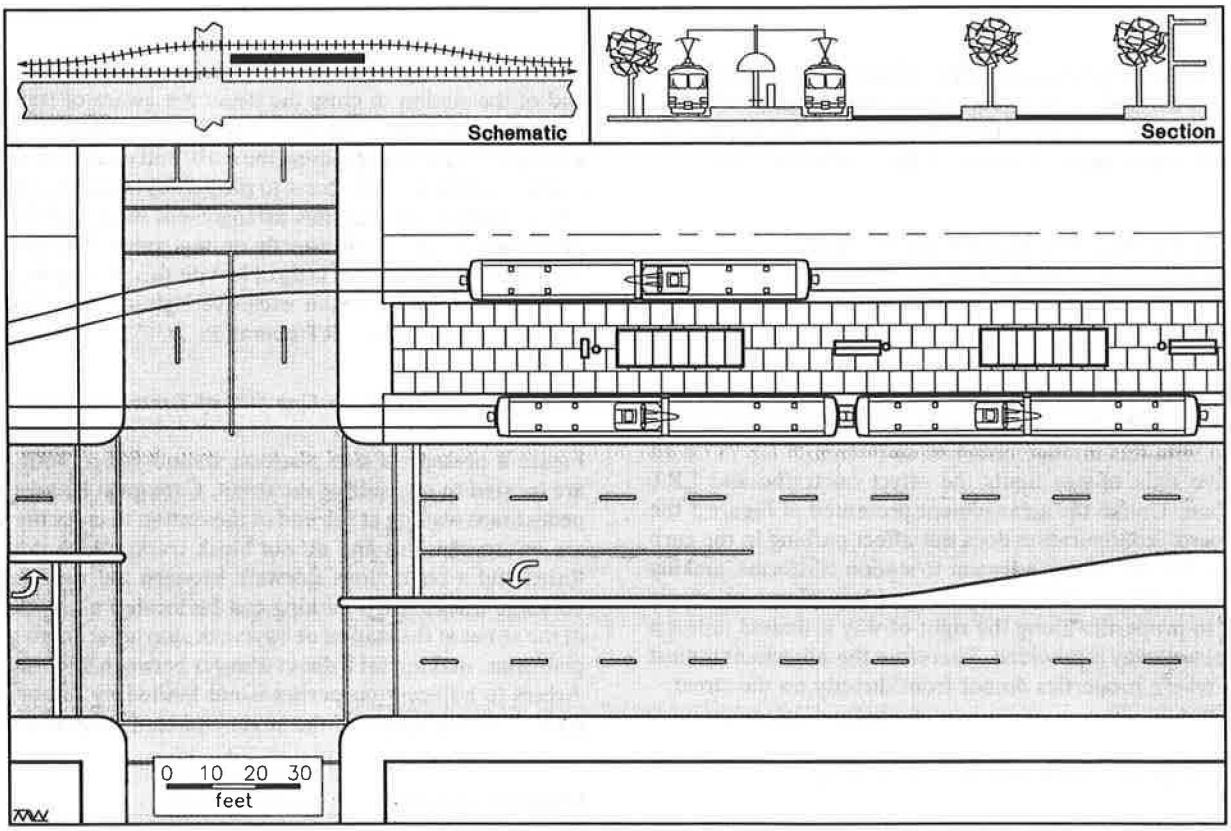

FIGURE 7 Center platform station on one side of the street.

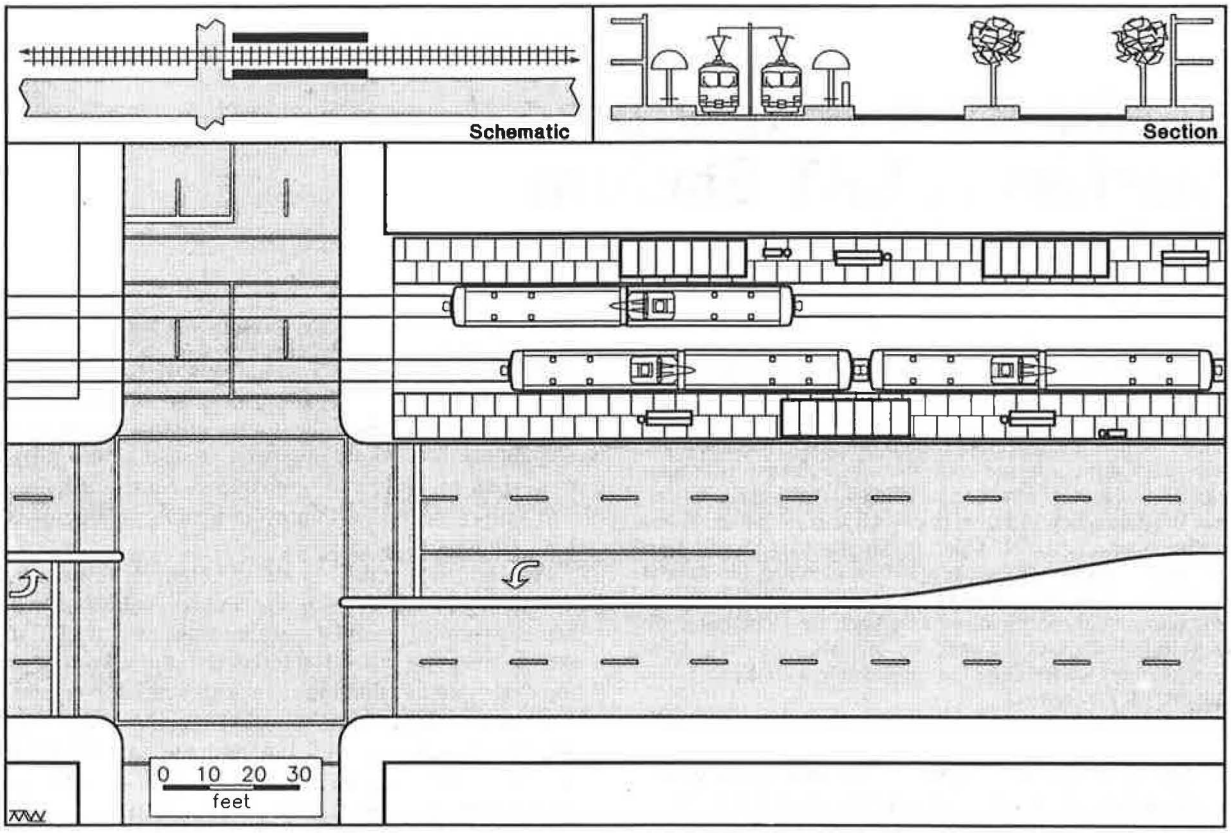

FIGURE 8 Side platform station on one side of the street.

A midblock station may be located where a major trip generator or pedestrian route lies between intersections. A midblock location also avoids the traffic congestion and competition for limited space found at intersections.

Stations on Transit Malls

Closing a street to general traffic and developing a transit/pedestrian mall is the ultimate answer to minimizing pedestrian-automobile and transit-automobile conflicts. This option is useful where traffic can be diverted, where pedestrian volumes are heavy, or where available space is limited. A transit mall may be limited to LRVs, or may allow buses to share the same roadway and station facilities.

ACKNOWLEDGMENT

This paper was prepared with support from the William Barclay Parsons Fellowship Program.