# BRT

## BUS RAPID TRANSIT SERVICE DESIGN GUIDELINES


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## 1. VISION STATEMENT

A rapid, high quality, brand-distinguished bus service that provides the same level of service as rail transit (in terms of frequency, capacity, quality, and reliability), except with greater flexibility and lower capital investment costs.

## 2. MODAL OVERVIEW

Bus Rapid Transit (BRT) is an approach to providing high quality rapid transit service with rubber-tire buses. Buses are primarily standard 40 foot and articulated 60-foot buses; however, in cases where demand is high double- and triple-articulated buses are used, as is the case in Curitiba, Brazil. BRT systems can offer many of the same features as rail transit — high frequency, high capacity, high quality, and high reliability, along with providing riders a sense of permanence — but with greater flexibility and comparatively lower costs. Figure 1 provides an example of an articulated BRT vehicle.

**Figure 1** Stylized Articulated BRT Vehicle (Los Angeles Metro Rapid)

BRT provides a premium level of service, with fewer stops, faster service, enhanced reliability, higher quality amenities, and specially branded buses and stations compared to local bus service. BRT systems can combine Intelligent Transportation System (ITS) technology, as well as signal and roadway design priority treatments for transit, with cleaner and quieter vehicles, rapid and convenient fare collection, and enhanced integration between stations and adjacent land uses. BRT services may operate in a range of environments, such as mixed-traffic lanes, designated bus-only arterial lanes, or on its own transitway (either at-grade or grade-separated).

BRT is typically implemented on longer corridors dotted with higher density activity centers or development nodes linking cities or providing connections between large city centers and outlying residential and commercial centers. When transit-preferential operating facilities are in place, such as a bus-only lane, BRT travel times can compete with the automobile on congested urban corridors, which helps to attract choice riders. The permanent operating facilities can support diverse, high-density land uses particularly around station areas. BRT has the flexibility to be upgraded and expanded to meet increasing demand along a corridor, and can serve as a precursor for light rail transit (LRT).

VTA is developing two types of BRT, which differ according to capital investment requirements and the level of infrastructure provided. These two BRT types are defined as follows:

- **BRT 1** – BRT 1 is a premium level service, with higher operating speeds, greater reliability, and fewer stops above local bus service. Buses and stations are brand identified, typically with standard amenities, such as shelters, benches, and real-time passenger information. BRT 1 may operate in:

- » Mixed-flow traffic lanes;
- » Designated bus-only lanes, created out of an existing mixed-flow lane;
- » Converted parking lanes used as bus-only lanes in the peak period or during weekday working hours;
- » Converted HOV lanes on highways/expressways where existing travel lanes are re-striped for HOV and bus only use; and
- » A combination of the four running ways noted.

BRT 1 often operates along corridors equipped with transit priority elements, such as Bus Signal Priority (BSP) and queue jump lanes, and utilizes a headway-based schedule. BRT 1 requires a lower level of investment than BRT 2, especially if the ROW or lane already exists. VTA's Rapid 522 is an example of a BRT 1 type service.

- **BRT 2 –** BRT 2 requires considerably higher capital investment than BRT 1 due to specialized or dedicated running ways, related infrastructure, such as high-capacity stations with enhanced amenities similar to those for light or heavy rail lines, and passing lanes at stations to allow vehicles the flexibility to bypass stations. BRT 2 operates in:

  - » Designated bus-only lanes constructed on new ROW, requiring center median conversion or street widening for curbside lanes;
  - » New HOV lanes on highways and expressways, where new lanes are built within the median or shoulder ROW for dedicated HOV and bus lanes;
  - » At-grade transitways; and
  - » Grade-separated transitways.

  BRT 2 infrastructure investments help minimize or eliminate conflicts between buses and mixed-flow traffic, and allow BRT to operate faster and more reliably than BRT 1. BRT 2 systems also employ Bus Signal Priority (BSP) and other transit priority techniques such as queue jump lanes. BRT 2 is designed for higher peak passenger demand than BRT 1 and can often provide a carrying capacity on par with that of light rail.

BRT can operate as a hybrid system that uses a combination of running way types based on demand and infrastructure available. Los Angeles's Orange Line is an example of a hybrid system that originates and terminates on bus-only streets, while the core system operates on an at-grade transitway. General characteristics of BRT 1 and BRT 2 are defined in Table 1.

**Table 1** Characteristics of BRT 1 and BRT 2

| Characteristics | BRT 1 | BRT 2 |
|---|---|---|
| Service | Long corridors serving major destinations | |
| Running Way | Mixed traffic lane, bus-only lane created out of an existing mixed-flow or parking lane, or HOV lane converted out of existing highway/expressway lane. | Bus-only lane — physically separated and created in a new ROW, HOV lane — created in a street median or shoulder of a highway or expressway, at-grade, or grade-separated transitway |
| Transit Priority | Bus Signal Priority (BSP) and/or queue jump lanes | Bus Signal Priority (BSP) and/or queue jump lanes |
| Capacity | Medium | Medium to High |
| Vehicle Type | Standard 40 Foot | Standard 40-foot to Articulated 60-foot (with double-triple articulated vehicles if demand warrants, as in Curitiba) |
| Operating Characteristics | Limited Stop Service | Limited/Express Stop Service |
| Headway | 10–15 minutes | 5–15 minutes |
| Station Spacing | 0.75 miles on average (may be shorter to serve key activity nodes) | |
| Station Amenities | Basic amenities including unique signage and real-time passenger information. | Enhanced and more robust amenities similar to rail stations, including real-time passenger information, fare ticket machines, enhanced lighting, larger distinctively designed shelters, and higher-capacity boarding areas, such as curb bulbout stops. |
| Vehicle Branding | Special branding, unique to BRT services | |
| Cost | Low to Medium | Medium to High |
| Construction Requirements | Limited, often involving striping and landscaping | May require major construction |
| ROW Requirements | ROW already exists and does not need to be purchased/converted. | May require ROW purchase/conversion |
| Examples | VTA's Rapid 522<br>Los Angeles Metro Rapid<br>Vancouver B-Line<br>AC Transit San Pablo Rapid | Pittsburgh's Busways<br>Miami-Dade Busway<br>Ottawa Transitways<br>Las Vegas MAX<br>Los Angeles Orange Line<br>Lane Transit (Eugene, OR)<br>Houston Metro HOV System |

## 3. PLANNING AND IMPLEMENTATION PROCESS

The design, implementation, and operation of all BRT service shall result from a comprehensive planning process. Prior to implementation all potential new lines or service changes will be subject to an initial planning study to determine the feasibility and structure, and identify the local commitments and funding necessary. The following Service Design Guidelines are part of this process for planning, designing, implementing, and monitoring new service. Specific steps to evaluate existing and proposed service are as follows:

### EXISTING SERVICE EVALUATION

Step 1 – Assess existing service versus established service standards
Step 2 – Devise and implement an Improvement Plan, if necessary

### IMPLEMENTATION OF NEW SERVICE

Step 1 – Conduct market research and estimate ridership and revenue potential.
Step 2 – Identify and design route alignments.
Step 3 – Establish bus station location.
Step 4 – Design stations, facilities, and street improvements necessary.
Step 5 – Develop an operation plan and implementation schedule.
Step 6 – Develop a marketing plan and brand management strategy.
Step 7 – Monitor service performance (Existing Service Evaluation).

### Policy Notes

- New service shall be implemented for a 24-month trial period. After this, VTA's Board will decide whether to retain, drop, or modify service.

## 4. BRT POLICIES

### 4.1 BRT SYSTEM PERFORMANCE STANDARDS

VTA BRT services shall be evaluated on a corridor-wide basis (e.g., the combination of all bus lines in a corridor shall be used in the evaluation). This section identifies a set of performance standards needed to ensure that routes and stations contribute to productive and efficient service.

Existing BRT lines shall be evaluated according to three metrics, as shown in Table 2. The primary evaluation standard is:

- **Boardings per Revenue Vehicle Hour** – This measures the number of boardings during a given revenue hour of vehicle service. It has served as VTA's long-established evaluation criteria to assess productivity of transit services. This indicator shows how well a unit of cost — vehicle revenue hours — is utilized. It also indicates whether the transit level of service offered is appropriate, and how well operating resources are deployed to provide service.

Secondary evaluation standards are:

- **Boardings per Station** – This measures the number of daily boardings entering a given transit station to gauge how well a station is being utilized. This is important when considering the capital costs for selecting and constructing stations, as well as the operating and maintenance costs associated with keeping a station operational. An under-used station impacts transit operating performance, as well as farebox recovery and cost efficiency. This is especially true for BRT 2 type dedicated stations. Highly utilized stations can be considered for additional station amenities.

- **Boardings per Route Mile –** This compares the number of daily boardings versus the total length of a BRT route or network to determine whether a route is effectively designed, given its length, and whether extraneous destinations are included in the schedule that may reduce overall productivity and efficiency. Furthermore, it can be used to identify route segments with higher demand, allowing VTA to tailor service and capacity to meet this.

As reported in VTA's 2007 First Quarter Transit Operations Performance Report (July through October), the El Camino corridor carried approximately 22,300 daily weekday riders (Line 22 had approximately 16,300 riders and Rapid 522 had approximately 6,000 riders), and approximately 45 weekday passengers per revenue hour. In addition, in March 2006 Rapid 522 stops served an average of 150 boardings per day. Table 2 provides the performance standards for existing and new BRT routes.

### Policy Notes

- The goal of BRT is to achieve a 20 to 25% farebox recovery ratio consistent with VTA's Board adopted objective for all routes in the system.
- All standards must be met for implementation of new service.
- For implementing new service, the highest ridership lines shall have priority.
- For a corridor to be fit for BRT 1, local bus lines must meet the minimum standards in Table 2 and operate at a minimum 15 minute headway during the peak and midday periods of operation.

**Table 2** VTA Ridership Standards for Existing and New BRT Routes[A]

| Ridership Standards | Study Area | Existing and/or New BRT Route | BRT 1 | BRT 2 |
|---|---|---|---|---|
| Average Boardings per Revenue Hour | Corridor/Segment | Existing/New | 45[B] | 55[C] |
| Boardings per Station | Station | Existing/New | 150[D] | 350[E] |
| Average Boardings per Route Mile[F] | Corridor/Segment | Existing/New | 200 | 350 to 475 |

Table Notes:

[A] These are examples of the performance standards as presented in VTA's Fall 2006 annual Route Productivity evaluation. The performance standards will be updated periodically to reflect annual average ridership performance.

[B] The existing BRT 1 service standard is based on VTA's 2007 1st Quarter Transit Operation Performance Report, where the Rapid 522 serves 34 and Route 22 serves 49 weekday passengers per revenue hour, respectively. Line 22 and Rapid 522 operate in mixed-flow travel lanes, Rapid 522 has bus signal priorities, brand-identified stations and stops, and limited stop service. Combined, these two lines were used to define the El Camino BRT corridor.

[C] VTA currently does not operate a BRT 2 type system; therefore, the performance threshold is based on higher-end capabilities of VTA's BRT 1 and a peer review of North American systems with similar land uses as Santa Clara County. BRT 2 systems, such as Vancouver's British Columbia's bus-only lane has 62 boardings per revenue hour, Ottawa's Transitway Routes 95, 96, and 97 serves 115 passengers per revenue hour, and Los Angeles Wilshire Rapid and Ventura Rapid serve 65 and 43 boardings per revenue hour, respectively

[D] Standard based on March 2006 average boardings per station on the El Camino BRT Corridor.

[E] Standard based on the assumption that BRT 2 will have higher boardings per station than BRT 1 and a peer review of North American systems with similar land uses as Santa Clara County and similar provision of transit amenities.

[F] Standrds based on weekday BRT ridership per station and a minimum assumed stop spacing of ¾ mile.

- Any route, route segment, or station consistently performing at or above 175% of the standards in Table 2 shall be considered for service upgrades.
- An existing line not meeting the primary standard (boardings per revenue hour) shall be subject to an Improvement Plan (IP), which may include actions, such as reducing service, either in terms of route length or number of trips operated, to improve operating performance and efficiency.
- An existing line, satisfying the primary standard, but not meeting one or both of the secondary evaluation standards shall be subject to an Improvement Plan or a modification in service (e.g. modification of the route and operating hours of the service) to improve corridor and segment ridership. Any modifications to service must produce results that meet the average boardings per revenue hour standard.
- A station not meeting the Daily Boardings standard in Table 2 shall be subject to an Improvement Plan to improve station usage, or service reductions, which may include a shift to peak-hour operations only, a shortening of operating hours, the introduction of skipped stop services, or the closure of the station.
- Stations not meeting daily boarding standards may still be warranted, on a case-by-case basis. Considerations include stations that:
  - » Link to key transfer points and connecting routes;
  - » Serve nearby hospitals and other public service facilities;
  - » Serve other special trip generators, such as schools, stadiums, and shopping malls; and/or
  - » Serve new or proposed developments with high potential for transit use.
- Those stations that are privately funded partially or fully by sources other than VTA may be subject to relaxed standards upon agreement between VTA and the private funding source.

### 4.2 MARKET RESEARCH AND RIDERSHIP/ REVENUE FORECASTS

Prior to the implementation of new service VTA shall undertake a market research to comprehend market needs and ridership potential. The steps shall be to identify:

- Major trip generators and origin and destination patterns within the community.
- Types of infrastructure improvements needed.
- Optimal routing and service design characteristics (i.e. acceptable travel times, origins and destinations, route directness, types of vehicles, service span, days of operation, and fare structure).
- Potential locations along the route that generate maximum ridership and revenues.

Even though a market may exist for a given route, the ridership and revenues may not be sufficient to satisfy VTA average boardings per revenue hour requirements and board approved 20 to 25% fare box recovery goal. Thus, VTA shall conduct a ridership and revenue analyses on potential new routes and service segments to assure they meet the performance standards. Considerations in these analyses are as follows:

- Ridership estimates shall be developed through a comprehensive planning process using VTA's Countywide Transportation Model, Transit Service Planning Tool (TSP), and other Direct Demand Models.

Local jurisdictions shall have access to these tools through the *Improvement Plan Process.*

- Line and service levels may be incrementally implemented and expanded as demand and ridership potential increase.
- All local bus lines will charge a fare consistent with VTA's fare policy.
- The minimum line ridership shall be sufficient to generate the respective average passengers per revenue hour. If ridership forecasts indicate that the line can achieve the target analysis, but does not meet the one-year target, service will be evaluated for changes, including marketing, service, and/or route modifications designed to increase passenger boardings per revenue hour.

## 4.3 IMPROVEMENT PLAN (IP)

As part of the Transit Sustainability Policy (TSP), an Improvement Plan (IP) may be developed to incrementally improve transit ridership for BRT corridors that do not meet Table 2 performance standards. This process shall occur prior to implementation of any service changes or route modifications. IPs shall include corridor recommendations for: (i) Land Use Policies; (ii) Urban Design; and/or (iii) Roadway Improvements. In addition, local jurisdictions may undertake Community Outreach efforts to promote transit ridership.

In instances where an IP is not desirable or practical, provisions for service reduction and/or service modifications shall be considered.

The following sections identify local jurisdiction and VTA actions to take under the IP to build transit ridership along a corridor and improve productivity, efficiency, and cost recovery of the BRT service in question.

### 4.3.1 LOCAL JURISDICTION ACTIONS

Local jurisdictions can undertake activities under the IP to encourage residential and commercial developments around stations, including encouraging high-quality urban design and pedestrian environments, improving the last-mile connection between stations and surrounding land uses, roadway and/or policy improvements to enhance transit operations, and conduct community outreach to encourage transit ridership.

#### LAND USE POLICIES

There is a reciprocal relationship between diverse, higher-density land uses and transit ridership. These factors are primary inputs to ridership estimation models. Land use policies that encourage denser mixed-use developments built to a pedestrian scale are much more likely to generate transit ridership than dispersed communities that are designed around the personal car. Actions to promote densification and mixed use may include:

- Adopting land use plans and strategies promoting higher densities.
- Adopting TOD policies and overlay zones to promote mixed use development.
- Developing TOD design guidelines, Specific Plan overlay zones, or corridor plans.
- Funding pedestrian improvements to encourage pedestrian access to stations.

Table 3 summarizes residential and commercial land use policies and urban design recommendations around BRT 1 and BRT 2 stations.

**Table 3** Urban Design and Development Requirements ⅓ Mile from BRT Corridor

| Type of BRT | Urban Design Guidelines | Land Use | Ideal Service Area/Points | Transit Policies |
|---|---|---|---|---|
| BRT 1 | • Bus station access/ amenities<br>• Pedestrian access<br>• Street connectivity | • Medium to high-density residential<br>• Medium-high commercial<br>• Employment nodes<br>• Mixed Use | • Urban areas<br>• Activity nodes (e.g. hospitals, schools, malls) | • Bus station policies<br>• Pedestrian guidelines<br>• Transit priority zones[A] in select areas |
| BRT 2 | • Pedestrian access<br>• Street connectivity<br>• Lane dedication<br>• Station/Station Design | • High-density residential<br>• High-density commercial<br>• Employment nodes<br>• Mixed Use | • Dense, established corridors<br>• Dense Employment nodes<br>• Dense Downtowns | • TOD policies/overlay zones<br>• TOD design guidelines<br>• Specific Plan overlay zones<br>• Station area plans |

Table Note:

[A] A transit priority zone is a designated area where transit is given the operating advantage over other modes. Measures include transit-only lanes or malls, bus signal priority, as well as turn prohibitions for automobiles.

VTA's Community Design and Transportation (CDT) Manual has established recommended densities along bus corridors and around Bus and Rail Stations for residential developments in terms of Dwelling Units per Acre (DUA) and commercial developments in terms of Floor Area Ratio (FAR) to promote conditions that facilitate transit use. Optimal densities for BRT have been formulated based on these CDT recommendations, as well as industry research.

BRT corridor and station densities are divided into three categories as follows:

- **Minimum Densities** – Areas meeting the minimum densities shall be considered for BRT service or a station, or if agencies have prepared a phased approach with an adopted Improvement Plan to increase density, development, and land use along a corridor or around a station.
- **Target Densities** – Areas meeting the target densities shall be considered suitable for BRT service or stations.
- **Preferred Densities** – Areas meeting the preferred densities shall be given the highest priority for BRT service or stations.

The following tables, Table 4 though Table 7, detail the residential and commercial density targets along new BRT corridors and around new BRT stations. Table 8 provides examples of the typical land use characteristics in Santa Clara County.

**Table 4** Residential Density Targets along New BRT Corridors

| Line Type | Optimal Densities (DUA) (Within 1–2 blocks or 330–660 feet of corridor) | | |
|---|---|---|---|
| | Minimum[A] | Target | Optimal |
| BRT | 12–16 | 25–32 | 30–50+ |

Table Notes:
Source: Based on CDT Manual, Table D-1.
[A] Considerations will be allowed if there are signs that efforts are being made to increase residential densities along the corridor.
[B] Envisioned BRT station area guidelines will be similar to those for LRT stations.
[C] Based on the Optimal and Minimum FARs.

**Table 5** Residential Density Targets around New BRT Stations

| | Optimal New Residential Project Density (DUA within 1/3 mile of BRT station) | | |
|---|---|---|---|
| | Minimum[A, B] | Target[C] | Optimal |
| BRT Station (Regional) | 20 | 27.5 | 35+ |
| BRT Station (Local) | 10 | 15 | 20+ |

Table Notes:
Source: Based on CDT Manual, Table D-1.
[A] Considerations will be allowed if there are signs that efforts are being made to increase residential densities along the corridor.
[B] Envisioned BRT station area guidelines will be similar to those for LRT stations.
[C] Based on the Optimal and Minimum FARs.

**Table 6** Commercial Density Targets along New BRT Corridors

| Line Type | Target Floor Area Ratio (Within 1–2 blocks or 330–660 feet of corridor) | |
|---|---|---|
| | Train Station or Transit Corridor | Major BRT stations |
| BRT | 2.0 | 1.0 |

Table Notes:
Source: Based on CDT Manual, Table D-1.
[A] Considerations will be allowed if there are signs that efforts are being made to increase residential densities along the corridor.
[B] Envisioned BRT station area guidelines will be similar to those for LRT stations.
[C] Based on the Optimal and Minimum FARs.

**Table 7** Commercial Density Targets around New BRT Stations

| Line Type | Target Floor Area Ratios (FAR within 1/3 mile of BRT station) | | |
|---|---|---|---|
| | Minimum[A, B] | Target[C] | Optimal |
| BRT Station (Regional) | 1.0 | 1.5 | 2.0 |
| BRT Station (Local) | 0.5 | 0.75 | 1.0 |

Table Notes:
Source: Based on CDT Manual, Table D-1.
[A] Considerations will be allowed if there are signs that efforts are being made to increase residential densities along the corridor.
[B] Envisioned BRT station area guidelines will be similar to those for LRT stations.
[C] Based on the Optimal and Minimum FARs.

**Table 8** Typical Land Use Characteristics in Santa Clara County

| Category | Density Range | Characteristics | Examples |
|---|---|---|---|
| Low-Density | 4–12 DUA | • Represented primarily by single-family residential homes.<br>• Low-density development surrounds many VTA LRT stations and bus routes.<br>• Classified as Suburban Area by CDT Manual.<br>• Suitable for local bus service and possibly BRT on the higher end.<br>• 7 DUA is the minimum VTA threshold for local bus service.<br>• 10 DUA is the minimum VTA threshold for BRT service. | **Figure 2** Low-Density Single Family Homes (San Mateo)<br> |
| Medium-Density | 13–40 DUA | • Represented by high-density, detached single family homes, town homes, and lower-density multi-family residential. Higher end of this range includes 2–3 story apartments with surface parking and 3–4 story apartment over parking.<br>• Represented by residential density patterns in more urban areas of Santa Clara County, such as Downtown San Jose.<br>• Classified as County/Local Core by CDT Manual.<br>• In the intermediate-high range; suitable for local buses and BRT. | **Figure 3** Medium-Density Three-Four Story Apartments (San Jose - Pacific Rim)<br> |

**Table 8** Typical Land Use Characteristics in Santa Clara County

| Category | Density Range | Characteristics | Examples |
|---|---|---|---|
| Medium to High Density | 40–65 DUA | • Represented by multi-story (4–5 story) podium apartments over parking.<br>• Found in transit-oriented development areas in Santa Clara County.<br>• Classified as Regional Core by CDT Manual; suitable for BRT and possibly LRT. | **Figure 4** Medium-High Density, Multi-Story Podium Apartments (San Mateo)<br> |
| Very High Density | 65 + DUA | • Represented by four-story apartments over two levels of parking or multi-level flats over multiple garage levels (towers).<br>• Found in Downtown San Jose, the Crossings in Mountain View, or the Rivermark in Santa Clara.<br>• Classified as Regional Core by CDT Manual; suitable for BRT and LRT. | **Figure 5** High Density, Multi-Story Residential Developments along Stevens Creek Corridor<br> |

**Figure 6** High-Density Development Adjacent to Los Angeles Metro Orange Line


The following table illustrates examples of typical density ranges found in Santa Clara County and describes the most suitable transit service for particular densities.

### Land Use Policy Notes

- Recommended minimum densities and FARs do not apply in areas along major established corridors linking key activity nodes and regional centers or in areas along roads linking a major corridor with a major multimodal transit center or a major trip generator node.
- Recommended minimum densities and FARs do not apply at stations that are funded by a non-VTA source, at stations that serve specific social functions, such as hospitals or schools, and at stations serving as key transfer or intermodal stations.
- Recommended minimum densities should guide development until the corridor and/or station usage increases enough (from further development and TOD supportive policies/measures) to exceed noted performance standards.
- Corridors that exhibit growth potential and/or approved projects to achieve the preferred densities shall be considered high priority.
- For station areas requiring an IP, explicit policy language or approved plans that encourage residential and commercial densities around Station Areas shall be detailed and adopted by the affected local jurisdictions.

## URBAN DESIGN

Integrating transit- and pedestrian-oriented urban design practices around transit stations is critical for transit riders to feel comfortable making last-mile connections from the station to their destination. In the IP, potential urban design improvements that local jurisdictions can undertake include:

- **Pedestrian and Bicycle Access Enhancements –** This may include the provision of contiguous sidewalk and bicycle lanes on both sides of the street, and removal or mitigation of barriers that prohibit pedestrian and bicycle traffic from accessing surrounding Station Areas.
- **Appropriately Designed and Sited Parking Facilities –** Provide appropriate parking spaces to meet the parking demand. These parking facilities must not impede pedestrian and bicycle access to both the transit station and surrounding destinations. In addition, the design and location of the parking facilities must assure that transit operations are not disrupted.
- **Creation of Origin-Destination Pairs** – Provide high quality mixed use developments along a corridor can, in sufficient quantity, create the necessary origin-destination pairs to encourage transit use and additional transit supportive developments.

### PHYSICAL MEASURES

Various physical measures can be implemented to improve transit travel speeds, reliability and land use along a corridor. Local jurisdictions can work with VTA to provide transit preferential roadway treatments and implement policies and projects that improve transit speeds and increase efficiency. Within the IP, VTA shall identify potential service enhancements, while the local jurisdictions shall identify the physical and policy actions needed to implement and achieve these enhancements.

#### Physical Measures Policy Notes

Improvements may include the following:

- Providing right-of-way to construct bus stop bulbouts, queue jump lanes, or bus-only lanes.
- Restricting curbside parking to create a bus-only lane during peak periods.
- Assuring that all traffic signals in a corridor are equipped with, or have the ability to be upgraded to handle, Bus Signal Priority (BSP).
- Providing sufficient sidewalk width for new BRT stations compliant with ADA requirements.
- Establishing or raising parking fees in urban cores.
- Reducing parking supply, capping parking capacity, or instituting parking charges along a corridor, in key areas, or at select stations.

### COMMUNITY OUTREACH

In addition to the improvements mentioned previously, local jurisdictions can actively promote and support transit through community outreach efforts. These may include:

- Offering free trial and tourist passes.
- Conducting transit-specific marketing/branding campaigns to provide access to commuter/transit information and other useful promotional materials.
- Building partnerships with area associations, such as downtown business associations, to promote transit ridership.
- Providing transit information, promotional and informational material.

## 4.3.2 VTA EFFORTS

VTA can improve route structure or modify service to better meet corridor and station performance targets. For routes and stations failing to meet the performance standards, VTA may:

- Restructure the operating plan and services to improve ridership and reduce operating costs.
- Reduce service hours, revenue miles operated (particularly in the off-peak), or service frequency until service meets the criteria (minimum BRT headways are 15 minutes).
- Introduce peak hour service only.
- Introduce skip stop service to bypass unproductive stations on scheduled runs.
- Scale back services to Local Bus until routes are able to meet BRT performance criteria.
- Temporarily close particularly unproductive segments or stations.

### 4.4 NEW SERVICE CRITERIA AND POLICIES

All new service shall be provided provisionally, subjected to at a minimum an annual review. New service shall be given two years to reach the performance standards in Table 2, with intermediate performance expectations as shown in Table 9. Lines that do not meet the performance expectations and that do not have an approved Improvement Plan (IP) shall be discontinued, with resources reallocated to services that meet or exceed the standard.

## 5. TRANSIT PRIORITY ELEMENTS

Transit priority elements, such as running ways, queue jump lanes, transit signal priority, and regulatory signs, are major factors that allow BRT to maintain high operating speeds and service reliability, and help make BRT more competitive with the automobile than Local Bus service. Typical transit priority elements and specific application to VTA operations are detailed below.

### 5.1 BRT RUNNING WAYS

BRT vehicles operate on running ways, which serve as the major determining factor in the speed, reliability, and total cost of a BRT system. Greater separation between the running way and mixed traffic produces faster operating speeds, and greater reliability, but increases capital costs.

BRT 1 service typically operates on three types of running ways:

- **Mixed-Flow Traffic Lanes** – Travel lanes used by both buses and regular traffic, such as VTA's Line 522. See Concept Boxes BRT 16–17 for details on Mixed-Flow Traffic Lanes.
- **Converted Bus-Only Lanes** – Lanes, usually at the curb, that have been converted from mixed-flow or parking lanes to bus only lanes. These lanes may be used exclusively for buses during peak periods or throughout the day. At night, they often revert back to their original purpose — mixed-flow or parking lanes. The lanes are not physically separated from adjacent mixed-flow lanes and are usually

**Table 9** Route Performance Expectations

| Time from Implementation (Months) | % Compliance with New Service Standard |
|---|---|
| 6 | 70 |
| 12 | 80 |
| 18 | 90 |
| 24 | 100 |

delineated by pavement striping or signage. See BRT 18–21 Concept Boxes for details on Converted Bus-Only Lanes.

- **Converted High Occupancy Vehicle (HOV) Lanes –** Highway or expressway lanes that have been converted to HOV and bus use only lanes. These lanes may be exclusively for HOV and buses during peak periods or throughout the day. At night, they often revert back to mixed-flow travel lanes. Pavement striping or signage usually demarcates converted HOV lanes. See Concept Boxes BRT 32–37 for details on HOV Lanes.

BRT 2 service operates with more physical separation and segregation from general traffic than BRT 1 systems running on mixed traffic lanes or on bus-only lanes in the form of:

- **Dedicated Bus-Only Lanes –** Similar to a converted bus-only lane, except a new ROW must be created within the street for the bus-only lane, either in the center median or at the curb. Dedicated bus-only lanes are purpose-built for transit and are physically separated from mixed traffic by barriers, bollards, or raised medians/curbs. As such, physical implementation and capital costs are sufficiently higher for dedicated bus-only lanes compared to converted ones. See Concept Boxes BRT 26–27 for details on designated curbside bus-only lanes, and Concept Boxes BRT 28–31 for Designated Median Bus-Only Lanes.
- **HOV Lanes (in New ROW) –** Similar to converted HOV lanes, except a new ROW must be created within the median or on the shoulder of a freeway, highway, or expressway. These facilities are separated from mixed traffic by barriers or bollards. Physical implementation and capital costs are much higher for dedicated HOV lanes compared to converted lanes. At night, they can revert to mixed-flow travel lanes. See Concept Boxes BRT 32–37 for details on HOV Lanes.
- **At-Grade Transitways –** These are dedicated transit right-of-ways that are physically separated from mixed-flow traffic, with exceptions at intersections and at transitway entrances and exits. See Concept Boxes BRT 34–37 for details on At-Grade Transitways.
- **Grade-Separated Transitways –** These are similar to at-grade transitways; however, all crossings are grade-separated with overpasses or underpasses. See Concept Boxes BRT 38–41 for details on Grade-Separated Transitways.

The following Concept Boxes describe various BRT running way-operating environments.[2] The Concept Boxes define the running way, identify key operating advantages and disadvantages, and describes the applicability of each running way option available to VTA and Santa Clara County (SCC).

2 The Concept Boxes will be useful as a stand-alone tool for local jurisdictions and other related stakeholders to quickly review and evaluate the potential for a particular concept.

## MIXED-FLOW TRAFFIC LANES

DEFINITION: Mixed-flow lanes are used by buses and regular traffic.

OPERATING ENVIRONMENT: Both transit and non-transit vehicles, including trucks, private automobiles, and motorcycles, share mixed-flow traffic lanes.

POTENTIAL DESIGN FEATURES:

- Queue jump lanes at congested intersections (see definition of queue jump lanes in Section 5.2.1, Queue Jump Lanes).
- Traffic signal improvements, such as centralized coordination and Bus Signal Priority (BSP).
- Intersection channelization, longer curb radii, and rounded corners.

ADVANTAGES: Mixed-flow traffic lanes have minimal capital costs since major physical modifications or expansions to the roadway are not necessary. Intersection delays can be reduced when Bus Signal Priority (BSP) and queue jump lanes are implemented along a corridor. Buses benefit from a range of street and traffic improvements, which reduce overall traffic delay.

DISADVANTAGES: Bus operations are impacted by traffic conditions and congestion resulting in reduced speeds and reliability, and increased chances for collisions. Delay to buses may also result from turning, queuing, or double-parked vehicles and merging, turning, and/or loading/unloading buses may delay mixed-flow traffic. The absence of fixed infrastructure or guideway makes the system seem less "permanent," which may reduce development potential along the corridor.

ESTIMATED CAPITAL COSTS: Minimal, if no physical changes are required to the lanes; typically queue jump lanes costs between $100,000 and $300,000 per intersection (2006 dollars) and bus signal priority (BSP) costs between $8,000 and $35,000 to enable a signal.

POTENTIAL APPLICATION TO VTA: BRT shall operate in mixed-flow travel lanes when traffic conflicts do not impact operating speeds, reliability, daily boardings, and route performance; and/or average boardings per day are within the BRT 1 performance standard range. BRT shall also operate in mixed-flow travel lanes when bus-only lanes or transitways are impractical.

EXAMPLES:

- VTA's Rapid 522 (Figure 7).
- AC Transit's San Pablo Rapid (Figure 8).
- Los Angeles' Metro Rapid on Wilshire Boulevard.
- Vancouver British Columbia's B-Line (Lines 97 and 99).

**Figure 7** BRT 1 Operations in Mixed-Flow Traffic Lane (VTA's Rapid 522)


**Figure 8** BRT 1 Operations in Mixed-Flow Traffic Lane (San Pablo Corridor—AC Transit)

## CONVERTED BUS-ONLY LANE

DEFINITION: Curbside parking or mixed-flow lanes converted for transit vehicle use only during peak periods or throughout the day. These lanes revert back to mixed-flow traffic after operating hours. Converted bus-only lanes do not require physical alterations, such as median conversion or street widening, to the street ROW.

OPERATING ENVIRONMENT: Lanes are usually designated as bus-only during peak periods or during daytime hours, depending on traffic conditions and route demand throughout the day. The lanes may be partially reserved (i.e., taxis, high-occupancy vehicles, or turning vehicles may be allowed to use the lane) or fully reserved (for buses only). Intersection crossings are made at-grade. Mixed traffic is typically allowed to enter or cross bus-only lanes to turn or park at designated parking spots along the curb.

POTENTIAL DESIGN FEATURES:

- Addition of a queue jump lane at congested intersections (see definition of queue jump lanes in Section 5.2.1 Queue Jump Lanes).
- Traffic signal improvements, such as centralized coordination and Bus Signal Priority (BSP).
- Demarcated by appropriate pavement signage (e.g. diamond symbol), wide striping, and pavement coloring.
- Operates "with flow" of traffic.
- If parking lane exists adjacent to converted bus-only lane, then peak period parking bans may need to be adopted.

ADVANTAGES: Increased competitive advantages can be gained versus automobiles and buses traveling in mixed-flow lanes. Buses operating in their own lane can operate faster, more reliably, and more safely than buses operating in mixed-flow traffic lanes. Higher peak period loads can be accommodated and shorter headways maintained since mixed-flow traffic does not conflict with bus movements. When combined with BSP and queue jump lanes, travel delays can be further minimized at intersections. Mixed-flow traffic does not conflict with merging, turning, and/or unloading and loading buses. There is a potential for development intensification and diversification along the corridor.

DISADVANTAGES: Buses still cross intersections at-grade. Lanes are not physically separated from mixed-flow lanes, which may result in conflicts with turning or parked vehicles. To prevent conflicts with parked vehicles peak period parking bans may be required. Travel time advantages compared to the automobile are only achieved during hours when buses travel in bus-only lane. Conversion of lanes to bus-only lanes may require the displacement of parking, traffic, businesses, and pedestrians. Capital costs are higher than for BRT operating in mixed-flow traffic lanes. Active enforcement is necessary to keep lanes clear of non-designated vehicles.

*(Concept box continued)*

**ESTIMATED COSTS:** Converted bus-only lanes employing striping or pavement treatments cost approximately $200,000 per mile.

**POTENTIAL APPLICATION TO VTA:** Applicable when: (i) delay from mixed traffic impacts route performance; (ii) sufficiently wide (11'–13') parking or mixed-flow traffic lanes are available; (iii) sufficient financing exists for roadway improvements and lane demarcation; and (iv) daily boardings approach the upper bounds of BRT 1 type service.

**EXAMPLES:**

- San Francisco has a converted bus-only lane during daytime hours (Figure 11).
- Seattle converts parking lanes to bus-only lanes during peak periods in downtown (Figure 12).
- Ottawa employs all-day bus-only lanes in downtown.
- London's Red Routes utilize colored pavement to demarcate bus-only lanes (Figure 13).
- Boston's Silver Line operates bus-only lanes on converted mixed-flow traffic and parking lanes. The lanes are demarcated with pavement signage (Figure 14).

**REFERENCE FIGURES:**

- Figure 9. Curbside Bus-Only Lane Concept –Typical Lane Configuration
- Figure 10. Curbside Bus-Only Lane Concept – Typical Station Configuration

**Figure 9** Curbside Bus-Only Lane Concept—Typical Lane Configuration

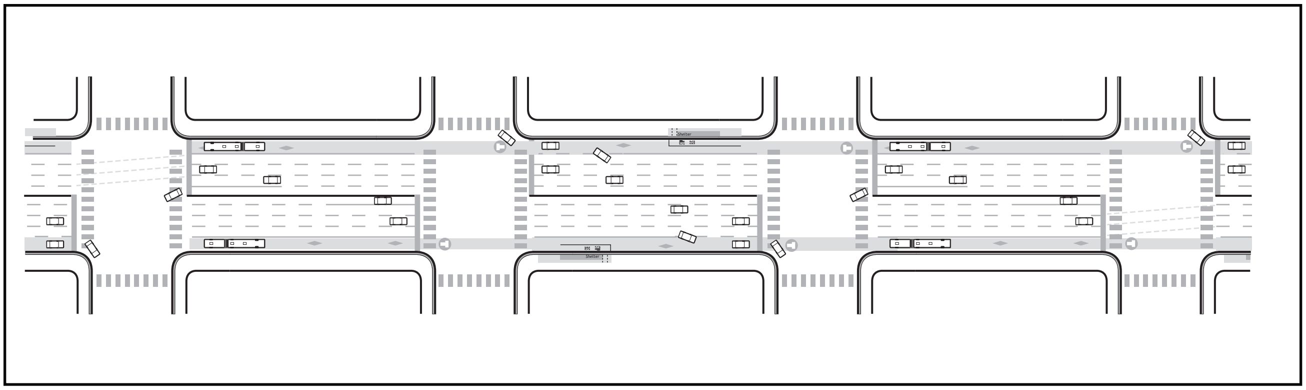


**Figure 10** Curbside Bus-Only Lane Concept—Typical Station Configuration

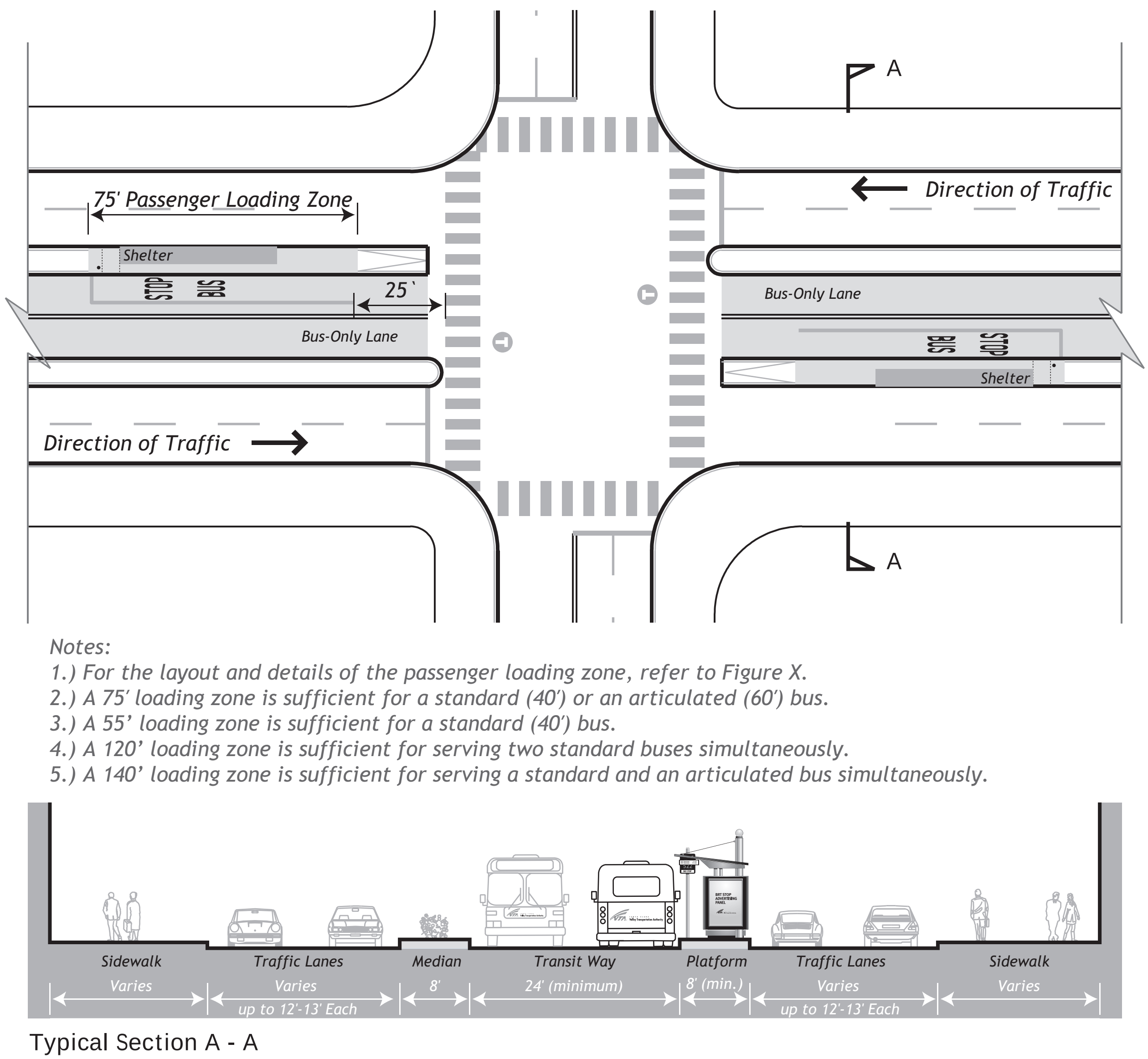


**Figure 11** Converted Bus-Only Lanes for Daytime Use (San Francisco)


**Figure 12** Converted Bus-Only Lanes for Peak Period Use (Seattle)


**Figure 13** Converted Bus-Only Lane with Colored Pavement (London—Red Routes)


Note: In the United Kingdom, vehicles drive on the left side of the street.

**Figure 14** Converted Bus-Only Lane with Bollard Barrier (Boston—Silver Line)

## CONVERTED HOV LANE

DEFINITION: A High-Occupancy Vehicle (HOV) lane is located along the shoulder or median of a freeway, highway or expressway for HOVs and buses. These lanes are created out of existing traffic lanes. Converted HOV lanes may require re-striping and some minor road widening, although additional ROW within the freeway, highway, or expressway profile is not needed. Converted HOV lanes can operate in both directions of traffic.

OPERATING ENVIRONMENT: HOV lanes typically operate during peak periods or during daytime hours, depending on traffic demand throughout the day. Striping and signage are used to differentiate HOV lanes from other lanes. Converted HOV lanes revert back to mixed lanes after the peak or daytime hours. Where BRT operates on shoulder lanes, exclusive HOV on- and off-ramps may be provided to reduce entry and exit times.

POTENTIAL DESIGN FEATURES:

- Exclusive HOV on/off lanes on existing access ramps for BRT operating on shoulder lanes.
- Where exclusive ramps are unavailable, special metering lights at the mouth of on-ramps to allow buses and HOVs to proceed.
- Demarcated by appropriate pavement signage (e.g. diamond symbol), double striping, or rumble strips.

ADVANTAGES: Converted HOV lanes allow buses to operate faster, more reliably, and more safely than buses in mixed-flow lanes, while also allowing HOVs to bypass congestion. Greater stop spacing allows buses to travel at much higher operating speeds than they may with the bus-only lane option. For shoulder HOV lanes, entry and exit off the freeway, highway, or expressway is easier, especially with direct on/off ramps (existing ramps with an added HOV/bus only lane), while median HOV lanes are not impacted by conflicts at interchanges. Costs are likely comparable to convertible bus lanes as pavement striping is the preferred means of delineating such lanes. Right-of-way exists already, which reduces implementation timeframe and costs.

DISADVANTAGES: Since buses share a lane with HOVs, automobiles may impede bus operations, which make HOV lanes less efficient than converted bus-only lanes. Median HOV lanes can be more difficult to access (enter and exit) when there are no direct access ramps. As lanes are not physically separated from normal flow lanes, non-HOV vehicles can enter the lane. This is especially a challenge on shoulder lanes, where non-HOV vehicles merge into the lane from on-ramps and cause delays when using the lane to exit at off-ramps. Strong enforcement is required to keep non-HOV vehicles out of the lane. If the BRT stations are located on the shoulder, buses may experience difficulty merging back into the HOV lane. Likewise, if the lane is located in the median, station access may be difficult for riders. Buses serving intermediate stations located off the freeway, highway, or expressway may also experience delay from merging traffic.

*(Concept box continued)*

ESTIMATED COSTS: Costs range based on the terrain, type of striping, pavement treatments required, the degree of segregation from mixed traffic lanes, if any, road widening required, and the number of grade-separations and bridges. Implementation of an HOV lane for Highway 87 costs about $1.0 million per lane per mile (one direction).

POTENTIAL APPLICATION TO VTA: Applicable when: (i) a BRT route operates on some segment of a freeway or expressway; (ii) existing traffic demand on the freeway/expressway impacts bus operations significantly; (iii) convertible lanes exist, without the need for ROW creation; (iv) demand is insufficient to warrant a dedicated bus-only facility or new ROW within the freeway profile for additional HOV lanes; (v) sufficient financing exists for roadway improvements and lane demarcation; and (vi) daily boardings approach the upper bounds of BRT 1 type service.

EXAMPLES:

- VTA operates buses on Montague and Thomas Expressways HOV lanes (Figure 17).
- A new HOV facility is being constructed on Highway 87 within Santa Clara County (Figure 18).

REFERENCE FIGURES:

- Figure 15. BRT in Median Freeway, Highway or Expressway HOV lane.
- Figure 16. BRT on Shoulder Median Freeway, Highway or Express HOV Lane.

**Figure 15** BRT in Median HOV Lane (Freeway, Highway, or Expressway)

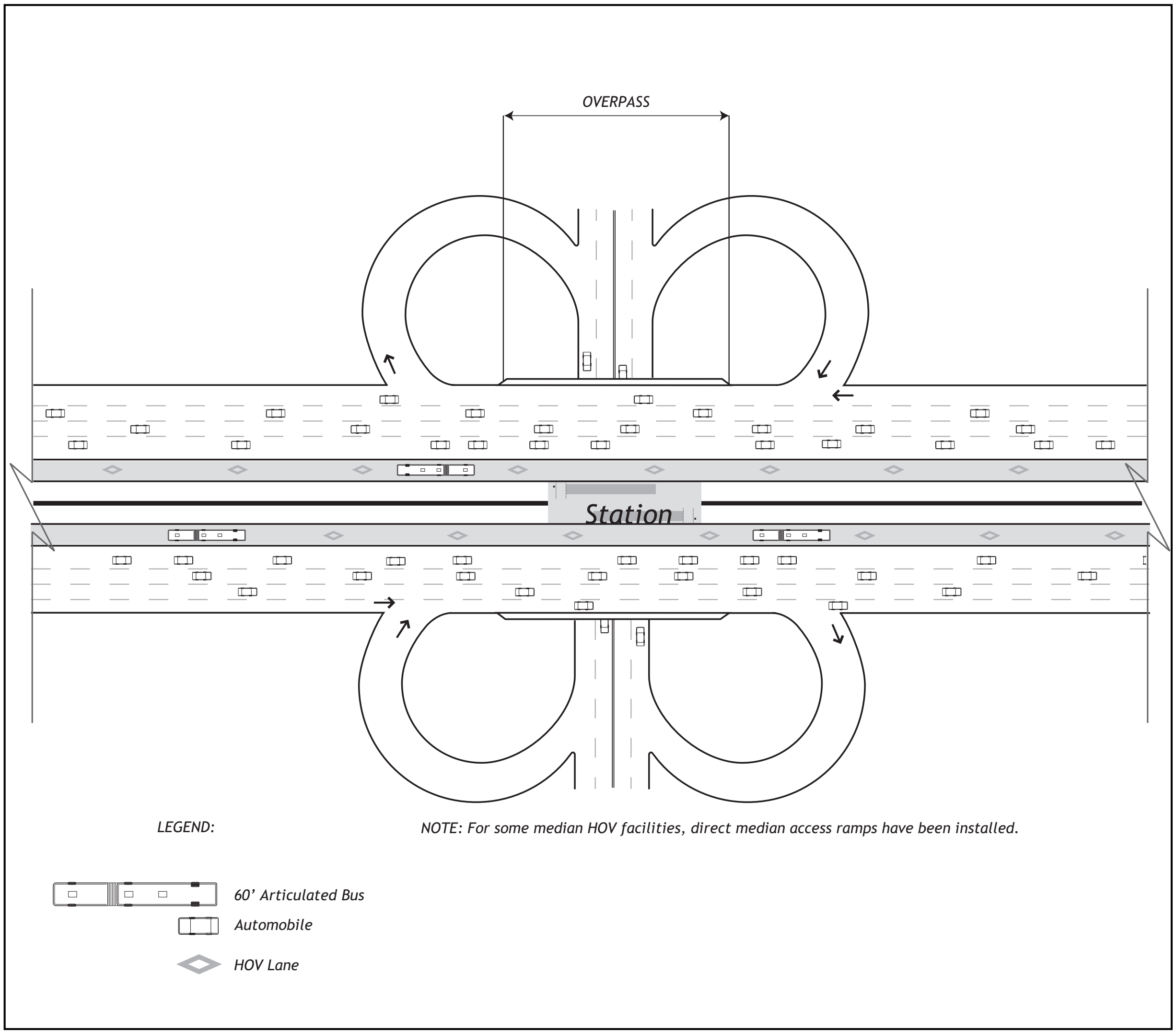


**Figure 16** BRT on Shoulder Median HOV Lane (Expressway/Freeway)

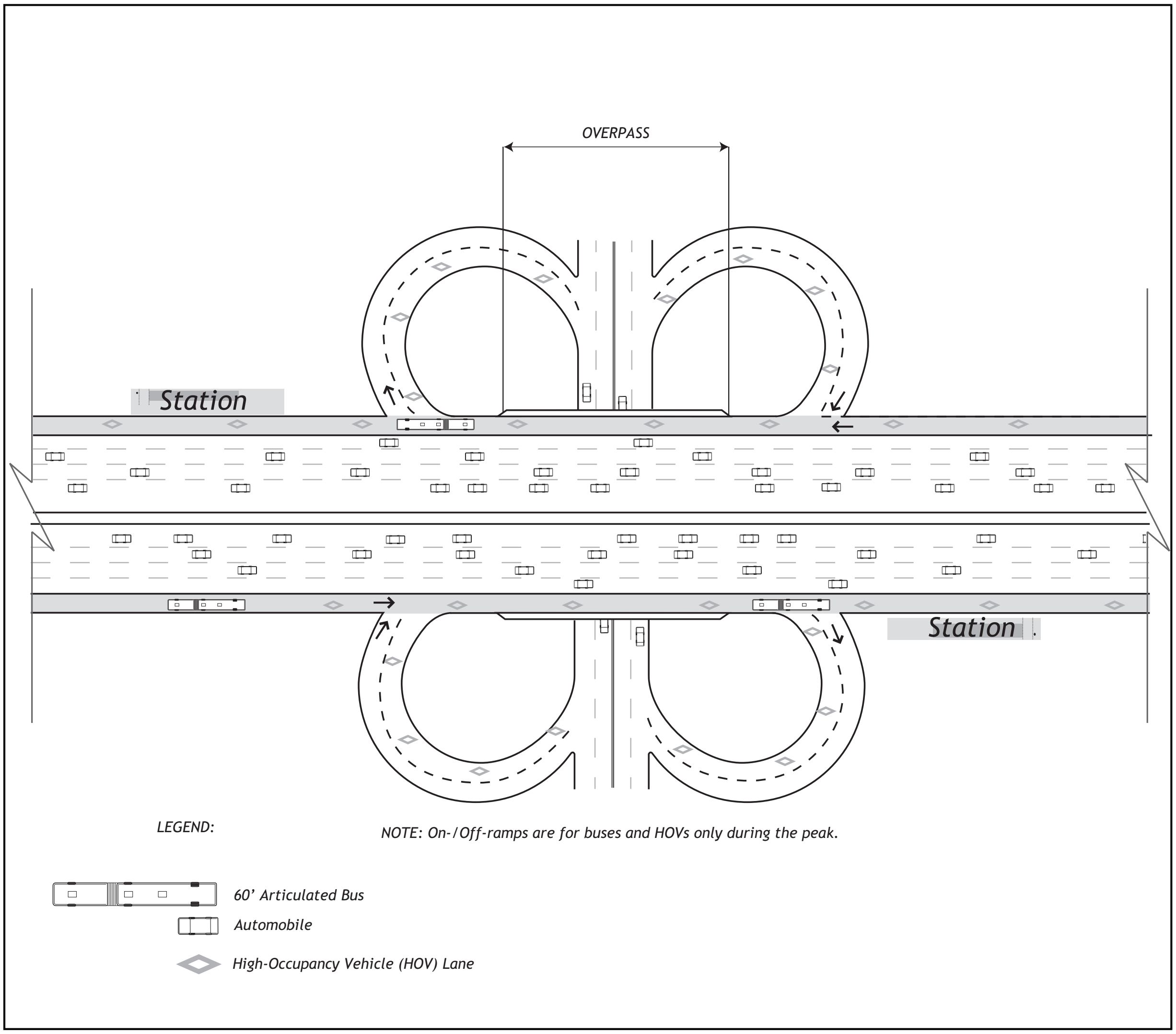



**Figure 17** Median HOV Lane on Freeway with Striping

**Figure 18** Direct-Access HOV On-Ramp

## DESIGNATED CURBSIDE BUS-ONLY LANE

DEFINITION: Physically separated, purpose-built curbside lanes for transit vehicles only. Designated curbside bus-only lanes require physical alterations (widening) to the street ROW. Physical separation is accomplished with concrete barriers, raised medians or pavement, or bollards. Designated curbside bus-only lanes do not revert to mixed-flow traffic use like converted bus-only lanes.

OPERATING ENVIRONMENT: Bus-only lanes may be partially reserved to allow taxis, high-occupancy vehicles (HOVs), or turning vehicles or can be fully reserved for buses only. The lane is physically separated throughout the entire length of the lane, except at intersections where crossings are made at-grade and at lane entrance and exit. Mixed traffic is typically allowed to enter or cross bus-only lanes to turn or park at designated parking spots along the curb.

POTENTIAL DESIGN FEATURES:

- Design is similar to those for converted curbside bus-only lanes.
- To accommodate street widening, additional curbside lanes (11–12 feet) required.
- Physically separated from mixed-flow lanes by concrete barriers, bollards, or raised pavement/curbs.
- Demarcated by pavement/vertical signage and pavement coloring (especially at intersections and merge points).
- Addition of a queue jump lane at congested intersections (defined in Section 5.2.1 Queue Jump Lanes).
- Traffic signal improvements such as centralized coordination and Bus Signal Priority (BSP).

ADVANTAGES: Improved BRT travel times can be attained in designated curbside bus-only lanes, making buses in these lanes more competitive with the automobile. Buses operating in their own lane can operate faster, more reliably, and more safety than buses in mixed-flow lanes. Such systems can accommodate higher peak period loads and operate at lower headways. When combined with BSP and queue jump lanes, travel delays can be further minimized at intersections. Mixed-flow traffic does not conflict with merging, turning, and/or unloading or loading buses. There is a potential for development intensification and diversification along the corridor and near stations. More cost-efficient than designated median bus-only lanes (See Designated Median Bus-Only Lane Concept Box).

DISADVANTAGES: Buses still cross intersections at-grade. Implementation of new curbside bus lanes and street widening may displace parking, pedestrian and bicycle paths, and nearby residents and businesses. Higher capital costs compared to converted bus-only lanes. Active enforcement necessary to keep non-transit vehicles out of the bus-only lanes.

*(Concept box continued)*

ESTIMATED COSTS: More elaborate bus-only lanes, such as barrier separation can range from $2.5–3.5 million per lane mile, excluding ROW acquisition.[A]

POTENTIAL APPLICATION TO VTA: When: (i) delay from mixed traffic impacts route performance; (ii) existing traffic and street conditions prevent the conversion of a parking or mixed-flow traffic lane to a bus-only lane; (iii) the street profile is wide enough to add an 11' to 13' curbside lane; (iv) permits to modify the ROW have been or can be obtained; (v) sufficient financing exists for proposed capital improvements; and (vi) daily boardings are within the lower to middle range of BRT 2 type service.

EXAMPLES:

- Las Vegas operates their BRT line on a dedicated curbside lane (Figure 19).
- Eugene permanently converted the shoulder lane to a dedicated bus-only lane (Figure 20)

[A] Derived from project related experience and Characteristics of Bus Rapid Transit for Decision Making, Office of Research, Demonstration and Innovation, Federal Transit Authority (FTA), August 2004.

**Figure 19** Designated Curbside Bus-Only Lane (Las Vegas MAX)


**Figure 20** Designated Curbside Bus-Only Lane (Eugene)


## DESIGNATED MEDIAN BUS-ONLY LANE

DEFINITION: Physically separated median lanes for transit vehicles only. Designated median bus-only lanes require physical alterations to the street ROW, in terms of median conversion and/or the takeover of adjacent mixed-flow lanes for bus-only operations. Physical separation is accomplished with concrete barriers, raised medians or pavement, or bollards. Designated bus-only lanes do not revert to mixed-flow traffic use like converted bus-only lanes.

OPERATING ENVIRONMENT: Designated median bus-only lanes may be partially reserved to allow taxis, high-occupancy vehicles (HOVs), or turning vehicles to use the lane or fully reserved for buses only. The lane is physically separated throughout, except at intersections where crossings are made at-grade and at lane entrance and exit. Mixed traffic is typically allowed to enter or cross bus-only lanes to turn or park at designated parking spots along the curb.

POTENTIAL DESIGN FEATURES:[A]

- Generally requires width of 75'–90' for bi-directional dual lane configuration with specialized stations (See Figure 22 Median Bus-Only Lane Concept Typical Cross Section).
- Requires median conversion and possible conversion of adjacent mixed-flow traffic lanes.
- Physically separated from mixed-flow lanes by concrete barriers, bollards, and raised pavement/curbs.
- Demarcated by pavement/vertical signage and pavement coloring, especially at intersections and merge points.
- Addition of a queue jump lane at congested intersections (defined in Section 5.2.1 Queue Jump Lanes).
- Traffic signal improvements, such as centralized coordination and Bus Signal Priority (BSP).

ADVANTAGES: Improved BRT travel times can be attained compared to automobiles and buses traveling in mixed-flow traffic lanes, making dedicated bus-only lanes more competitive with the automobile. Buses operating in their own lane can operate faster, more reliably, and more safely than buses and vehicles traveling in mixed-flow traffic lanes. Such systems can accommodate higher peak period loads and operate at lower headways. When combined with BSP and queue jump lanes, delay can be further minimized at intersections. Mixed-flow traffic does not conflict with merging, turning, and/or unloading or loading buses. There is potential for development intensification and diversification along the corridor and near stations.

*(Concept box continued)*

DISADVANTAGES: Buses still cross intersections at-grade. Implementation of new median lanes may displace landscaping, median recreation areas, and adjacent traffic lanes. Considerably higher capital costs compared to converted bus-only lanes. Relatively higher capital costs compared to dedicated curbside bus-only lanes. Active enforcement necessary to keep non-transit vehicles out of the bus-only lanes. Left hand turning movements by vehicles may be banned to keep them out of the busway. Center bus-only lanes require wider ROW than curbside bus-only lanes for provision of barriers and stations.

ESTIMATED COSTS: More elaborate bus-only lanes such as barrier separation can range from $3.0–4.0 million per lane mile, excluding ROW acquisition.[B]

POTENTIAL APPLICATION TO VTA: Applicable when: (i) delay from mixed traffic impacts route performance; (ii) existing traffic and street conditions prevent the conversion of a parking or mixed-flow traffic lane to a bus-only lane; (iii) the existing street profile is not wide enough to accommodate adding 11’–13’ curbside lanes; (iv) sufficiently wide enough center medians exist (in addition to adjacent lanes) for a busway; (v) permits to modify ROW have been or can be obtained; (vi) sufficient financing exists for proposed capital improvements; and (vii) daily boardings are within the lower-middle range of BRT 2 type service.

EXAMPLES:

- Cleveland, Ohio is building a center median BRT lane.
- Eugene, Oregon has a center median lane along a portion of the BRT network (Figure 23).
- Vancouver, British Columbia’s Richmond 98-B Line[C] (Figure 24).
- Internationally, Quito, Ecuador, and Barcelona, Spain have center median bus lanes.

REFERENCE FIGURES:

- Figure 21. Median Bus-Only Lane Concept – Typical Lane Configuration
- Figure 22. Median Bus-Only Lane Concept – Typical Station Configuration

[A] See TCRP 90, Volume 2 for more specific design information regarding median busways.

[B] Derived from project-related experience and Characteristics of Bus Rapid Transit for Decision-Making, Office of Research, Demonstration and Innovation, Federal Transit Authority (FTA), August 2004.

[C] The route is currently being converted to an LRT corridor.

**Figure 21** Median Bus-Only Lane Concept – Typical Lane Configuration

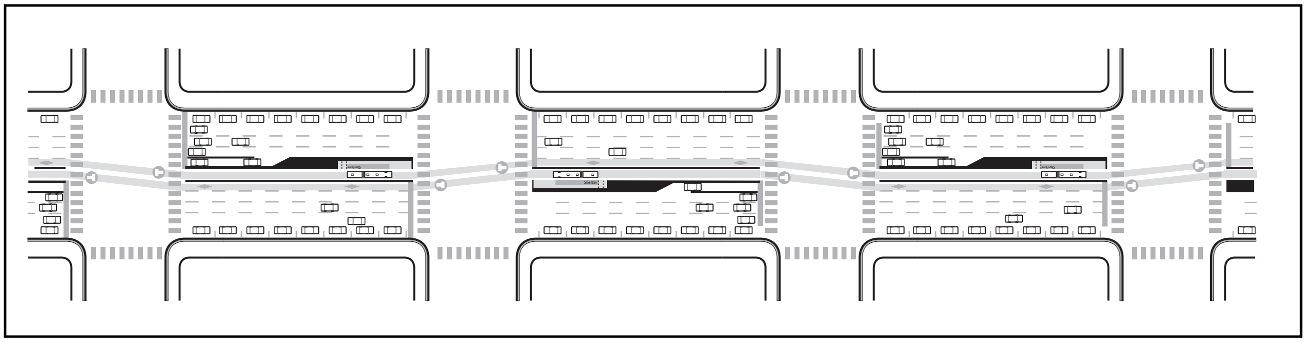
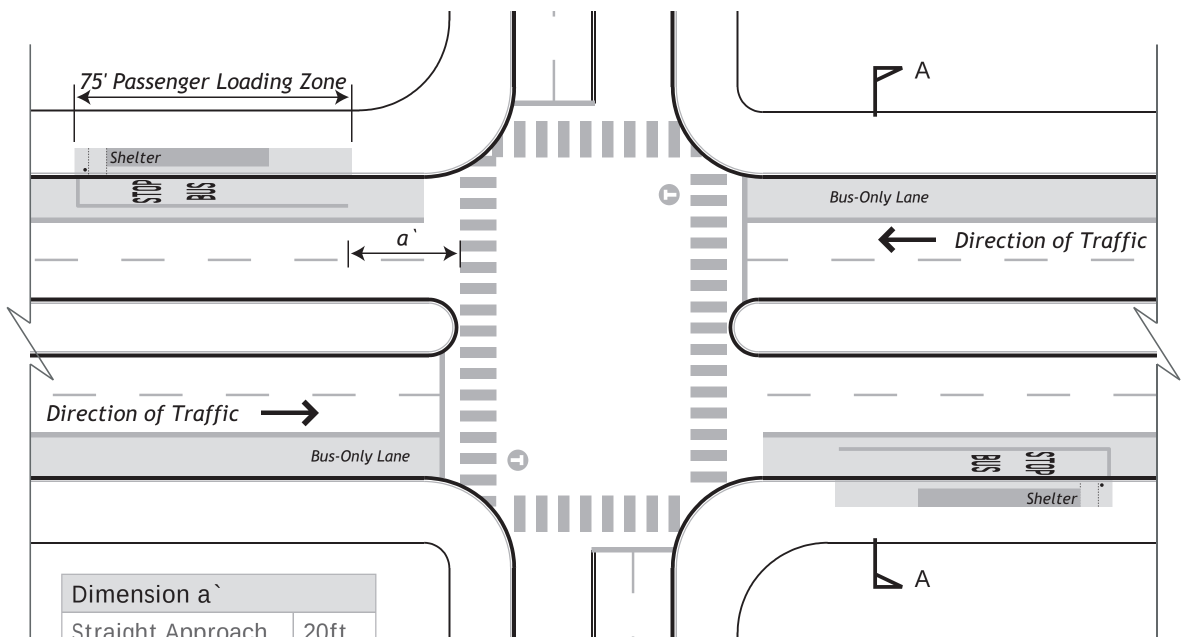
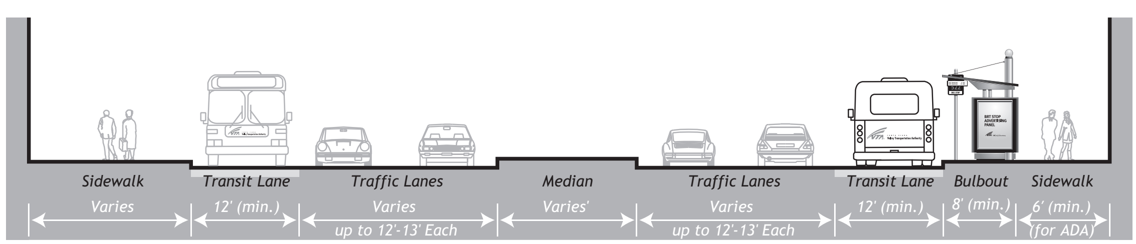


**Figure 22** Median Bus-Only Lane Concept—Typical Station Configuration




| Dimension a` | |
|---|---|
| Straight Approach | 20ft |
| After Right Turn | 75ft |
| After Left Turn | 50ft |

*Notes:*
*1.) For the layout and details of the passenger loading zone, refer to Figure 8.*
*2.) A 75′ loading zone is sufficient for a standard (40′) or an articulated (60′) bus.*
*3.) A 55’ loading zone is sufficient for a standard (40′) bus.*
*4.) A 120’ loading zone is sufficient for serving two standard buses simultaneously.*
*5.) A 140’ loading zone is sufficient for serving a standard and an articulated bus simultaneously.*
*6.) If a BRT station is on a bulbout, the minimum taper length is 50’ after the station.*




Typical Section A - A

**Figure 23** Median Bus-Only Lane (Eugene, OR)


**Figure 24** Median Bus-Only Lane (Vancouver, British Columbia — 98B Line)

## HOV LANES (IN NEW ROW)

DEFINITION: A lane located on the shoulder or median of a freeway, highway, or expressway designated for high-occupancy vehicles (HOVs) and buses. These lanes are constructed in new and separate ROWs, unlike converted HOV lanes, which are converted mixed-flow traffic lanes. Construction of two or more HOV lanes (one in each direction) within the median or the construction of new lanes along the shoulders in both directions (one in each direction) is required. Newly constructed HOV lanes are typically separated from mixed-flow traffic lanes with barriers or bollards.

OPERATING ENVIRONMENT: HOV and bus-only lanes typically operate during the peak period or throughout the day, depending on traffic conditions. In some cases, these facilities may be used by mixed-flow traffic after the peak periods or outside of working hours. Barriers are the primary means of segregating HOVs traffic from mixed-flow traffic, with lane stripping and signage at approaches. When BRT operates on shoulder lanes, exclusive HOV on- and off-ramps are added to reduce entry and exit times. When BRT operates on median HOV lanes, special direct access ramps may be provided. In addition, center median facilities may be reversible, serving the peak travel direction.

POTENTIAL DESIGN FEATURES:

- Exclusive HOV on/off ramps for BRT operating on shoulder lanes.
- Special direct median access ramps for BRT operating in the median HOV lanes.
- Where exclusive ramps are unavailable, special metering lights at the mouth of on-ramps to allow buses and HOVs to proceed.
- Separated by barriers or bollards and demarcated by appropriate pavement signage (e.g. diamond symbol), double striping, or rumble strips.
- Center median facility can be reversible to flow in the peak direction only.

ADVANTAGES: HOV lanes allow buses to operate faster, more reliably, and more safely than buses in mixed-flow lanes, while also allowing HOVs to bypass congestion. The greater stop spacing and fewer conflicts from turning movements allows buses to travel at much higher operating speeds than they may with the bus-only lane option. For shoulder HOV lanes, entry and exit off the freeway, highway, or expressway is easier, especially with direct on/off ramps, while median HOV lanes are removed from ramp conflicts at interchanges with convenient access provided by special median access ramps to crossroads.

DISADVANTAGES: Since buses and HOVs operate in these lanes, automobiles may impede bus operations, which make HOV lanes less efficient than dedicated bus-only lanes or at-grade or grade-separated transitways. Median lanes are more difficult to enter and exit the lane when direct HOV access cannot be provided. Shoulder lanes that do not have priority ramps are more susceptible to delays from non-HOV vehicles merging into the lane from on- and off-ramps. If the BRT stations are located on the shoulder, buses may experience

*(Concept box continued)*

difficulty merging back into the HOV lane. Conversely, if the lane is located in the median, stations may be difficult for transit riders to access. Buses serving intermediate stations located off the freeway, highway or expressway may experience delay from having to merge back onto the facility. Capital costs are higher than for converted HOV lanes. Appropriate ROW is necessary, which may be unavailable.

ESTIMATED COSTS: Costs range based on the terrain, scope of construction and ROW conversion required, the degree of segregation from mixed-flow traffic lanes, and the number of grade-separations, bridges, and direct HOV on/off ramps required. For instance, the cost for the El Monte Busway on the San Bernardino Freeway was $6.3 million/lane mile, while the Houston HOV lanes cost approximately $8.8 million/lane mile.[A]

POTENTIAL APPLICATION TO VTA: Applicable when: (i) a BRT route operates on some segment of a freeway or expressway; (ii) existing traffic demand on the freeway/expressway significantly impacts bus operations significantly; (iii) existing traffic volumes do not permit conversion of traffic lanes to HOV lanes; (iv) adequate ROW exists to place new HOV lanes; (v) sufficient financing exists for roadway improvements and lane demarcation; and (vi) daily boardings are within the range of BRT 2 type service.

EXAMPLES:

- Houston, Texas has dedicated HOV lanes on 6 of their freeways (Figure 25 and 26).
- El Monte Busway in San Bernardino.

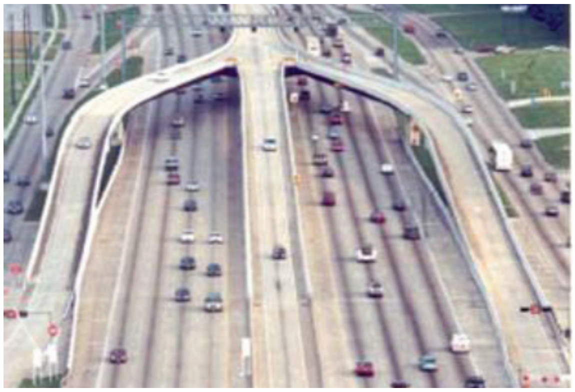
REFERENCE FIGURES:

- Figure 25. BRT in Median HOV Lane (Expressway/Freeway).
- Figure 26. BRT on Should Median HOV Lane (Expressway/Freeway).

[A] ibid., see BRT 29 Footnote B

**Figure 25** Median HOV Facility with Barrier (Houston)

**Figure 26** Direct Median HOV Access (Houston)



## AT-GRADE TRANSITWAY

DEFINITION: Exclusive at-grade transit lanes, built in its own right-of-way or transitway, which is completely segregated from mixed traffic, except at intersection crossings and at the entrance and exit of the transitway.

OPERATING ENVIRONMENT: At-grade transitways are often implemented in new or existing right-of-ways, including highway medians, shoulders, or abandoned railway right-of-ways. They sometimes parallel busy road corridors as well. At-grade transitways in urban areas generally have fewer intersection crossings than bus-only lanes. Outside of entry and exit points and a few intersection crossings, the transitway is only accessible to buses. At-grade transitways may flow in both directions or only in the peak travel direction of flow.

POTENTIAL DESIGN FEATURES:

- Exclusive transit lanes established in dedicated right-of-way.
- Physically separated from mixed-flow traffic except at intersections and transitway entrances and exits by concrete barriers, bollards, and raised pavement/curbs.
- Demarcated by pavement/vertical signage and pavement coloring, especially at intersections and merge points.
- Addition of a queue jump lane at congested intersections (defined in the Section 5.2.1 Queue Jump Lanes).
- Traffic signal improvements, such as centralized coordination and Bus Signal Priority (BSP).
- Appropriate signage to keep mixed traffic out of the transitway and pedestrians safe.
- Appropriate linkages with nearby sidewalk and bicycle path networks.
- Specialized stations with ADA compliant facilities and walkways.

ADVANTAGES: Fewer intersection crossings and greater physical segregation permits faster, safer (fewer conflicts with mixed traffic), and more reliable bus operations than mixed traffic or bus-only lanes. Passengers enjoy greater timesaving benefits than on BRT in mixed or bus-only lanes. Buses can operate at shorter headways, increasing the carrying capacity of the corridor. Delays at intersections can be further minimized through BSP. Buses merging into through-traffic lanes do not disrupt mixed vehicle traffic. Permanent stations with a distinctive design and appeal provide opportunity for development intensification and diversification along the corridor and near stations. This also allows pedestrian and bicycle infrastructure to develop around station areas.

*(Concept box continued)*

DISADVANTAGES: Conflicts from at-grade crossings reduce operating speeds and reliability. Capital costs are much higher than those for BRT 1 type running ways or dedicated bus-only lanes. Pedestrians and nearby residents, businesses, and parking may be impacted by the placement or operation of an at-grade transitway. Turning movements by mixed vehicular traffic may be banned causing inconvenience to motorists. Specialized stations increase capital costs, while appropriate right-of-way may be difficult or expensive to obtain.

ESTIMATED COSTS: At-grade transitways, cost approximately $6.5–10.2 million per lane mile, excluding ROW acquisition. Cost variables include transitway location, as well as the type and scale of stations.

POTENTIAL APPLICATION TO VTA: At-grade transitways shall be built when: (i) mixed-flow traffic conflicts significantly degrade transit operations and performance; (ii) bus-only lanes (either converted or dedicated) are infeasible on a given corridor due to roadway traffic and/or geometric/physical constraints); (iii) an adequate right-of-way corridor exists; (iv) sufficient funding exists for capital and ROW improvement costs; (v) permits to modify ROW have been or can be obtained; and (vi) performance is within BRT 2 standards.

EXAMPLES:

- MTA’s Orange Line in Los Angeles County (Figure 29).
- South Miami- Dade Busway in Miami (Figure 30).

REFERENCE FIGURES:

- Figure 27. At-Grade Transitway Concept – Typical Lane Configuration.
- Figure 28. At-Grade Transitway Concept – Typical Station Configuration.

**Figure 27** At-Grade Transitway Concept—Typical Lane Configuration

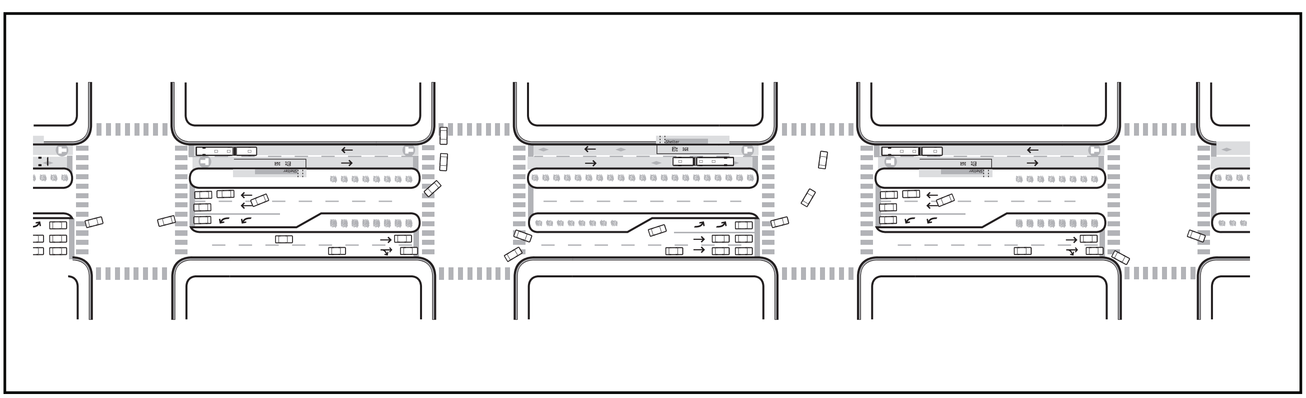
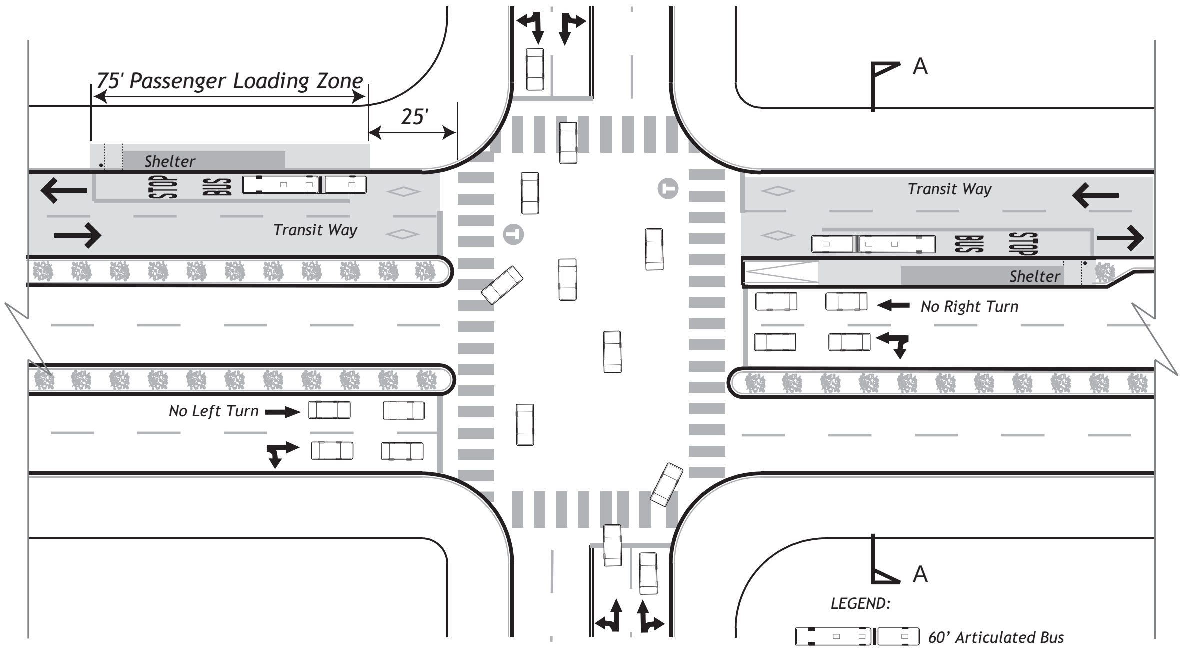
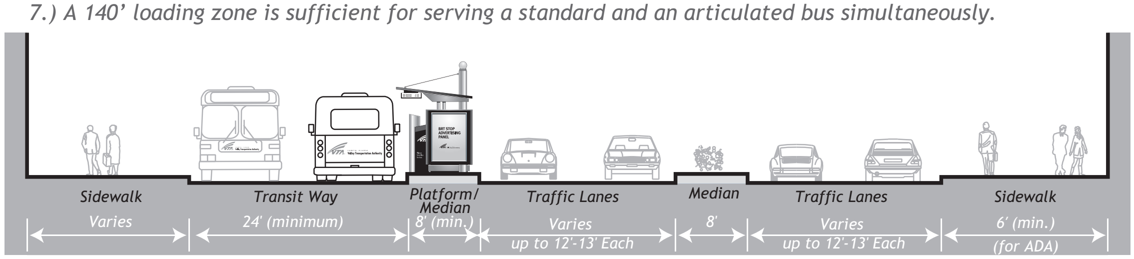


**Figure 28** At-Grade Transitway Concept—Typical Station Configuration




Notes:
1.) At-grade transitways are fully segregated from mixed traffic flows except at intersections and the entrance/exit to the transitway.
2.) In this scenario, only north-south traffic movements are permitted to cross the transitway to shorten delay. Prohibited turning movements in this scenario can also be permitted, although this will further delay buses.
3.) For the layout and details of the passenger loading zone, refer to Figure 8.
4.) A 75' loading zone is sufficient for a standard (40') or an articulated (60') bus.
5.) A 55' loading zone is sufficient for a standard (40') bus.
6.) A 120' loading zone is sufficient for serving two standard buses simultaneously.
7.) A 140' loading zone is sufficient for serving a standard and an articulated bus simultaneously.




Typical Section A - A

**Figure 29** At-Grade Transitway (Los Angeles—Metro Orange Line)


**Figure 30** At-Grade Transitway (South Miami-Dade Busway)

## GRADE-SEPARATED TRANSITWAY

DEFINITION: Grade-separated transitways provide complete separation from mixed-flow traffic. At-grade transitways can often be upgraded to grade-separated transitways so that all crossings are separated from mixed-flow travel lanes.

OPERATING ENVIRONMENT: Grade-separated transitways may use old railway right-of-ways, travel in the middle or alongside major freeways, travel in underground tunnels, along major arterial roads, or some combination of these. Buses may operate on flyovers or underpasses to avoid intersection conflicts. Multiple lanes may be required on a corridor or at stations where boarding volumes are high and/or both local and express/skip-stop service is jointly operated. Grade-separated transitways may act as "open" systems where buses enter/leave at intermediate points or as a "closed" system, where the bus only operates on the transitway.

POTENTIAL DESIGN FEATURES:

- New purpose-built transit lanes constructed in dedicated right-of-way.
- All crossings are grade-separated and bus operations are not impacted by mixed-flow traffic conflicts at all.
- Specialized stations with ADA compliant facilities and walkways.

ADVANTAGES: Grade-separated transitways permit vehicles to operate totally unimpeded by mixed traffic and provide the highest travel time saving, level of safety, and reliability of all types of running ways. In addition, they can accommodate the highest peak passenger flows of all BRT running way options. Bus traffic does not interfere with mixed traffic at all. There is potential for development intensification and densification, particularly if the transitway is along one side of a freeway.

DISADVANTAGES: Grade-separated transitways have the highest capital costs of any BRT option. Constructions impacts are similar to those for LRT, with pedestrians, businesses, traffic, and parking potentially displaced. An appropriate right-of-way throughout the corridor may be unattainable, which could potentially compromise operational efficiency and impact other portions of the line.

ESTIMATED COSTS: Costs (2006) for grade-separated transitways vary as follows: (i) aerial transitway – $12.0-30.0 million per lane mile; (ii) below-grade transitway – $60-105 million per lane mile; and (iii) additional lanes – $2.5–3.0 million per lane mile within the existing roadway profile ($6.5–10.1 million per additional lane mile). Determining factors for the cost of a grade-separated transitway are similar to those for the at-grade transitways.

*(Concept box continued)*

POTENTIAL APPLICATION TO VTA: Grade-separated transitways are applicable when: (i) bus-only lanes are unfeasible given street and traffic conditions; (ii) at-grade transitway performance is impacted by conflicts at intersections; (iii) appropriate vertical and horizontal clearance exists at a particular intersection or crossing; (iv) adequate funding is available; and (v) ridership standards are within upper BRT 2 type performance levels.

For grade-separated transitways on a freeway: (i) busways located within a freeway median are desirable where freeways are suitably located for ridership potential and cost constraints make it essential to minimize rights-of-way; and (ii) busways located along one side of a freeway provide easier access to stations, and simplify intermediate and terminal access points; they are also conducive to transit-oriented development along one side of the freeway.

## EXAMPLES:

- Ottawa's Transitway (Figure 33).
- Pittsburgh's Busways (Figure 34.)

## REFERENCE FIGURES:

- Figure 31. Grade-Separated Transitway Concept – Typical Lane Configuration.
- Figure 32. Grade-Separated Transitway Concept – Typical Lane Configuration.

**Figure 31** Grade-Searated Transitway Concept—Typical Lane Configuration

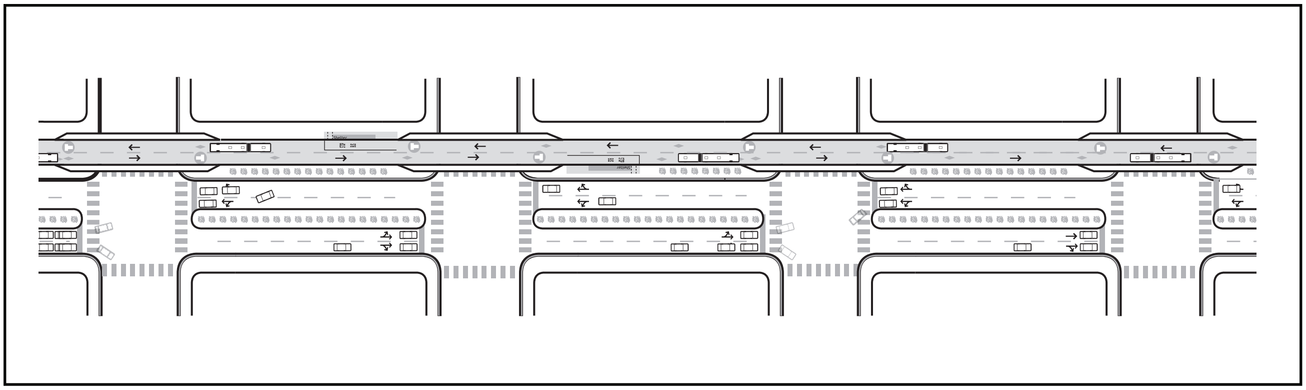
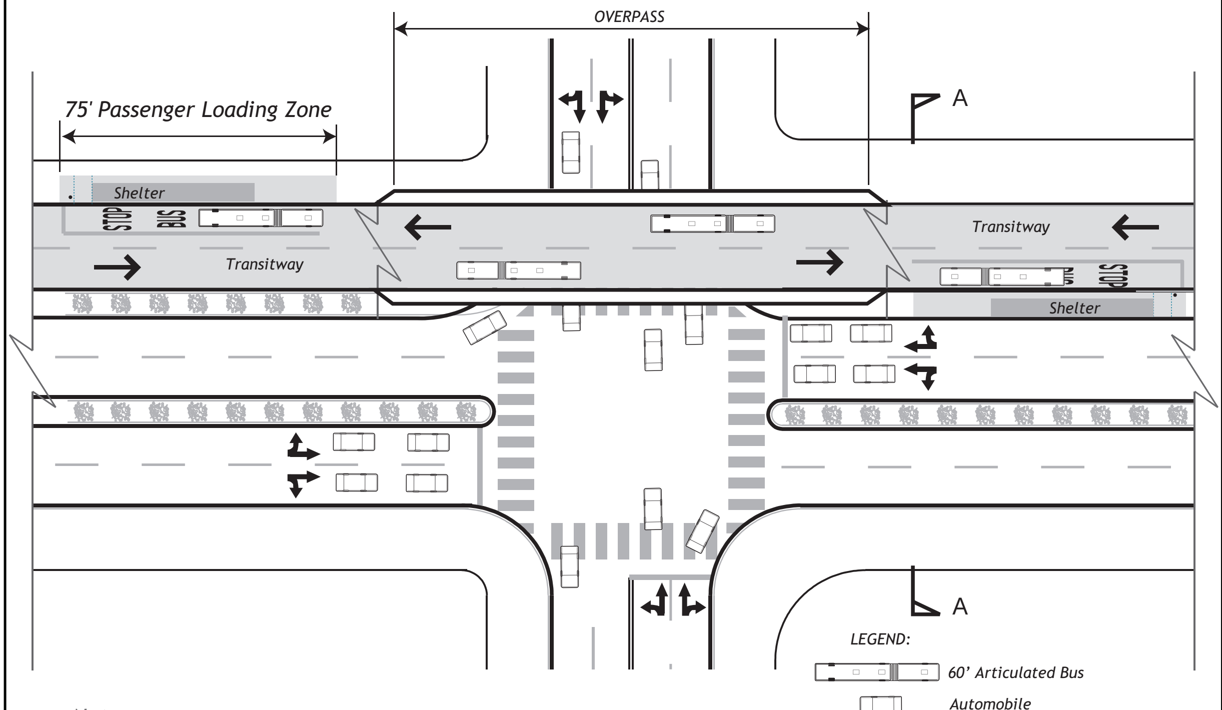
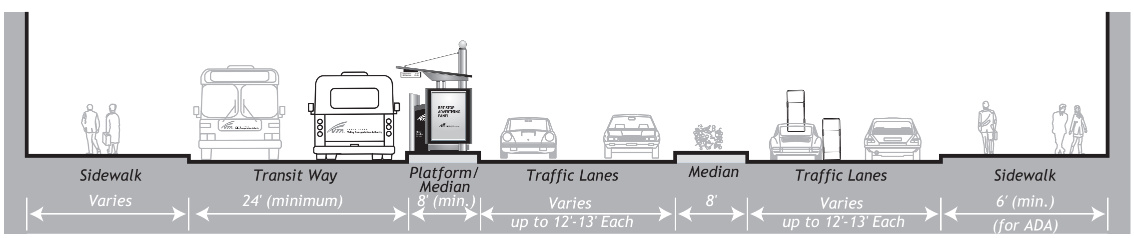


**Figure 32** Grade-Searated Transitway Concept—Typical Station Configuration




*Notes:*
*1.) Grade-separated transitways employ overpasses or underpasses to cross intersections. As such, there is no physical conflicts between buses and mixed traffic on the transitway at all.*
*2.) In this scenario, stations are located right after the transition from the overpass and possess pedestrian connections from the main intersection.*
*3.) For the layout and details of the passenger loading zone, refer to Figure 8.*
*4.) A 75' loading zone is sufficient for a standard (40') or an articulated (60') bus.*
*5.) A 55' loading zone is sufficient for a standard (40') bus.*
*6.) A 120' loading zone is sufficient for serving two standard buses simultaneously.*
*7.) A 140' loading zone is sufficient for serving a standard and an articulated bus simultaneously.*




Typical Section A - A

**Figure 33** Grade-Searated Transitway (Ottawa—Transiways)


**Figure 34** Grade-Searated Transitway (Pittsburgh—Busway)

## 5.2 INTERSECTION IMPROVEMENTS

### 5.2.1 QUEUE JUMP LANES

Delay at intersections from queuing vehicles impacts bus performance. The cumulative impact of intersection delay can significantly hinder bus on-time performance and operating speed. Queue jump lanes are away to minimize the travel time delays through special priority lanes, often right hand turn lanes that permit transit through movements. This can allow transit vehicles to bypass long queues at congested points, including intersections and bridge approaches, and can provide an important competitive advantage in heavily congested corridors. Queue jump lanes reduce transit delays, improve travel speeds, and increase schedule reliability. The ability to provide queue jump lanes could mean the difference between VTA's ability to provide local bus service or BRT service. Figures 35 through 38 are examples of different queue jump configurations.

Queue jump lanes are typically installed at heavily congested intersections, with priority given to those intersections offering the greatest benefits to transit. They are often combined with Bus Signal Priority (BSP) and can be integrated with advanced stop bars — an approach where the main stop bar for mixed traffic is offset from the intersection by several car lengths, giving transit a one to two car length advantage to pull out from the intersection compared to the mixed-flow travel lane. Figure 35 Scenario 3 shows an example of an advanced stop bar.

Queue jump lanes can be designed to facilitate straight-ahead movements through intersections or turning movements (left or right). Queue jump lanes can be placed adjacent to the curb or the center median, or in an adjoining lane. The length of a queue jump lane can vary on the relative length of the peak period queue in adjacent lanes. In some cases, HOVs may use queue jump lanes.

Typical queue jump configurations are described in Table 9 and shown in Figure 35.

At present, VTA has installed two curbside right-turn only with buses exempt lanes for straight-ahead movements along El Camino Real. These lanes are used by VTA buses, including Rapid 522, to bypass traffic queues. Queue jump lanes shall be implemented along VTA BRT corridors as follows:

- At primary intersections, where traffic congestion significantly impacts bus performance, benefits to transit are potentially the highest, and opportunities exist, such as adequate right-of-way to place a queue jump lane.
- Intended for straight-ahead movements only and implemented along the curb.
- Built to a length that exceeds the average queue length observed in adjacent mixed traffic lanes during peak periods, so that buses can enter the lane prior to the start of the queue itself.
- Combined with bus signal priority at particularly congested intersections with severe delay.
- Combined with bus-only lanes, where present.
- Distinctively identified with special pavement treatments.
- In the case of a near side bus station at an intersection with BSP, the queue jump lane shall be located downstream of the bus station.
- Adequate distance shall be provided on the far side of the intersection to enable easy re-entry of the bus.
- Implemented on a limited, as needed basis, since they must be constantly enforced.

**Table 9** Various Queue Jump Lane Configurations

| Scenario # | Queue Jump Configuration | Description | Operational/Design Issues |
|---|---|---|---|
| 1 | Right-Turn Lane with Transit Exemption | Transit vehicles are allowed in the right-turn only lane, are exempt from making the turn, and permitted to make a straight-ahead movement across the intersection | Bus flow may be disrupted by right-turning vehicles and loading/unloading vehicles at the curb. Signage is necessary to show that straight-ahead movements are prohibited for general traffic. |
| 2 | Adjacent to Right-Turn Lane (Chevron Lane) | A transit only lane prior to the intersection and adjacent to the right-turn only lane. Buses can bypass the queues in the through and right turn traffic lanes. | An additional right hand turn lane maybe necessary, which may increase costs or require road widening. Signage is necessary to alert motorists that the lane is for buses only. |
| 3 | With Advanced Stop Bar | A transit only lane is created at the curb, which ends at the main stop line. Adjacent mixed-flow lanes fall short of the intersection by several car lengths or more. This permits the transit vehicle to pull out ahead of the mixed-flow traffic. | Allows buses to enter the intersection earlier than mixed traffic flows, allowing it to merge more safely and effectively. The bus must cut across at least one lane, which may cause safety concerns. Right-turning vehicles may accidentally use the queue jump lane if signage is poor or confusing. |
| 4 | With Transit Exemption | Similar to Scenario 1, except the curbside lane is a bus-only lane. | Bus flow may be disrupted by right-turning vehicles and loading/unloading vehicles at the curb. Signage is necessary to show that general traffic is prohibited from using the lane. |
| 5 | Integrated with Curbside Bus-Only Lane and "Porkchop" Island | Similar to Scenario 4, except a "porkchop" island is used to segregate buses from turning traffic. | Right turning vehicles are better segregated from the straight-ahead bus movement. This is less confusing to drivers than Scenario 4. It also provides an island refuge for pedestrians. Bus flow may be disrupted by right-turning vehicles and vehicles parked at the curb to load/unload. Signage is necessary to show that straight-ahead movements are prohibited for general traffic. |

## QUEUE JUMP LANE CONCEPTS

DEFINITION: A special lane allowing transit vehicles to bypass queues at congested points, such as intersections and bridge approaches.

OPERATING ENVIRONMENT: Queue jump lanes can be designed to facilitate straight-ahead movements through intersections or turning movements (left or right). Queue jump lanes can be placed adjacent to the curb, the center median, or in an adjoining lane. In some cases, HOVs may utilize queue jump lanes. The length of a queue jump lane can vary depending on the relative length of the peak period traffic queue and traffic volumes in adjacent lanes.

POTENTIAL DESIGN FEATURES:

- Various options include: Right-Turn Lane with Transit Exemption (Figure 35 Scenario 1); Queue Jump Lane Adjacent to Right-Turn Lane (Scenario 2); Queue Jump Lane with Advanced Stop Bar (Scenario 3); Queue Jump Lane Integrated with Curbside Bus-Only Lane (Scenario 4); and Queue Jump Lane Integrated with Curbside Bus-Only Lane and "Porkchop" Island (Scenario 5).
- Generally intended for straight-ahead movements only.
- Built to a length that exceeds the average queue length observed in adjacent mixed traffic lanes during the peak period so that buses can enter the lane prior to the start of the queue itself.
- Combined with BSP at particularly congested intersections causing severe delay.
- Combined with bus-only lanes, where present.
- In the case of a near side bus station at an intersection with BSP, the queue jump lane shall be placed downstream of the bus station.
- Adequate distance shall be provided on the far side of the intersection to enable easy re-entry of the bus into mixed-flow traffic.
- The lanes are distinctively identified by special pavement delineation.

ADVANTAGES: Advantages include travel time saving, increased transit competitiveness, improved image of transit, and increased corridor carrying capacity. Furthermore, time saving can be achieved if the lane is integrated with a bus-only lane and/or Bus Signal Priority (BSP). Capital costs are relatively low compared to large-scale physical measures, such as grade separation, to reduce intersection delay.

*(Concept box continued)*

**DISADVANTAGES:** Installation may result in: (i) a small increase in traffic delay; (ii) a decrease in roadway width for mixed traffic lanes; (iii) displacement of parking, pedestrians, and/or traffic; and (iv) increased danger for motorists and pedestrians, if they are unaccustomed to early entry of the bus into the intersection. Insufficient roadway width may prevent the installation of queue jump lanes at key congested intersections. Without other improvements (e.g., Bus Signal Priority) queue jump lanes may be ineffective in reducing bus delay. Concurrent flow curb lanes are usually the least effective in terms of image and travel time saved. Lanes require constant enforcement. If right turns are allowed out of the queue jump lane, this may interfere with bus flow.

**ESTIMATED COSTS:** The costs can range from the low end, where no land acquisition is required (concurrent flow lane), to the moderate, which requires reprogramming of signals and detectors, to the high end, which includes both signal and detector installation and land acquisition

**POTENTIAL APPLICATION TO VTA:** Queue jump lanes shall be implemented on a limited, as needed basis, at primary intersections, where delay significantly impacts bus performance, where adequate right-of-way exists to place a queue jump lane, and where benefits to transit are potentially the highest. Queue jump lanes provide the greatest benefits to buses when combined with BSP and/or bus-only lanes.

**EXAMPLES:** Queue jump lanes have been widely implemented throughout North America, examples include:

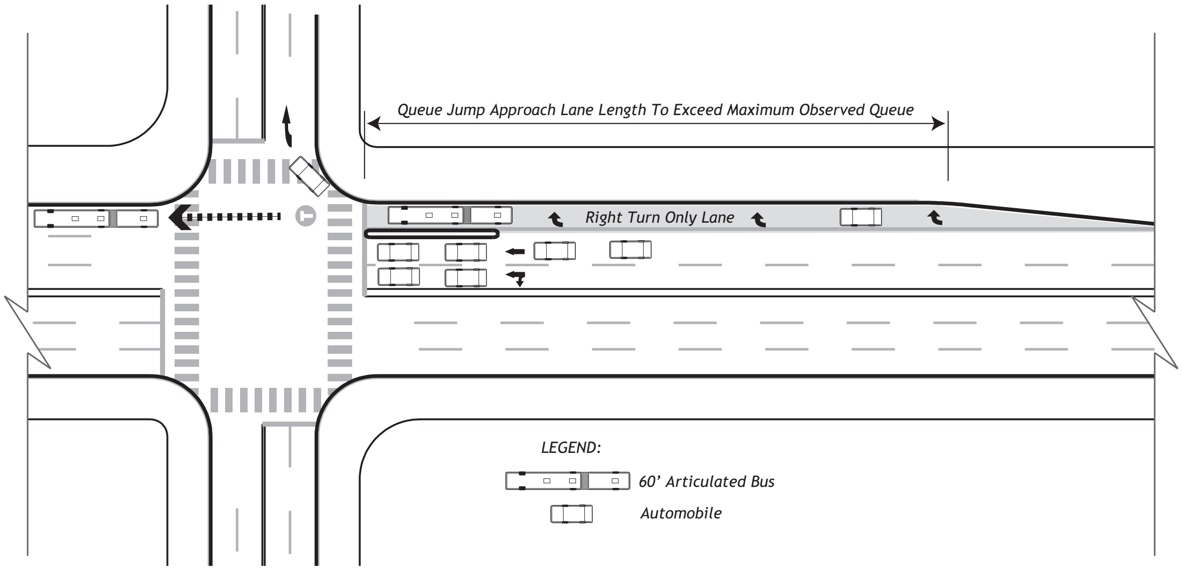
- San Diego has examples of a queue jump lane with a porkchop island (Figure 36).
- Ottawa in Canada has examples of a queue jump lane with a porkchop islands (Figure 37).
- El Camino Real in Santa Clara County has a right turn with transit exemption (Figure 38).
- Del Norte BART Station in El Cerrito.

**REFERENCE FIGURES:**

- Figure 35. Queue Jump Lane Configuration.

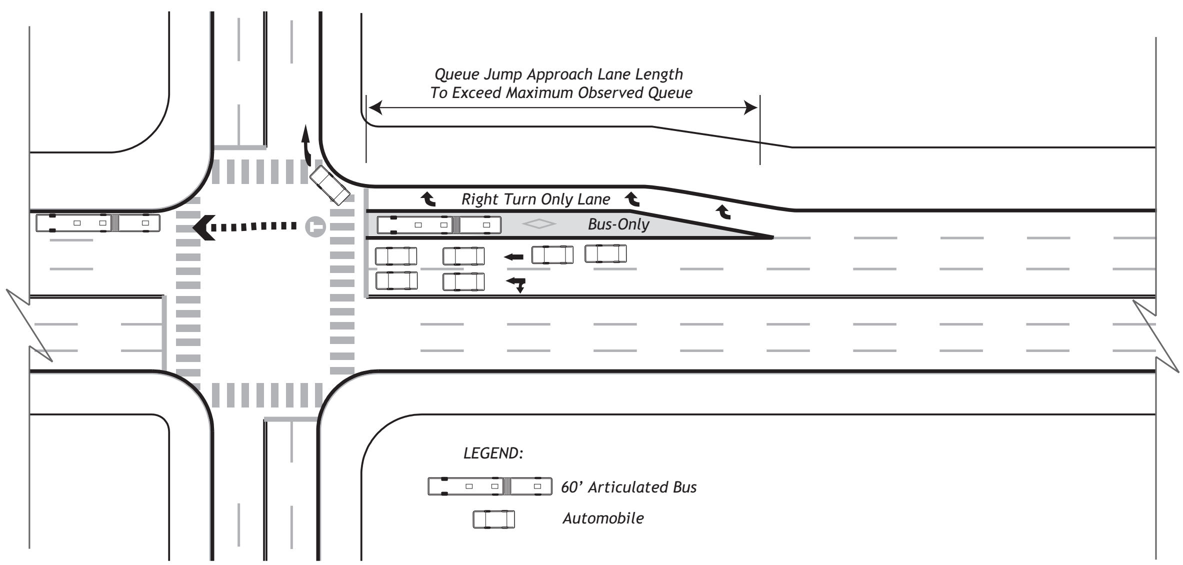
**Figure 35** Queue Jump Lane Configuration

Scenario 1: Right-turn Only Lane as Queue Jump Lane with Transit Exemption




*Notes:*
*1.) Only transit vehicles permitted to make straight-ahead movement out of the right-turn lane.*
*2.) Effectiveness will be improved if the queue jump lane is integrated with transit signal priority.*

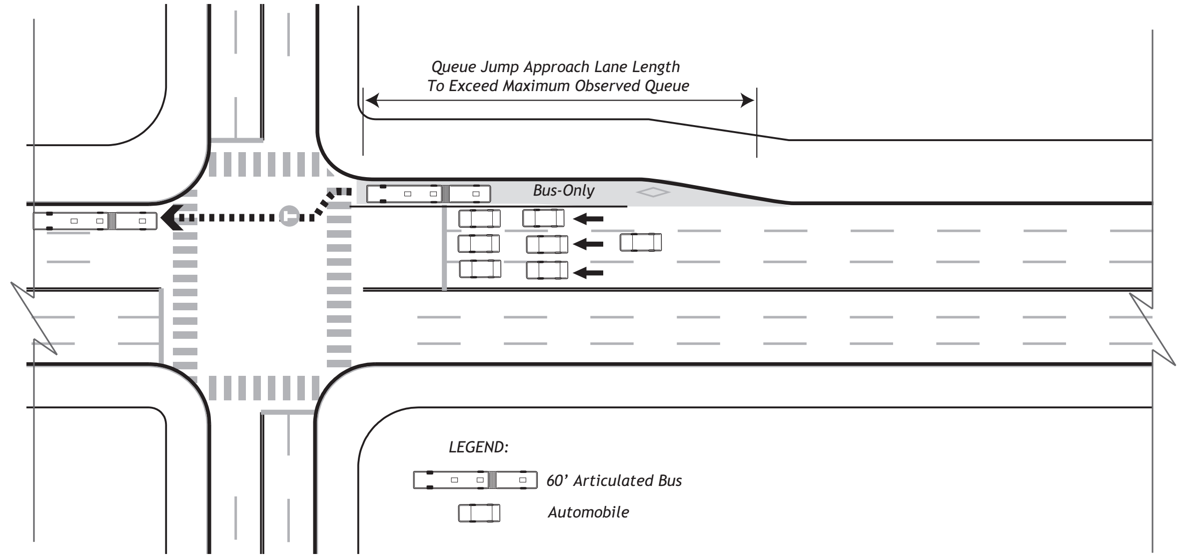
Scenario 2: Queue Jump Lane Adjacent to Right Turn Only Lane




*Notes:*
*1.) The length of the queue jump approach shall exceed the maximum observed queue length in the adjacent mixed traffic lanes.*
*2.) Only buses are allowed in the queue jump lane.*
*3.) Effectiveness will be improved if the queue jump lane is integrated with transit signal priority.*

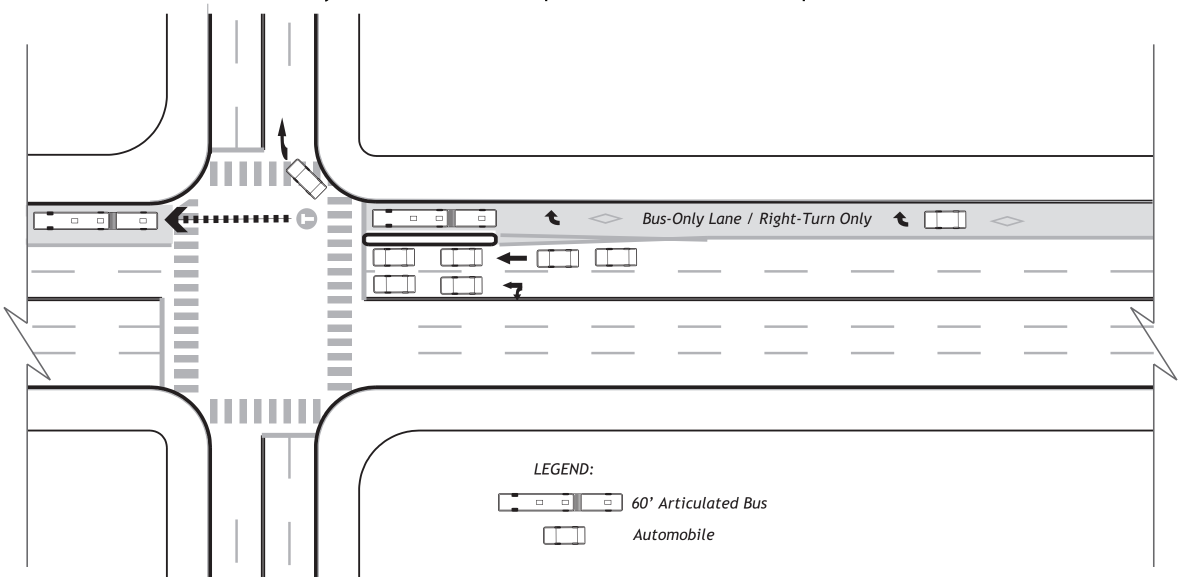
**Figure 35** Queue Jump Lane Configuration (continued)

Scenario 3: Queue Jump Lane with Advanced Stop Bar




*Notes:*
*1.) Right-turn movements are prohibited in this scenario.*
*2.) This type of queue jump lane may also be employed with a curbside bus-only lane.*
*3.) Effectiveness will be improved if the queue jump lane is integrated with transit signal priority.*

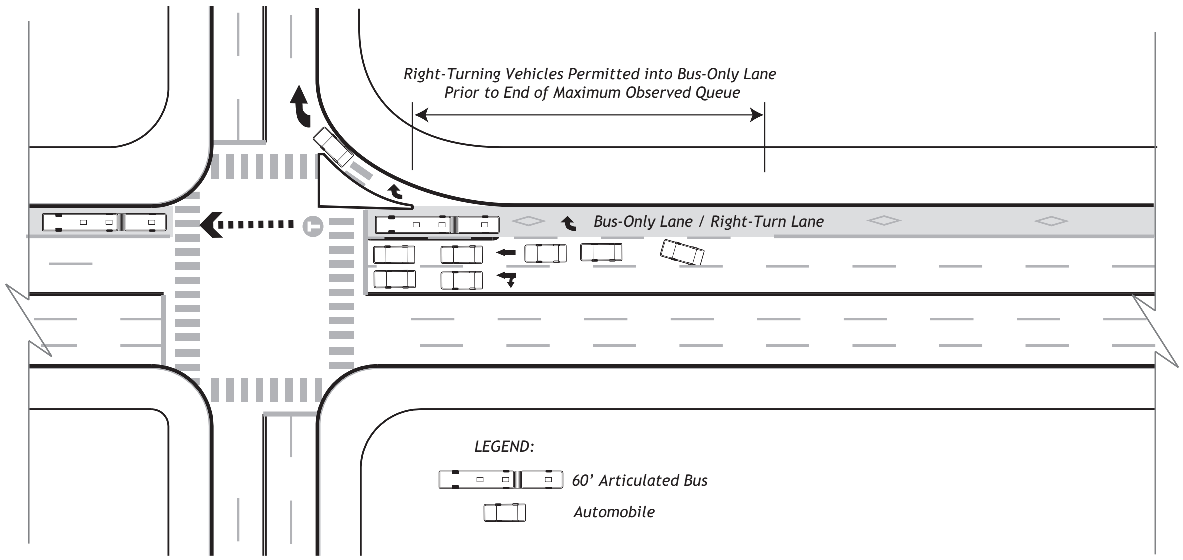
Scenario 4: Curbside Bus-Only Lane as Queue Jump Lane with Transit Exemption




*Notes:*
*1.) Right-turning vehicles are allowed into the bus-only lane in this scenario, but only transit vehicles may make straight-ahead movements.*
*2.) In this scenario, mixed traffic may also be banned from entering the bus-only lane and right-turning movements prohibited completely.*
*3.) Bus-only lane is continuous through the intersection in this scenario.*
*4.) Effectiveness will be improved if the queue jump lane is integrated with transit signal priority.*

**Figure 35** Queue Jump Lane Configuration (continued)

Scenario 5: Curbside Bus-Only Lane as Queue Jump Lane with "Porkchop" Island




*Notes:*

*1.) Right-turning vehicles are allowed into the bus-only lane in this scenario, but only transit vehicles may make straight-ahead movements.*

*2.) Right-turning vehicles allowed into the bus-only lane prior to the end of the maximum observed queue.*

*3.) Bus-only lane is continuous through the intersection in this scenario.*

*4.) Effectiveness will be improved if the queue jump lane is integrated with transit signal priority.*

**Figure 36** Queue Jump Lane Examples (San Diego)

**Figure 37** Queue Jump Lane Examples (Ottawa)


**Figure 38** Right–Turn Lane with Transit Exemption (El Camino Real and Oregon Expressway)


## 5.2.2 BUS SIGNAL PRIORITY (BSP)

In addition to installing queue jump lanes, Bus Signal Priority (BSP) is another way to reduce travel time delay and variability of delay at a traffic signal. In general, signal priority can be implemented in two ways: (i) passively, where signals are programmed according to transit running times or to optimize general traffic flow, as is done in the Denver Transit Mall; or (ii) actively, where priority is granted to a bus after it is detected. Active priority is either: (i) conditional, where only late buses are given priority (as is done on AC Transit's San Pablo Rapid and Los Angeles's Metro Rapid); or (ii) unconditional, where all buses are given priority regardless of whether they are early or late (as is done in Ottawa).[3] Along the El Camino Corridor, VTA employs active, unconditional priority.

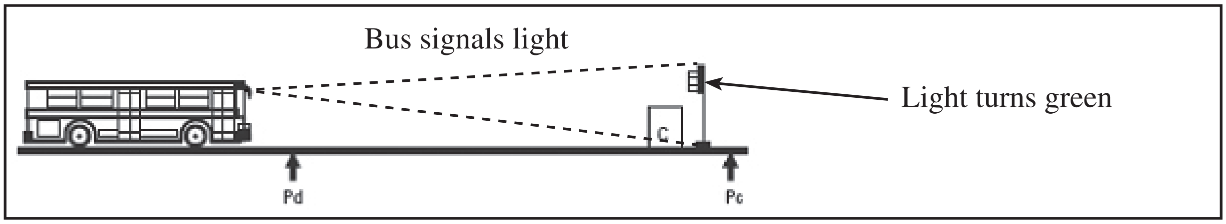
BSP requires three main elements as described in Table 11[4]. Figure 39 shows how BSP functions at an intersection.

Table 11 BSP Components
Source: An Overview of Bus Signal Priority, ITS America, 2004.

3 For systems adopting headway-based schedule control, a bus is evaluated "early" or "late" against its expected arrival headway at a given station.

4 More specific information on these systems may be found in: An Overview of Transit Signal Priority, ITS America, 2004.

**Figure 39** Typical BSP Configuration[5]




VTA does not have the authority over traffic control signals, signs, and pavement markings and cannot make changes independent of local jurisdictions and entities. Therefore, the implementation of BSP requires full cooperation and coordination between VTA and those local jurisdictions and agencies that manage the traffic signal system. Additionally, since BSP impacts non-prioritized intersections and roadway segments, involvement with relevant stakeholders and the public is required before BSP implementation.

The current working policy for BSP on the El Camino Corridor for the Rapid 522 is as follows:

- Early green or extended green is permitted, but may only account for 10% of the cycle length at the most.
- Skipping a signal phase is not permitted.
- No priority is granted during signal transition.
- Priority is granted every other cycle, at the most.
- The set order of priority is railroad preemption, emergency vehicle preemption, and then transit priority.

VTA shall implement BSP in the following incremental stages, based on existing corridor, intersection, and traffic conditions, as well as local jurisdiction, stakeholder, and public opinion:

Stage 1 – Coordination and synchronization of existing traffic signals.
Stage 2 – BSP at intersections with high levels of delay.
Stage 3 – BSP where queue jump lanes exist.
Stage 4 – BSP along an entire corridor.

5 Note: Pd represents the detection point, where the priority request is first made. Pc represents a checkout point after the bus passes through the intersection, where the signal controller is informed to restore the normal signal timing. Source: Transit Signal Priority Handbook, ITS America, 2005.

## BUS SIGNAL PRIORITY[A]

DEFINITION: Bus Signal Priority (BSP) is an operational strategy that facilitates the movement of in-service buses through traffic signal controlled intersections. By reducing the time that transit vehicles spend delayed at intersection queues, BSP can reduce transit delay and travel time and improve transit service reliability, thereby increasing the quality of transit service. It also has the potential for reducing overall delay at an intersection on a per-person basis. At the same time, BSP attempts to provide these benefits with minimum impact to other facility users, including cross-traffic and pedestrians.

OPERATING ENVIRONMENT: BSP is employed along corridors to reduce delay at intersections and improve transit competitiveness compared to the automobile. Two primary strategies are used to give vehicle active priority: (i) early green (red truncation), where the red phase is shortened to quicken the return of the green for an approaching transit vehicle; or (ii) green extension, where the green time is extended after a transit vehicle is detected to allow it to pass through the intersection. BSP is provided: (i) conditionally, where only late buses are given priority (as is done on AC Transit's San Pablo Rapid and Los Angeles's Metro Rapid); or (ii) unconditionally, where all buses are given priority regardless of whether they are early or late (as is done in Ottawa).

POTENTIAL DESIGN FEATURES:

- BSP can be implemented at a single problematic intersection, a series of intersections along a corridor, at non-consecutive intersections in a corridor, or at every intersection along a corridor.
- BSP requires a vehicle detection/priority request system, a communications system, and a traffic signal control system as shown in Figure 39.
- Various approaches exist for generating priority requests including: (i) wayside detection of the vehicle by the local traffic control system; (ii) loop detectors in the pavement; (iii) direct active communication from the transit vehicle (transponder); or (iv) communications via the transit and/or traffic management center, based on real-time knowledge of vehicle position (Automatic Vehicle Location – AVL).
- Median bus-only lanes will require additional phases (and longer cycle times) to avoid turning conflicts between buses, automobiles, and pedestrians.
- Detection can be on a first-come, first-served basis or give priority to particular travel directions or routes. For instance, BRT priority may be given priority over local bus.
- BSP will not be processed in consecutive signal cycles or if the traffic signal timing is in transition (e.g., the traffic signal is transitioning back to its normal mode after BSP operation or emergency vehicle preemption).
- Intersection signal controllers within a recognized priority corridor shall be equipped to handle BSP, even if they are not initially equipped with BSP.
- Appropriate vertical and horizontal signage on intersection approaches is needed to inform motorists of potential interventions of an approaching bus.

*(Concept box continued)*

ADVANTAGES: Advantages include transit travel time saving, increased transit competitiveness, improved corridor performance for all traffic, increased corridor carrying capacity and an improved image of transit. Further time saving can be achieved if BSP is integrated with a bus-only lane and/or a queue jump lane along an entire corridor. Capital costs are very low compared to large-scale physical measures to reduce intersection delay such as grade-separation. If conditional priority is adopted, "early" buses can be refused priority so that operations will be more in line with expected arrival windows. Signal timings do not need to be reset regularly to account for ambient traffic conditions and changing operating schedules.

DISADVANTAGES: BSP may result in a small increase in traffic delay for side street users. BSP deployment requires consensus among all affected jurisdictions, relevant stakeholders, and the general public, which may delay project implementation. BSP functions best with far side stations, meaning near side stations need to be moved, which entails additional capital costs. Conditional priority may require an AVL system, detectors aboard each vehicle, and a more complicated control system, which collectively increases deployment costs.

ESTIMATED COSTS: Cost depends on the scope of the configuration, the existing systems and their compatibility with requisite systems, and the type of hardware and software installed. Implementation costs are relatively low. Prior VTA projects have cost between $8,000–$35,000 per intersection.[B]

POTENTIAL APPLICATION TO VTA: BSP can be installed at an intersection or along an entire corridor. As a stand-alone initiative, BSP can result in improved travel speeds and time saving for transit. When combined with bus-only lanes and queue jump lanes, the achievable time saving can be even more significant. Along BRT corridors, deployment of BSP is optimal, with new signals equipped with BSP capabilities and existing signals upgraded to handle BSP. In some cases, transit priority is not required outside of the peak, thus assessments should be made to determine if and when BSP should be made available at corridor intersections. If not needed during particular times of the day, controllers have the capability to disregard priority requests, as desired by the operator and signal the responsible local entities.

The overall impact of BSP on both the corridor and relevant side streets and intersections shall be considered such that BSP is desirable when:

- The person-minutes saved by bus and automobile passengers along the corridor or at a single intersection exceed the person-minutes lost by side street automobile drivers/ passengers.
- Side-street green time can be reduced and still provide adequate clearance time for pedestrians.
- Increased queues on side streets are manageable.

*(Concept box continued)*

EXAMPLES: BSP is widely employed throughout the world. Examples include:

- Rapid 522 along El Camino Corridor.
- Oakland's San Pablo Rapid along San Pablo Avenue for AC Transit.
- Los Angeles' Metro Rapid along Wilshire Boulevard.
- Ottawa's Transitways.

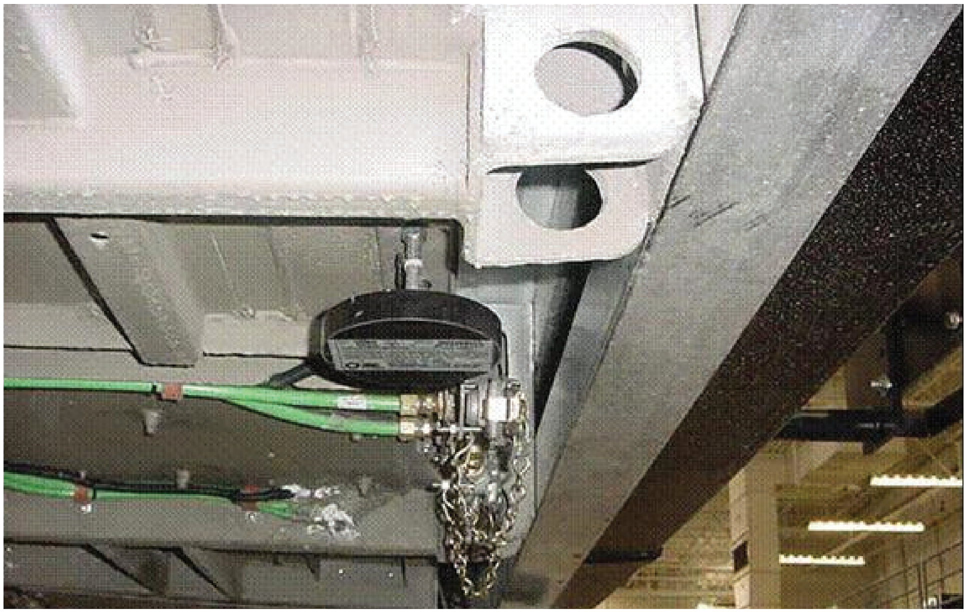
REFERENCE FIGURES:

- Figure 39. Typical BSP Configuration (see figure in Section 5.2.2).
- Figure 40. Transponder on Bus Underbelly to Activate Detection Loops.

[A] More detailed information is available in An Overview of Transit Signal Priority, ITS America, 2004. http://www.itsa.org/itsa/files/pdf/finaltspoverviewupdate.pdf

[B] Source: An Overview of Transit Signal Priority, ITS America, 2004.

**Figure 40** Transponder on Bus Underbelly to Activate Detection Loops



## 5.3 ADDITIONAL MEASURES SUPPORTING TRANSIT PRIORITY

The physical transit priority measures described above are only as effective as traffic management, regulation and enforcement measures in place to assure that these facilities and infrastructure function well and give transit a competitive advantage over the automobile. This is particularly true for buses operating within the street ROW (e.g. in mixed lanes or in bus-only lanes).

Traffic management, regulation and enforcement measures are described in the subsequent Concept Boxes. The recommended application of these measures is also described in the Concept Boxes below.

## MEASURES SUPPORTING TRANSIT PRIORITY— TRAFFIC CONTROL AND MANAGEMENT

DEFINITION: Traffic controls relate to curb use, turning movements, and street directions. These can be applied at individual locations, on selected segments, or on an entire BRT route.

OPERATING ENVIRONMENT: Traffic controls may be implemented along corridors where existing roadway traffic, parking, or turning movements reduce operating efficiency.

POTENTIAL DESIGN FEATURES: Three types of traffic control are generally adopted[A]:

- Curb Parking Restrictions and Loading Controls. Imposed during peak periods or working hours to increase the lane width available to buses, reduce conflicts with vehicles entering or leaving a parking space, and increase transit operating speeds. These lanes may also be used as bus-only lanes if parking is banned throughout a corridor.
- Turn Controls (Banning of Left/Right Turns). Reduces the time lost behind queuing automobiles and reduces the chance of conflict with turning vehicles.
- One-Way Streets. Improve traffic flow and transit operations in a single direction.

ADVANTAGES: Traffic controls improve transit-operating speeds, reduce the chance for collisions, and reduce travel delays from conflicts with other vehicles.

DISADVANTAGES: Initial opposition to these regulatory measures may appear if public "buy-in" is not obtained, especially for the prohibition of on-street parking, which can affect retail and commercial areas.

ESTIMATED COSTS: Striping and signage costs.

POTENTIAL APPLICATION TO VTA: Curbside parking and unloading/loading may be restricted during the peak period or throughout the day on the curbside either to create bus-only lanes or to minimize conflicts between vehicles and buses. Left and right turn movements for vehicles shall be restricted when they delay BRT travel times or impact safety.

EXAMPLES:

- Seattle converts their parking lane on a major street in their downtown to a bus-only lane during working hours (Figure 12).
- Los Angeles restricts parking along its Wilshire Metro Rapid Line.

*(Concept box continued)*

REFERENCE FIGURES:

- Figure 41. Signs along Bus-Only Lanes (London – Red Routes).
- Figure 42. Sign along Bus-Only Lane.
- Figure 43. Transit 'Cigar' Signal.

[A] Transit exemptions may also be considered a traffic control regulation. For instance, in right-turn lanes, transit is given an exemption and allowed to proceed through the intersection. However, for this document this is considered a type of queue jump lane and is described in Section 5.2.1 Queue Jump Lanes.

**Figure 41** Signs Along Bus-Only Lanes (London—Red Routes)


**Figure 42** Sign Along Bus-Only Lane (Eugene, OR)

## MEASURES SUPPORTING TRANSIT PRIORITY—SPECIALIZED REGULATORY SIGNS AND SIGNAL DISPLAYS

DEFINITION: Special signage and traffic signal displays are essential along a transit or BRT route to keep motorists out of bus-only lanes or to differentiate bus-only signals from conventional signals.

OPERATING ENVIRONMENT: Special signs and signal displays are most applicable in areas where the potential for conflict with mixed traffic is the highest or conflicts have proven problematic in the past.

POTENTIAL DESIGN FEATURES: Signs and displays may include the following:

- Traffic Signs – Diamond symbols in bus-only/HOV lanes, pavement striping, horizontal signage, such as “Bus-Only” lane (see Figure 41), and vertical signage, such as warning and regulatory signs about staying out of the bus-only lanes and turning prohibitions (see Figure 43).
- Signal Displays – Transit-specific signal displays, which are most applicable on median bus-only lanes, at-grade transitways, and queue jump lanes. These signals are used to differentiate the transit signal from signals meant for normal traffic.

ADVANTAGES: Signs and displays can keep mixed traffic from conflicting with transit vehicles and allows transit to operate more efficiently and safely.

DISADVANTAGES: Special signal displays may be mistakenly viewed by motorists, causing confusion. Motorists may not heed signs unless enforcement is strong. Signs may be stolen, while pavement signage will need to be repainted periodically.

ESTIMATED COSTS: Striping, signage, and signal modification costs to install new displays.

POTENTIAL APPLICATION TO VTA: Special pavement signage and regulatory/warning signs shall be adopted along bus-only lanes to define transit running ways and to inform motorists of at-grade bus lane crossings. Special BRT traffic signal indicators shall be provided to minimize confusion, especially along median arterial busways and at queue jump lanes.

EXAMPLES:

- San Diego uses a special sign circled white “T” to illustrate a queue jump lane (Figure 36).
- Ottawa uses a “cigar” signal to illustrate a queue jump lane (Figure 43).
- Figure 41. Signs along Bus-Only Lanes (London – Red Routes).
- Figure 42. Signs along Bus-Only Lanes (Eugene, Oregon).

**Figure 43** Transit "Cigar" Signal (Top Signal Head)

## MEASURES SUPPORTING TRANSIT PRIORITY—ENFORCEMENT

DEFINITION: Bus-only lanes and transitways must be enforced to be effective. Without the active enforcement interference and improper use by automobiles, taxis, and trucks, can significantly reduce bus performance and safety.

OPERATING ENVIRONMENT: Enforcement is necessary along bus-only lanes and transitways where potential exists for vehicular turning, or parking conflicts.

POTENTIAL DESIGN FEATURES: Enforcement must include the agencies and entities that will be involved in enforcement activities, such as the transit agencies, state DOTs, local and state police, state and local judicial systems, local municipalities, metropolitan planning organizations (MPOs), and federal entities, as well as the type of strategy employed. The following are the types of enforcement methods available:

- Routine Enforcement – Random enforcement along a corridor throughout the day.
- Special Enforcement – Team patrols for a specific purpose.
- Selective Enforcement – A combination of routine and special enforcement, often focusing on problematic sections or locations.
- Public Enforcement – The public can call in violators.
- Automated Enforcement – Closed-circuit television (CCTV) may be used to identify violators and direct enforcement personnel accordingly. Also, cameras mounted on buses or at the wayside along the corridor, may be used to record violators and then subsequently issue summons or fines after accessing state or DMV databases.

Violators shall be fined, have their cars towed, or be given penalty points against their driving record. These penalties are often publicized through public awareness programs.

ADVANTAGES: Effective enforcement can improve compliance with bus-only lanes and traffic movement prohibitions, which can enhance transit operational efficiency and speed.

DISADVANTAGES: Widespread disregard for bus-only lanes can significantly reduce operating performance of buses in these lanes. The higher the level of enforcement desired, the higher the costs. Enforcement does not receive the same attention as infrastructure improvements, thus staffing and funding may be insufficient. Not every violator can be caught. Automated or video enforcement requires regulatory changes to existing legislation, which may delay or sideline deployment.

ESTIMATED COSTS: Depends on the size of the corridor and the number of personnel and hours devoted to this task. Special and selective enforcement cost more than routine enforcement. Automated solutions have much higher initial capital costs, but are more cost-effective in the long term, especially if they can reduce the number of assigned enforcement personnel.

*(Concept box continued)*

POTENTIAL APPLICATION TO VTA: Enforcement shall be conducted consistently around existing BRT stations and queue jump lanes. If a bus-only lane or transitway is implemented, routine enforcement, combined with CCTV and automated cameras, can most effectively regulate the corridor, although, as noted, regulatory changes must be made to existing legislation. It shall also be a priority to reduce operating expenses, so the introduction of automated cameras is very appropriate.

EXAMPLES: In Houston, a "HERO" program has been adopted so that the public can report violations of the HOV lanes, which are also used by buses. London has introduced CCTV monitoring, as well as bus-mounted cameras to automatically document violations.

REFERENCE FIGURES:

- Figure 44. Bus-Mounted Cameras to Photograph Violating Vehicles (London).
- Figure 45. HOV Hero Program to Report Violations.

**Figure 44** Bus-Mounted Cameras to Photograph Violating Vehicles (London)


**Figure 45** HOV Hero Program to Report Violations

## 6. BRT ROUTE DESIGN

BRT systems primarily operate on major arterials and corridors to maintain consistently higher operating speeds and reliability, and thus typically do not branch off into collector or minor roads to serve demand. Route structures are also simple and easy for passengers to understand with few, if any, circuitous route segments. Figure 46 shows a typical BRT route structure.

VTA BRT routes shall:

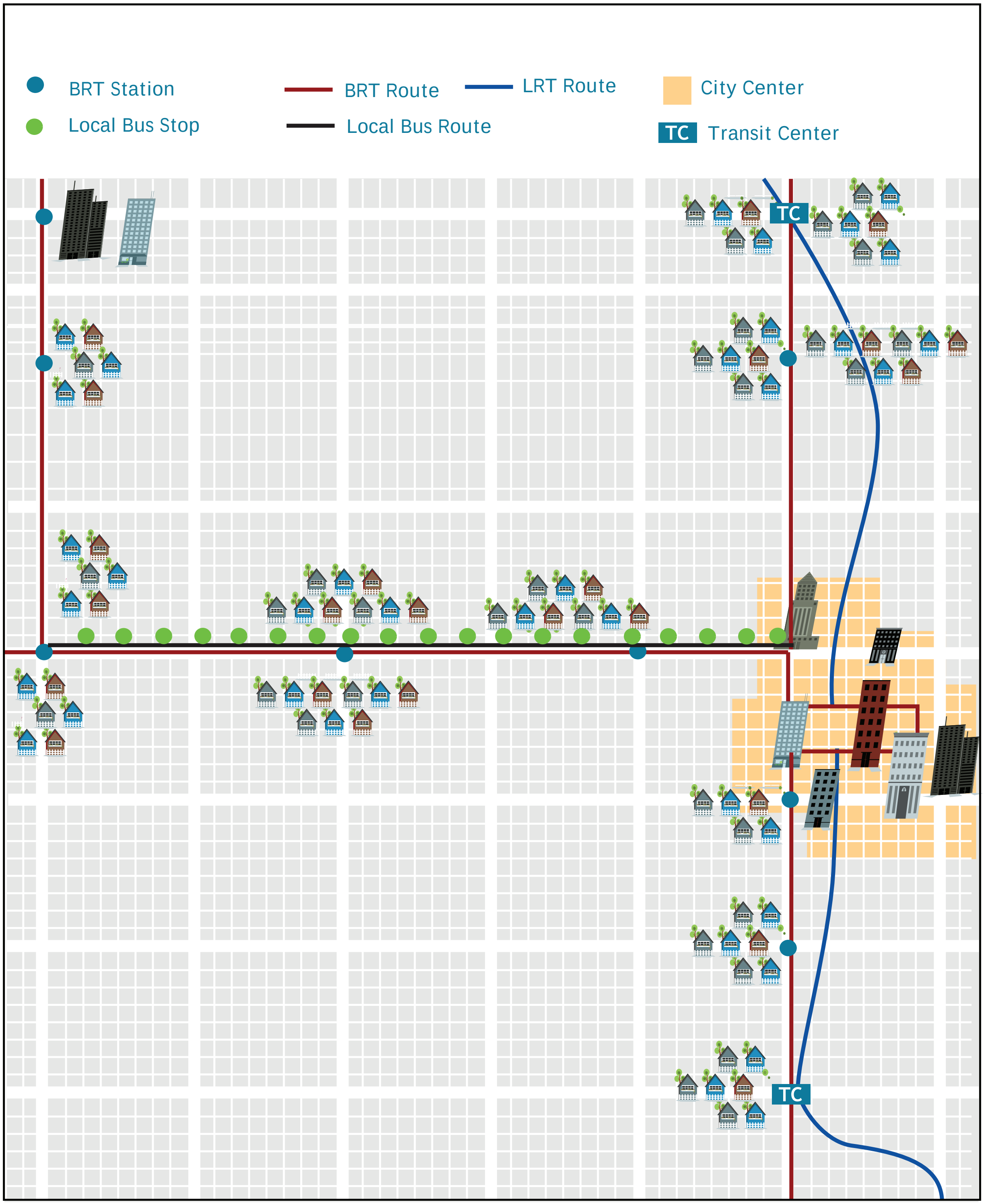
- Operate along major arterials that connect major activity nodes and high-density residential areas and radiate out from the city center.
- Provide adequate stops in the downtown area to serve major distribution points in the city center.
- Avoid out-of-direction travel.
- Operate a simplified route structure with branch lines minimized to promote route identify, maintain frequent service, and keep dwell times low.
- Allow for high-speed operations, as transit speeds need to be comparable to automobile speeds for the same trip along the corridor.
- Integrate service with existing BRT and other regional local transit routes to create a seamless and integrated system.
- Provide express, skipped-stop, or feeder services if demand warrants BRT 2 type systems.

Along the proposed route, BRT services shall meet the following physical criteria:

- Turning movements with an inside radius of 25 feet if the bus can use more than one travel lane; 30 feet if it turns onto a two-lane road.
- Street composition adequate to support the weight of the bus.
- Maximum lane widths of 12 feet. Where circumstances warrant, narrower lane widths shall be considered if bus and traffic operations can be safely maintained.
- Minimum overhead clearance of 12 feet.
- No unusually deep drainage dips that may cause the bus to scrape.
- No speed bumps or other traffic calming devices that would cause the bus to scrape or impede efficient operation.
- Have sufficient ROW for stations (See Section 8 BRT Station and Facility Design) and necessary lane configurations.

Service on private property will be considered only under special circumstances and will require a Memorandum of Understanding (MOU) or other formal agreement with the property owner holding VTA harmless for pavement damages.

**Figure 46** Typical BRT Route, Operating on Primary Arterials and Making Fewer Stops than Local Bus Service



## 7. BRT STATION LOCATION

The bus stop/transit station is the most prominent icon of public transit, and with more than 4,300 stops in Santa Clara County, the functionality, safety, and visual appearance of stations is critical to attracting and maintaining transit riders in any location. Accordingly, local jurisdictions that proactively work to improve the public perception of transit and access to transit stations shall receive priority considerations for service improvements when there are competing opportunities or proposals. BRT station location guidelines are as follows:

- BRT services shall utilize existing bus stops to the extent possible to reduce capital costs.
- Stations shall, on average, be located every ¾ of a mile, with exceptions for major trip generators, to maintain competitive operating speeds and efficiency.
- Specific station placement shall be optimally located to best capitalize on major trip generators nearby such as civic and employment centers, mixed-use districts and high-density residential areas, colleges and universities, and shopping centers.
- Station usage forecasts shall satisfy minimum daily boardings per station performance standards as outlined in Table 2.
- Stations shall be placed at locations with potential for high-density residential and commercial development and densification, as outlined in Table 5 and Table 7 to encourage transit usage.
- The specific location of a station shall depend on surrounding safety conditions and physical constraints.
- Stations shall be provided in pairs, to the extent possible, in locations that facilitate safe street and rail crossing.
- Stations located at intersections shall be placed at the far side of the intersection. In cases where safety or physical constraints prohibit the adoption of a far side station, a near side or midblock station shall be considered.
- In unique cases where an activity generator is located midblock and is some distance from the nearest intersection, the placement of a midblock station shall be considered.
- Station locations shall have adequate sidewalk width to accommodate ADA standards and requirements. Stations shall not be placed on streets without sidewalks or on streets where the sidewalks are not wide enough to meet ADA requirements.
- Station locations shall have sufficient ROW to construct shelters, install fare equipment and other passenger amenities, and provide adequate space to accommodate planned passenger demand. Passenger amenities may include benches, lighting, poles, informational signage, and trash receptacles (See Section 8.2 for a list of Station Amenities),
- Stations shall be provided in locations with sufficient red-curb space for buses to move into and away from the curb.
- On-street parking considerations include the following:
  - » Optimal station locations, determined by planning studies, shall have priority over on-street parking spaces in those locations[6]; and
  - » Opportunities for shared parking facilities, including agreements with private parties, adjacent to or within 500 feet of a major

6 VTA may choose to skip over potentially high-ridership stop locations that are obstructed by on-street parking spaces

station, shall be pursued jointly by the local jurisdiction and VTA.

## 8. BRT STATION AND FACILITY DESIGN

Along with potentially high construction costs, BRT stations require routine maintenance and operational costs to stay in service. However, stations remain an important first impression towards the total transit experience. In addition, stations provide riders a sense of permanence, while creating a link between the trip and community. For a station to be successful, the station shall be designed to meet the existing or anticipated ridership throughout the day, meet the unique needs of the community, and assure that optimal performance can be attained. Recommended station configurations, designs and amenities are described below.

### 8.1 STATION CONFIGURATION

The configuration of stations has two key components, station layout on the street curb or on the median, and the layout of the passenger boarding areas.

#### 8.1.1 STATION LAYOUT

Station layout is determined by the type of running way employed, the vehicles that are being operated, the intended location of the station, as well as the proximity and ease of access to nearby pedestrian and bicycle networks.

VTA BRT stations shall follow the preferred configuration discussed in Table 12. Figure 47 shows an example of the amenities available at a modern bus stop

**Figure 47** Modern Bus Stop with Real-Time Passenger Information (London)

**Table 12** Preferred VTA BRT Station Configurations

| Running Way | Preferred BRT Station Configuration |
|---|---|
| Mixed-flow lane<br><br>Curbside Bus-Only Lane | • Bulbout configurations (see Figures 48, 53, and 55 Scenario 1) shall be considered when one or more of the following exist:<br>» Urban design opportunities exist to enhance sidewalks and improve pedestrian circulation around busy stations;<br>» Insufficient ROW (sidewalk width) prohibits placement of station facilities;<br>» Conditions that delay vehicles by more than 90 seconds from merging back into traffic from a curbside station; and<br>» Serious safety issues for vehicles merging from a curbside station.<br>• Conventional curbside configurations shall be considered if bulbout stations are inappropriate given ambient traffic and transit operating conditions.<br>• Duckout configuration (see Figures 48, 53, and 55 Scenario 2) shall be considered if passing lanes are needed for express or limited stop services. |
| Median Bus-Only Lane<br><br>BRT Operating in HOV Lanes<br><br>At-Grade Transitway<br><br>Grade-Separated Transitway | Side platform stations are preferred due to:<br>1) Lower capital costs<br>2) Existing buses have right-side doors (center platforms would require buses with left-side doors)<br>3) Side platform stations provide easier and safer access to passengers.<br>Passing lanes at stations are necessary if express or limited stop services are in operation. |

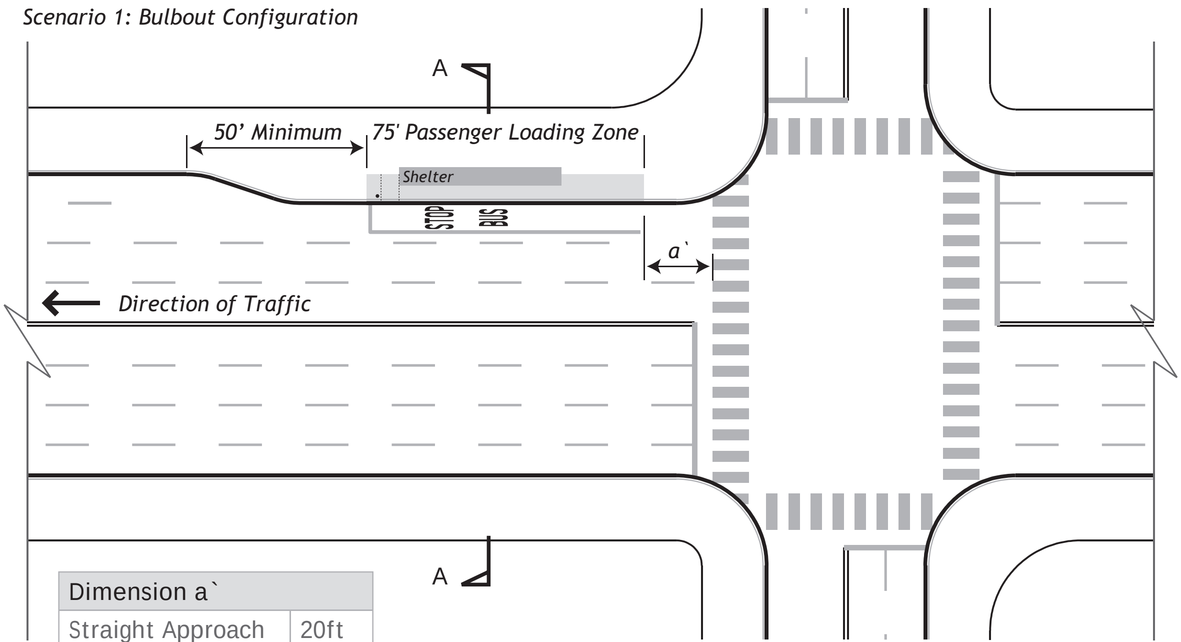
The following figures show various station layouts and configurations. Table 13 lists these figures for quick reference.

**Table 13** List of BRT Station Figures

| Figure | Description |
|---|---|
| Figure 48 | Typical Far Side BRT Station Configuration |
| Figure 49 through Figure 52 | VTA Far Side BRT Station Designs |
| Figure 53 | Typical Midblock BRT Station Configuration |
| Figure 54 | VTA Midblock BRT Station Designs |
| Figure 55 | Typical Near Side BRT Station Configuration |
| Figure 56 through Figure 58 | Phased Development of BRT Station Area, Infrastructure, and Amenities |

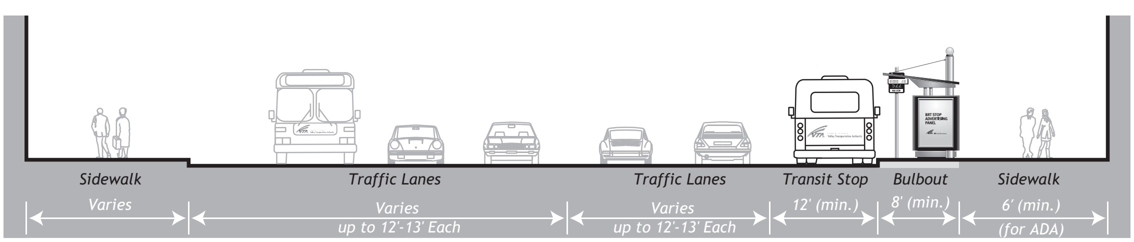
**Figure 48** Typical Far Side BRT Station Configuration

*Scenario 1: Bulbout Configuration*




| Dimension a` | |
|---|---|
| Straight Approach | 20ft |
| After Right Turn | 75ft |
| After Left Turn | 50ft |

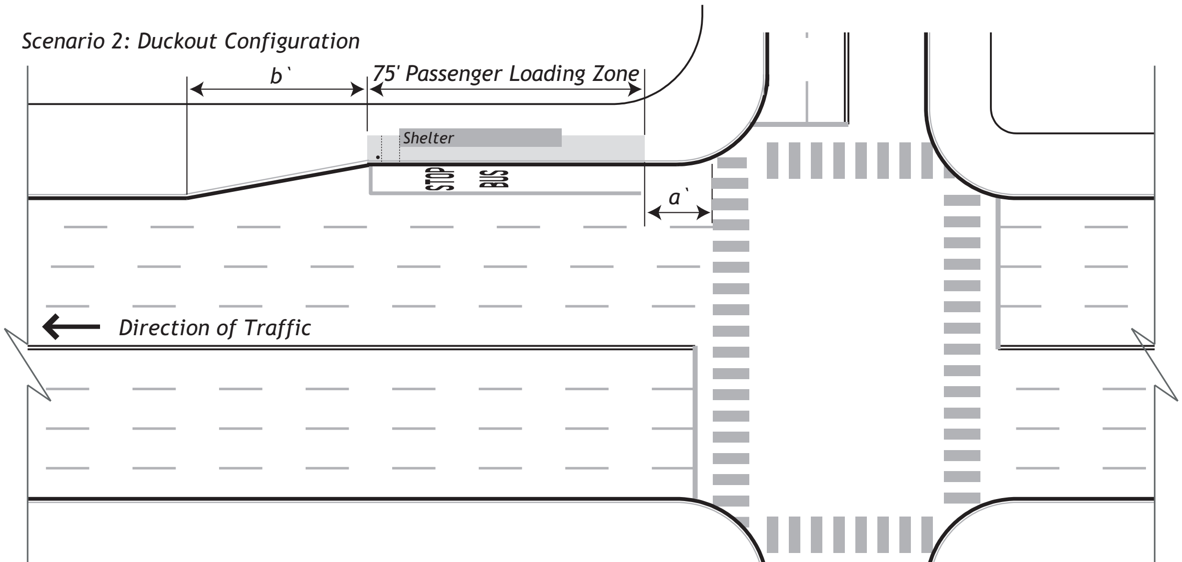
*Notes:*
1.) *Dimension a’ is to be measured from the edge of crosswalk or end of curb radius, whichever is further from the intersection.*
2.) *For the layout and details of the passenger loading zone, refer to Figure 14.*
3.) *A 75’ loading zone is sufficient for a standard (40’) or an articulated (60’) bus.*
4.) *A 55’ loading zone is sufficient for a standard (40’) bus.*
5.) *A 120’ loading zone is sufficient for serving two standard buses simultaneously.*
6.) *A 140’ loading zone is sufficient for serving a standard and an articulated bus simultaneously.*
7.) *Unless safety or physical constraints prohibit their implementation, far-side stops are preferred.*
8.) *The type of stop chosen shall be decided on a case-by-case basis, however, bulbout stops are preferred to facilitate optimal operations (thus a section view is only shown for bulbouts). Conventional curbside stops may be appropriate considering traffic, geometric, and safety conditions. Duckout stops may be appropriate when requested by a local jurisdiction.*




Typical Section A - A

**Figure 48** Typical Far Side BRT Station Configuration (continued)

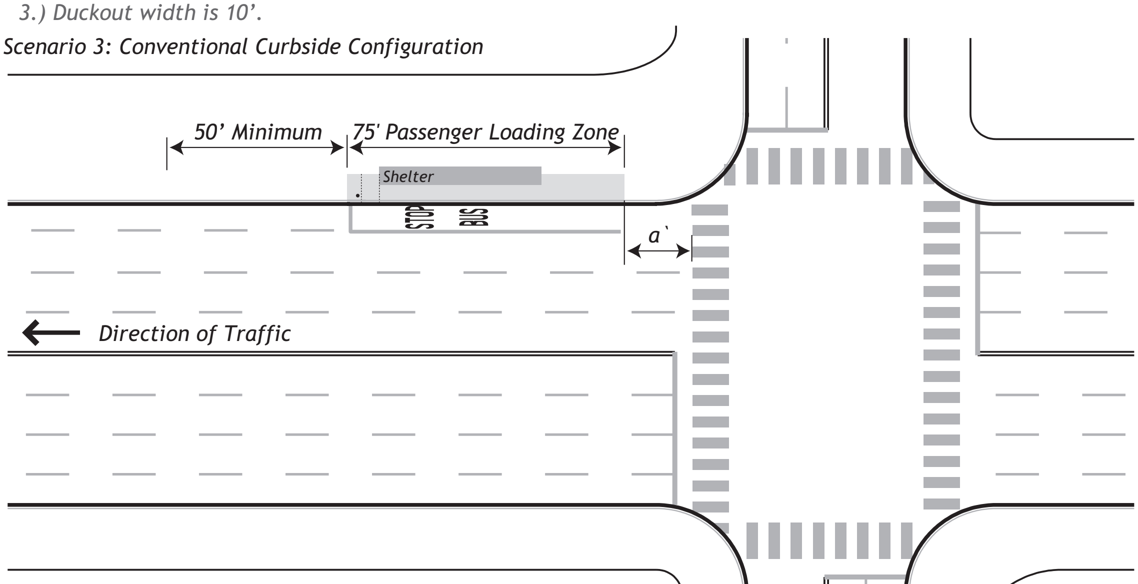
*Scenario 2: Duckout Configuration*




| Dimension a` | | Dimension b` | |
|---|---|---|---|
| Straight Approach | 20ft | < 20 mph approach | 50ft min |
| After Right Turn | 75ft | 20-30 mph approach | 80ft min |
| After Left Turn | 50ft | 30-40 mph approach | 125ft min |

*Notes:*
*1.) Refer to previous page for notes.*
*2.) Duckout taper length varies according to approach speed.*
*3.) Duckout width is 10'.*

*Scenario 3: Conventional Curbside Configuration*




| Dimension a` | |
|---|---|
| Straight Approach | 20ft |
| After Right Turn | 75ft |
| After Left Turn | 50ft |

*Notes:*
*1.) Refer to previous page for notes.*

**Figure 49** Far Side BRT Station Design on El Camino Corridor (El Camino Real & Castro St. - Northbound)

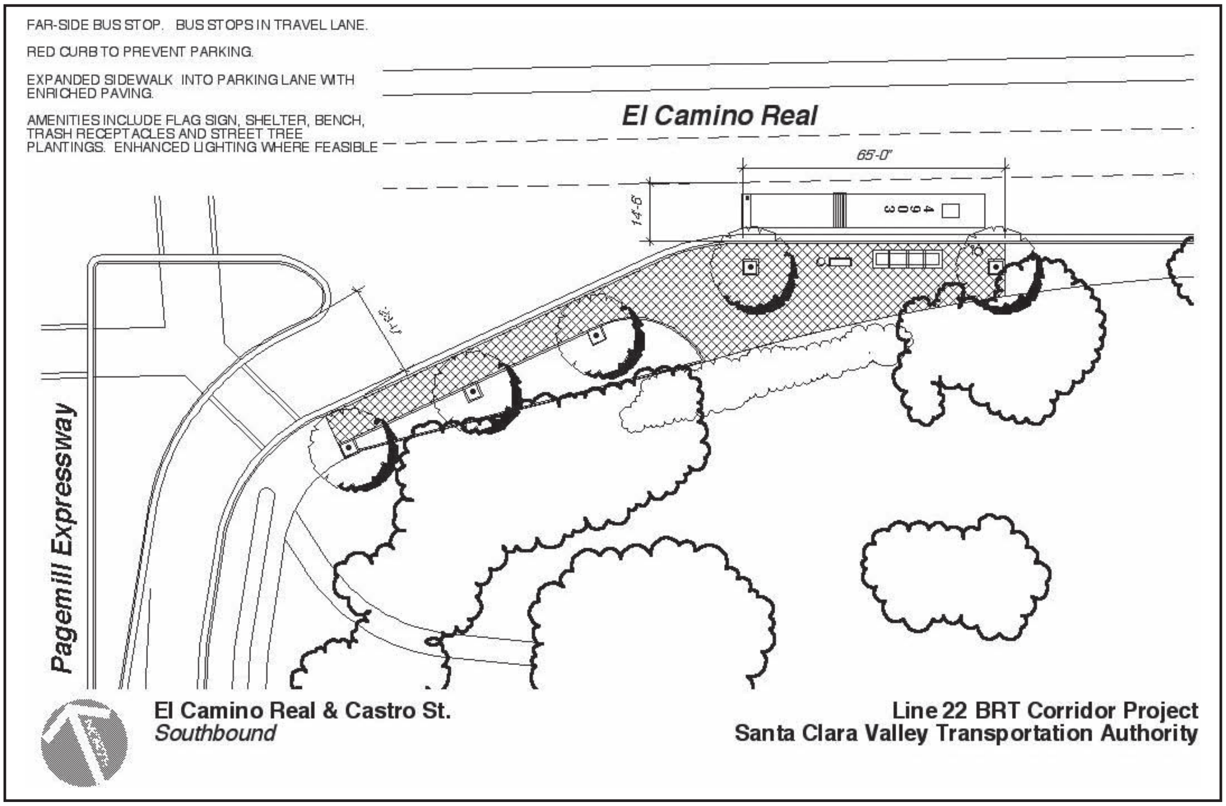



**Figure 50** Far Side BRT Station Design on El Camino Corridor (El Camino Real & Castro St. Southbound)

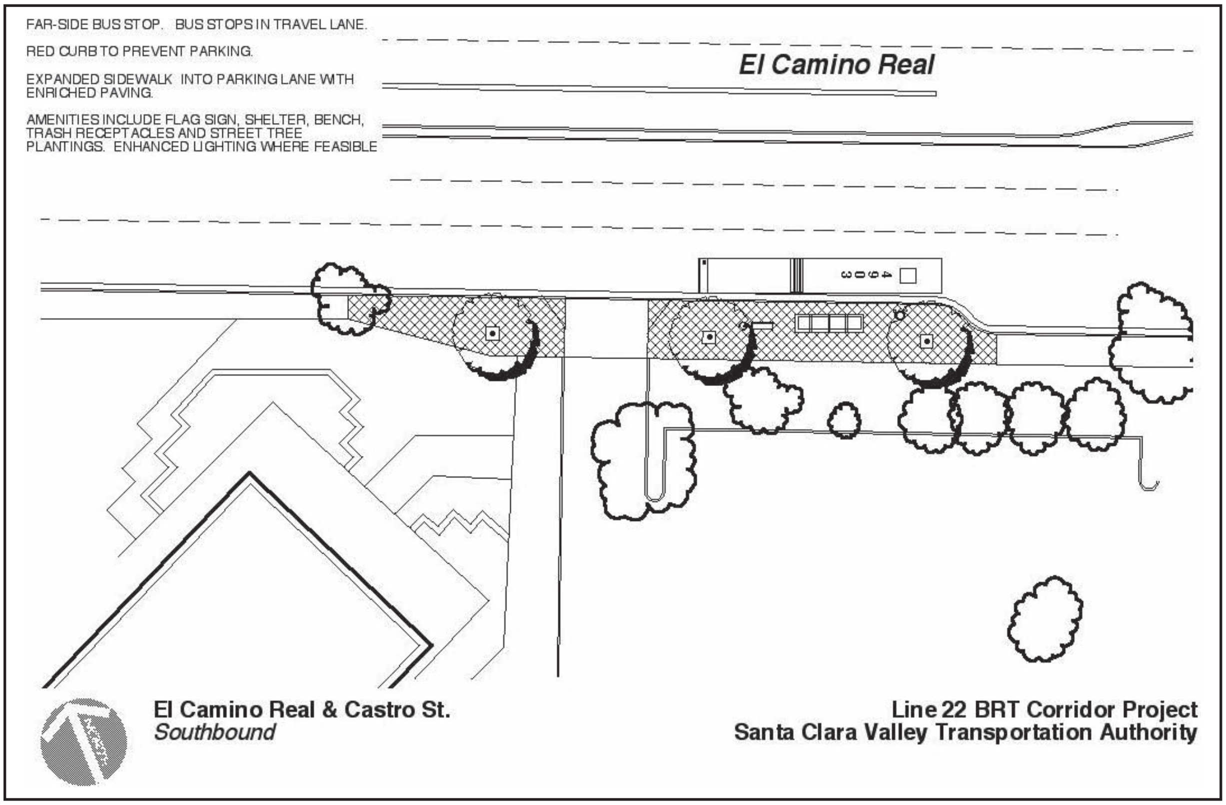


**Figure 51** Far Side BRT Station Design on El Camino Corridor (El Camino Real & Bernardo Ave. - Southbound)

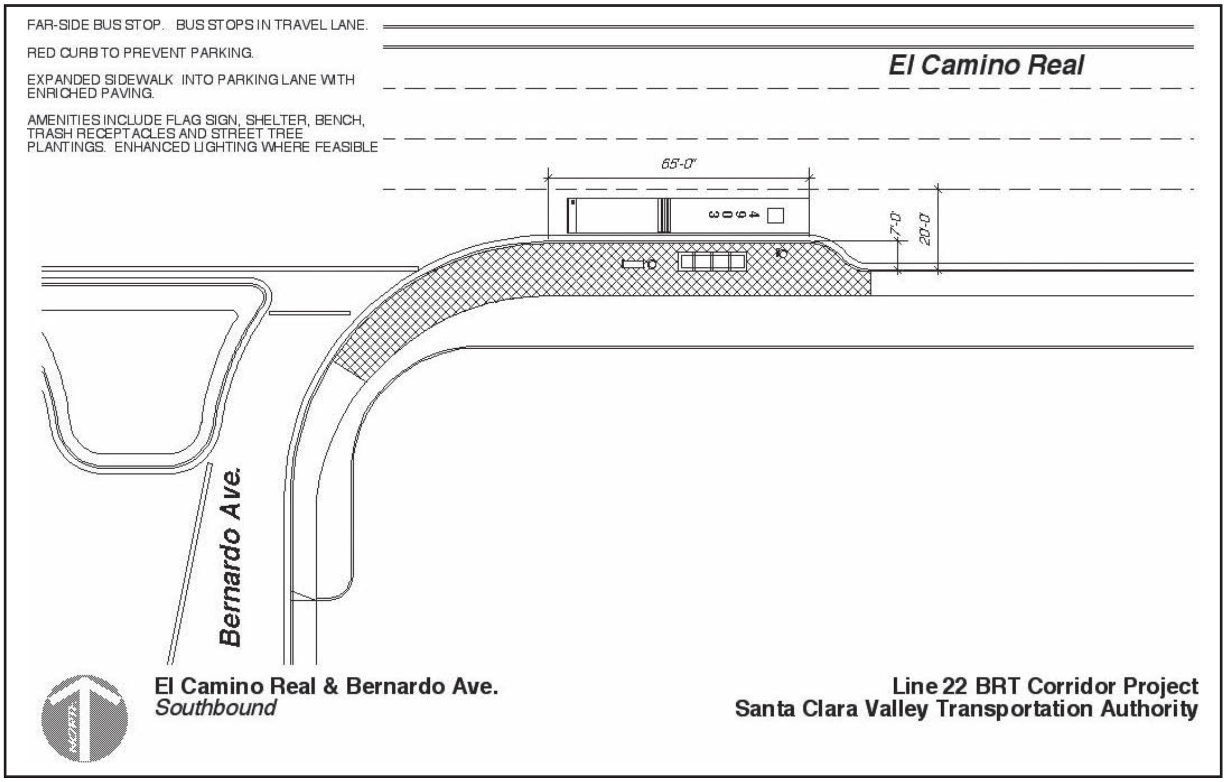



**Figure 52** Far Side BRT Station Design on El Camino Corridor (El Camino Real & Bernardo Ave. - Northbound)

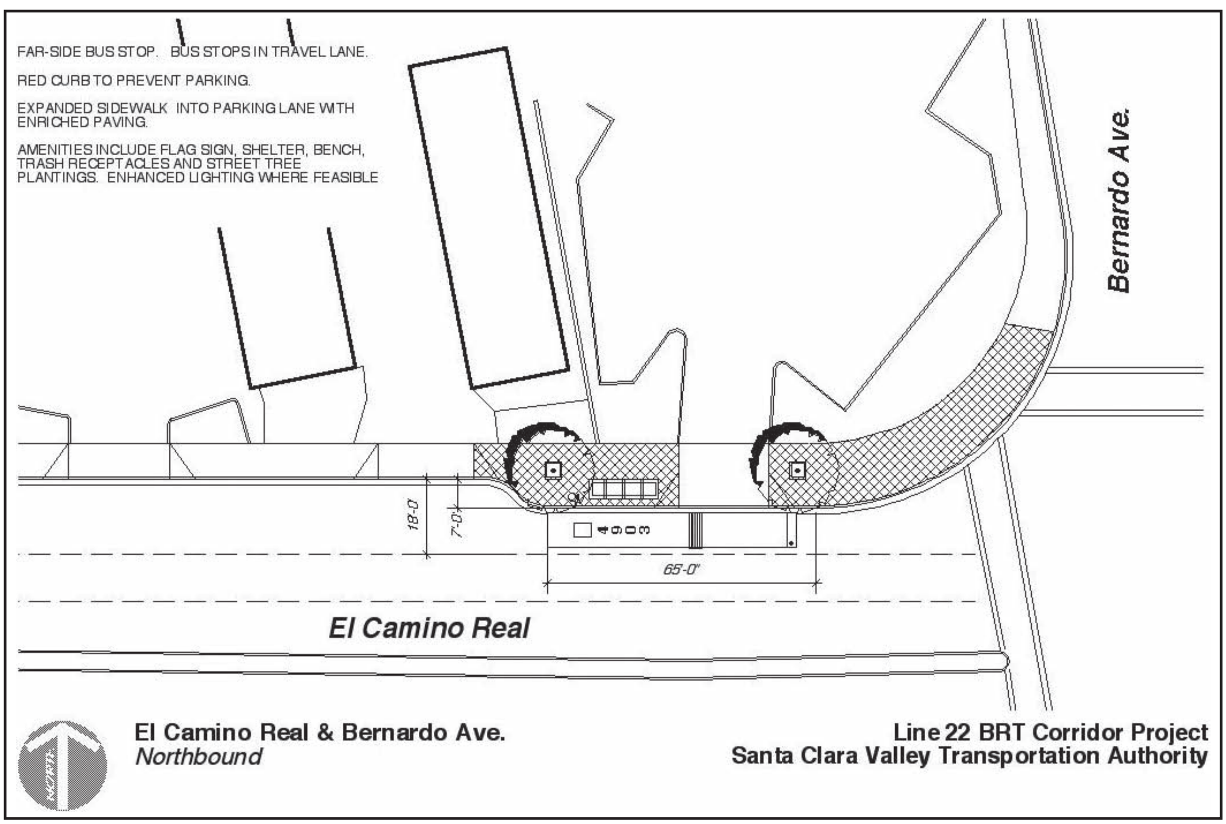
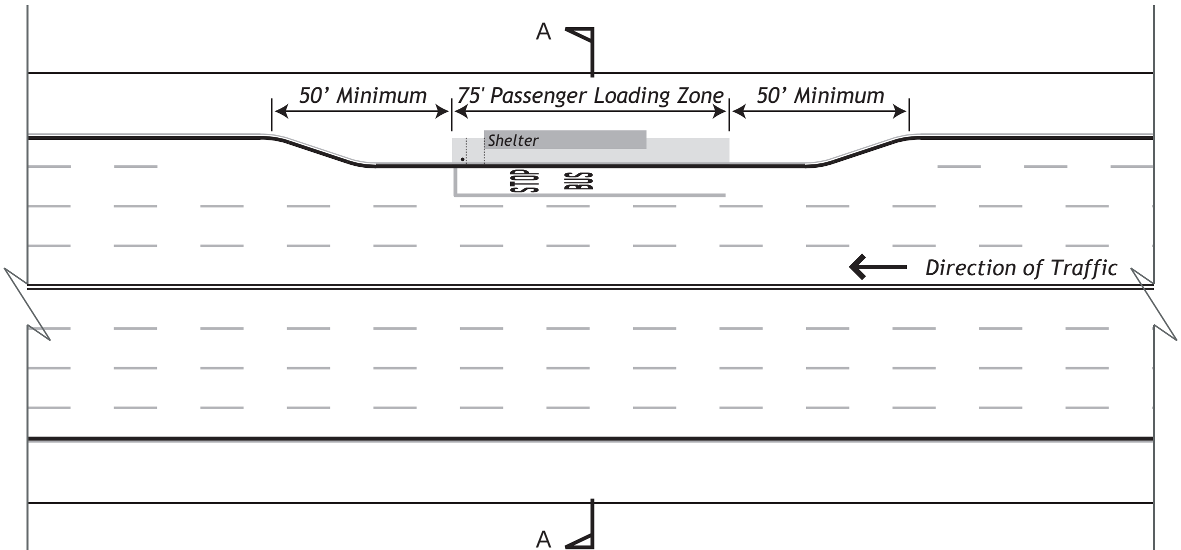


**Figure 53** Typical Midblock BRT Station Configuration

*Scenario 1: Bulbout Configuration*




*Notes:*

*1.) The type of stop chosen shall be decided on a case-by-case basis, however, bulbout stops are preferred to facilitate optimal operations (thus a section view is only shown for bulbouts). Conventional curbside stops may be appropriate considering traffic, geometric, and safety conditions. Duckout stops may be appropriate when requested by a local jurisdiction.*

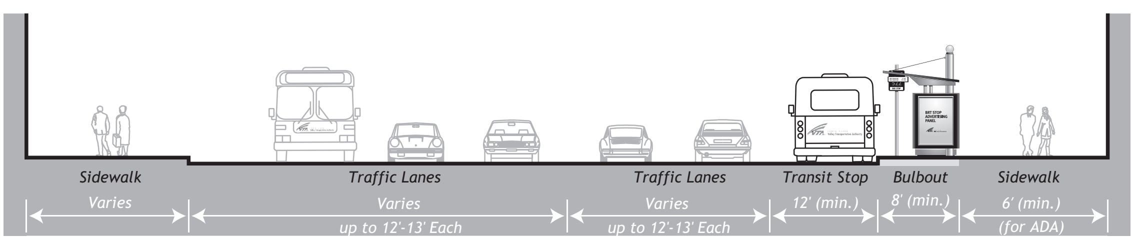
*2.) For the layout and details of the passenger loading zone, refer to Figure 14.*

*2.) A 75’ loading zone is sufficient for a standard (40’) or an articulated (60’) bus.*

*3.) A 55’ loading zone is sufficient for a standard (40’) bus.*

*4.) A 120’ loading zone is sufficient for serving two standard buses simultaneously.*

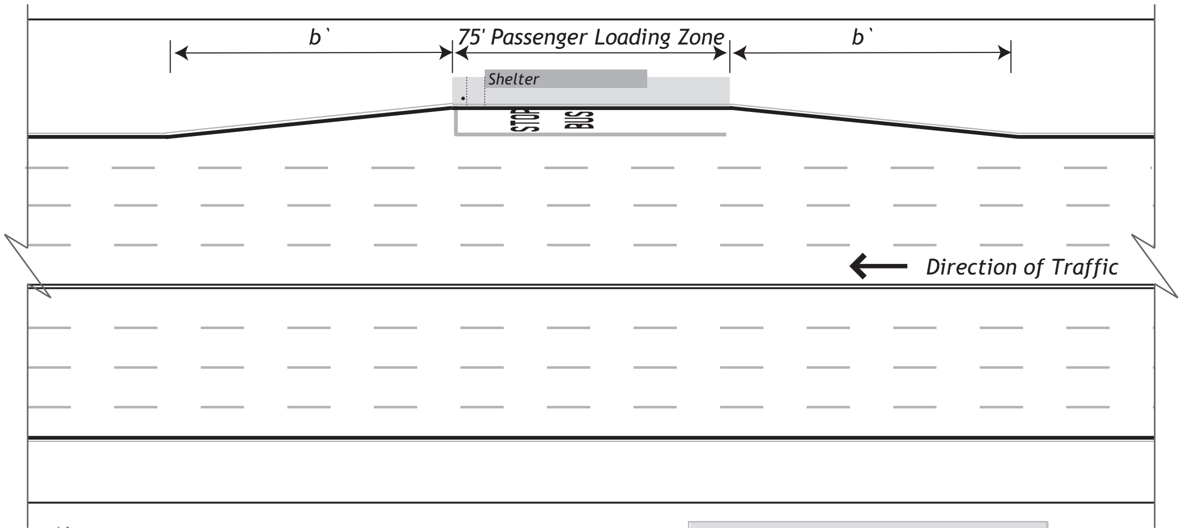
*5.) A 140’ loading zone is sufficient for serving a standard and an articulated bus simultaneously.*




Typical Section A - A

**Figure 53** Typical Mid Block BRT Station Configuration (continued)

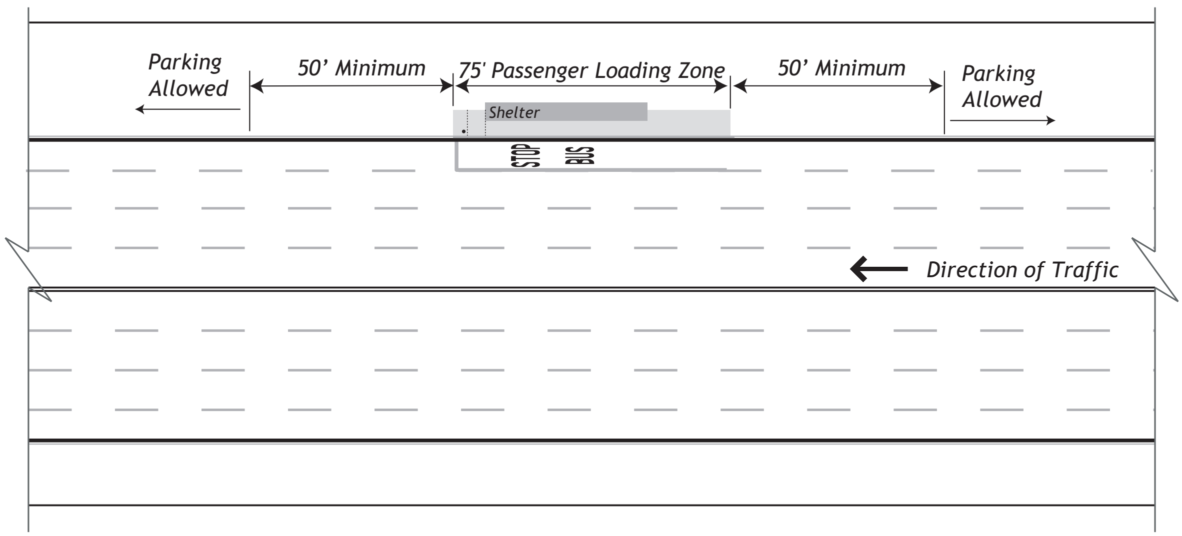
*Scenario 2: Duckout Configuration*




*Notes:*
*1.) Refer to previous page for notes.*
*2.) Duckout taper length varies according to approach speed.*
*3.) Duckout width is 10'.*

| Dimension b` | |
|---|---|
| < 20 mph approach | 50ft min |
| 20-30 mph approach | 80ft min |
| 30-40 mph approach | 125ft min |

*Scenario 3: Conventional Curbside Configuration*




*Notes:*
*1.) See previous page for notes.*

**Figure 54** Mid Block BRT Station Design on El Camino Corridor (El Camino Real & Arastredero Ave. - Southbound)

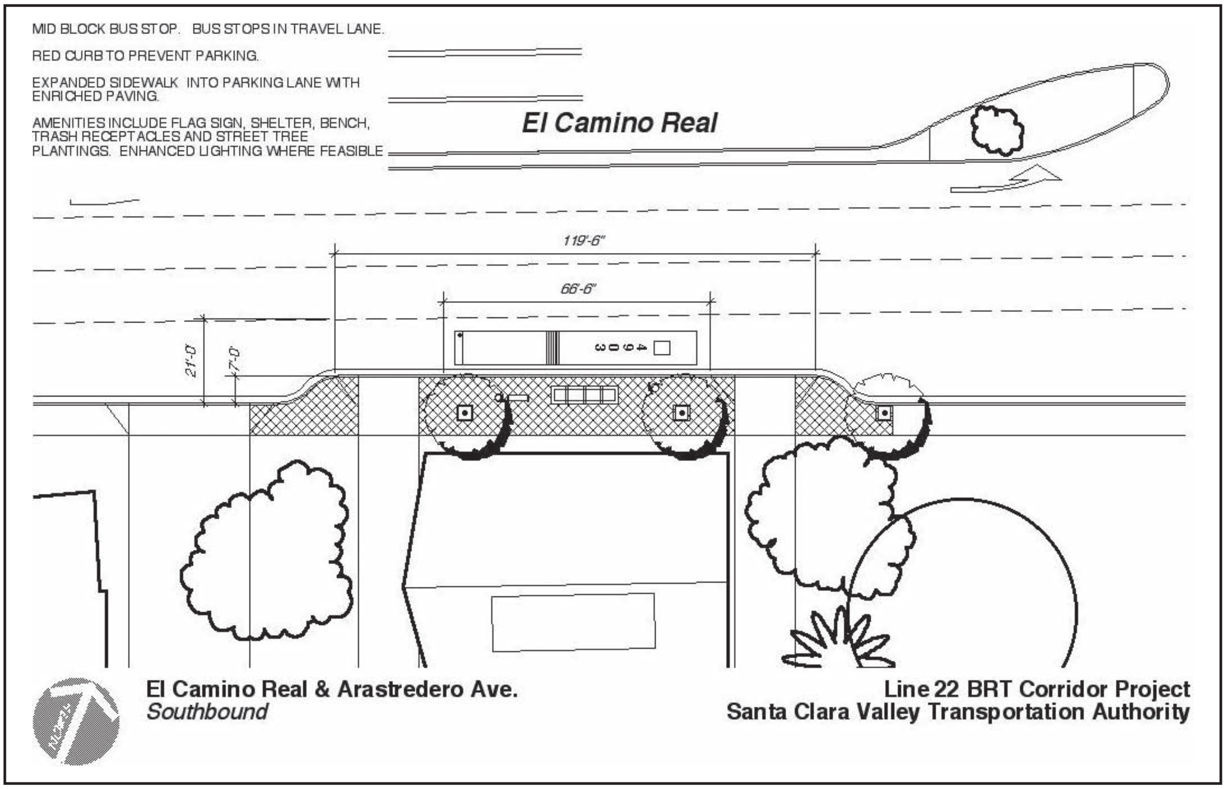
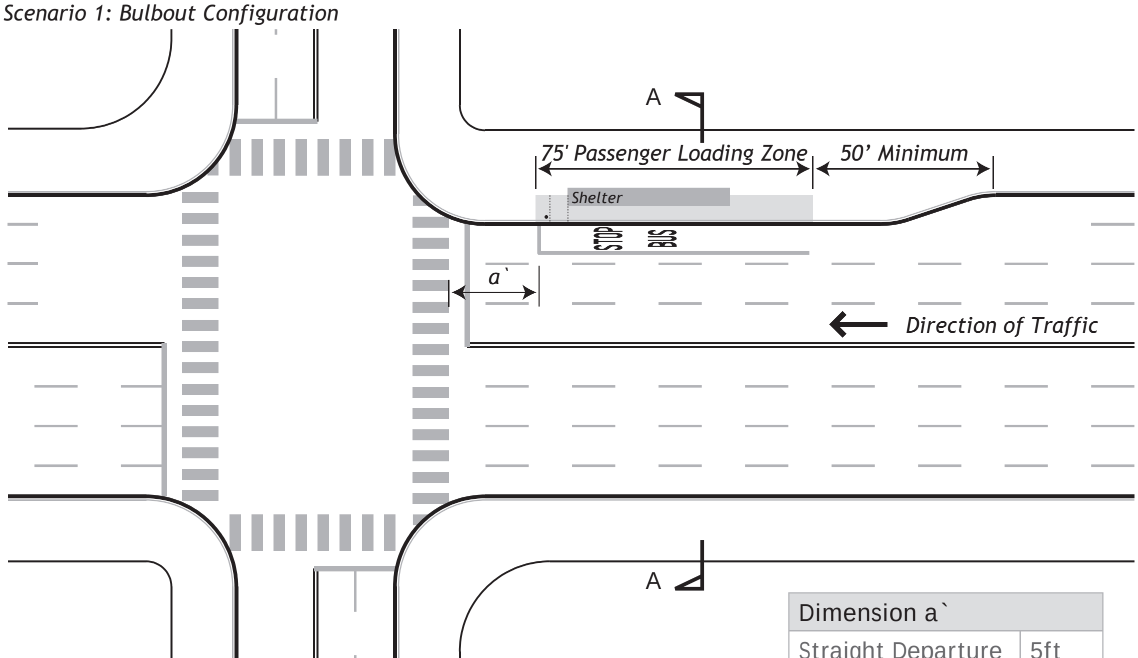


**Figure 55** Typical Near Side BRT Station Configuration

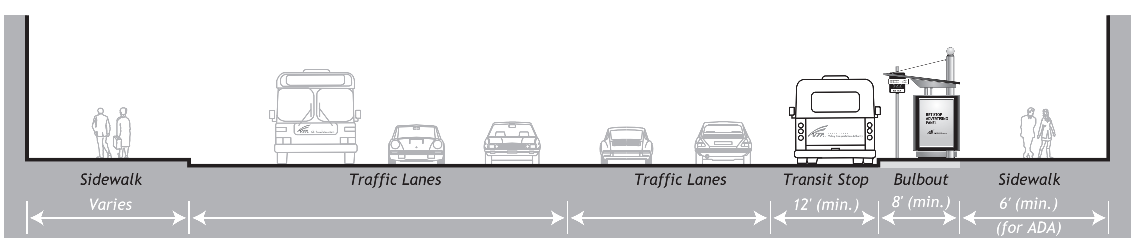
*Scenario 1: Bulbout Configuration*




| Dimension a` | |
|---|---|
| Straight Departure | 5ft |
| Before Right Turn | 20ft |

*Notes:*

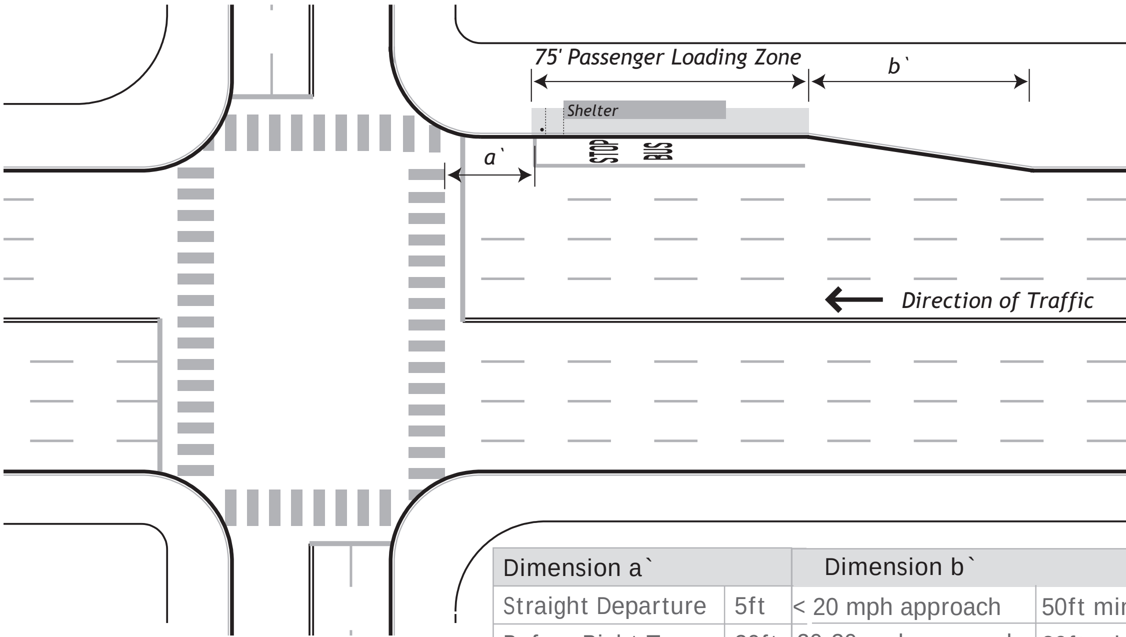
*1.) Dimension a' is to be measured from the edge of crosswalk or end of curb radius, whichever is further from the intersection.*
*2.) For the layout and details of the passenger loading zone, refer to Figure 14.*
*3.) A 75' loading zone is sufficient for a standard (40') or an articulated (60') bus.*
*4.) A 55' loading zone is sufficient for a standard (40') bus.*
*5.) A 120' loading zone is sufficient for serving two standard buses simultaneously.*
*6.) A 140' loading zone is sufficient for serving a standard and an articulated bus simultaneously.*
*7.) Nearside bus stops shall only be adopted when the placement of a far-side stop is constrained by safety issues or physical limitations or improves operational efficiency.*
*8.) The type of stop chosen shall be decided on a case-by-case basis, however, bulbout stops are preferred to facilitate optimal operations (thus a section view is only shown for bulbouts). Conventional curbside stops may be appropriate considering traffic, geometric, and safety conditions. Duckout stops may be appropriate when requested by a local jurisdiction.*




Typical Section A - A

**Figure 55** Typical Near Side BRT Station Configuration (continued)

*Scenario 2: Duckout Configuration*

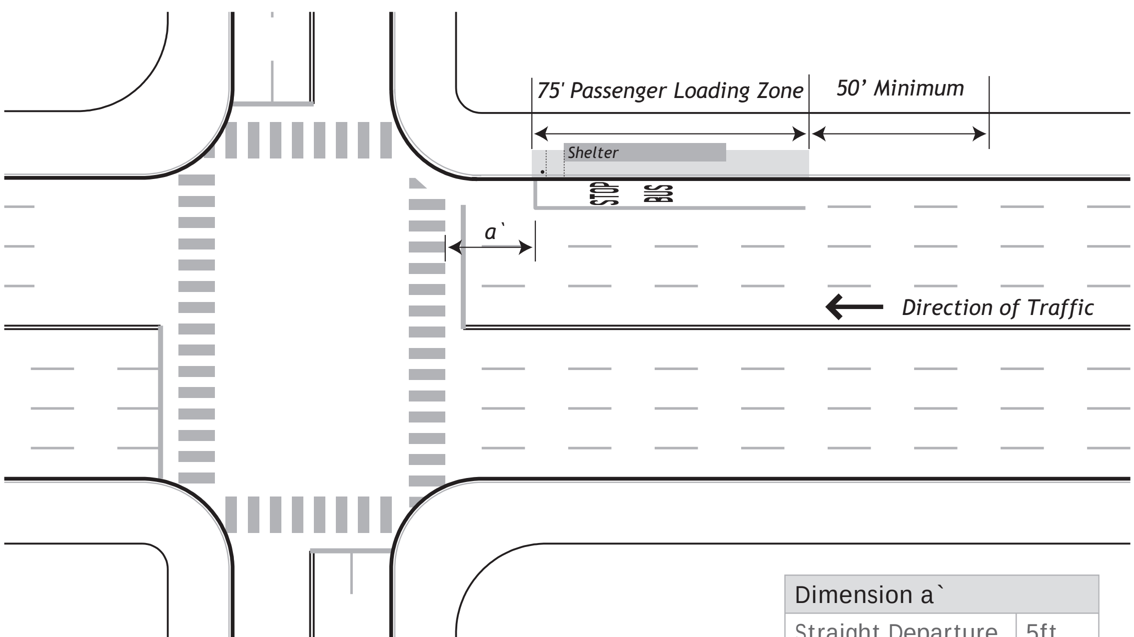



| Dimension a` | |
|---|---|
| Straight Departure | 5ft |
| Before Right Turn | 20ft |

| Dimension b` | |
|---|---|
| < 20 mph approach | 50ft min |
| 20-30 mph approach | 80ft min |
| 30-40 mph approach | 125ft min |

*Notes:*
*1.) Refer to previous page for notes.*
*2.) Duckout taper length varies according to approach speed.*
*3.) Duckout width is 10'.*

*Scenario 3: Conventional Curbside Configuration*




| Dimension a` | |
|---|---|
| Straight Departure | 5ft |
| Before Right Turn | 20ft |

*Notes:*
*1.) Refer to previous page for notes.*

**Figure 56** Phased Development of BRT Station Area, Infrastructure, and Amenities along El Camino Corridor – Schematic 1

**a.** Existing Roadway Facility


**b.** Phase I: Added Bus Only Lane, Shelter, and Bicycle Lane


**c.** Phase II: Intensified the Land Uses Around the Station

**Figure 56** Phased Development of BRT Station Area, Infrastructure, and Amenities along El Camino Corridor (continued)
**d.** Phase IIIa: Added Alternative Pavement Color/Texture Bus Only Lane to Differentiate the Lane from the Mixed-Flow Travel Lane


**e.** Phase IIIb: Night View of Roadway Configuration


**Figure 57** Phased Development of BRT Station Area, Infrastructure, and Amenities along Stevens Creek Corridor
**a.** Existing Roadway Facility

**Figure 57** Phased Development of BRT Station Area, Infrastructure, and Amenities along Stevens Creek Corridor (continued)

**b.** Phase I: Added Bus Only Lane, Wide Sidewalk, Sidewalk Crossing, and Street Trees Along the Median Lane

**c.** Phase IIa: Intensified the Land Uses Around the Station

**d.** Phase IIb: Continued Intensification of Land Use Around the Station

**e.** Phase III: Painted the Bus Only Lane to Differentiate it from the Mixed-Flow Lanes

## 8.1.2 PASSENGER LOADING ZONES

The length of the passenger-loading zone depends on the vehicles being served simultaneously – for instance, a transfer point may require a longer or wider area. Passenger loading zones at VTA BRT stations shall comply with the standards set out in the CDT Manual and illustrated in Figure 59, such that:

- A 55-foot loading zone is sufficient to handle a single standard 40-foot vehicle.
- A 75-foot loading zone is sufficient to handle either a standard 40-foot or an articulated 60-foot vehicle at a single time.
- A 120-foot loading zone is sufficient to handle two standard 40-foot vehicles simultaneously.
- A 140-foot loading zone is sufficient to handle a standard 40-foot and an articulated 60-foot vehicle simultaneously.

These guidelines are shown graphically in the following figures:

**Figure 58** BRT Station Passenger Loading

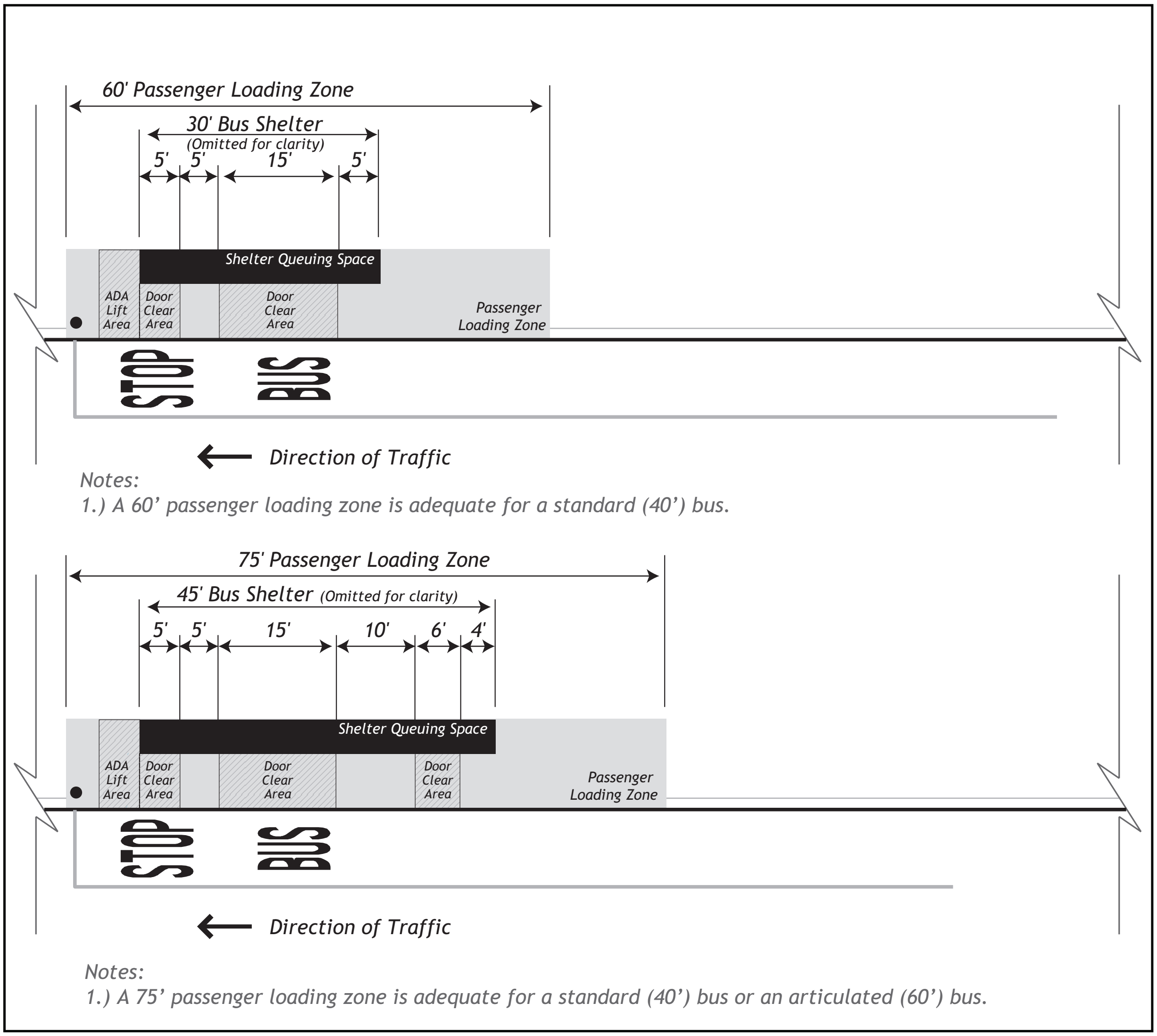
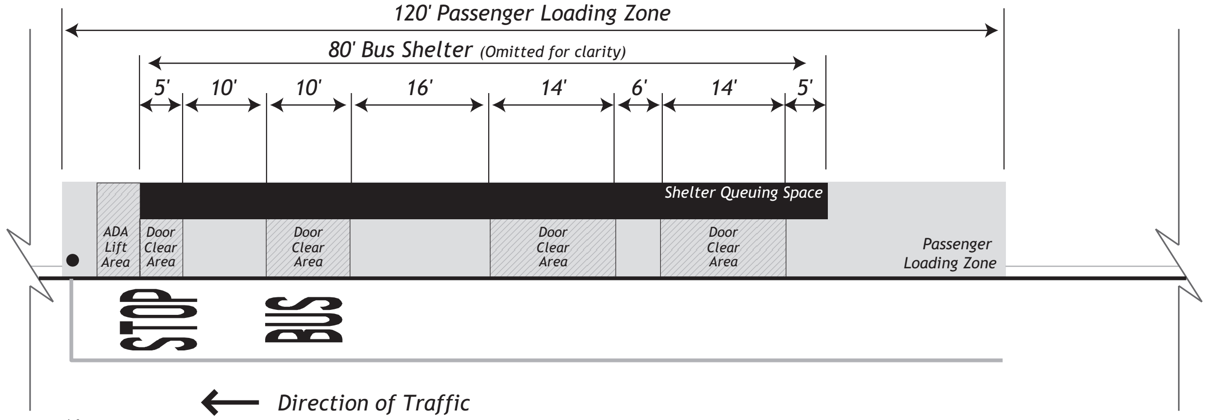
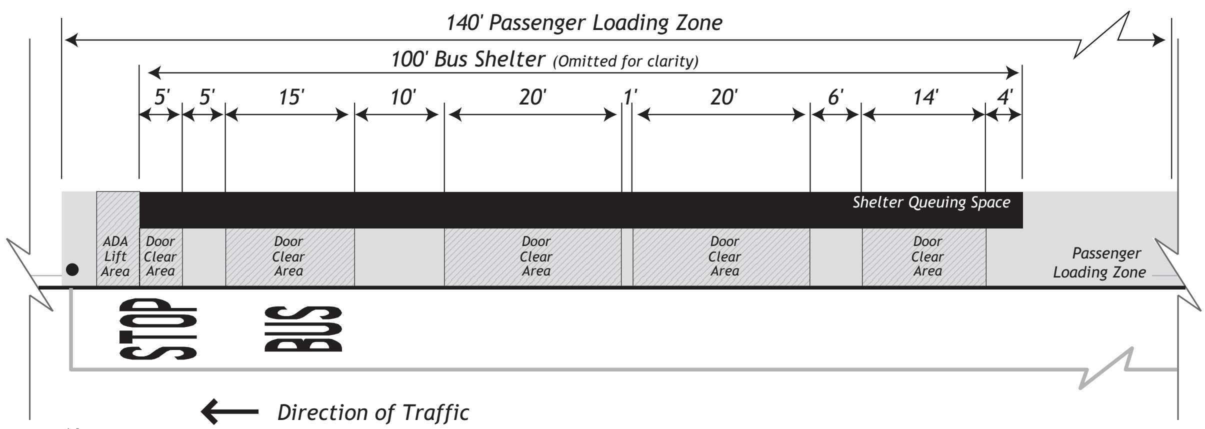


**Figure 58** BRT Station Passenger Loading (continued)




*Notes:*
*1.) A 120' passenger loading zone is adequate for a standard (40') bus and a standard (40') bus.*
*2.) For simultaneous arrivals, this configuration assumes that the rear bus will not depart until after the front bus, with a 5' gap between the front and rear buses. If buses have bicycle racks, this is 9'.*
*3.) If the rear bus is permitted to leave prior to the departure of the front bus, the pull-out distance between the two buses will vary according to the width of the lane it is entering.*




*Notes:*
*1.) A 140' passenger loading zone is adequate for an articulated (60') and a standard (40') bus.*
*2.) For simultaneous arrivals, this configuration assumes that the rear bus will not depart until after the front bus, with a 5' gap between the front and rear buses. If buses have bicycle racks, this is 9'.*
*3.) If the rear bus is permitted to leave prior to the departure of the front bus, the pull-out distance between the two buses will vary according to the width of the lane it is entering.*

## 8.2 STATION DESIGN, AMENITIES, AND RELATED FACILITIES

BRT stations have a unique design to distinguish them from other services including Community, Local and Express Bus. Because BRT 1 and BRT 2 have different performance requirements, the two services have unique station designs and amenity requirements. The following vision statements identify the difference between the two services.

**BRT 1 VISION STATEMENT:** *Provides a premium level of service, with higher quality amenities, and specially branded stations compared to local bus including brand distinguished signage at stations and bus* *shelters. Figure 62 provides an example of BRT 1 type station amenities.*

**BRT 2 VISION STATEMENT:** *Provides considerably higher capital investments than BRT 1 stations to resemble rail stations rather than bus stops. Enhanced amenities could include enhanced real-time information, interactive maps, and regional fare collection machines to integrate service with light and heavy rail. Figures 59 through 61 provide examples of BRT 2 type station amenities.*

Based on the BRT Shelter Concepts in the CDT Manual (Appendix A), VTA BRT 1 and BRT 2 stations shall at a minimum, be equipped with the following designs, amenities, and facilities:

**Table 14** Typical Characteristics and Amenities for VTA BRT Stations

| Station Characteristics | BRT 1 | BRT 2 |
|---|---|---|
| ADA-compliant designs | S | S |
| Benches | S | E |
| Bicycle racks | S | S |
| Branded shelters | S | E |
| Branded or special signage | S | E |
| Bus stop pole and sign | S | E |
| Capability to simultaneously serve two vehicles | S | S |
| Closed Fare Collection capabilities similar to Heavy Rail Stations or other Off-Board Fare Collection (see section 9, BRT Fare Collection Systems) | – | E |
| Concrete stopping pads | S | S |
| Elongated stopping areas capable of handling conventional and articulated vehicles | S | S |
| Enhanced amenities similar to rail stations | – | E |
| High-capacity platforms for heavy loads | – | E |
| Level boarding capabilities | S | S |
| Lighting | S | E |

Table note: S = Standard Design; E = Enhanced Design

**Table 14** Typical Characteristics and Amenities for VTA BRT Stations (continued)

| Station Characteristics | BRT 1 | BRT 2 |
|---|---|---|
| Operator break and layover facilities at the start/end of the route | S | S |
| Passing lanes | — | E |
| Real-time passenger information panels | S | E |
| Red curb space for stopping | S | S |
| Route maps | S | E |
| Trash receptacles | S | S |
| Unique identity | S | E |

Table note: S = Standard Design; E = Enhanced Design

Figures 59 through 62 illustrates recommended concepts for VTA BRT stations and amenities and shows typical BRT shelter with a unique and modern design, real-time passenger information panels, leaning rails, light standards, a flag pole, and a ticket machine. Figures 63 through 68 provide examples of amenities recommended at BRT stations.

In addition, VTA BRT 1 and BRT 2 stations shall:

- Have a unique identity/theme to complement the surrounding environment, architecture, and buildings, are well integrated into the community with pedestrian-oriented and transit friendly developments around station areas, and comply with design standards detailed in the CDT Manual (CDT Manual, Appendix A) for station installation.
- Provide adequate support facilities, such as layover bays, covered walkways, real-time information panels, turnaround areas, red-curb space, space for stations, inter-modal transfer facilities at locations where transit lines meet and transfers occur to:
  - » Allow for safe and easy pedestrian flow;
  - » Provide for adequate signage and visual cues;
  - » Accommodate waiting transfer passengers;
  - » Permit seamless and quick transfers; and
  - » Accommodate multiple transit modes simultaneously at a single facility.

  (Figure 69 shows an optimal BRT 2 and local bus configuration allowing seamless, easy, and safe transfers from a median bus-only lane to a local bus stop.)
- Accommodate and integrate existing bicycle lanes and paths into station design, to the extent possible. Figure 70 shows how bicycle lanes may be integrated into station design and layout.

- Provide sufficient ROW for Park & Ride lots in suburban areas where there is/are:
  - » Available open space for parking lots;
  - » Appropriate access roads; and
  - » Demand for auto trips.
- Provide sufficient ROW for Kiss & Ride lots in suburban areas where there is/are:
  - » Available curbspace and sidewalk width for pickup and dropoff zones;
  - » Appropriate access roads; and
  - » Demand for auto trips.

**Figure 59** VTA BRT Station and Amenity Concept A

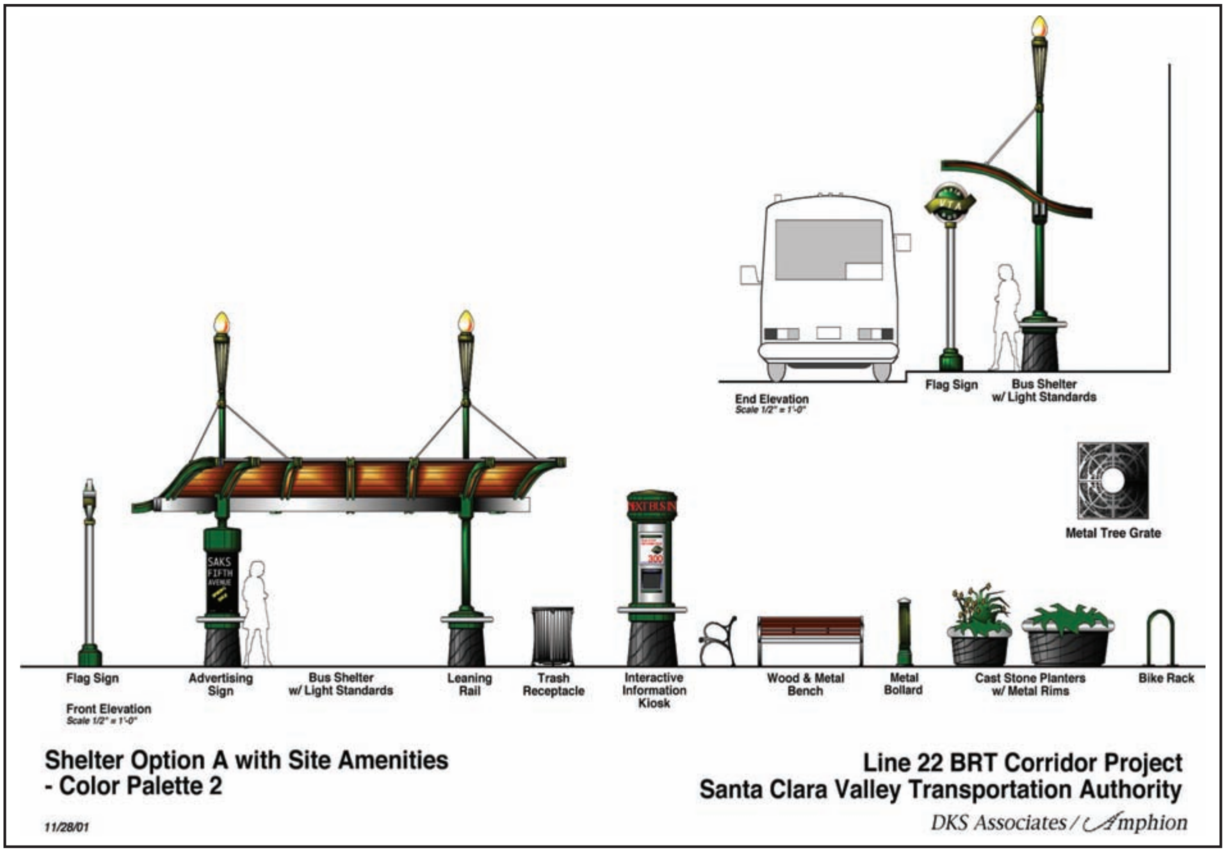


**Figure 60** VTA BRT Station and Amenity Concept B

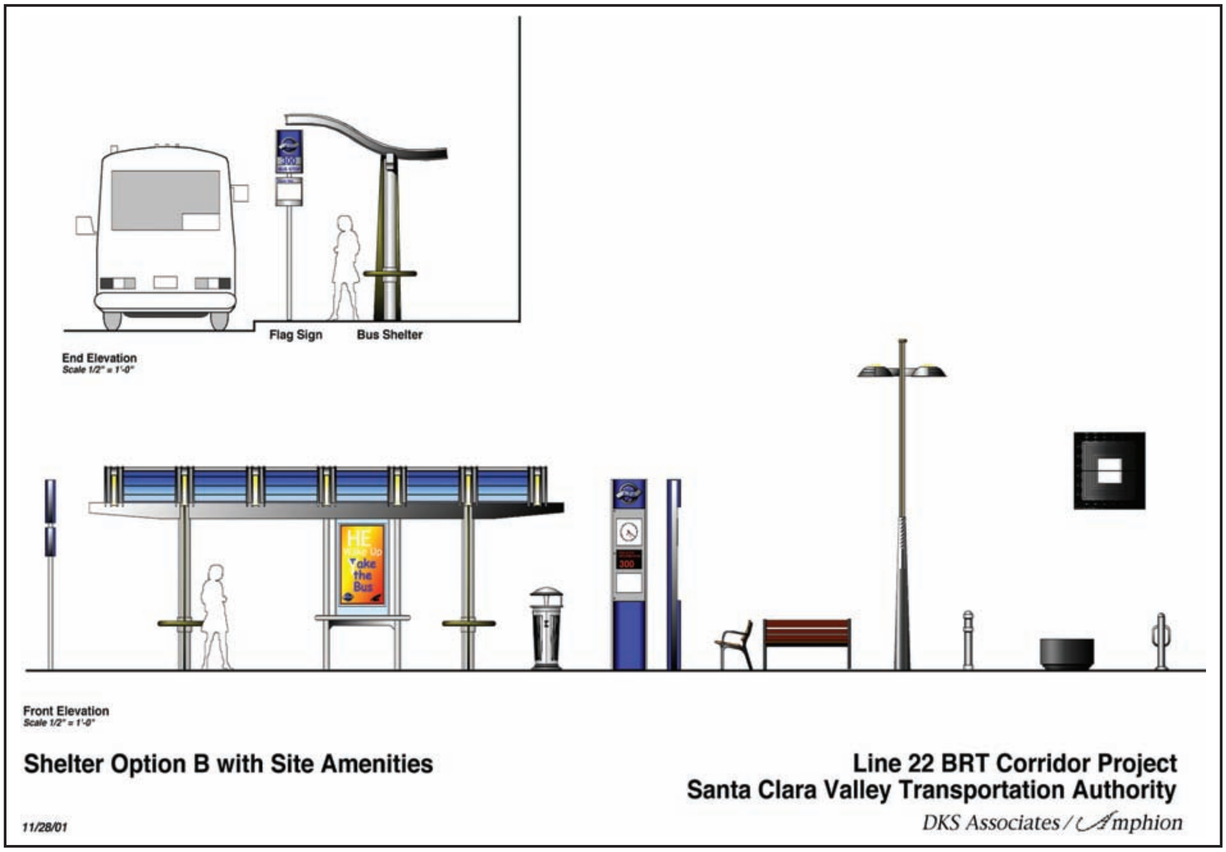



**Figure 61** VTA BRT Station and Amenity Concept C

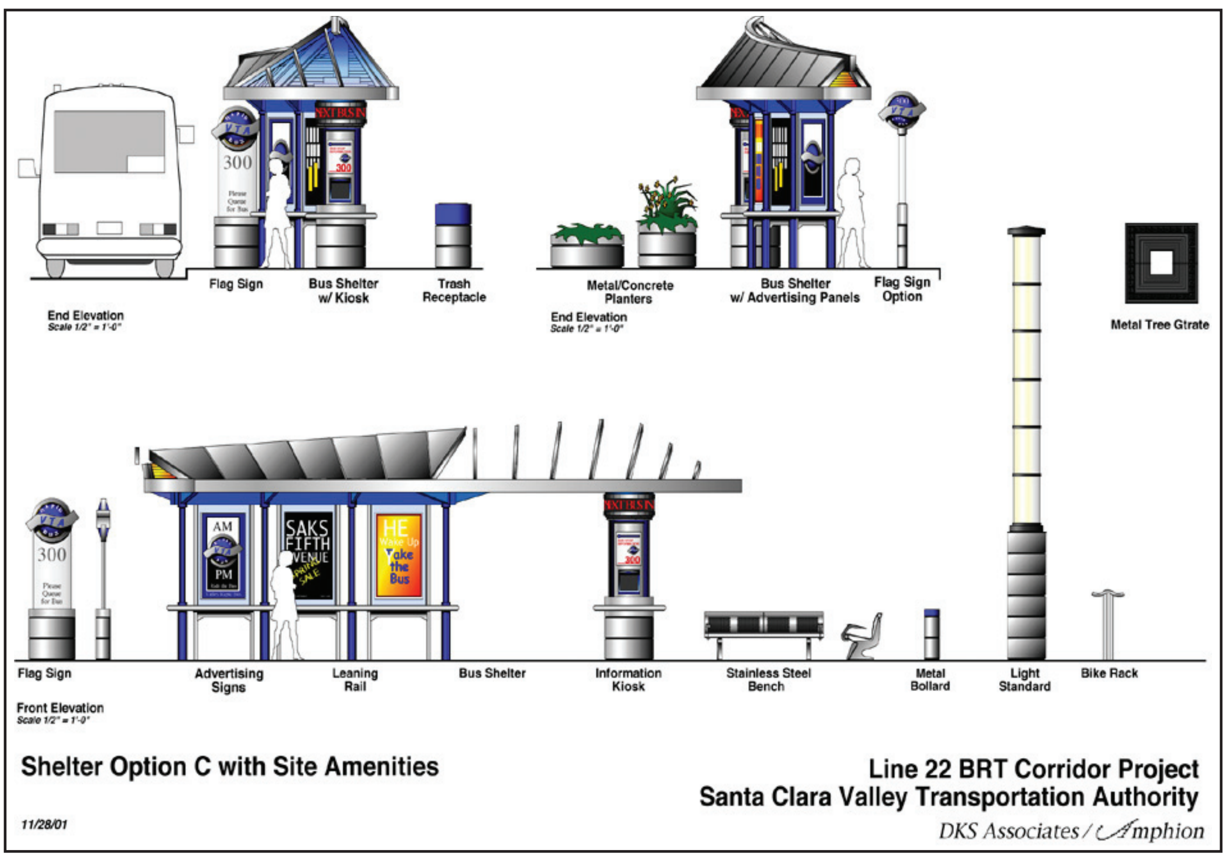
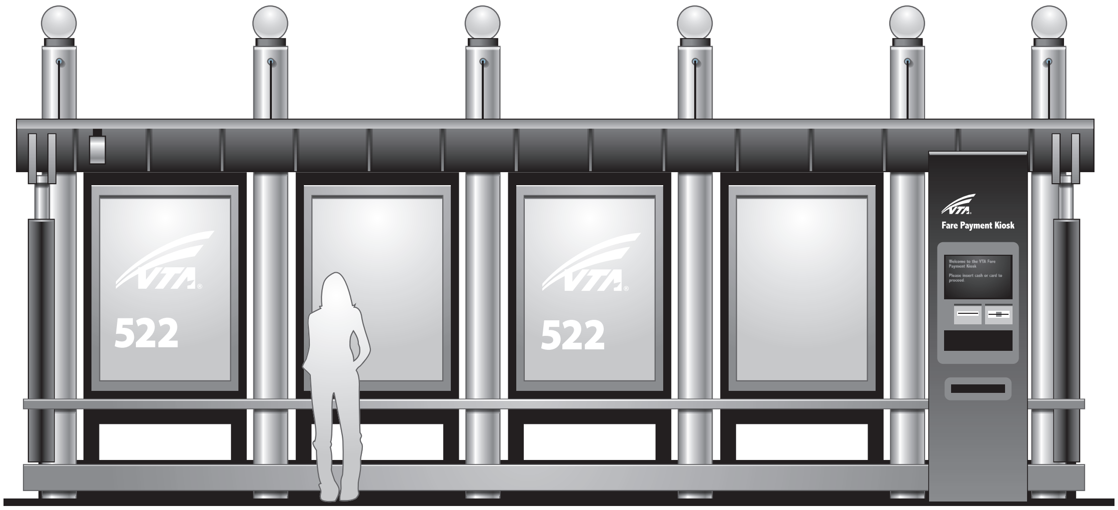
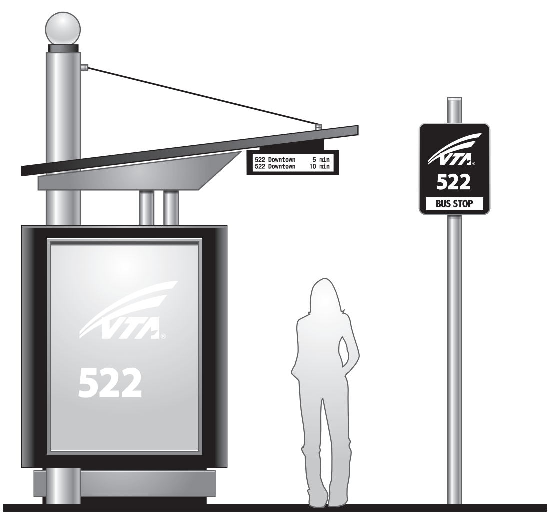


**Figure 62** Example of BRT Station Concept Concepts and Amenities




Bus Shelter (Front) with Ad Panels, Leaning Rail, Light Standards & Ticket Vending Machine




Bus Shelter (Side) with Bus Stop Pole and Sign & Light Standard


Flag Sign

**Figure 63** Real-Time Passenger Information Showing Next Arrival and Route (Berlin)


**Figure 64** BRT 1 Type Curbside Station for BRT Using Mixed-flow Traffic Lanes (Wilshire Metro Rapid)

**Figure 65** BRT 1 Station on Bus Bulge (Ottawa)

**Figure 66** BRT 2 Type Station along Curbside Bus-Only Lane (Las Vegas MAX)

**Figure 67** BRT 2 Type Station along At-Grade Transitway (Los Angeles - Metro Orange Line)

**Figure 68** BRT Station on Grade-Separated Transitway (Vancouver, BC)

**Figure 69** Pedestrian Connectivity Concepts—Median Bus-Only Lane and Curbside Local Bus Service

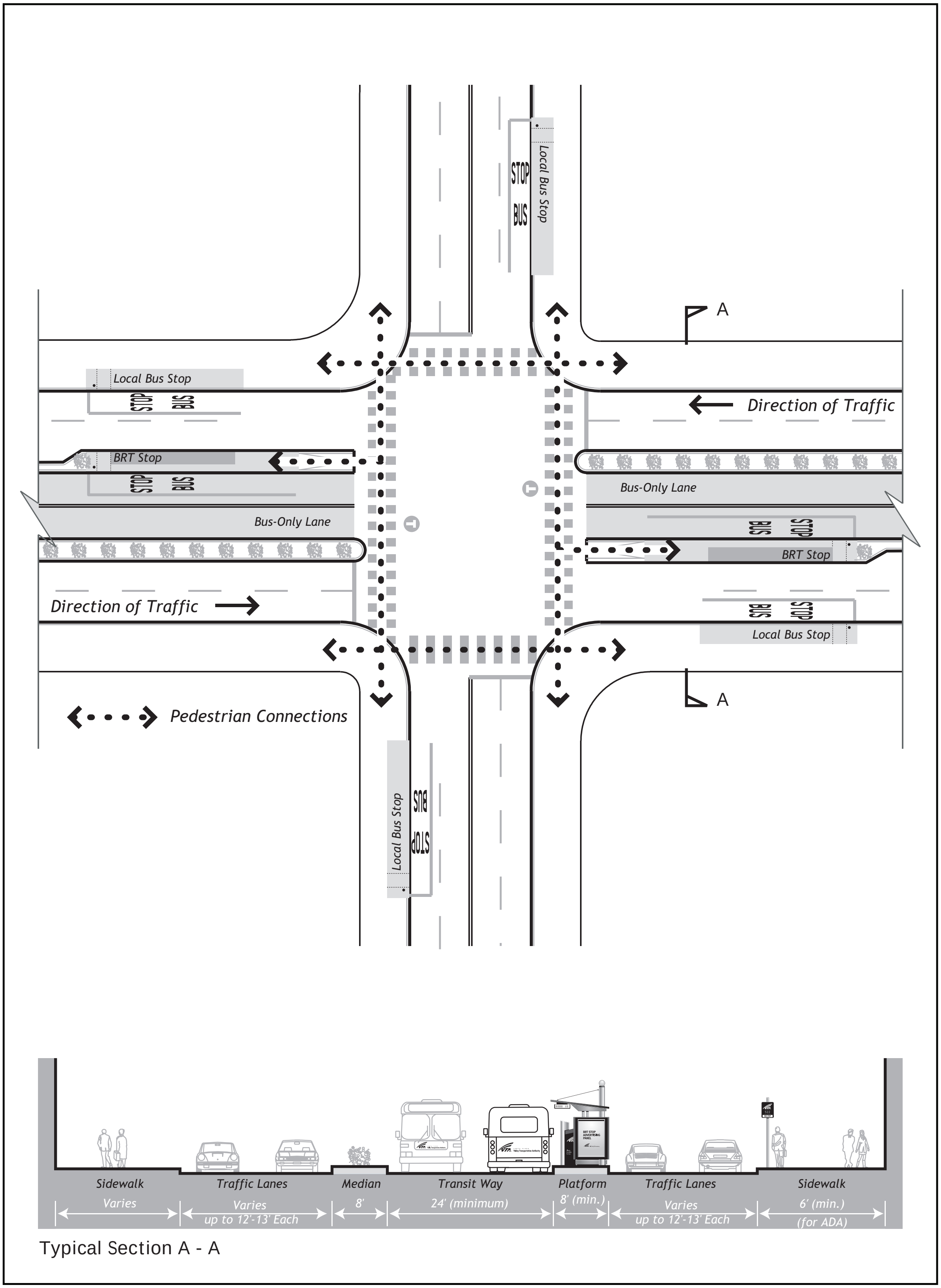
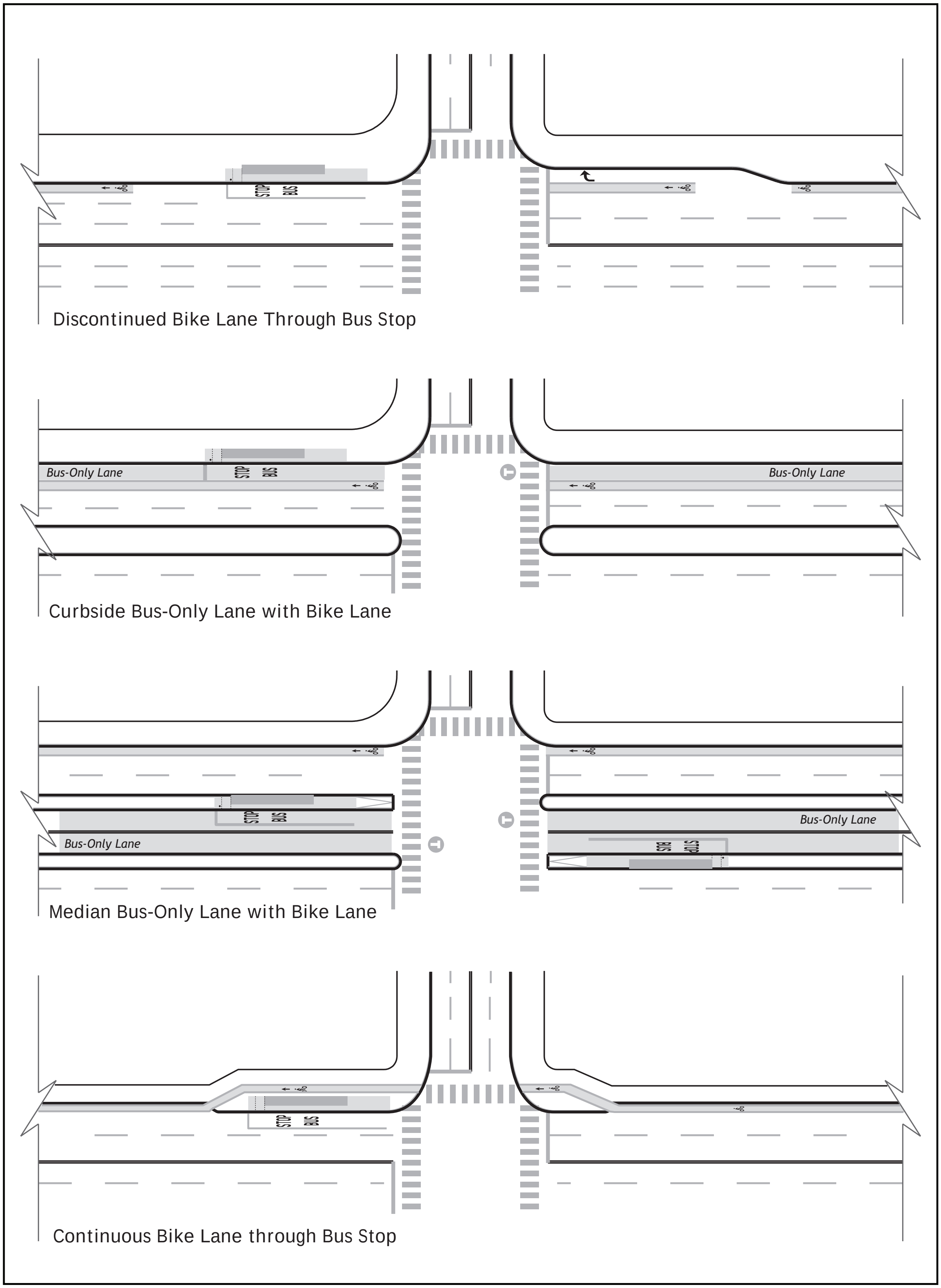


**Figure 70** Integration Concepts for Bicycle Lanes and BRT Stations



## 9. BRT FARE COLLECTION SYSTEMS

To lower dwell time and improve operating speeds and corridor travel time, BRT systems often adopt proof-of-payment or at-station payment approaches. At the same time, however, deployment of ticket machines at all BRT stations can be expensive in terms of capital, operating and maintenance costs. The range of BRT fare collection systems are briefly described in Table 15:

**Table 15** BRT Fare Collection Systems

| Fare System | Characteristics | Applicability to VTA BRT Services |
|---|---|---|
| On-Board Payment (Farebox) | Passengers board a transit vehicle and either deposit money in the farebox or flash their pass/ticket to the driver for verification. This slows boarding of the bus and results in added dwell time and delay. This system requires that every bus has a farebox, but does not require additional ticketing infrastructure at stations. This system is the most inexpensive, since it does not require the procurement of ticketing machines. | Not recommended for BRT 2 due to dwell time and delay. |
| Hybrid Farebox/ Ticket Machines | Ticket vending machines for proof-of-payment are installed at major stations to speed boarding. At lesser-used stations, passengers still pay aboard the bus. This is a cheaper option than proof-of-payment, which requires ticket machines at each station. Figures 71 and 72 provide examples of farebox ticket machines. | Realistic for BRT 1 given long dwell times at busy stations and relative cost of ticket machines. |
| Proof-of-Payment (POP) | Similar to what is done for many LRT systems, tickets are pre-purchased at stations or in booklets prior to boarding the vehicle. Roving inspectors check riders and fine those that are traveling without valid tickets or passes. This requires ticketing machines at all BRT stations, which is extremely costly. The advantage of this system is that dwell time and delay is minimized at stations. | Recommended for BRT 2 systems, to improve operating efficiency. |
| Closed Fare System | Similar to what is done for heavy rail (such as BART) systems, a closed fare system adopts faregates or turnstiles at all stations to control access to the boarding areas. This approach requires significant infrastructure investment at every station. The advantage over proof-of-payment systems is that fare payment is assured, while dwell time and delay is reduced at stations. This has been adopted in BRT systems in Curitiba, Bogota, and Jakarta. Figure 73 provides an example of a closed fare system. | Applicable to high volume BRT 2 systems, especially if fare evasion is a significant problem. Station areas must be large enough to control access to boarding areas. |

**Figure 71** Ticket Machines at BRT Station (Las Vegas MAX)


**Figure 72** Ticket Machines at BRT Station (Los Angeles Metro Orange Line)

**Figure 73** In-Station BRT Fare Control and Turnstiles (Jakarta, Indonesia)


## 10. BRT OPERATING PLAN

An operating plan describes how a particular transit service is to be provided. It is based on expected/observed operating demand on a route, as well as the operator's intended level of service for the route. Operating plans include specifics, such as the type of route operated, the frequency, the hours of service to be provided, and the station spacing. The proposed BRT operating plan for VTA shall consist of the following details:

**Table 16** BRT Operating Plan Details

| Aspect | BRT 1 | BRT 2 |
|---|---|---|
| Route Type/Structure | Conventional BRT route type, typically long and straight with limited stops compared to local bus service | Conventional BRT routes possibly including specialized express, limited stop, and/or feeder services if demand warrants |
| Span of Service | 6:00AM to 8:00PM (can be extended if demand warrants) | |
| Operating Period | Monday–Saturday (with Sunday service if demand warrants) | |
| Minimum Headways | 10–15 minutes, with lower headways if warranted in the peak | 5-10 minutes in the peak, and 15 minutes in the off-peak |
| Minimum Average Operating Speed | 20 mph (mixed traffic lane)<br>30 mph (bus only lane)<br>30–40 mph (HOV lane) | 30 mph (bus only lane)<br>30–40 mph (HOV lane)<br>30–50 mph (at-grade/grade-separated transitway) |
| Bus Station Spacing | 0.75 miles (on average) – may be shorter to serve key activity nodes | |
| Fares | Consistent with VTA fare policy | |

## 11. BRT VEHICLE CHARACTERISTICS

Standard 40-foot coaches are typically the initial choice to provide BRT services due to their smaller capacities, lower operating costs, and quicker acceleration. If demand warrants, 60-foot articulated units are then typically deployed. In Brazil, notably Curitiba, and other cities in Western Europe, bi-articulated vehicles are served, which are 82-feet long, carry up to 270 passengers, and have five sets of doors.

Usually, BRT vehicles have low-floors and multiple wide doors for easier and quicker boarding. Doors maybe used for both alighting and boarding. BRT vehicles may have a conventional boxy design or stylized design with rounded curves and an aerodynamic front, mimicking the contours of a rail transit car. BRT vehicles are brand distinguished from other services with unique colors, designs, or bus wraps. Low-emission BRT buses are often deployed to further differentiate service and emphasize the unique services and time saving and environmental benefits resulting from BRT service. Vehicles are designed for comfort and a smooth ride. Interiors are characterized by high-quality amenities, such as comfortable seats, better lighting, and real-time arrival and information displays.

Typically, BRT vehicles possess one of four types of propulsion systems:

- Diesel Internal Combustion Engines (ICE).
- Electric catenary.
- Dual mode engines (having both a combustion engine — diesel, CNG, or gas turbine — and an electric motor).
- Hybrid electric (having on-board energy capabilities that can be diesel, CNG, or gas turbine, allowing buses to operate at maximum fuel efficiency and minimum emissions).

In addition, propulsion system fuel cells (typically hydrogen) are being tested by some operators, including VTA (2006).

Currently, VTA deploys low-floor conventional 40-foot standard and 60-foot articulated buses for its BRT services with diesel internal combustion engines. For all BRT services, VTA shall deploy 40-foot and 60-foot buses with the following characteristics:

**Table 17** Recommended VTA BRT Vehicle Characteristics

| Vehicle Characteristics | 40-Foot Standard | 60-Foot Articulated |
|---|---|---|
| Floor Height | Low-floor (14"–15") | |
| Seating Capacity | 35–44 | 31–65 |
| Seating + Standing Capacity | 50–60 | 80–90 |
| Minimum # of Doors | 2 | 3 |
| Boarding/Alighting | Doors used for boarding or alighting, not both | |
| Bicycle Racks | Compliance with VTA Bicycle Policy required | |
| Style | Conventional (Shorter-term)<br>Stylized (Longer-term) | |
| Propulsion System | Currently Diesel, (Variable in the Future) | |
| On-Board Intelligent Transportation Systems (ITS) | Automatic Vehicle Location (AVL), Automatic Passenger Counters (APC), Automatic Mobile Data Terminal (AMDT), and audio/visual next station announcement (see Figure 80) | |
| Branding | Specialized wraps and designs (see Section 12 Specialized Branding/ Marketing) | |
| ADA Compliance | Vehicles shall be fully compliant with ADA requirements, including amenities such as lifts, low-floor vehicles, and wheelchair storage areas. | |

Source: Characteristics of Bus Rapid Transit for Decision-Making, Office of Research, Demonstration and Innovation, Federal Transit Administration, August 2004.

BRT 2 service typically involves the procurement of new buses, while BRT 1 typically uses conventional buses. BRT 1 as shown in Figures 74 through 75 and BRT 2 as shown in Figures 76 through 78 are specially painted or wrapped to give them a unique branding, if the operator desires this. In addition, Figure 79 shows the type of ITS equipment available, Figure 80 shows an example of a BRT vehicle, and Figure 81 shows an example of the real-time/ passenger information available on BRT. As conventional BRT buses approach their expected lifespan, VTA shall consider the procurement of special stylized BRT buses.

The following figures show various types of BRT vehicles.

**Figure 74** VTA Standard 40′ Bus


**Figure 75** VTA Rapid 522 Articulated Unit


**Figure 76** Stylized BRT Vehicle (LA Metro Orange Line)


**Figure 77** Stylized BRT Vehicle (Las Vegas—MAX)

**Figure 78** Double Articulated BRT Vehicle

**Figure 79** Typical ITS Equipment aboard Buses

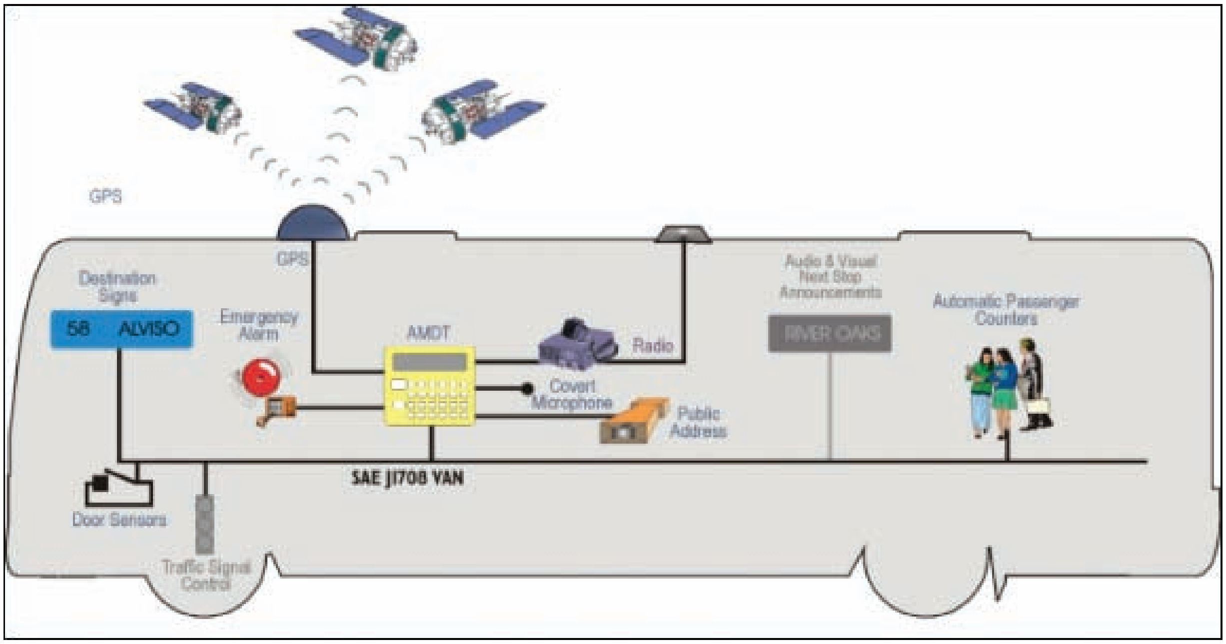


**Figure 80** Typical Interior of a BRT Vehicle (Los Angeles Metro Orange Line)

**Figure 81** Real-Time Information Panel and Television (Los Angeles Metro Orange Line)

## 12. SPECIALIZED BRT BRANDING/ MARKETING

To distinguish BRT service as a higher quality and faster alternative to conventional local bus services, BRT vehicles and related infrastructure are often specially branded and designed. Typically BRT services are branded with the same distinctive logo and colors, unless the operator desires differently. Some operates may choose to brand distinguish various lines with different colors, logos and/or vehicles, while other operates will employ the same colors and designs on all their vehicles.

The existing VTA Rapid 522 employs specialized designs and bus wraps that vividly differentiate these buses from other local and express bus services. In addition, bus station signs are similarly colored to identify specific stations served by the Rapid 522. VTA also uses the Rapid 522 design on all marketing materials.

For BRT services, VTA shall:

- Employ specialized branding on all BRT vehicles, bus stations, and marketing materials (as shown in Figure 82) to differentiate BRT service from local bus services and to accentuate the "premium" nature of the service.
- Create a specialized VTA BRT website similar to those created by other transit operators by employing similar branding, images, and coloring as adopted on the marketing materials and vehicles.
- Adopt a Marketing Plan that integrates the specialized branding selected, as the Marketing Plan is key to promoting service and market identity.

It is noted that buses painted with BRT wraps and colors shall not be used on normal bus routes, unless in an emergency situation. This will prevent confusion among riders.

**Figure 82** Example of Special Focused Marketing of Rapid 522 BRT Service

**Figure 83** Specially Branded Rapid 522 Vehicles