Figure A-53. No Parking sign.

Figure A-54. No Parking tape along curb.

behind the stopped bus or attempt to pass the bus using the main travel lanes.

Tri-Met used the standards shown in Figure A-57 for the construction of the bus bulbs along northeast Broadway Street. All dimensions are in meters. The *Portland Pedestrian Design Guide* (*3*) provides guidelines on using curb extension (Figure A-58).

SEATTLE, WASHINGTON

The city of Seattle is actively considering the use of bus bulb configurations at bus stops. Currently, there are three general locations of bus bulbs within Seattle proper—northwest Market Street, northeast Lake City Way, and University Way (Figure A-59). The University Way location is serving as a test case for bus bulbs in the region. The city is considering using bulbs in other locations; however, the city is awaiting the outcome of the demonstration project on University Way. Several suburban communities surrounding Seattle are also considering bus bulbs; however, some of the potential sites create concerns because of the use of van services with very slow lift deployment, which can block traffic for extended periods of time.

In the greater Seattle region, there are two sites where "bulbs" have been in place for a number of years—northwest Market Street and northeast Lake City Way. Each site has a pair of bulbs. Neither of these locations were planned or built as bus bulbs. Each of these sites has been in place for several years, prior to the advent of any design standard. Because of the age of each of these sites, a majority of the institutional experience in the region associated with the design and construction of bus bulbs will be fostered from the University Way Demonstration Project. Each existing site is unique in length and in design. A common sight at each of these locations is the large, well-defined pedestrian crosswalks at the intersecting streets. It was visibly apparent during the researchers' visit that strong attention is paid to pedestrian movement in the region. Two of the four existing bus bulb sites have bus shelters present at the bus stop.

Figure A-55. Pedestrian curb extension.

Figure A-56. Bike lane next to bulb.

Overview of Practices and Experiences

Width and Length of Bulbs

The northwest Market Street and northeast Lake City Way bulb sites were developed as a pedestrian amenity (e.g., pedestrian bulb or crosswalk location). Seattle Metro later made the bulbs into bus stop locations; therefore, no bus stop design standards were used for these sites.

The newly constructed bus bulbs on University Way are 80 ft (24.4 m) in length. This design allows for two articulated buses to be present at the same time and for the use of all doors for boarding and alighting. The University sites are retrofit designs; therefore, it is unclear whether the lengths used at those locations would be applied to entirely new locations in the future.

Parking

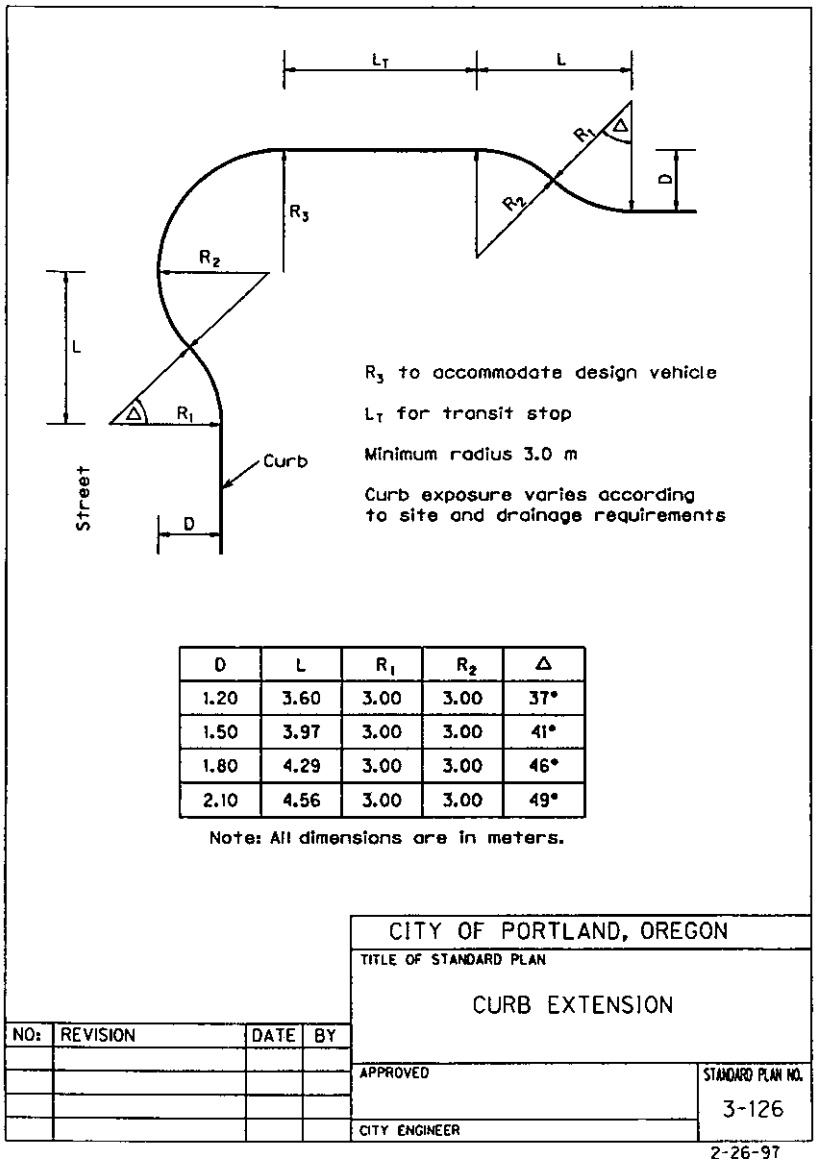
Five of the six locations in Seattle have curbside parking lanes, with the one exception of northwest Market Street at 15th Avenue where there is a 30 Minute Load and Unload Only zone just downstream of the bulb. The parking lanes adjacent to the bulbs are clearly marked. However, there are no No Parking signs on the bulbs. The bulbs are marked as bus stops with alternating yellow and red markings on the curb face. Each site also has a Bus Stop sign to help further delineate the purpose of the bulb.

ADA Wheelchair Lift Deployment

Complying with design standards as set forth by the ADA guidelines was mentioned as being a challenge. In the process of retrofitting the University Way demonstration sites, the city had to grind the street lower to achieve minimum slope standards. Seattle Metro also noted that installing bulbs in suburban locations would pose certain problems, especially to general-purpose traffic. Suburban sites are served by bus and van service. The lift deployment systems in vans are very slow, thereby prolonging the length of time a stopped vehicle would be present in the travel lane. This fact would discourage the construction of bulbs for most suburban locations with high travel speeds and high traffic volumes.

Drainage

Like other regions that are considering installing bus bulbs, Seattle found drainage to be a major issue associated with the design and cost of the bulbs. In Seattle, retrofitting sites with bulbs poses unique problems with drainage because of the regional climate—plenty of rain and occasional ice in winter. Therefore, designers are concerned not only with on-street drainage but also with on-sidewalk drainage. Standing water on the sidewalk could become ice and pose potential dangers to pedestrians and waiting passengers. This problem is



D	L	R_1	R_2	Δ
1.20	3.60	3.00	3.00	37°
1.50	3.97	3.00	3.00	41°
1.80	4.29	3.00	3.00	46°
2.10	4.56	3.00	3.00	49°

1 ft = 0.305 m

Figure A-57. Potential bus bulb design standards.
SOURCE: City of Portland, Oregon.

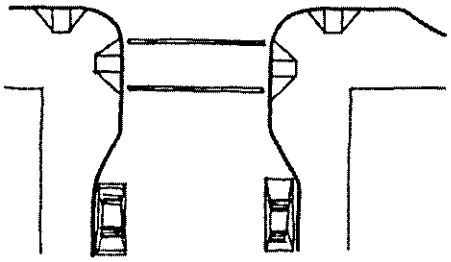
particularly acute where the bulb joins the sidewalk. Designers are wary of creating joints that would allow water to accumulate rather than to drain.

Bus Stop Location

The preferred location for bus stops in Seattle is the far side of the intersection. With the one exception of the midblock stop on northeast Lake City Way, all of the bus stops observed were farside locations. The midblock stop was initially constructed as part of a pedestrian crossing zone along a retail shopping center. The bus stop was added at a later date.

Pedestrians

Safe pedestrian movement is a high priority in the region. Well-defined crosswalks and signs assist with the safe movement of pedestrians in and around the existing bulbs. The University Way Demonstration Project is a clear example of



Curb extensions

Curb extension

Purpose: To minimize pedestrian exposure during crossing by shortening crossing distance and give pedestrians a better chance to see and be seen before committing to crossing.

Reference: (new standard plan under development)

Where to use: Appropriate for any crosswalk where it is desirable to shorten the crossing distance and there is a parking lane adjacent to the curb. (Note that if there is no parking lane, the extensions may be a problem for bicycle travel and truck or bus turning movements.)

Guidelines:

- In most cases, the curb extension should be designed to transition between the extended curb and the running curb in the shortest practicable distance.
- For purposes of efficient street sweeping, the minimum radius for the reverse curves of the transition is 2.5 m (8 ft) and the two radii should be balanced to be nearly equal.

Curb ramps

Purpose: to make the sidewalk accessible from the roadway level of the crosswalk.

Reference: Title 17.28.035; Standard Plans 3-119a through 3-124; ADA Intermim Final Rule 36 CFR Part 1191, Appendix A: Accessibility Guidelines14.2.4.

Where to use: At every intersection location where there is a crosswalk, whether or not the crosswalk is indicated with pavement markings.

Guidelines: See Section B, Guidelines for Street Corners and Curb Extensions

SOURCE: Tri-County Metropolitan Transportation District of Oregon. *Portland Pedestrian Design Guide*. Portland Pedestrian Program, Portland, OR (1998).

Figure A-58. Curb extension guidelines.

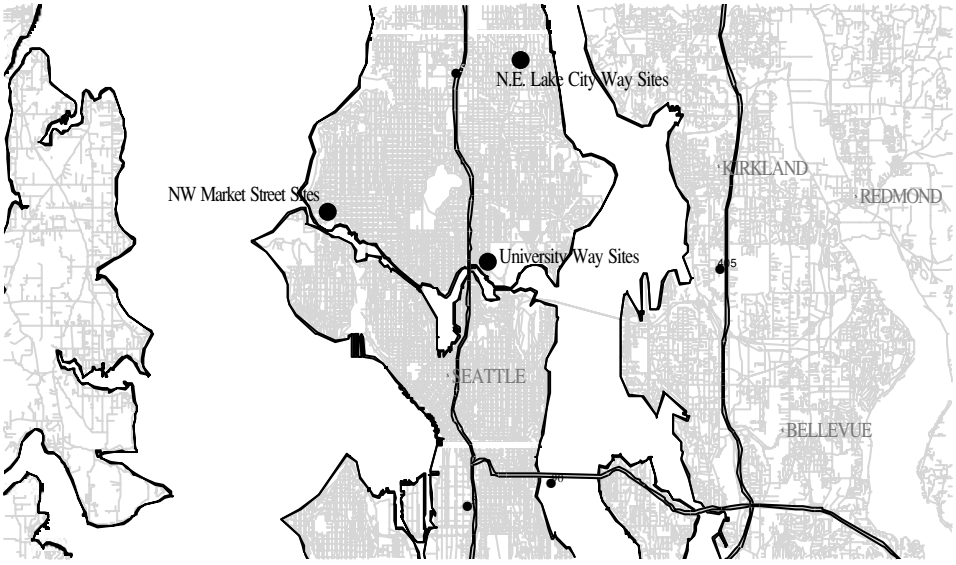


Figure A-59. Location of existing bus bulbs in Seattle, Washington.

placing greater importance on pedestrian and transit movement in a corridor.

Bus Bulb Demonstration Project—University Way

The University Way Demonstration Project was originally conceived of by the city of Seattle. The city approached Metro with the bulb idea. The retail core of the area was deteriorating and the Greater University Chamber of Commerce, business owners, and community members wanted to improve the streetscape as part of a greater redevelopment plan to improve the aesthetics of the corridor. The first phase of the redevelopment plan is a 6-month bus bulb demonstration project. The concept of bus bulbs in the corridor was actually discussed as a possible transit priority strategy more than 20 years ago. High-occupancy-vehicle lanes have also been discussed because of the high transit volumes.

University Way is directly north of the University of Washington campus and has several stores with above-store lofts that cater to students. The area links the campus with surrounding student housing. More than 50 percent of travel in the corridor occurs as either pedestrian or bicycle or on transit vehicles. Responding to the high degree of pedestrian volumes, a local community group requested that the sidewalks be widened to better accommodate pedestrians. Simply widening the sidewalks would create a situation in which the buses would partially block through-traffic movement anyway. The bus bulb concept would essentially increase the effective sidewalk width at these points and segregate bus patron activity from pedestrian activity. To further accommodate pedestrians, the city also approached Metro about consolidating bus stops on University Way to reduce the number of bottlenecks on the sidewalk created by waiting bus patrons.

Bus re-entry problems were also cited as reasons to study the bus bulb configuration on University Way. Prior to installing the test bulbs, the buses used curbside stops in parking lanes, which essentially operate as pull-outs. Pull-outs are considered an operational problem on two-lane facilities. Illegal parking in the zone and double-parking just beyond the bus stop zone were also problems in this corridor.

Vehicular traffic and speeds along University Way are low. However, the intersecting street, 45th Street, does have high vehicular volumes. The bus bulb project on University Way was created to demonstrate or to provide the following improvements:

- An increase in the pedestrian-carrying capacity of the sidewalks,
- An improvement in transit travel times in the corridor by consolidating stops and eliminating the bus re-entry problem,
- A reduction in or elimination of adaptive use of storefronts by providing a defined space for waiting bus patrons,
- The provision of a potential location for bus patron amenities (e.g., bus shelter), and
- A demonstration of and/or the development of "reasonable criteria" for installing bus bulbs at bus stops.

As previously mentioned, the neighborhood is highly involved in the demonstration project. Figures A-60 through A-62 show the demonstration bulbs as constructed on University Way.

Public interviews can determine reactions to the project from both pedestrians and store owners. Interviews were conducted in early 1998 prior to construction of the bulbs in April 1998. Early reactions to the project are favorable. Local businesses like how the bulbs reinforce separation between bus activities and businesses. Because there are no bus shelters at these stops, waiting patrons stand under storefront awnings, using them as shelter against the elements. Bus ridership levels have not changed since the advent of the bulbs. At the end of the project, the city will determine whether the bulbs are to remain in place. The following pages are "lessons learned" and issues encountered during the initial stages of the bus bulb demonstration project on University Way.

Transit Vehicle Travel Time and Dwell Time at Stops

A major objective of the bus bulb demonstration project was to determine whether the installation of bus bulbs improved transit vehicle travel times. Prior to the installation of the bulbs, transit vehicles were encountering bus re-entry problems with the curbside stops. University Way is only a two-lane facility, which further exacerbates the problem. The bulbs would allow the bus to stop in the travel lane rather than weave in and out of traffic. Another strategy to improve transit vehicle travel times was the consolidation of bus stops in the corridor. The University Way Demonstration Project calculated travel-time savings per person for the transit riders

Figure A-60. Nearside bus bulb—University Way at 45th Street.

Figure A-61. Midblock demonstration bus bulb—University Way.

using average ridership volumes within the study segment and average transit travel times (*4*). Transit ridership was found to be approximately 1,091 passengers in the northbound direction and 574 passengers in the southbound direction between the study hours of 3 P.M. and 6 P.M. A comparison between the pre- and post-installation transit travel time data shows a savings of 50 s in the northbound direction and 2 s in the southbound direction. The total P.M. peak transit travel-time savings in terms of person-hours equates to 15.4 person-hr. Vehicle travel times were not collected as part of the impact assessment; however, the magnitude of vehicle delay was estimated using the number of vehicles during peak period, an assumed vehicle occupancy rate of 1.6, and intersection approach delay data collected at University Way and northeast 42nd Street. In the post-installation study period, vehicles on the northbound and southbound approaches experienced 7 s more delay than did the vehicles in the pre-installation study period, a total travel impact of 3.2 person-hr. Transit travel-time savings and pedestrian flow improvements outweighed the estimated vehicle delay that resulted from the use of bus bulbs.

Figure A-62. Bus operations at nearside demonstration bulb.

Parking

As in other cities, parking or the availability of parking can be a controversial issue in Seattle. The length of the bus stop zone prior to the installation of the bulbs was 120 ft (37 m). The length of the bulbs after installation is approximately 80 ft (24.4 m), with additional space for the dual curb returns. With this configuration, an additional parking space was added to each side of the street, which helped ease any fears that business owners may have had about the removal of parking spaces in their corridor. Furthermore, the consolidation of stops also provided additional room for parking because two curbside stops have been temporarily removed for the demonstration project. Figure A-63 shows the parking lane near one of the bulbs.

The city believes that the bus bulb configuration will help reduce the number of illegally parked cars in the bus stop

Figure A-63. Parking lane prior bulb.

zone. This is a major issue with curbside stops in this corridor. An alternating red-and-yellow marking was added to the curb edge of the bulb to further define the area as a bus stop (Figures A-64 and A-65). Parking signs are also located on either end of the bulb to further define legal parking spaces.

ADA Wheelchair Lift Deployment

The bulbs have been designed and built to meet all current accessibility guidelines. To accommodate wheelchair lift deployment, a 2-percent grade is needed at each site. The city ground the entire street to provide the necessary slope at the bulb sites. Maintaining accessibility is a major issue associated with sites that are reconstructed to handle the bulb configuration. The overall cost of the project is dramatically affected by the extent and nature of the reconstruction.

Drainage

The most expensive element of the project is drainage. The street had to be ground down to provide the necessary slope for drainage and lift deployment. The curb extension is an impediment to water flow along the curb effacement. Furthermore, the area where the bulb joins the sidewalk is another potential drainage problem. Water needs to be removed from the sidewalk before the water is allowed to freeze. The curb radii are 20 ft/20 ft (6.1 m/6.1 m) to allow for sweeping. Figure A-66 shows the drainage treatment at the downstream end of the nearside demonstration bulb. A smaller radii is also being used to consume fewer parking spaces (10 ft/20 ft [3.1 m/6.1 m]). Figure A-67 illustrates the potential drainage concerns associated with a retrofitted bus bulb.

Figure A-64. Example of curbside markings.

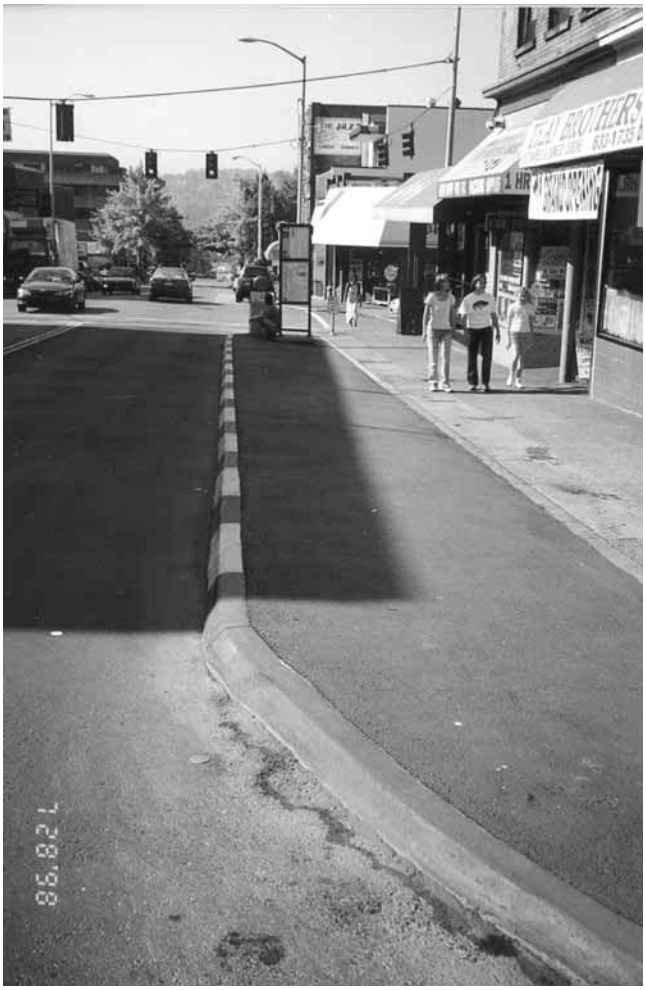


Figure A-65. Another example of curbside markings.

General-Purpose Traffic

A major benefit of installing bus bulbs is eliminating the potential for sideswipes that might occur during bus re-entry into the general flow of traffic. University Way was restriped with double-yellow lines on the centerline to prohibit passing near the demonstration bulbs. Additional parking enforcement

Figure A-66. Drainage solution.

was added to minimize illegal parking or double-parking before and after the bulbs. Queuing behind a stopped bus is a concern that is being closely monitored during the demonstration project (Figure A-68).

Bus Stop Location

The general policy regarding bus stop location at Seattle Metro is to locate stops at the far side of the intersection. However, the location of the bus bulb demonstration raised some concerns that vehicles would queue in the intersection behind a stopped bus. The high vehicular volumes on 42nd Street increased the concerns of locating the bus bulb on the far side of the intersection of University Way and 42nd Street. University Way is a two-lane facility with no passing in the vicinity of the bus stops. In response to this configuration, a decision was made to locate one stop at the near side of the intersection of 42nd Street and the other at the mid-block of University Way. Figure A-69 illustrates the location of the two demonstration bulbs with respect to 42nd Street.

Length of the Demonstration Bulbs

The demonstration bulbs are approximately 80 ft (24.4 m) in length. The length was determined by considering several factors: the desire to consolidate bus stops and to add parking, the potential for having two buses arrive at the same time, and the ability to accommodate an articulated bus at the bulb if all doors are used for boarding and alighting. The width of the bulb is the same width as the existing parking lane. Figures A-70 and A-71 illustrate the basic dimensions of the two demonstration bus bulbs on University Way.

Pedestrians

As mentioned previously, pedestrian volumes are extremely high on University Way. Prior to the installation of the bus bulbs, there were no bus stop amenities, such as shelters or benches, at the stops. Consequently, there was a high degree of adaptive use of the awning overhangs by waiting patrons to avoid exposure to the elements. If the bus bulb demonstration project is deemed successful, Seattle Metro plans to install shelters at the stops to help further segregate pedestrian and business activities from bus stop activities. Thus far, Metro has received several positive comments concerning the relief of pedestrian congestion along University Way's sidewalks (Figure A-72). Local business owners also have approved of the bulbs, which encourage patrons to congregate away from storefronts. There have been some concerns about how the bulbs have reduced the crossing distance across University Way and how this reduction might encourage jaywalking. Crosswalk visibility is another closely watched issue.

Bicycles

There is no special treatment for bicyclists in this corridor. The lane widths are too small to stripe a lane, and parking-lane use is too high for bicycle riders to use the lanes. Each approach to the bulb has a bike rack located on the sidewalk.

Cost

The cost to construct the two demonstration bulbs was $35,000. A majority of the expenses are related to drainage and accommodating wheelchair lift deployment. Seattle Metro is considering using bulbs in other locations, pending the outcome of the demonstration project.

Northwest Market Street at 20th Avenue

The first northwest Market Street site is located at the far-side intersection of 20th Avenue. The "bulb" was originally installed as a pedestrian improvement for the area, which is a local urban shopping and retail district. A pedestrian bulb is also present on the approaching curb intersection, which further reduces pedestrian exposure in the intersection (Figure A-73).

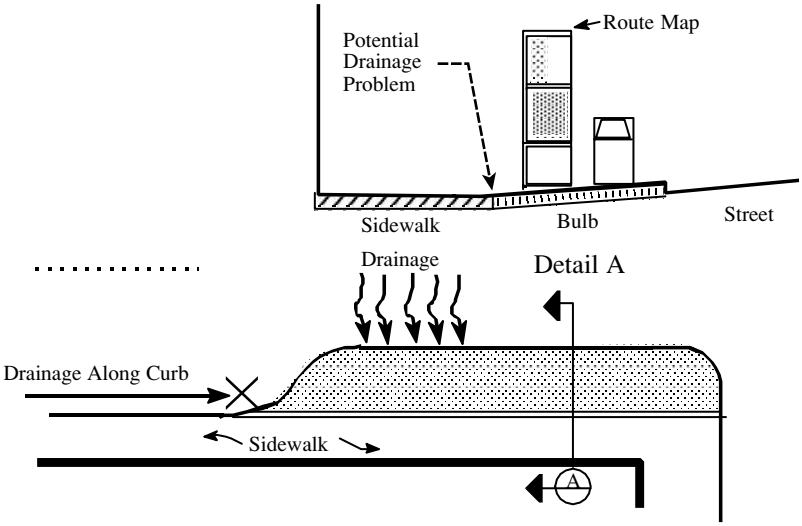


Figure A-67. Potential drainage issues with bus bulbs.

Figure A-68. Traffic queued behind stopped bus.

Seattle Metro later installed a bus stop at the bulb, thereby having the site function as a bus bulb. The site does not have a bus shelter or bench, but the bulb clearly provides a waiting area for bus patrons (Figures A-74 and A-75). The overall length of the bulb is only 35 ft (10.7 m) (Figure A-76). The pedestrian bulb is highlighted by the presence of an object warning marker located at the crosswalk. The marker warns motorists of the curb extension at the intersection (Figure A-77).

Northwest Market Street at 15th Avenue

The second bus bulb on northwest Market Street is also a farside configuration at the intersection of 15th Avenue. Unlike 20th Avenue, the site does not have a pedestrian bulb

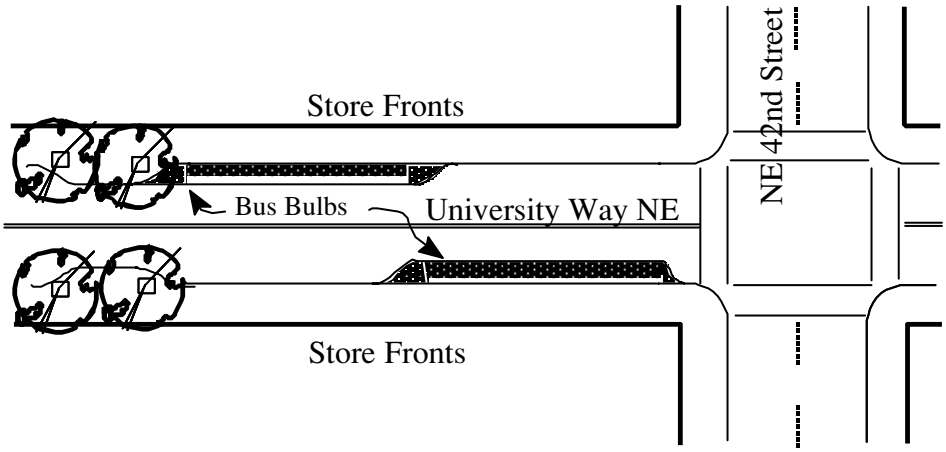


Figure A-69. Location of bus bulb demonstration project.

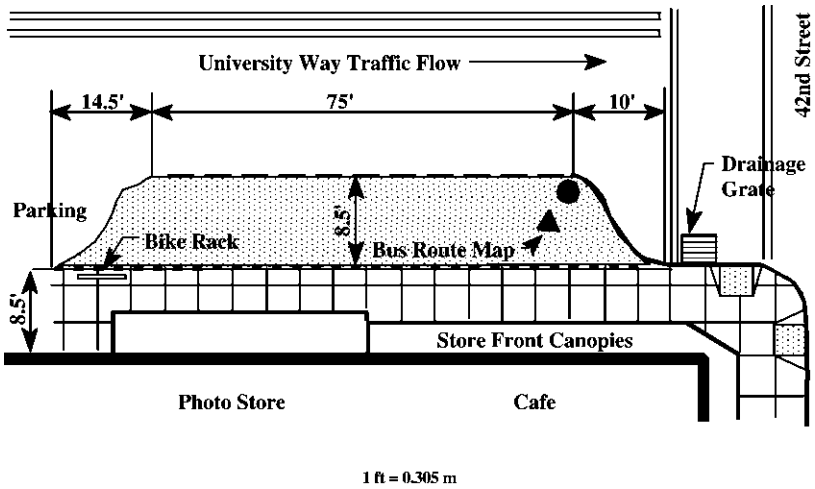


Figure A-70. Detail of southbound demonstration bulb.

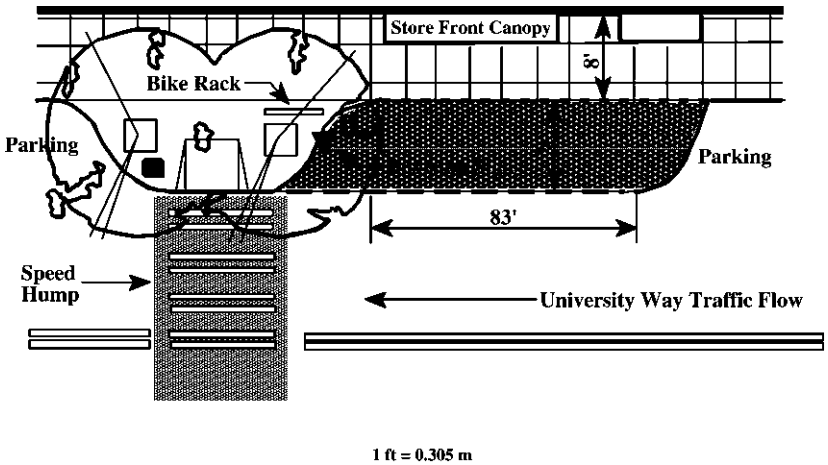


Figure A-71. Detail of northbound demonstration bulb.

Figure A-72. Pedestrians queuing on bus bulb to board bus.

on the opposing curb at the crosswalk, and a bus shelter was installed at the site to provide a defined waiting area for bus patrons (Figure A-78). At approximately 95 ft (29 m), the bulb is also three times longer. Like the bulb on 20th Avenue, the Market Street bulb has street trees planted along its outer edge. The bulb clearly provides the additional space needed to plant street trees that would not otherwise be present at this site (Figure A-79). A unique feature of this site is the loading area just beyond the end of the bus bulb (Figures A-80 and A-81). Cars were observed using this space as a temporary parking area.

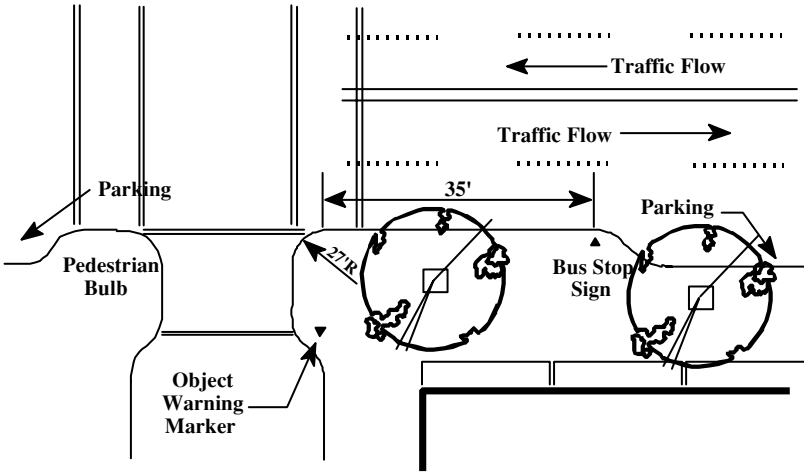
Northeast Lake City Way—Midblock Site

Similar to the northwest Market Street sites, the two bus bulb sites on northeast Lake City Way—one midblock stop

Figure A-73. Approaching pedestrian bulb.

Figure A-74. Farside bus bulb on northwest Market Street at 20th Avenue.

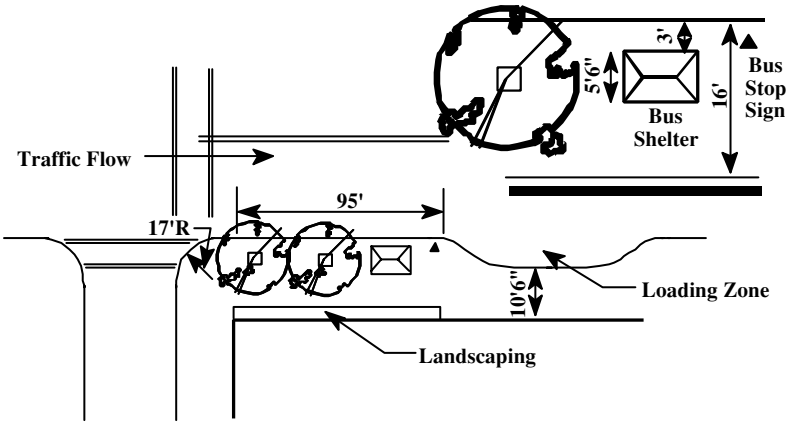
Figure A-75. Traffic approaching northwest Market Street bus bulb.



1 ft = 0.305 m

Figure A-76. Northwest Market Street at 20th Avenue: farside bus bulb.

Figure A-77. Warning marker in bulb.



1 ft = 0.305 m

Figure A-78. Northwest Market Street at 15th Avenue: farside bus bulb.

Figure A-79. Extra sidewalk space, northwest Market Street at 15th Avenue.

Figure A-81. Loading zone downstream of bus bulb.

Figure A-80. Bus shelter on bulb.

and one farside stop—were preexisting. Both sites appear to be pedestrian and traffic-calming projects adopted as bus stop sites at a later date. The one block area of northeast Lake City Way is an older shopping district that may have had significant walk-in customers at one time. The bus stops are located at high pedestrian-crossing locations. The midblock site has a pedestrian bulb across the street that is connected by a wide pedestrian crossing; pedestrian exposure is further reduced by the presence of a median in the road (Figure A-82). A flashing pedestrian crosswalk sign is cantilevered over the road to further warn motorists of the pedestrian activity (Figure A-83).

Both sides of the street and the median are tree-lined, which further reduces the scale of the area. The site is physically and visibly tighter than the typical cross section along other parts of northeast Lake City Way. There are no benches or shelters for waiting patrons (Figure A-84).

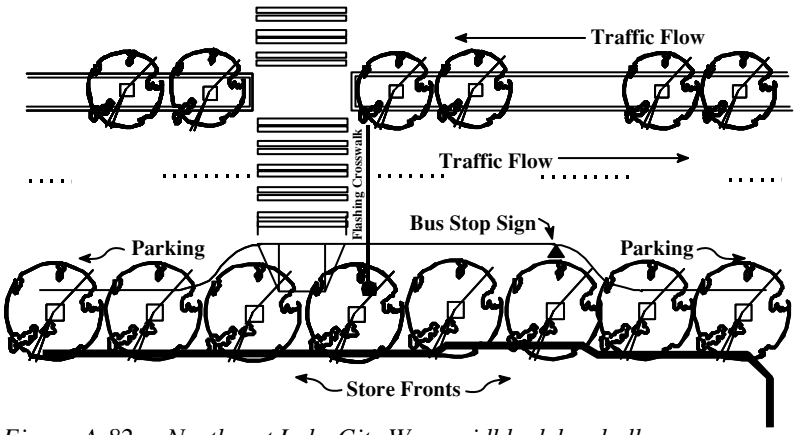


Figure A-82. Northeast Lake City Way: midblock bus bulb.

Figure A-83. Midblock bus bulb with pedestrian crossing sign, Lake City Way.

Figure A-85. Sidewalk clearance created by bulb.

Northeast Lake City Way at 125th Street—Farside Site

Another bus bulb exists on northeast Lake City Way. The bulb is located on the far side of 125th Street in the southbound direction. The bus bulb created the necessary sidewalk clearance for the inclusion of a bus shelter (Figure A-85). An alternating red-and-yellow stripe along the curb identifies the bulb as a transit stop as well as a No Loading zone. The same markings exist on the midblock stop down the street.

The posted speed limit on this facility is 30 mph (48.3 km/h) (Figure A-86). General-purpose traffic was also rather heavy in the corridor. It appears as though the area, at one time, served more pedestrians than vehicles; however, the corridor now appears to be serving more vehicles that travel through the area than those that stop and shop. As with previous bus bulb examples, a parking lane exists downstream of the bus bulb (Figure A-87).

Figure A-86. Farside bus bulb, northeast Lake City Way at 125th Street.

Figure A-84. Waiting patron on midblock bus bulb, Lake City Way.

Figure A-87. Parking lane downstream of farside bus bulb.

REFERENCES

1. Texas Transportation Institute and Texas A&M Research Foundation. *TCRP Report 19,* "Guidelines for the Location and Design of Bus Stops." Transportation Research Board, National Research Council, Washington, D.C. (1996).

2. Watry, D., and J. Mirabdal. Transit Preferential Streets Program in San Francisco. In *Compendium of Technical Papers: Institute of Transportation Engineers 66th Annual Meeting*, Institute of Transportation Engineers, San Francisco (1996) pp. 314–318.

3. Tri-County Metropolitan Transportation District of Oregon. *Portland Pedestrian Design Guide*. Portland Pedestrian Program, Portland, OR (1998).

4. "Transportation Impact Assessment for the University Way Bus Bulb Demonstration Project." King County Metro Transit Division. Prepared by The Transpo Group, Inc., and Makers Architecture and Urban Design. King County Department of Transportation, Seattle, WA (1999).

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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