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TRANSIT FACILITY DESIGN GUIDE

Conducted for: Capital Metropolitan Transportation Authority

Authors: Kathryn Albee, Stephen Banks, Antonio Gonzalez, Luis Hernandez, Allen Hoffman, Theunis Kruger, Michael Ouimet, Robert Spillar, Darlene Szlama, Andrew Wimsatt

Supervisor: Dr. C. Michael Walton

June 1988

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by the

CENTER FOR TRANSPORTATION RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

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PREFACE

The objective of the "Transit Facility Design Guide" is to provide a resource document to assist, through proper facility design, in integrating transit considerations into new and existing land use developments. The document, which focuses on engineering design criteria and pertinent guidelines, addresses the following subject areas: design vehicle characteristics, geometric and pavement design, the physical components comprising transit facilities, and transit facility development.

This report, supported by Capital Metropolitan Transportation Authority (Capital Metro), was the product of the graduate students participating in the graduate course entitled "Transportation Planning: Methodologies and Techniques" (CE 391J - Spring 1988). The students, from the Graduate Program in Community and Regional Planning and Civil Engineering (Transportation), were responsible for all aspects of this study including preparation of the final report.

The study process, involving the ten graduate students under the supervision of Dr. C. Michael Walton, consisted of four major tasks:

- Identification and survey of transit operations in areas similar to the metropolitan area of Austin, areas known for their transit service, and areas of special interest
- Seminar series consisting of invited speakers representing community leaders, engineers and architects, developers, mall managers, transit professionals, and related professionals
- Development of an annotated bibliography used for reference and guidance
- Development and implementation of a study plan reflected in the report

C. Michael Walton
May 15, 1988

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii

PREFACE v

TABLE OF CONTENTS vi

LIST OF FIGURES viii

LIST OF TABLES ix

INTEGRATING TRANSIT 1

ENGINEERING DESIGN 3

- Design Vehicle Characteristics 3
  - Critical Dimensions 4
  - Capital Metro Transit Vehicle Fleet 4
  - Application of Vehicle Types 6
    - Fixed Route Service 6
    - Downtown Circulation Routes 11
    - Special Transit 11
  - Design Turning Templates 11
  - Vehicle Height 12
  - Ground Clearance 12
  - Vehicle Weights 12
- Geometric and Pavement Design 13
  - Width of Roadway 13
  - Vertical Clearances and Alignment 15
    - Ground Clearance 15
    - Overhead Clearance 15
  - Grades 17
  - Curb Return Radii 17
  - Delineation 24
  - Turnouts 24
  - Turnarounds 28
  - Bus Berthing 28
  - Pavement Design 37
- Physical Components of Transit Facilities 37
  - Waiting Areas 41
  - Benches 41
  - Shelters 43
  - Information Devices 44
  - Lighting 48
  - Vehicle Parking 48
  - Bicycle Storage 48
  - Facilities for the Mobility Impaired 48
  - Traffic Control Devices 50
  - Other Amenities 50
- Facility Development 50
  - Concept of Interaction / Separation of Modes 51
  - Park-and-Ride Facilities 52
    - Placement Consideration 52
    - Design Considerations 52
  - Transit Centers 55
  - Facility Component Matrix 55

CONCLUSION...... 61
REFERENCES..... ....R-1
APPENDIX A-1
GLOSSARY G-1
ANNOTATED BIBLIOGRAPHY..B-1

LIST OF FIGURES

Figure		Page
1	Inadequate Ground Clearances	5
2	Forty Foot Gillig	9
3	The 'Dillo	9
4	Over-the-Road Coach	10
5	Thirty-Two Foot Special Transit Vehicle	10
6	Design Criteria for Vertical Curves	16
7	Examples of Adequate and Inadequate Overhead Clearance	18
8	Curb Returns for Forty Foot Bus Design Vehicle	20
9	Curb Return for Articulated Bus Design Vehicle	21
10	Curb Return for 'Dillo Bus Design Vehicle	22
11	Compound Curb Return - Alternate Design	23
12	Driveway Curb Returns	25
13	Near Side and Far Side Bus Stop Turnouts	26
14	Mid-Block Bus Turnout	27
15	Mid-Block Turnout for Thirty Foot Design Vehicle	29
16	Mid-Block Bus Turnout Adjacent to Bike Lane	30
17	Bus Turnout Located After Free Right Turn	31
18	Counter-Clockwise Turnaround Located to the Left	32
19	Counter-Clockwise Turnaround Located to the Right	33
20	Minimum Lengths for Parallel Berths	34
21	Parallel Berths Located on the Street	35
22	Normal Lengths for Parallel Berths	36
23	Sawtooth Berths	38
24	Commonly Used City of Austin Pavement Designs	39
25	City of Austin - 120 Foot Concrete Pavement Bus Stop	40
26	Typical Curb Ramp	42
27	Presently Used Capital Metro Bus Shelter	45
28	Bus Shelter on The University of Texas Campus	45
29	Bus Shelter located at 11th Street and Congress	46
30	Capital Metro Park-and-Ride Facility	46
31	Presently Used Capital Metro Bus Stop Signs	47
32	Typical Bicycle Racks and Lockers	49
33	Illustrated Concept of Separation and Interaction of Modes	53
34	Typical Park-and-Ride Layout	56
35	Bus Awning at Capital Metro Park-and-Ride Facility: U.S. 183 and Lamar Blvd	57
36	Bus Passenger Shelter at Capital Metro Park-and-Ride Facility: U.S. 183 and Lamar Blvd.	57
37	Park-and-Ride Placement and Layout Design Options	58
38	A Typical Transit Center Site Layout	59

LIST OF TABLES

Table		Page
1	Critical Dimensions of Design Vehicles	7
2	Transit Vehicles Arranged by Function	8
3	Minimum Road Widths	14
4	Facility Component Matrix	60

INTEGRATING TRANSIT

The Capital Metropolitan Transportation Authority (Capital Metro) is a regional transit authority serving Austin, Texas and several surrounding communities. A major goal of Capital Metro is to improve the provision, and increase the patronage, of its public transportation system. The Transit Facility Design Guide document is one means by which Capital Metro is attempting to increase and improve the role of public transit in the Austin area. The guidelines provide the citizen and developer with information concerning the general and technical aspects of integrating public transportation into new and existing developments.

The advantages of a well-integrated transit system are many. A well-integrated transit system gives the individual a convenient, alternate form of transportation for work trips, especially into and within the Central Business District or CBD (Ref 18). For the citizen who has no other means of transportation, a well-integrated system allows that individual to interact with the city at-large, thus expanding that person's economic and social interaction within the city.

The benefits to the entire community are directly related to those experienced by the individual citizen. With a well-integrated transit system, the labor pool within the city expands due to the greater mobility of the individual worker. A well-integrated system also provides the city with a convenient, safe and economical transportation system to offer visitors. Conventions may be better serviced thus encouraging more use of the city's convention facilities, bringing in outside revenue. Another advantage in having a well-integrated public transportation system is that valuable real estate in the Central Business District can be utilized for buildings rather than for parking facilities. With the increased demand for downtown real estate, the efficient use of downtown space will depend on the provision of a well-integrated public transportation system.

The benefits to the developer may be less recognizable than those explained above. The primary benefit realized by the developer is an expanded available market. Because a well-integrated transit system provides mobility to a sector of the society often neglected by modern retail, housing, and entertainment markets, the developer offering an integrated project will profit by patronage from these sectors. A secondary, but no less important benefit realized by the developer is the recognition received for contributing to the community. A voluntary inclusion of integrated transit facilities in new developments is a strong gesture to the community on behalf of the developer.

This document provides general standards and criteria for facilities, and amenities associated with transit integration. It is emphasized that these standards and criteria should be applied in the context of site specific designs as various sites may require specific design modifications. One of the most important design criteria is the design vehicle. The characteristics of four different design vehicles are presented. Developers should be aware that the integration requirements could change with the introduction of new vehicles to the Capital Metro fleet and it is therefore necessary for the developer to work closely with Capital Metro in any design process.

Selection of the design vehicle criteria will directly impact the selection of the standards and guidelines set forth in the road and pavement design section. The emphasis again is on general standards, and site specific constraints. For example, soil conditions and types should be designed for on a site-by-site basis. There are many guidelines which apply in general terms to all types of developments, and developers can use the guidelines presented to project the number and cost of the features necessary for the successful integration of public transit.

Integration of design vehicle and pavement guidelines into developments is important, but the integration of public transit should also consider architectural and physical amenities which make the integration functional in human terms. These guidelines are presented in terms of their inclusion into all types of developments, and transit facilities such as transit centers or Park-and-Ride terminals. While there may be some site specific constraints connected to individual projects, these design criteria are generally applicable to all types of developments.

In conclusion, it is hoped that this handbook will answer many important questions about transit integration. It is also hoped that the book will encourage further integration efforts in the future. The citizen and developer is reminded that integrating transit into new and existing urban development symbolizes a partnership between the community and development industry. Such a partnership can be a positive commitment to the people of the greater Austin area.

ENGINEERING DESIGN

Engineering design, as defined in this document, is the physical design and placement of the transit-related facilities and roadway. It is the purpose of this document to provide both specific design information and general design considerations that should be addressed if transit operation within a development is to be successful.

The engineering design chapter begins with a section on the development of the design vehicle. Three design vehicles can adequately represent the specific types of current bus service. These vehicles are the 40 ft. bus, the 'Dillo, and a special transit vehicle for the mobility impaired. Design turning templates are provided for each of these three design vehicles. An additional design vehicle, the articulated bus, was included in the template set; however, Capital Metro does not have any plans for obtaining such vehicles. (Note: The designer should consult Capital Metro for appropriate vehicle application on a site-specific basis.)

The following two sections are the predominant sections relating to the actual design of the physical components. The section entitled "Geometric and Pavement Design" addresses the physical design of the roadway and bus related facilities while the section entitled "Physical Components and Amenities" addresses the design and placement considerations of the transit related facilities that are not a portion of the travel way.

The purpose of the final section of this chapter, which is entitled "Facility Development", is to present the reader with the concepts behind the development of transit facilities. This section begins with a discussion on the interaction and separation of the different mode types present within a transit facility. The development of individual facility types, from bus stops to transit centers, is also addressed. A facility component matrix is included as a summary of the types of amenities that should be considered when designing these transit facilities.

DESIGN VEHICLE CHARACTERISTICS

In order to determine the design criteria for the space that a vehicle occupies during a maneuver, it is necessary to determine the characteristics of the critical vehicle most likely to use a specific facility. These characteristics include the horizontal plane area described by the vehicle when turning, referred to as the swept path, the height of the vehicle, its ground clearance and other dimensions determining the minimum vertical alignment of the road surface, which the vehicle can negotiate. The axle loads of the vehicle also serve as an input to the pavement design process.

Critical Dimensions

When a vehicle negotiates a turn, its rear wheels do not follow the exact path of the front wheels. The rear wheels track inwards of the path traced by the front wheels and are thus said to "offtrack". The front and rear corners of the vehicle may also sweep outside the path tracked by the wheels. The amount of offtracking varies directly with the wheelbase of the vehicle and inversely with the radius of the turn (Ref. 21). The degree of turn, speed and turning ability of the vehicle, the latter a function of the design of the steering mechanisms, also affect the area required for the vehicle to maneuver. Other factors such as the inflation and condition of the tires; pavement conditions; superelevation of the roadway; driver ability and wind direction and strength, may also play a role, but usually only to a negligible extent at low speeds.

The height of the unloaded vehicle, from its highest point to the ground, is the critical dimension determining required vertical clearances. The ground clearance of the vehicle in combination with its wheelbase, and front and rear overhang, determines the approach angle, rollover angle and departure angle. These dimensions are critical in determining the absolute maximum allowable changes in roadway grades, where no gradual transition between grades are used, for the vehicle body not to scrape the road surface. This is illustrated in Fig. 1.

Capital Metro Transit Vehicle Fleet

At the beginning of 1988, the fleet owned by Capital Metro totalled 230 vehicles. This fleet comprises a variety of vehicle types used in a variety of applications. It is not practical to select a single critical vehicle to be used in the planning and design of transit facilities, since:

- particular types of developments may only be served by specific vehicle types, and
- the fleet may possibly in future be supplemented by additional types, including larger or smaller vehicles.

In addition to the regular fleet, Capital Metro also contracts with a private firm to operate over-the-road motor coaches, primarily to serve outlying Park-and-Ride facilities. These are 40 ft., 3-axled vehicles of the type most often used for intercity services.

The possibility that Capital Metro may in the future acquire larger vehicles, or that the type of vehicle used on a certain route may change, should be considered when designing facilities which will have a relatively long life. Distinction should be made between :

- components included which can easily be changed to accommodate larger vehicles (e.g. pavement markings) and

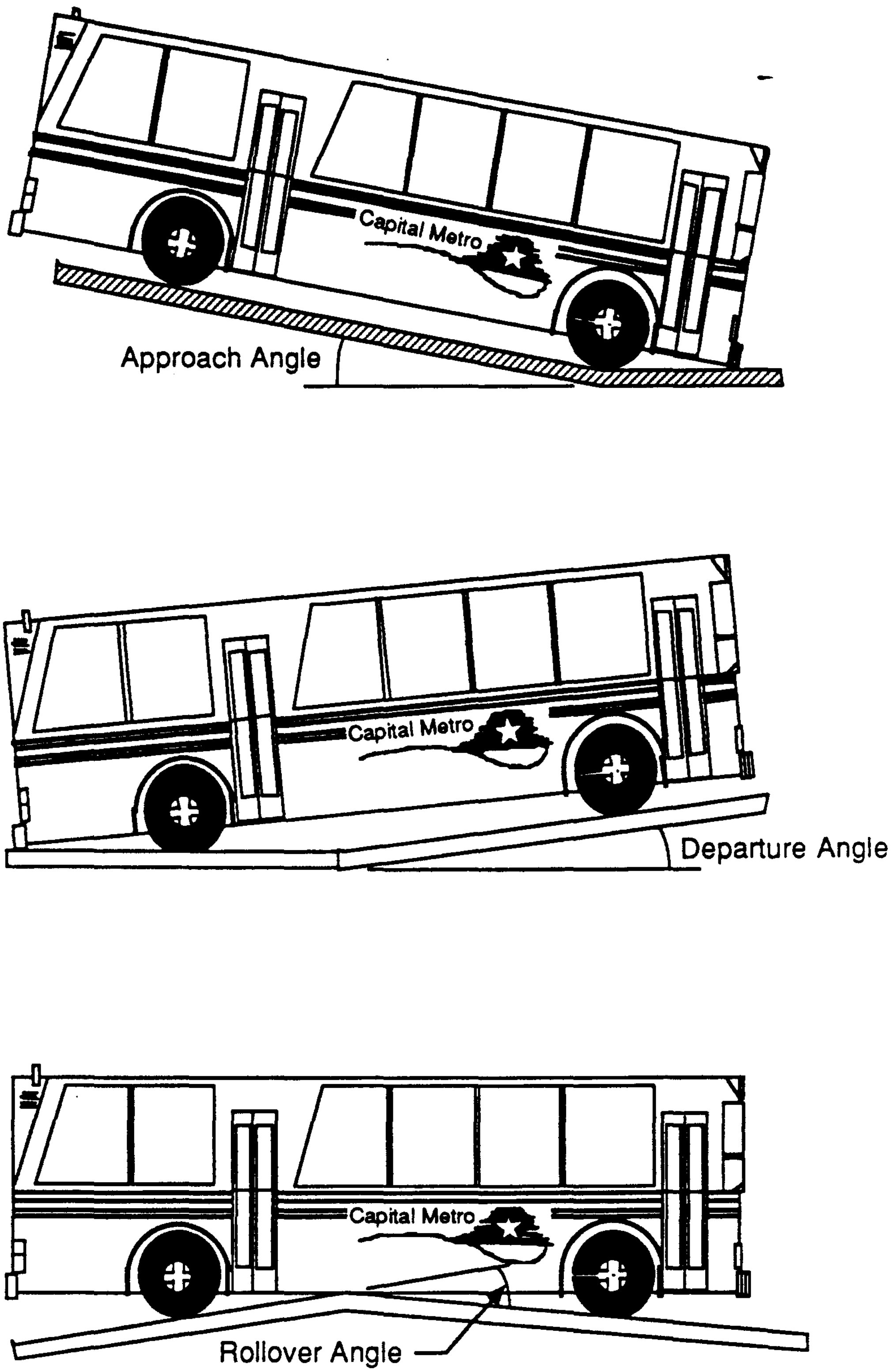


Figure 1 : Inadequate Ground Clearances

- components which may be impossible or very difficult and costly to adjust to suit a different size of vehicle (e.g. right of way, pavement strength).

It will be noted from the design turning templates included in the Appendix that an articulated bus requires a maneuvering area only marginally larger than the 40 ft. bus, despite having a wider swept path. Also, from Table 1 it may be noted that the axle weights of an articulated bus are less than that of the 40 ft. Gillig vehicle.

Vehicles currently in use are included in Table 2, by size and function. Table1 lists the critical dimensions of the selected design vehicles (40 ft. bus, special template, 30 ft. single unit truck/bus (S.U.), and articulated bus). Photographs of some of the vehicles referred to above are shown in Figs. 2, 3, 4 and 5.

Application of Vehicle Types

It is necessary to consider the critical vehicle most likely to use the transit facilities, when planning or designing a development with the intent to integrate transit.

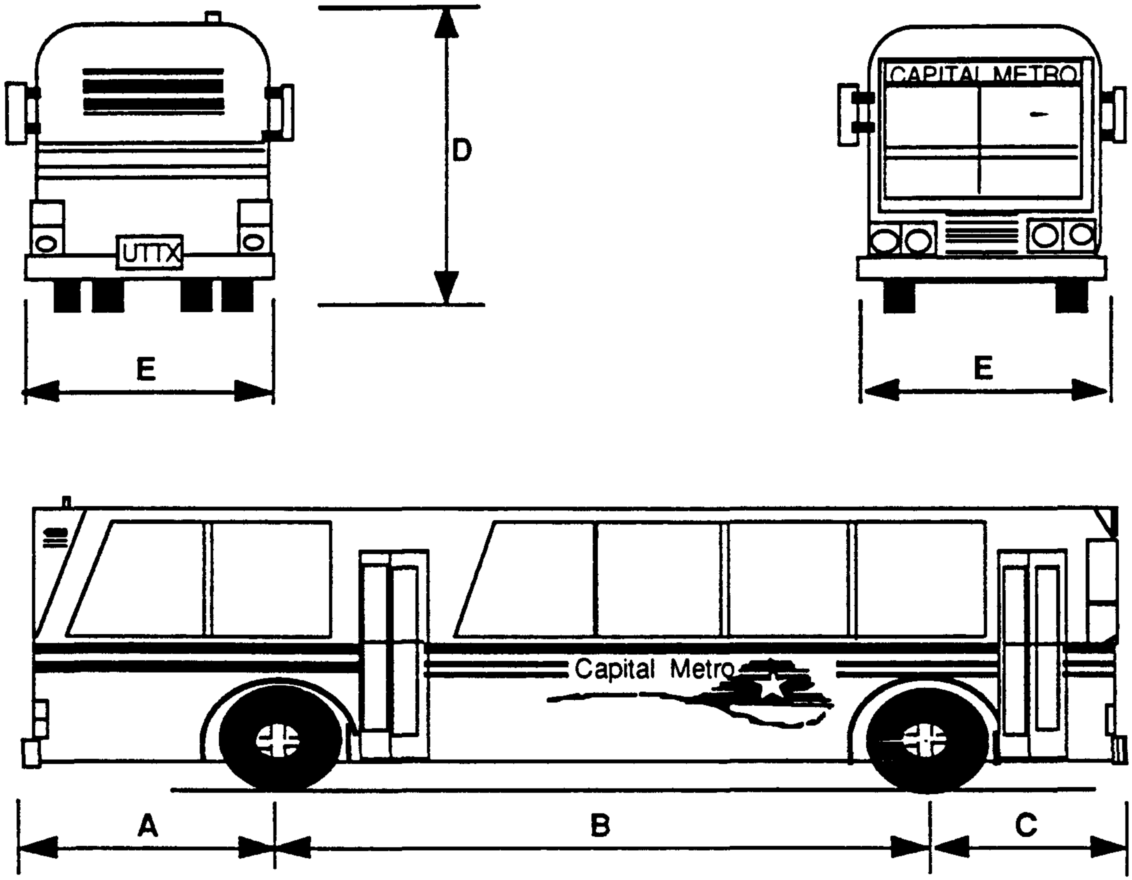
Fixed Route Service. If articulated buses were to be included in the fleet, they will most probably be exclusively used for fixed route services. The articulated bus could, therefore, become the critical design vehicle for the design of:

- turnouts and stops on streets classified as major collectors or arterials,
- major collectors and arterial streets themselves, all transit facilities that will generate large numbers of riders, such as major Park-and-Ride locations, transit centers or transfer locations.

However, since Capital Metro does not plan on acquiring articulated buses in the foreseeable future, the 40 ft. long, 102 in. wide bus can be considered as the most critical of the larger buses for design purposes. The use of the articulated bus as the design vehicle is left as an option to the designer.

It should be noted, however, that the largest design vehicle is not necessarily the most critical vehicle. For example, the physical requirements of the trolley lookalike, or 'Dillo, may be more critical, in some cases, even in comparison with the 40 ft. bus or articulated bus design vehicles. It is therefore recommended that design layouts be checked against this vehicle's requirements.

In principle, radii and maneuvering space should be provided such that vehicles never have to use opposing lanes or areas other than the specifically designated lanes. This should, without exception,



Critical Dimensions	40 Ft. Bus	'Dillo	30 Ft. Bus	Articulated Bus
A. Rear Overhang	8'	8'	6'	9' 5"
B. Wheelbase	25'	21' 4"	20'	24' rear 18' front
C. Front Overhang	7'	3' 10"	4'	8' 6"
D. Height	10' (Gillig)	10' 7"	13' 6"	10' 4" (typical) 11' 4" (intercity)
E. Width	8' 6"	8' 6"	8' 6"	8' 6"
Gross ** Vehicle Weight	39,600 lbs.	-	-	53,600 lbs. (typical)
Gross ** Axle Weights				
Front	14,600 lbs.	-	-	15,700
Center		-	-	19,400
Rear	25,000 lbs.	-	-	18,500

**Gross weight refers to weight of bus with passengers.

Table 1 : Critical Dimensions of Design Vehicles

	Seats	Length	Width	Applicable Template
Fixed Route Service				40' Bus
Gillig Phantom	47 to 49	40'	102"	
T.M.C.	31	36' 4"	96"	
A.M.G. 9635 A/B	41	35'	96"	
Gillig Phantom	29	30'	96"	
Motorcoach	46	40'	96"	
Downtown Circulation				Special Template
'Dillo	42	33' 2"	102"	
Special Transit				30' Single Unit (SU) Truck or Bus
Skillcraft Transmaster	19	32'	96"	
E-350	12 to 14	23'	96"	
Additional Provision				
Articulated Bus	65	60'	96"	Articulated Bus

Table 2 : Transit Vehicles Arranged by Function

Figure 2 : Forty Foot Gillig

Figure 3 : The 'Dillo

Figure 4: Over-the-Road Coach

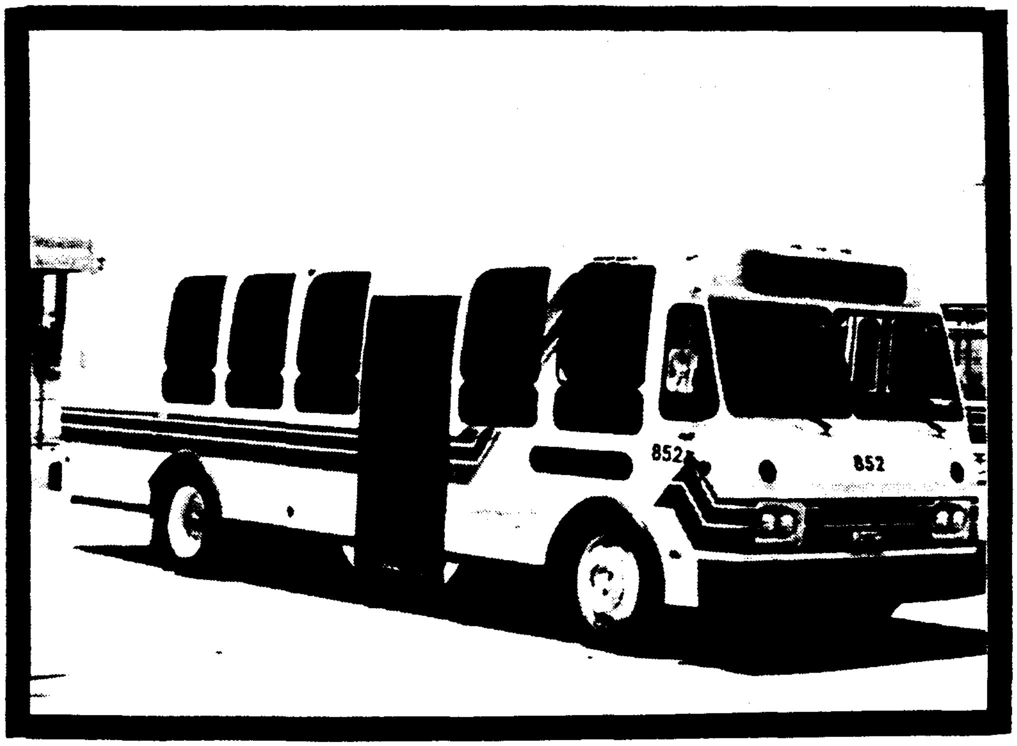


Figure 5 : Thirty-Two Foot Special Transit Vehicle

apply to all public streets and heavily travelled areas, such as parking and access areas of large developments. In cases where space is restricted, where less vehicle and pedestrian traffic is expected and no other options are available, some encroachment may be necessary. In such situations, the developer should consult with Capital Metro.

Downtown Circulation Routes. Capital Metro currently uses the 'Dillo buses on downtown circulation routes and routes to serve some Park-and-Ride lots close to the Austin Central Business District (CBD). These vehicles are also used for certain special events. The 'Dillos complement the regular fleet in an interesting way and can be considered as an attraction of the city. Planners of developments close to or in the Austin CBD should note the application of the 'Dillo service as this may, in many instances, be the only form of public transit that will serve a development in the mentioned areas. It will be noted that the 'Dillos have particular swept path requirements, due to its poor turning ability and long wheelbase, despite a relatively short body, and that they thus require special attention.

Special Transit. The most significant use of special transit vehicles by Capital Metro is for a demand responsive service for mobility impaired persons. The vehicles used are equipped with special doors and wheelchair lifting equipment for this application. Although the most commonly used vehicles are 23 ft. 3 in. and 23 ft. long vans with seating capacity of 12 to 14, a 32 ft. long bus with 19 seats is also used. The smaller van has a swept path close to that of the standard passenger car design vehicle. The Special Transit Service (STS) division uses a 40 ft. bus in a line haul mode to provide service to mobility impaired persons, but is unlikely that this vehicle will be used within the circulation areas of developments.

Developments, where special transit may be required, such as senior citizen homes, hospitals, centers for mobility impaired persons, schools, colleges etc., should provide space for at least the 30 ft. design bus. This will accommodate the 32 ft. Vehicle (see Fig. 5), which is the largest special transit vehicle likely to be used within the circulation areas of developments. Where facilities are on a main transit line, the designer may want to accommodate larger vehicles.

Design Turning Templates

A number of design turning templates, to various scales, are included in the Appendix. These cover:

- the 40 ft. design bus,
- the 30 ft. single unit (SU) design truck or bus,
- the Trolley lookalike 'Dillo, and
- the articulated design bus.

It is important to note that these templates indicate the minimum swept paths associated with the minimum turning radius and thus only apply to low speeds, i.e. less than 10 m.p.h. Where higher speeds are under consideration, designers should take factors such as sight distance, stopping distance, larger radii and driver reaction into consideration. Designs in these cases should conform to the applicable street design guidelines such as those listed in references 4, 9, and 10.

The templates only provide for the swept path between the front-most corner of the vehicle on the outside of the turn and the opposite side rear wheel. For setting curb lines an additional 1 to 2 ft. should be allowed. Any vertical obstruction higher than curb level, such as walls columns, poles or fire hydrants should be placed at least 2 ft. outside the swept path to allow for protruding mirrors, bumpers, etc.

There are some pitfalls in using design turning templates, and the templates included only give an approximation of required space. In all cases the design should be undertaken or verified by an experienced engineer.

Vehicle Height

The highest of the vehicles discussed above is the 40 ft. motor coach at approximately 135 inches (11 ft., 3 in.). The height of the 'Dillo is 127 inches (10 ft., 7 in.). As serious vehicle damage and damage to overhead structures can occur when inadequate headroom is provided, vertical clearance should be provided well in excess of the vehicle heights. Provision should also be made for the effect of the roadway being at a gradient beneath overhead structures and for future resurfacing of the roadway.

Ground Clearance

The approach and departure angles (see Fig. 1) of the selected design vehicles are approximately 9 to 10 degrees. The critical ground clearance can be defined as the lowest clearance combined with the longest wheel base. The Capital Metro vehicle with the most critical ground clearance is the 40 ft. Gillig Phantom with a clearance of 7.5 inches and a wheelbase of 279 inches (23 ft.3 in.). Using these dimensions as a base for determining maximum allowable changes in grades is not recommended, as they do not adequately allow for comfort and safety. Design values for allowable change in grades will be recommended in the following section .

Vehicle Weights

The critical vehicle weight, referred to as the gross weight, is the weight of the vehicle when fully loaded. Axle weights, however, are of more importance since they are normally used in the pavement design process. The 40 ft. Gillig, with a gross axle weight of 25,000 lbs. on the rear axle, has the most critical axle weight of the heavier vehicles. Gross vehicle weights and gross axle weights for the 40 ft. bus and articulated bus are presented in Table1.

GEOMETRIC AND PAVEMENT DESIGN

This section presents design information applicable to the various geometric and pavement elements of bus routes. In order for transit to be effectively integrated into a development, the potential transit routes must be physically compatible with the transit vehicles using that route. This means that street widths, clearances, curb returns, and grades must be designed to accommodate these vehicles rather than the smaller, less critical, passenger car. Facilities such as turnouts, turnarounds, and berthing areas, which are used exclusively by buses, must obviously be designed for geometric compatibility with the transit vehicle expected to use these facilities. The pavement structure should also be properly designed to handle the heavier bus loading that occurs along the route, and in particular, at the facilities intended for exclusive bus use.

The design elements of this section are generally based on the properties of the 40 ft. design vehicle which is the largest and most commonly used transit vehicle in the current Capital Metro fleet. In some cases, however, the transit vehicle using a certain facility may be smaller than the 40 ft. design bus and the facility should, therefore, be designed for the applicable vehicle. In such cases, the turning radius templates and vehicle dimensions supplied in the Appendix should be used to modify the basic designs presented in this section.

Width of Roadway

The roadway is defined as the paved area within the right-of-way ordinarily used for vehicular traffic movement. With curbs and gutters, the pavement width is measured from face-of-curb to face-of-curb; without standard curbs and gutters, pavement width is measured from the edge of the pavement, excluding any required shoulders or ribbon curbs. It is the purpose of this section to address the roadway width requirements necessary for proper bus operation (Ref. 9).

The required width of roadway is primarily a function of street classification. There are basically three types of through streets which are known as: local, collector, and arterial streets. For operational and safety reasons, bus traffic should be restricted to collector and arterial streets; however, in existing developments it may be necessary to include local streets in a bus route. If a new development is properly planned to include transit, the bus routes can be located exclusively on collector and arterial streets.

The width of a roadway must be designed to handle the largest vehicle expected to frequent that roadway. In Table 2 , it is seen that the maximum width of a Capital Metro transit vehicle is 102 inches (8.5 ft.). Since the American Association of State Highway and Transportation Officials (AASHTO) design vehicles for both buses and large trucks are 8.5 ft. wide (Ref. 4), the road width values presented within this policy manual can be considered as representative of the widths required to accommodate the current Capital Metro fleet. Table 3 presents the AASHTO minimum widths for the local, urban collector, and

Road Classification	Lane Width	Additional Auto Parking Width (As Needed)
Local	11' (Min) 12' (Pref)	7' (Residential Areas) * 9' (Commercial and Industrial Areas) **
Urban Collector	11' (Min) 12' (Pref)	7' - 10' (Residential Areas) * 8' - 10' (Commercial and Industrial Areas) **
Urban Arterial	12'	Restricted

* Provided as needed on one or both sides of roadway
** Usually provided on both sides of roadway

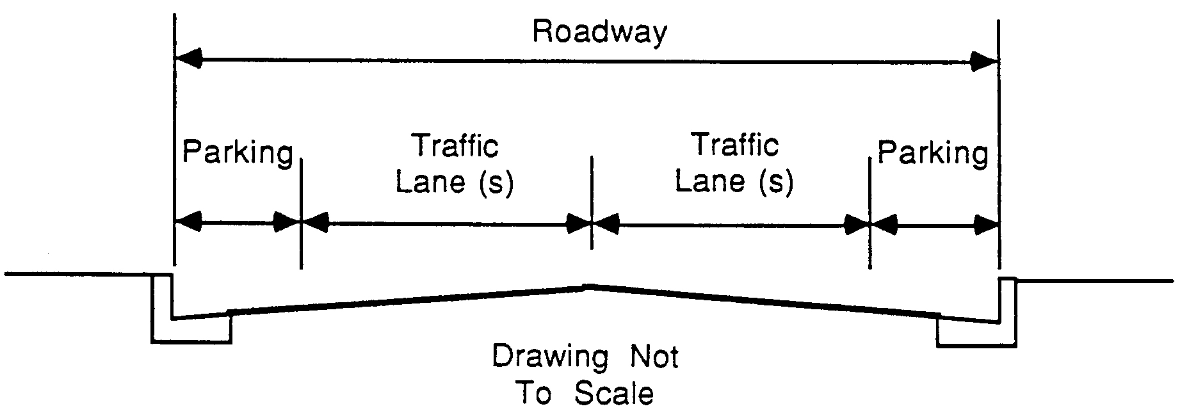


Table 3 : Minimum Road Widths

urban arterial streets. Guidelines and standards used and required by the relevant local government, such as the City of Austin's Transportation Criteria Manual (Ref. 9) should be consulted for specific design information.

Vertical Clearances and Alignment

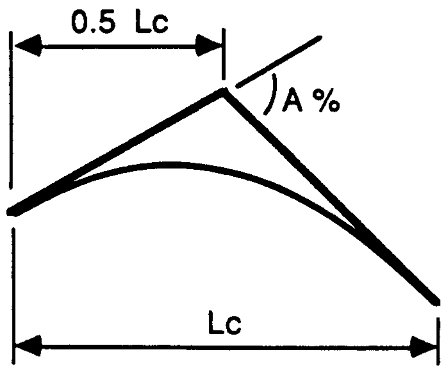
If large transit vehicles are to navigate the streets of a development, the roadways must be designed with adequate vertical and lateral clearances to accommodate these large vehicles. Vertical clearances pertain to ground and overhead clearances while lateral clearances pertain to road widths and curb radii. Road widths and curb radii are addressed in separate sections of this chapter. The purpose of this section is to make the street designer aware of the need for adequate ground and overhead clearances on routes where large transit vehicles are expected to operate.

Ground Clearance. Problems with ground clearances occur when there is a sharp change in grade resulting in a "bump" or "dip" in the road (see Fig. 1). The abrupt change from a positive (uphill) to negative (downhill) grade combined with the long wheel base of the 40 ft. transit coach can cause the undercarriage of the vehicle to scrape the pavement surface. Similarly, the sharp change from a negative to positive grade combined with the overall length of the bus, the wheel base, and the momentum of the moving vehicle, can cause the front bumper of the vehicle to scrape the pavement.

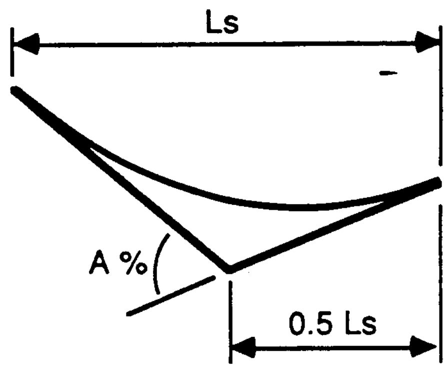
These problems with ground clearance may be avoided if the crest vertical curves and the sag vertical curves are properly designed. AASHTO policy, which is contained in A Policy on Geometric Design of Highways and Street, 1984, or the "Green Book", states that vertical curves should be parabolic curves of adequate length to provide minimum stopping sight distance at all points along the curve. Detailed guidelines for design of vertical curves are presented on pages 303-317 of the "Green Book". The curve lengths required for stopping sight distance can be calculated using the formula and values presented in Fig. 6. Curves calculated and designed in this manner are more than adequate in providing sufficient ground clearance.

Overhead Clearance. Overhead clearance must be supplied so that damage to tall vehicles and overhead structures is avoided. The amount of clearance required on a roadway is usually a function of the type of roadway. On freeways and other major facilities that serve large trucks, the AASHTO "Green Book" recommends an absolute minimum clearance of 14 ft. 6 in. and a desirable minimum clearance of 16 ft. 6 in. These minimum clearance values, which are based on the maximum allowable vehicle height plus 1 ft., should also be applied to arterials that connect these major facilities.

Collector streets and local streets are not required to maintain such high clearances; however, it is desirable to maintain these clearances since collectors do experience some truck traffic as do local streets (e.g. moving vans).



Crest Vertical Curve



Sag Vertical Curve

Design Speed (mph)	Crest Vertical Curves (Kc)	Sag Vertical Curves (Ks)
20	10	20
25	20	30
30	30	40
35	50	50
40	80	70
45	120	90
50	160	110
55	220	130
60	310	160
65	400	180
70	540	220

Length of Crest Vertical Curve : $Lc = Kc * A$

Length of Sag Vertical Curve : $Ls = Ks * A$

Absolute Minimum Length of Curve : $Lmin = 3 * V$

where A = Algebraic Difference in Grade (%)
V = Design Speed of Roadway (mph)

Figure 6 : Design Criteria for Vertical Curves (Ref 4)

Clearances in areas other than the public streets should be high enough to accommodate the tallest vehicle expected to navigate the area. In many cases this vehicle is the transit vehicle. The tallest vehicle in the current Capital Metro fleet is the 40 ft. Gillig coach with a height of 11 ft. 3 in. Adequate overhead clearance of 1 ft. above the vehicle must be available so that objects such as tree limbs, overhead signs, and awnings extending over a transit route or bus facility are avoided. Therefore, on level ground the distance between the overhead structure and the ground should be a minimum of 12 ft. 3 in.

In certain situations, however, more that 1 ft. clearance may be desired. Figure 7 illustrates the potential need for additional clearance on sloping roadways. Additional clearance should also be allowed for future roadway resurfacing. It should be noted that speed bumps are not desired within the travel paths of buses.

Grades

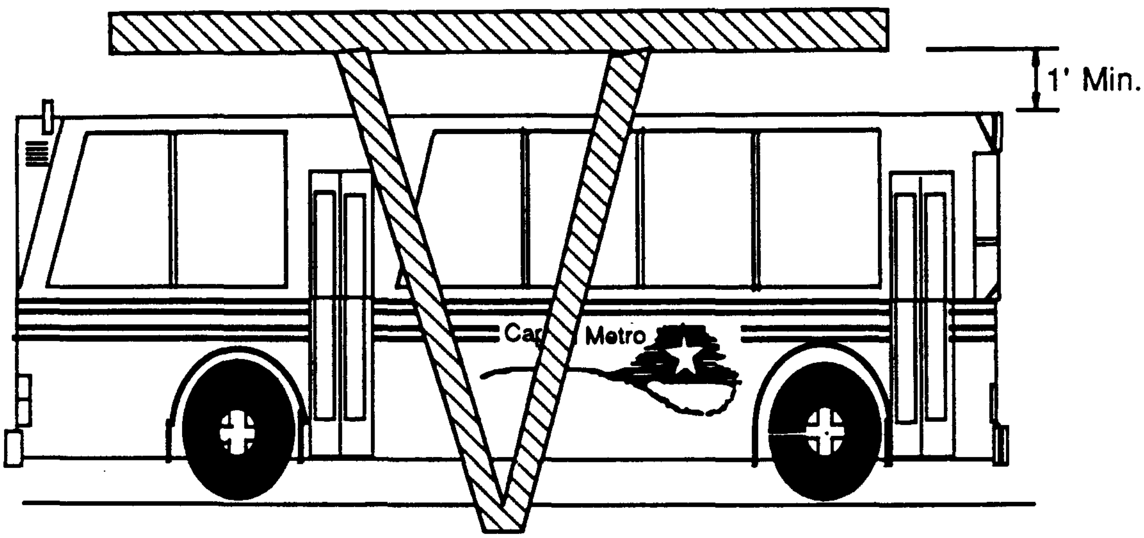
Road grades refer to the positive (uphill) and negative (downhill) slopes that a vehicle must negotiate. With increasing length and angle of positive grades, the vehicle experiences an increasing loss of speed and overall operating efficiency. If the street contains a substantial amount of bus and truck traffic, these slower moving vehicles may have an adverse effect on the capacity of the street. Similarly, a maximum negative slope is required as a means to maintain safe bus operations by controlling the speed and momentum of these large vehicles. Therefore, the City of Austin's Transportation Criteria Manual recommends a maximum grade of 6-8% on those streets expected to carry bus traffic.

Curb Return Radii

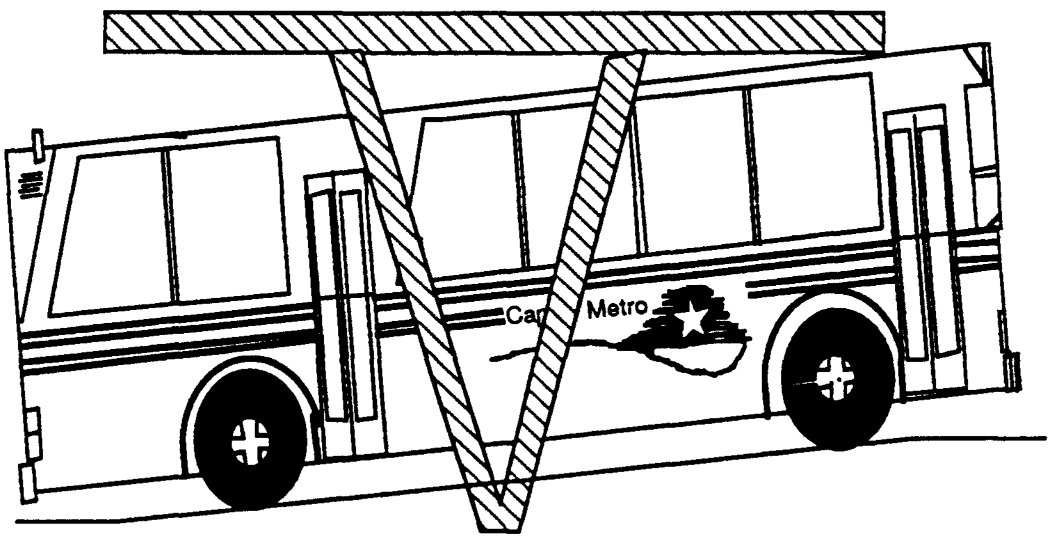
Properly designed intersections which allow easy and efficient transit access are essential for transit integration. Properly designed intersections not only reduce bus/auto conflicts at heavily used intersections but also increase bus operating speeds, reduce travel time, and, improve bus rider comfort (Ref. 31). Major intersections which should be designed using transit design standards include, collector-collector intersections, collector-arterial intersections, and arterial-arterial intersections.

When designing for transit use, the designer must examine the constraints which transit use places on the intersection design. The following are some of the more important design constraints which should be considered (Ref. 22 and 31):

- bus turning radius,
- angle of intersection,
- width and number of lanes on intersecting streets,
- allowable bus encroachment into adjacent or opposing lanes,



Adequate Overhead Clearance



Inadequate Overhead Clearance
Due To Roadway Gradient

Figure 7 : Examples of Adequate and Inadequate Overhead Clearance

- operating speed and speed reduction,
- parking at the intersection, and
- sight distance limitations.

Each of these constraints will require special design consideration. The designer should consult the latest AASHTO design guideline, A Policy on Geometric Design of Highways and Streets, (Ref. 4) to understand the implications of each constraint.

When designing 90° intersections, the engineer should consult Figs. 8, 9, and 10 which demonstrate the recommended minimum curb turning radii to be used in this common geometry. The figures are based on the 40 ft. bus design vehicle, the articulated bus design vehicle, and the 'Dillo bus design vehicle, respectively. The designer should refer to the section on design vehicle characteristics in this chapter, when choosing which design vehicle to incorporate into the design process. This choice is critical as it will determine the minimum design criteria for the intersection.

Along with the design criteria depicted in Figs. 8, 9 and 10, additional allowances in curb return radii should be made for (Ref. 31):

- bus speeds greater than 10 m.p.h.,
- reverse turns or turns greater than 90°,
- changes in pavement grade,
- restrictions to buses due to overhangs blocking bus passage, and
- restrictions to buses due to inadequate clearance between roadway and bus.

When restrictions of the types listed above are encountered or when the project is a retrofit project in confined work space, simple curve radii may not provide an adequate solution to the transit vehicle's requirements for maneuverability. In many cases, compound curb returns may be used successfully in answering these needs. Suggested compound curb returns are illustrated in Fig. 11. (Ref. 31). Though these types of curb returns require slightly more design effort, their use has proven to be effective in achieving transit-compatible intersections in areas with limited right-of-ways, and obstacle cluttered curb areas.

Another important curb return issue deals with providing access to driveway entrances. Special care should be placed in the design of driveways in centers such as shopping malls, retirement homes,

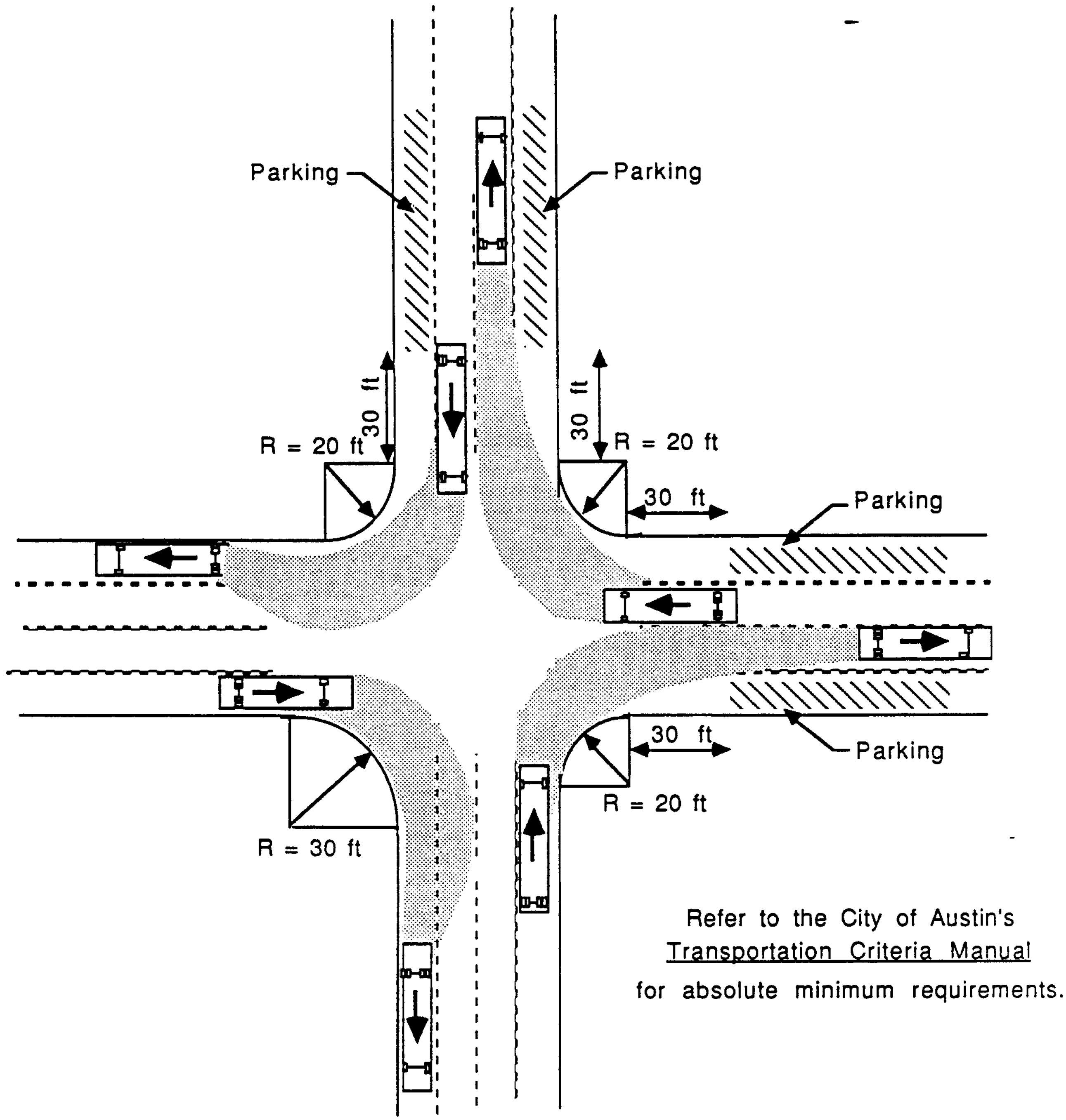
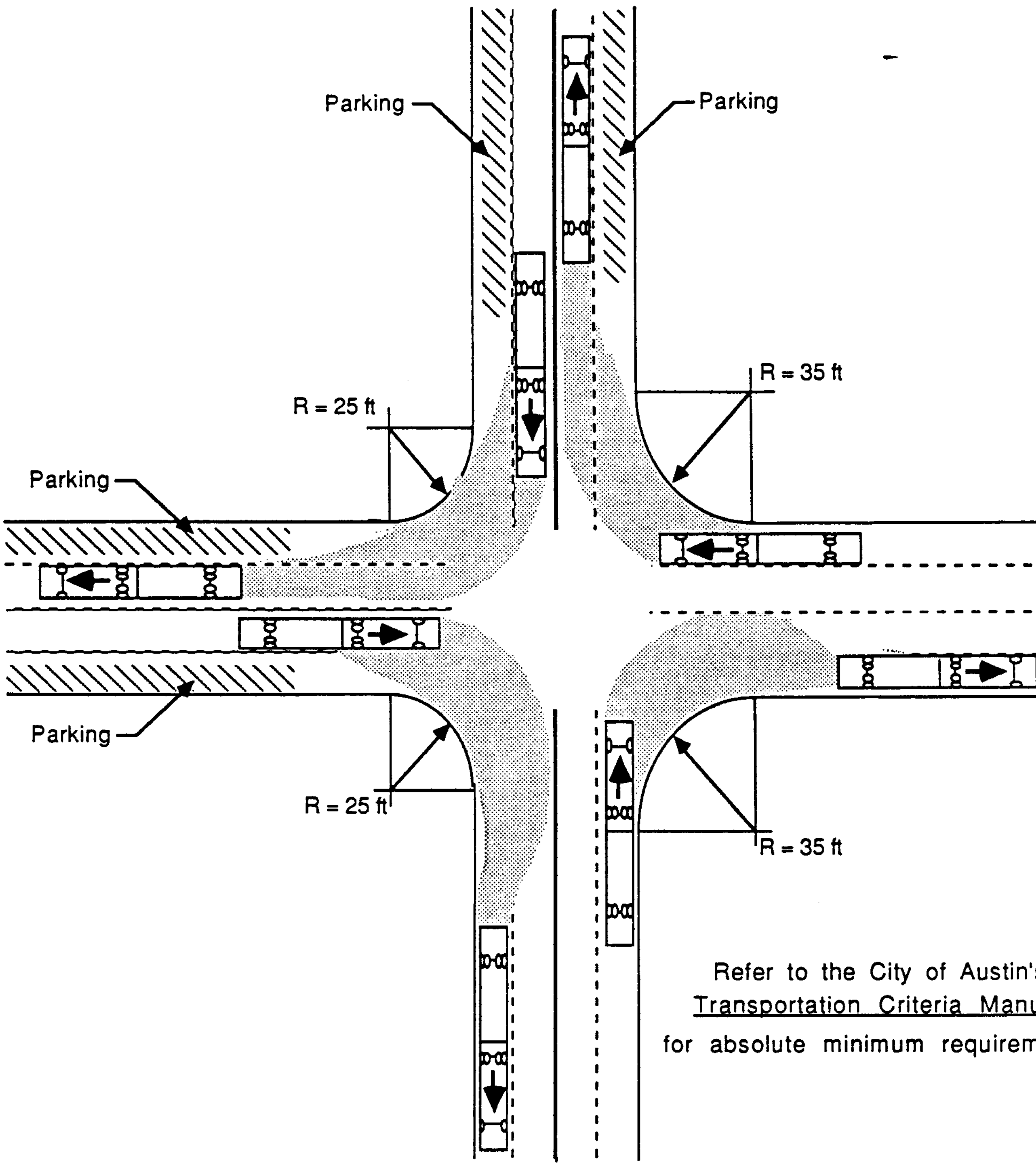


Figure 8 : Curb Returns for Forty Foot Bus Design Vehicle (Ref. 24)



Refer to the City of Austin's
<u>Transportation Criteria Manual</u>
for absolute minimum requirements.

Figure 9 : Curb Return for Articulated Bus Design Vehicle

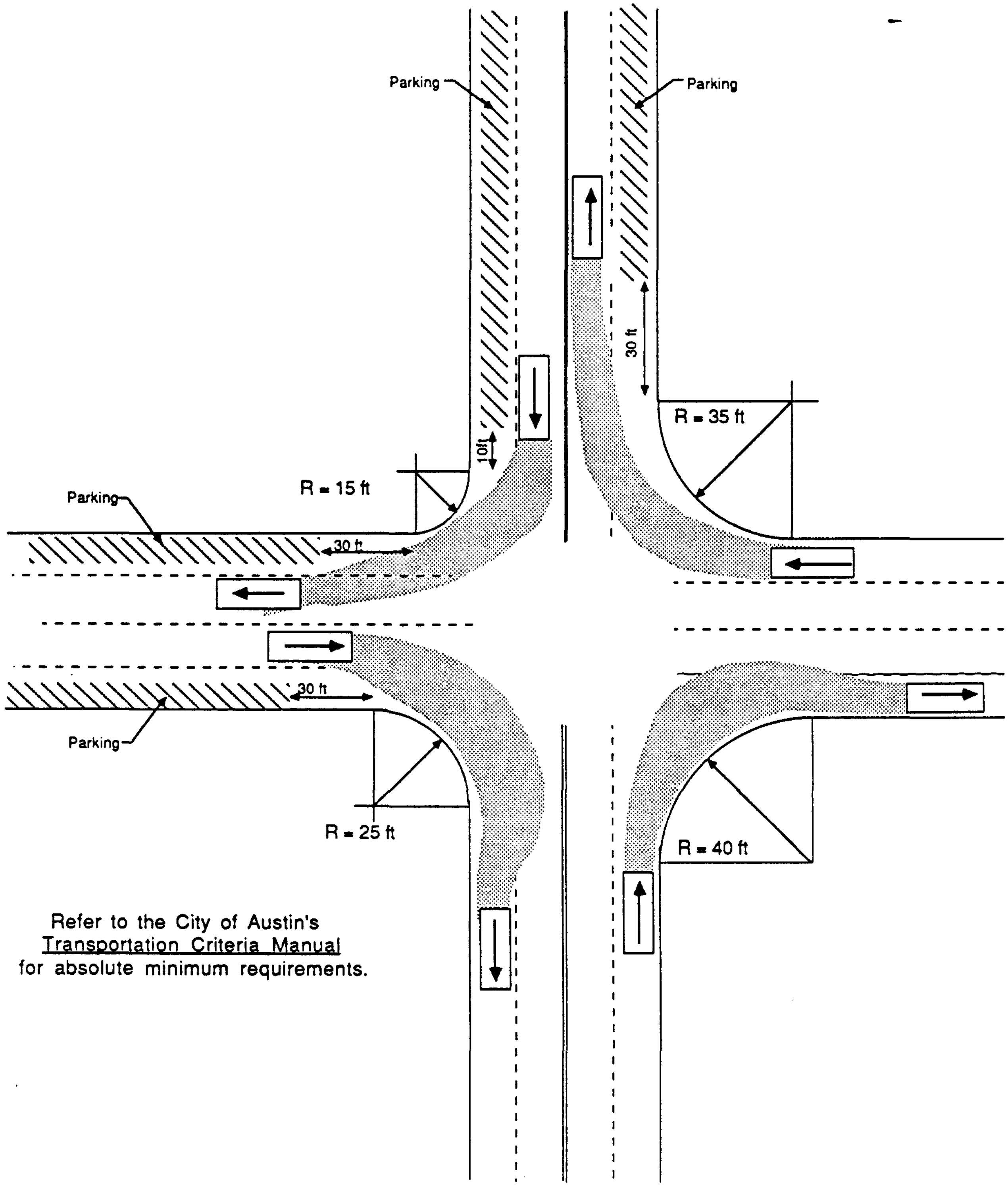
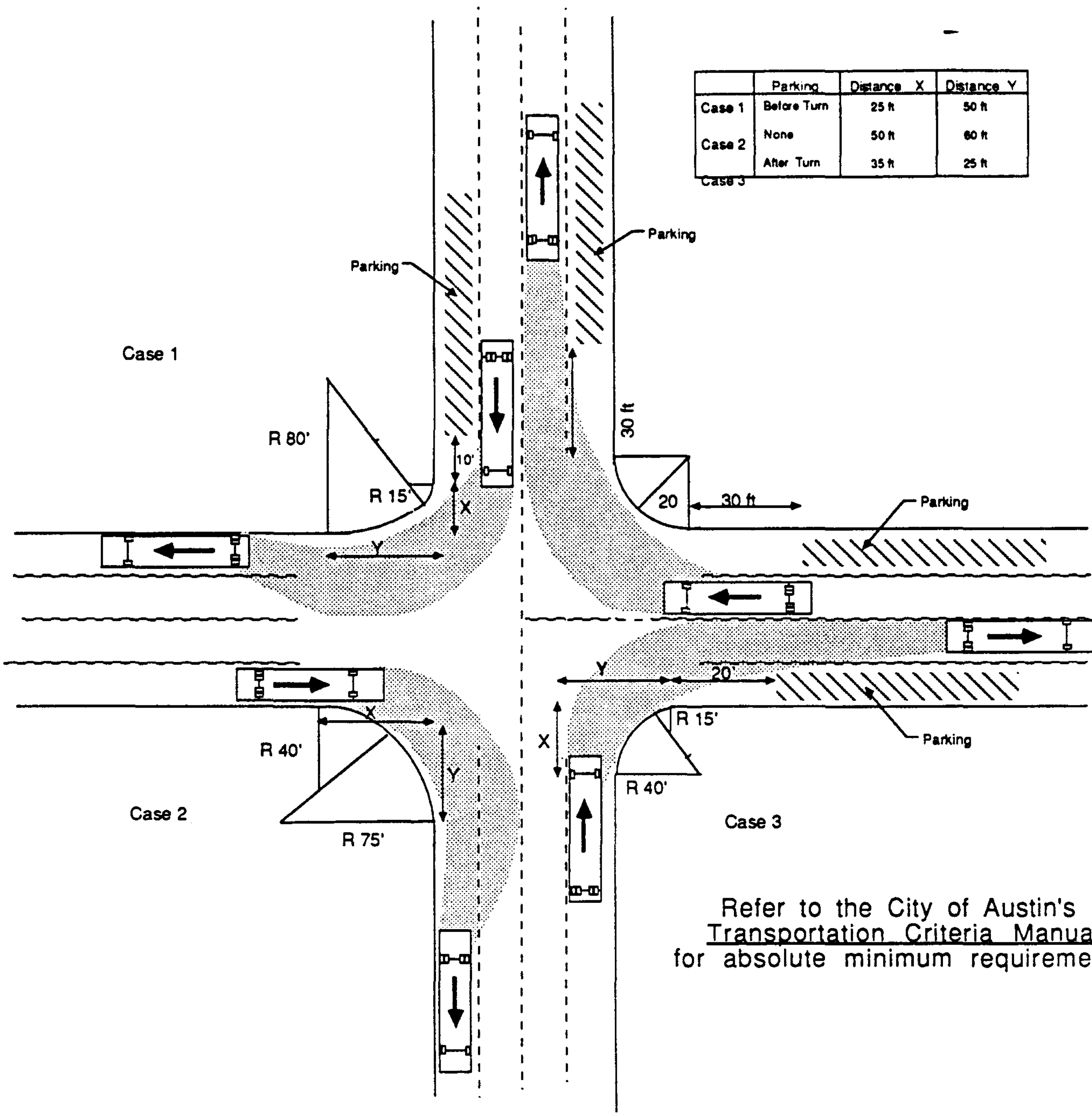


Figure 10 : Curb Return for 'Dillo Bus Design Vehicle



	Parking	Distance X	Distance Y
Case 1	Before Turn	25 ft	50 ft
Case 2	None	50 ft	60 ft
Case 3	After Turn	35 ft	25 ft

Refer to the City of Austin's
Transportation Criteria Manual
for absolute minimum requirements.

Figure 11 : Compound Curb Return - Alternate Design (Ref. 31)

schools, etc. so that transit vehicles servicing these facilities will be compatible. Typical suggested driveway designs are illustrated in Figure 12 (Ref. 22).

Delineation

Transit facilities should be conspicuously marked so as to separate the transit facility from the adjacent traffic and parking lanes. Pavement markings and signs regulating traffic and parking should conform to the Texas Manual on Uniform Traffic Control Devices for Streets and Highways. The relevant local authority must also approve such signs and markings.

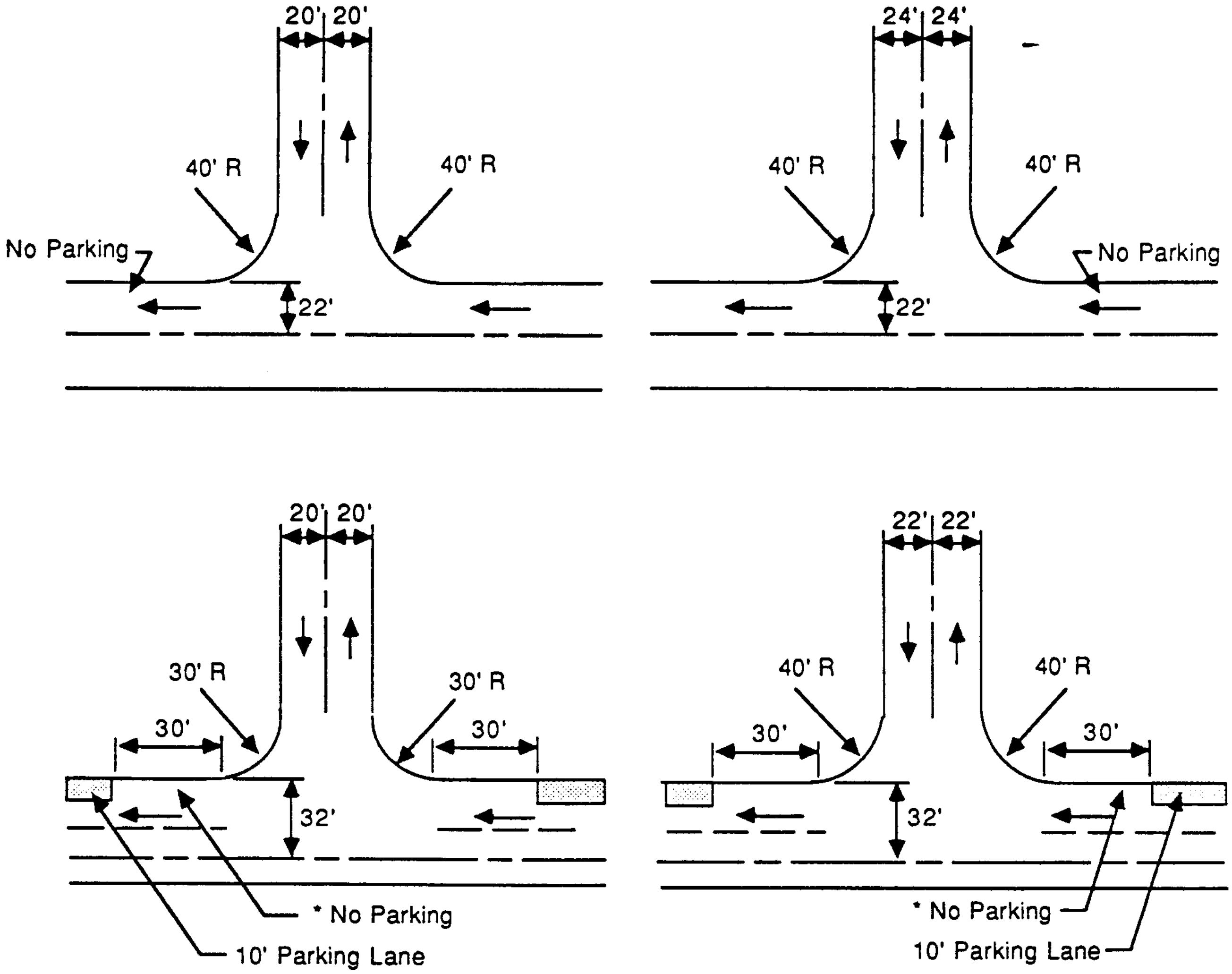
Turnouts

A bus turnout is a bus stop that is recessed in a curbed area away from the main traffic lanes of a roadway (Ref. 22). The main advantage of turnouts is that they separate stopped transit vehicles from moving traffic, thereby, reducing traffic congestion due to queuing. Such turnouts should allow buses to stop, load, and accelerate with little effect on through traffic. They are important especially in areas of high traffic volume, where congestion could be a problem if a bus stops in the main lanes of traffic; however, the driver may find it difficult to reenter the traffic stream of a high volume street. They can also be important where bus volumes and loading volumes are high. General rules of thumb concerning the use of bus turnouts are (Ref. 28):

- Curb parking is not allowed, especially during the peak hour.
- Five hundred (500) vehicles travel in the curb lane during the peak hour.
- Two-lane road with no designated curb parking.
- One hundred (100) buses per day and 10 to 15 buses carrying a total of 400 to 600 passengers in the peak hour traverse the street.
- The average dwell time is more than 10 seconds per stop.
- Right-of-way width is adequate to allow construction of the turnout without adversely affecting sidewalk pedestrian flow.

Figure 13 shows bus turnout designs, based on the standard 40 ft. bus, at nearside and farside locations of arterial street intersections (adapted from Ref. 28). Figure 14 shows the mid-block turnout design parameters (adapted from Ref. 19).

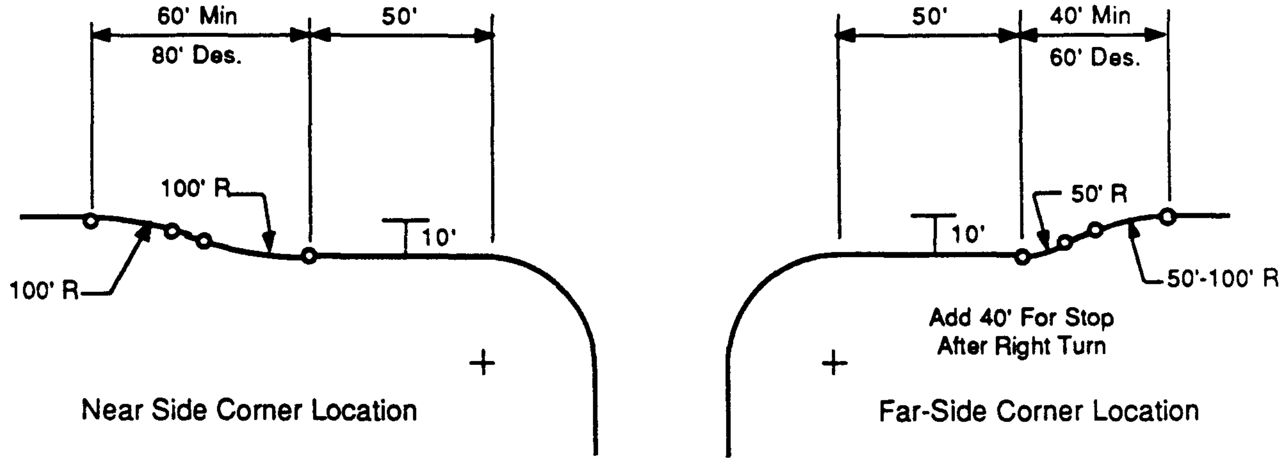
In order to reduce conflicts with traffic, a combination of the nearside and farside turnouts shown in Fig.13 should be used when the intersection is signalized and more than 250 right turns are made by traffic during the peak hour (Ref. 28). In this case, the farside turnout should function as the actual bus



Note: Parking should be prohibited for 30' where buses make a right-turn and heavy vehicle movement occurs or is anticipated.

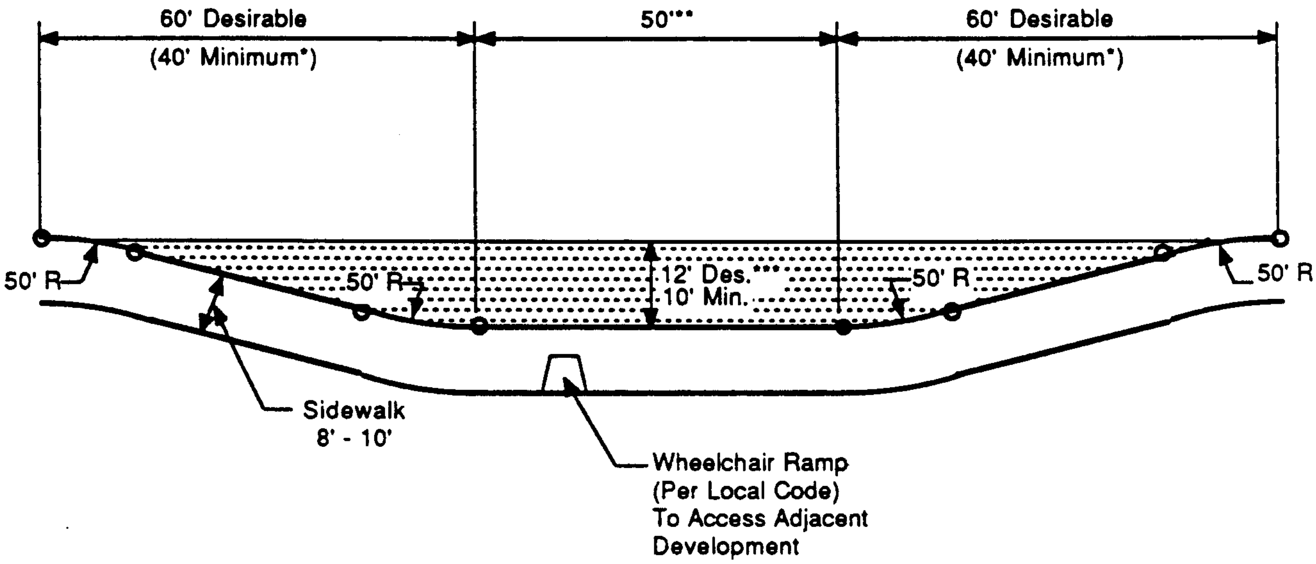
Refer to the City of Austin's <u>Transportation Criteria Manual</u> for absolute minimum requirements.

Figure 12 : Driveway Curb Returns (Ref. 22)



Note: When the intersection is signalized, and more than 250 right turns are made during the peak hour, the combination of the near-side and far-side corner locations should be used.

Figure 13 : Near Side and Far Side Bus Stop Turnouts (Ref 28)



* 40' Minimum for Low Speed and Low Volume Streets
60' Desirable for High Speed and High Volume Streets

** This 50' berth is for a single 40 foot vehicle. For articulated vehicles, a 70 foot berth is necessary. These dimensions are for one bus position only; if more positions are required at a stop, see Figure 20 on how to estimate the length needed for multiple berths.

*** 10' Minimum for Low Speed and Low Volume Streets
12' Desirable for High Speed and High Volume Streets

Figure 14: Mid-Block Bus Turnout (Ref 19)

stop with the nearside turnout providing an area for buses to exit the traffic stream and enter the farside stop.

Figure 15 and 16 provide turnouts for special design considerations (adapted from Ref. 19). Figure 15 contains 30 ft. vehicle turnout design parameters which can accommodate the Special Transit vehicles used by Capital Metro. Figure 16 provides a design for a bus stop turnout located adjacent to a bicycle lane.

Note on Fig.13 that 40 ft. should be added to the farside stop if it is after a right turn (Ref. 28). The right turn in this case should be controlled by a traffic signal or stop sign. The design parameters provided in Fig.17 should be followed if a turnout is to be located after a free right turn (a right turn not controlled by a traffic signal or stop sign) (adapted from Ref. 19). The extra space after the right turn and the bus turnout is needed so that stopped buses will not conflict with merging traffic operations.

Turnarounds

Bus turnarounds, which permit a bus to reverse directions, are especially important at locations such as Park-and-Ride lots and route termination points. They should be provided as a convenient way for a bus to reverse direction (Ref. 24). Figures 18 and 19 are suggested configurations for turnarounds (adapted from Ref. 2). They are given as examples only and should not be used as design templates for turnarounds. Turnarounds should be designed using the turning templates provided in this manual.

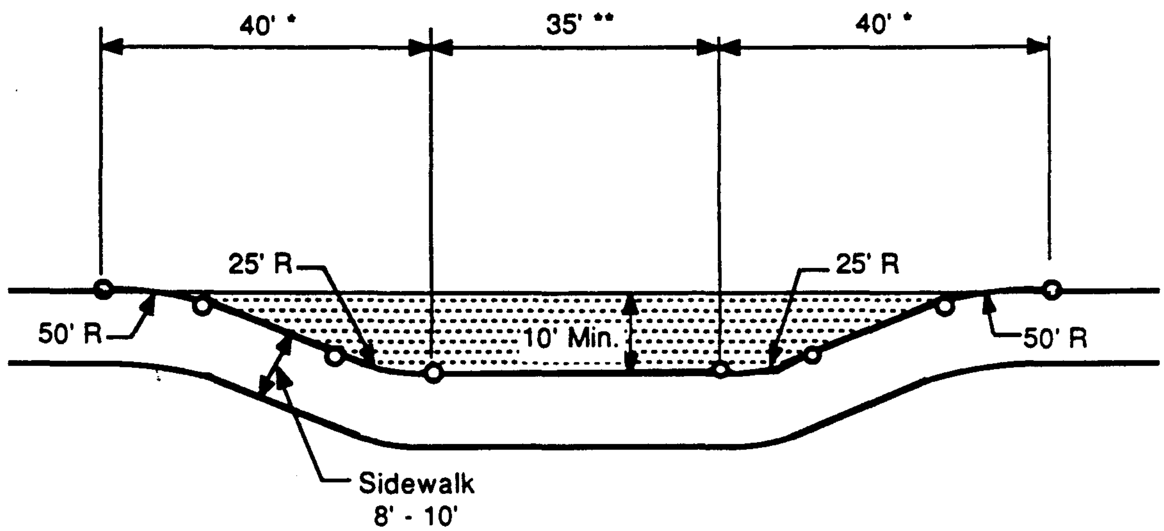
Bus Berthing

Bus berths are designated areas for exclusive bus use to load and unload passengers in major transit facilities such as Park-and-Ride facilities, transit centers and light rail stations (Ref. 22). Berthing is used, then, when more than one bus are expected to be at a transit facility at the same time. It should be added that berthing should also be used at bus stops where buses travelling different routes stop and transfer passengers.

Parallel berthing and sawtooth berthing are the two most commonly used types of bus berths. Sawtooth berths should be used for sites that cannot provide the required spaces for parallel berths; they are mainly for "major, off-street, boarding locations" such as Park-and Ride lots (Ref. 22).

Minimum berth lengths for parallel berths located on turnouts are shown in Fig. 20 (Ref. 19). For berths located on the street, the designer should consult Fig. 21 (Ref. 19). It should be noted that some of the above recommendations also provide for articulated buses, which are not currently used by Capital Metro.

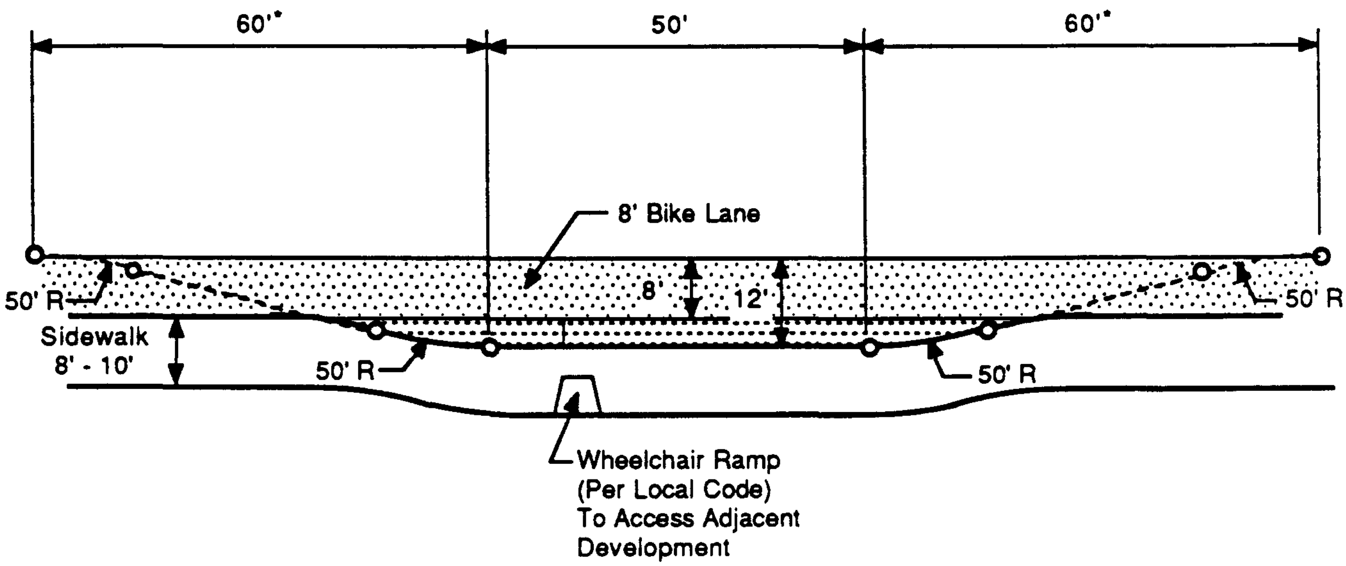
Figure 22 shows normal parallel berthing for certain tail-out distances (the desired distance between the bus stop curb and the right rear end of the bus) (Ref. 2). These longer lengths should be used



* 40' Minimum for All Streets

** This is for a single vehicle position. For each additional vehicle berth, add 35 feet.

Figure 15 : Mid-Block Turnout for Thirty Foot Design Vehicle (Ref 19)



* 60' Desirable For All Streets With Adjacent Bike Lanes

Figure 16 : Mid-Block Bus Turnout Adjacent to Bike Lane (Ref 19)

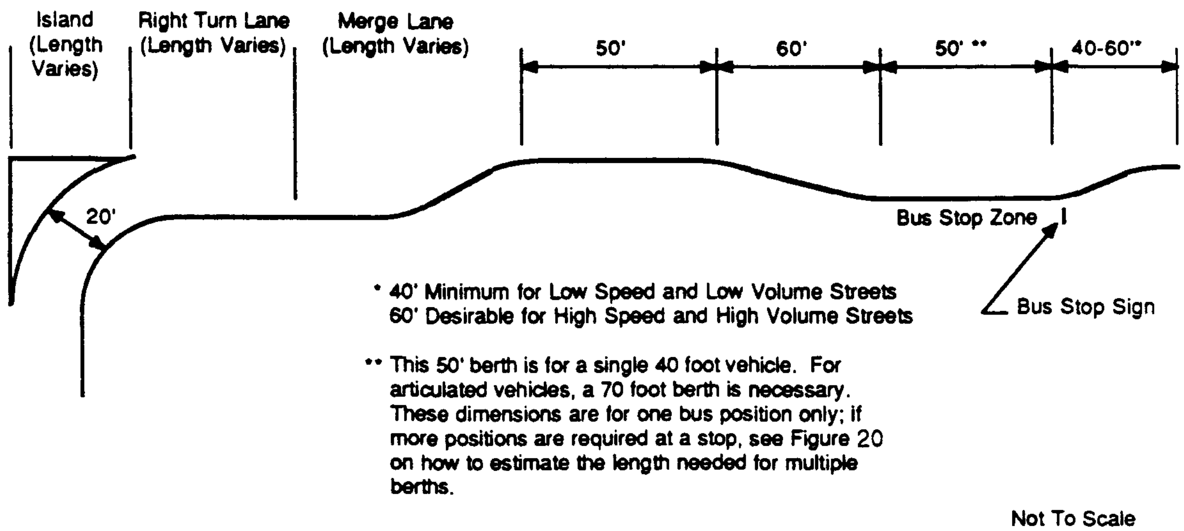


Figure 17 : Bus Turnout Located After Free Right Turn (Ref 19)

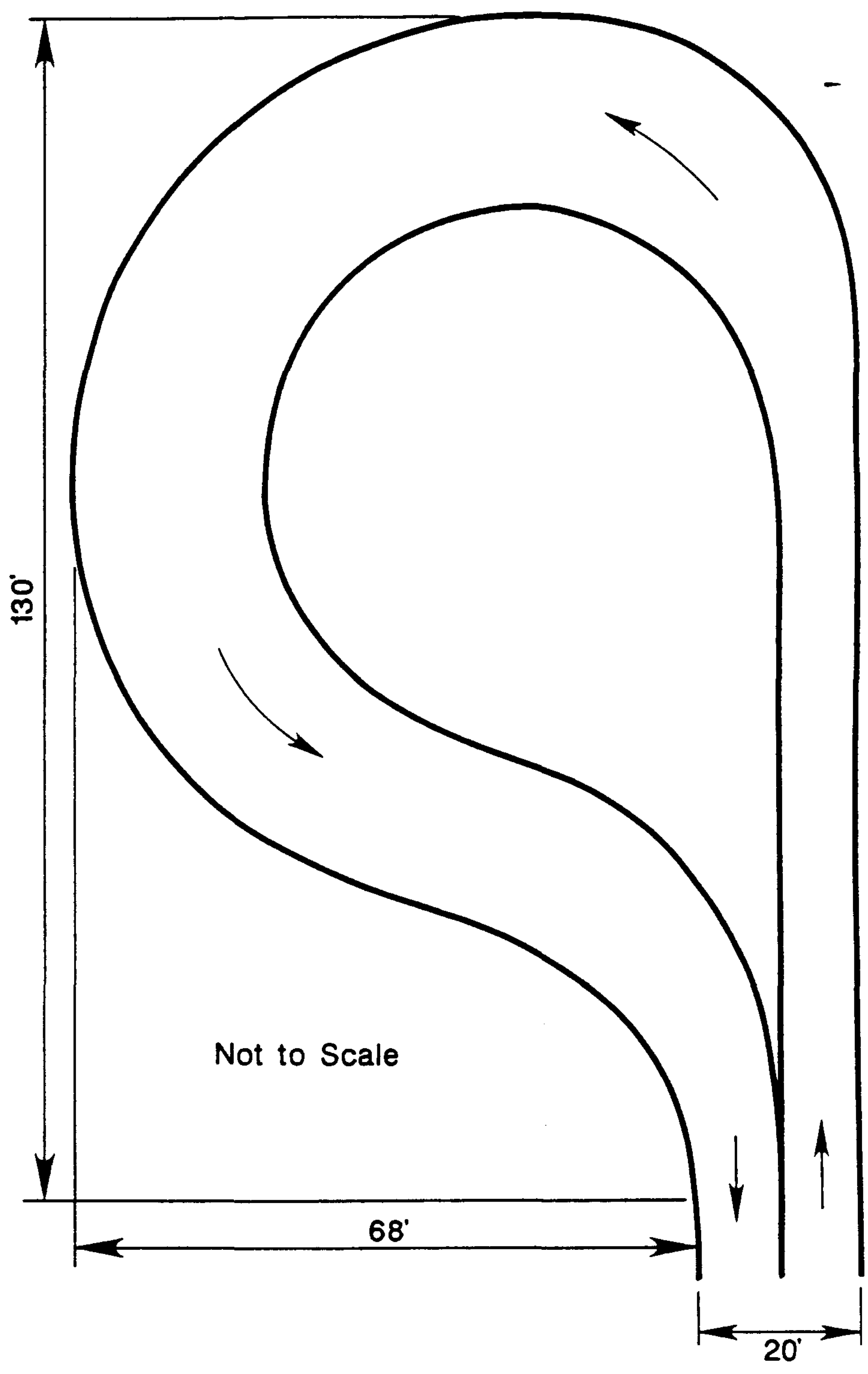


Figure 18 : Counter-Clockwise Turnaround Located to the Left (Ref 2)

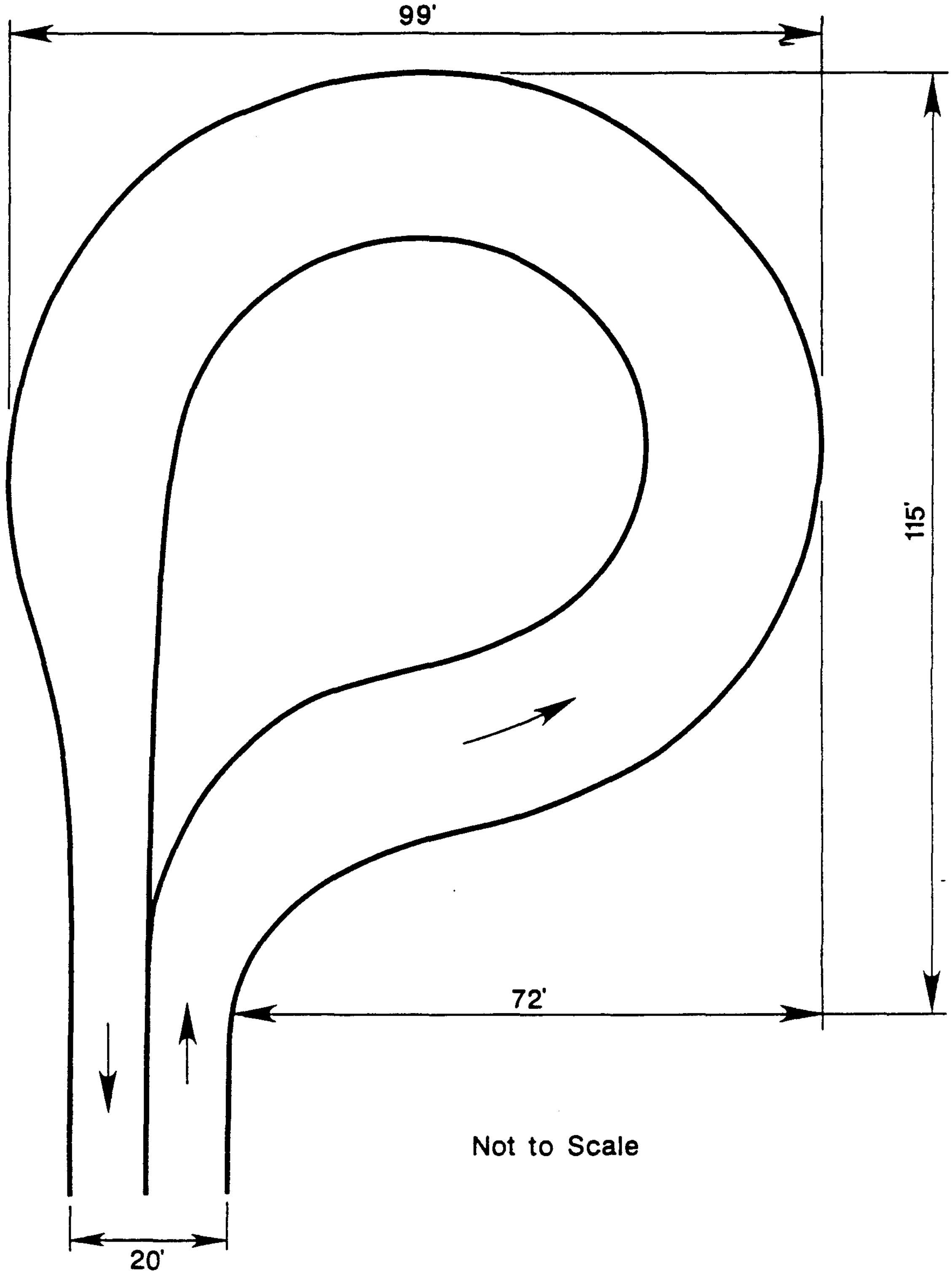
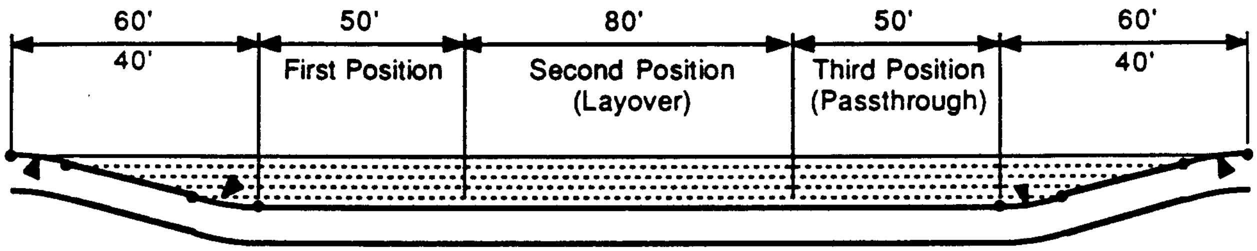


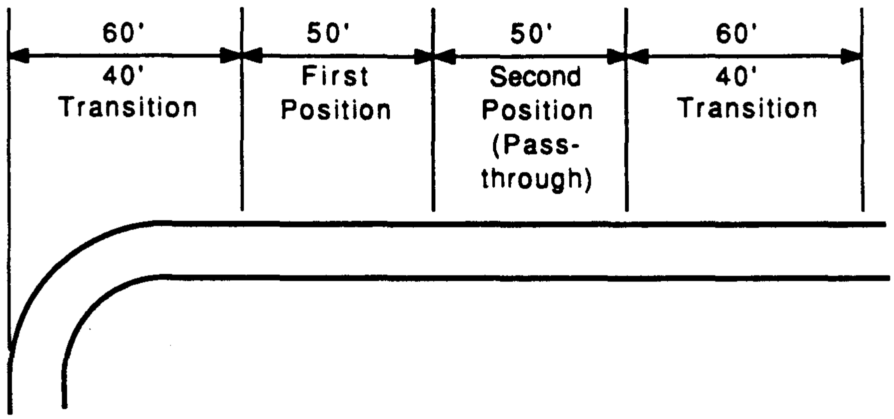
Figure 19 : Counter-Clockwise Turnaround Located to the Right (Ref 2)

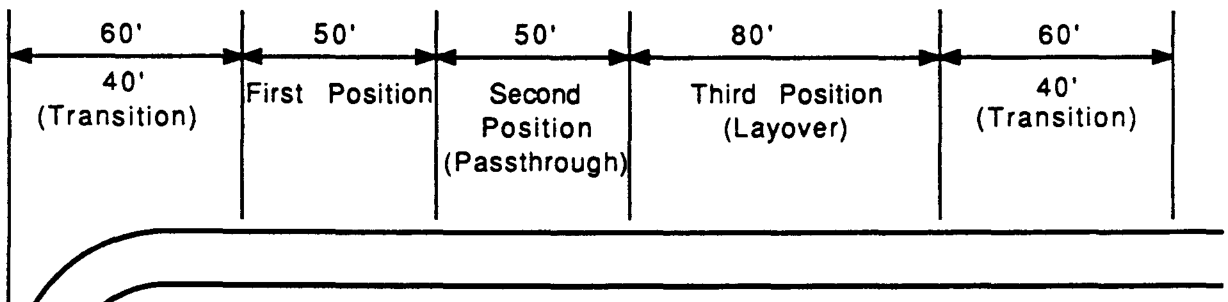


To determine the dimensions for a bus turnout with multiple berths:

- The first position should be 50 feet long for 40 foot vehicles (70 feet for articulated vehicles).
- For each additional passthrough bus, 50 feet should be added (70 feet for articulated vehicles).
- For each additonal layover bus, 80 feet should be added (100 feet for articulated vehicles).

Figure 20 : Minimum Lengths for Parallel Berths (Ref 19)





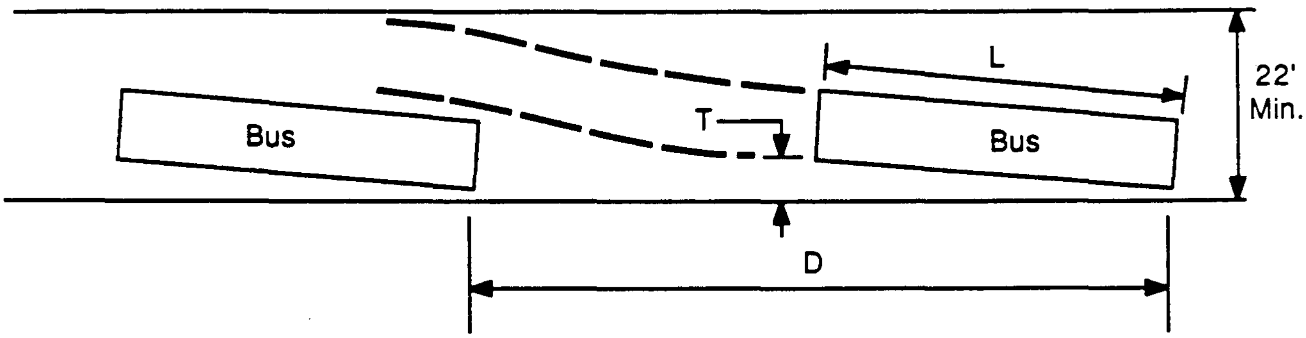
To determine the dimensions for a bus turnout with multiple berths:

—The first position should be 50 feet long for 40 foot vehicles (70 feet for articulated vehicles).

—For each additional passthrough bus, 50 feet should be added (70 feet for articulated vehicles).

—For each additional layover bus, 80 feet should be added (100 feet for articulated buses).

Figure 21 : Parallel Berths Located on the Street (Ref 19)



L= Length of bus
T= Tail-Out
D= Berth length, variable based on allowable T.
For proper length see the following table

Tail-Out Feet	Berth Length 40 Foot Bus	D Required (ft.) Articulated Bus
1	92	110
2	80	100
3	66	85
4	60	80
5	56	75

Figure 22 : Normal Lengths for Parallel Berths (Ref 2)

whenever possible. Note that for tail-out distances of 2 ft., berth lengths of 80 ft. are recommended for standard 40 ft. buses.

Finally, Fig. 23 shows plan views and dimensions for sawtooth berths (Ref. 2).

It is recommended that minimum berthing spaces of 50 ft. and bus layover berth lengths of at least 80 ft. should be provided in parallel berthing. Also, wherever possible, the normal berth lengths shown in Fig. 22 should be used. Figure 23 is the recommended design for sawtooth berths.

Pavement Design

The design of a proper pavement structure is as critical to the success of a transit facility as any other component. An improperly designed pavement could be very expensive to maintain over time. Pavement design must take into account the following factors:

- the soil type,
- the soil's support capacity,
- the magnitude and the frequency of the bus and other traffic loads that will service the area, and
- the strength of the pavement materials.

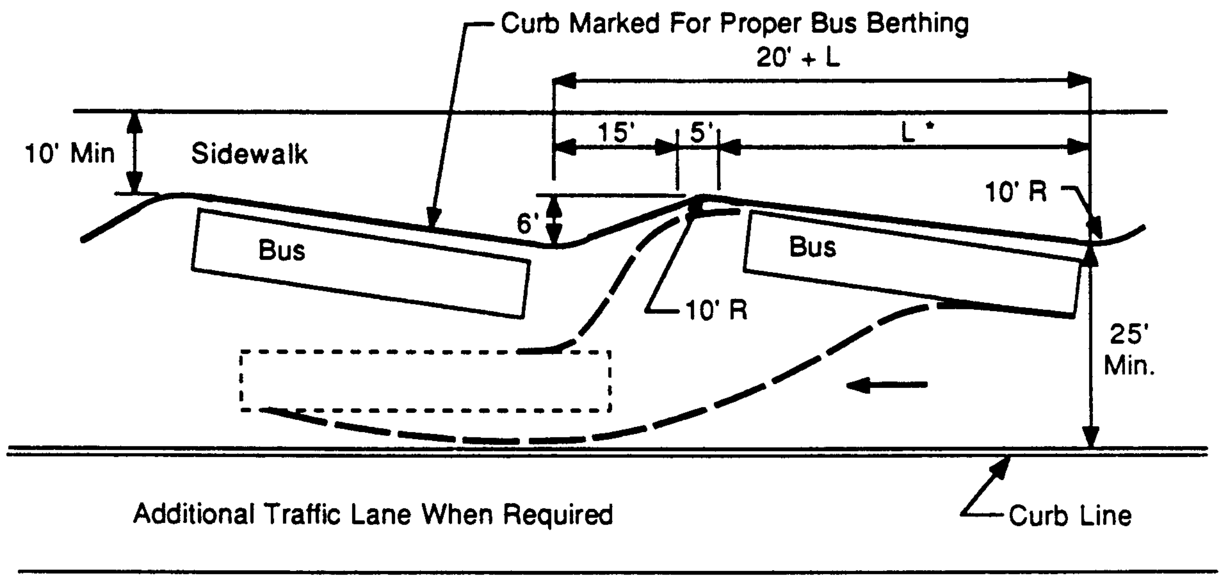
The soils in the Austin area vary widely, including swelling clays and limestone stratifications. Soil tests for the area of the development will contribute to a successful facility. Table1 contains the critical axle loads of some of the bus types used by Capital Metro. The engineer should, nevertheless, confirm the types of buses that will serve the development.

The City of Austin uses a range of pavement designs when pavements at bus stops are reconstructed (Ref. 6). These designs, which are examples only, are depicted in Fig. 24 and Fig. 25. It is recommended that pavements be designed in accordance with the City of Austin's Computerized Pavement Design program (Ref. 6). Information pertaining to these programs may be found in the City of Austin's Transportation Criteria Manual.

Concrete is recommended over asphalt in the pavement design, because concrete better withstands the shearing forces induced by bus acceleration and deceleration. Concrete also does not deteriorate due to spilled fuel from the buses. A factor to consider, however, is the location of utility lines in a development. Lines directly beneath concrete pads can be expensive to repair.

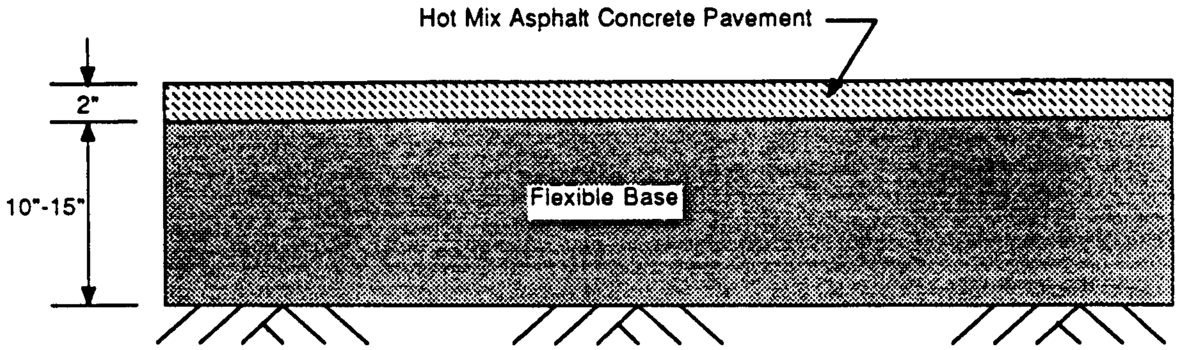
PHYSICAL COMPONENTS OF TRANSIT FACILITIES

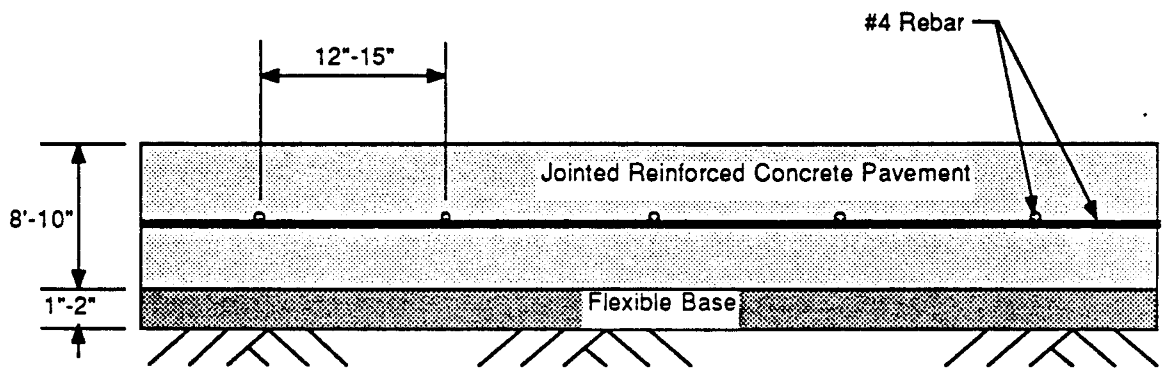
The provision of well designed transit facilities can significantly contribute to the passengers' safety, comfort and convenience as well as to the efficiency of the transit service provided. In general, when



* L = 45' for 40' Buses and 65' for 60' Articulated Buses

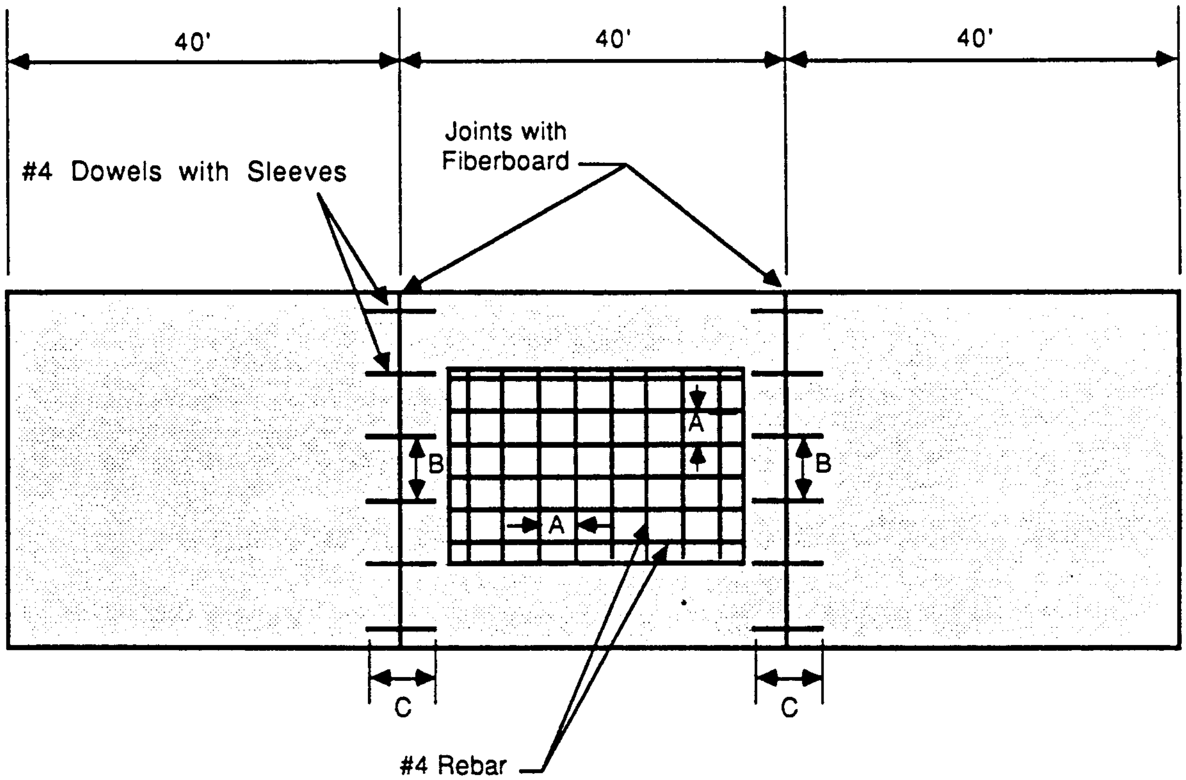
Figure 23 : Sawtooth Berths (Ref 2)





Note: The layer thicknesses increase and the bar spacings decrease for larger axle loads, higher numbers of vehicles, and poorer subgrade support. Bar spacings are the same in both the longitudinal and transverse directions. For further concrete pavement details, see Figure 25.

Figure 24 : Commonly Used City of Austin Pavement Designs (Ref. 6)



A = 12" to 15" Spacing
B = 24" Spacing
C = 18" Min., 30 " Preferred

8" to 10" Jointed Reinforced Concrete Pavement

Note: The layer thicknesses increase and the rebar spacings (A) decrease for larger axle loads, higher numbers of vehicles, and poorer subgrade support.

Rebars and dowels placed at mid-depth.

Figure 25 : City of Austin - 120 Foot Concrete Pavement Bus Stop (Ref. 6)

designing the various components of a transit facility, the following should be the objectives in the design and placement of those components:

- maximizing passenger safety, comfort and convenience,
- optimizing transit operational efficiency and passenger attractiveness,
- minimizing initial cost and long-term maintenance costs, and
- minimizing negative effects on traffic operations and impact on the environment.

In all cases where physical work is undertaken within public right-of-way, the approval of the relevant local authority and/or the Texas State Department of Highways and Public Transportation, as applicable, should be obtained.

Waiting Areas

Waiting areas should preferably be accessible via paved walkways, while the waiting area itself should be paved to minimize discomfort due to muddy or dusty conditions. Waiting area pavement design should be of the same design as walkways. Pavement should be large enough to accommodate all waiting and unloading passengers, and to connect the curb line to shelters, benches or other amenities. It should preferably be long enough to extend from the front door of the bus to beyond the rear door of the last bus in a queue.

In practice it will be found that the minimum design criteria to facilitate use by mobility impaired persons will be more than adequate to serve other passengers. These include:

- a 12 ft. minimum clear space at the bus door to accommodate loading by wheelchair lifts,
- curb ramps and non-skid textured surfaces,
- a maximum curb height of 10 inches,
- a maximum surface cross slope of 4% for the ramp, and
- a maximum surface slope of 2% for the paved waiting area or shelter pad.

A typical curb ramp configuration used by the City of Austin is shown in Fig. 26.

Benches

Benches can also add to the transit patrons' comfort. While certain guidelines are applicable, individual designs can be fitted to surroundings and special requirements. Almost all bus stops can benefit from a bench.

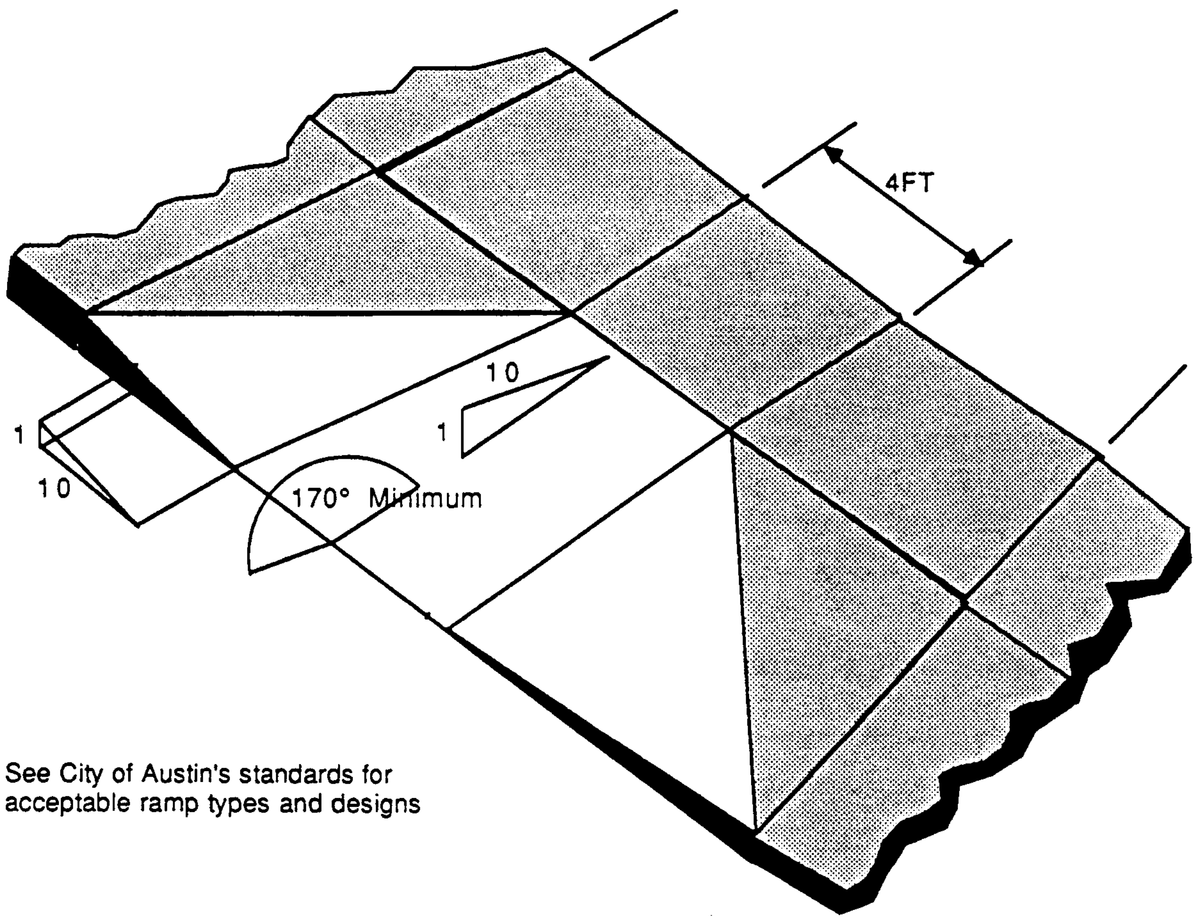


Figure 26 : Typical Curb Ramp

Benches should be placed on concrete pads, with a slope of no more than 2%, and should face the street. Benches should be placed no closer than 7 ft. from the forward end of any bus stop, to remove it from passenger loading and unloading areas. The area should be well drained with a concrete pad preferably provided. At least 4 ft. of space should be provided at the front or back and at least on one side of the bench for pedestrian movement and wheelchair access. In areas of heavy pedestrian movement this should be increased to a minimum of 6 ft.. Benches should be placed at least 3 ft. behind curb lines to provide space for passengers getting off the bus or waiting to board, and to provide protection for waiting persons from passing vehicles and opening bus doors. For the convenience and visibility of passengers, the bench should not be placed farther than 12 to 15 ft. from the curb line where the bus stops.

Benches are usually designed to seat 3 to 4 persons. Materials and design should be chosen to provide durability, resistance to weather and vandalism, and easy and inexpensive maintenance. Sharp protrusions should be avoided. Rounded seats not protected by a shelter should include drainage holes to prevent accumulation of rain water.

The developer should consult with Capital Metro in regard to the inclusion and type of benches at a particular site.

Shelters

Shelters to protect waiting passengers from the elements enhance the safety, security and comfort of transit users. Free standing shelters are most often used, but shelters incorporated into other buildings should also be considered. Shelters can also be designed to fit in with the landscape and the surrounding style of architecture.

Shelters should be provided wherever a significant number of transit patrons wait for buses. Existing guidelines require 30 persons per day for placement of a shelter by Capital Metro. It is obvious, however, that the provision of shelters demonstrates benefits irrespective of the number of passengers. Special consideration should be given to areas frequented by children, senior citizens, or mobility impaired persons. The proximity of alternative locations where shelter is provided should also be considered when deciding on the provision of a shelter.

In order to provide an adequate area for pedestrian circulation, including wheelchair space, the shelter should not be placed less than 4 ft. from the curb line and a space a minimum of 4 ft. wide should be provided on at least one side of the shelter. In addition, a clear area of 12 ft., measured from the curb, should be provided in front or to the side of the shelter to accommodate loading by wheelchair lifts. To provide visibility for waiting patrons and bus drivers, during day or night conditions, the shelter should be placed no further than 15 ft. from the curb. It is extremely important, however, that shelters are not placed in a manner that obscures the sight lines of the traffic. The following factors should also be considered in establishing the specific location of a shelter:

- adequate lighting,
- adequate drainage,
- ease of maintenance and cleaning, and
- positioning close to bus entrance doors.

The design of shelters should suit climatic conditions. The type of shelter currently used by Capital Metro, consisting of a solid back wall and roof unit, a concrete floor and two transparent sidewalls, suits conditions found in the Austin area. This type of shelter is illustrated in Fig. 27. The transparent sidewalls allows light to enter and make it possible for waiting patrons and bus drivers to see each other. Alternate bus shelter designs also found in the Austin area are illustrated in Figs. 28, 29, and 30.

The cost and ease of maintenance, as well as resistance to vandalism, should be taken into account when designing a shelter and selecting materials. Wooden components should be adequately treated to prevent weathering and all metal components should be corrosion resistant. All protruding parts should be rounded to prevent injury to transit users and passing pedestrians.

The developer should consult with Capital Metro in regard to the inclusion and type of shelters at a particular site.

Information Devices

Clear communication with transit patrons enhances the ease and comfort of transit use and support the goal of increasing ridership. Information devices used include: bus stop signs, schedule displays and map displays. Bus stops in the Austin area should be clearly marked using standard Capital Metro bus stop signs. Bus stop signs are the simplest information device and should be placed at every bus stop at a minimum height of 7 ft. from the ground, facing the oncoming vehicles. They could include the route number and a telephone number for further information. Maps and schedule displays are often located behind a transparent cover in an aluminium or wooden frame attached to bus shelters or bus stop post. Information devices should be placed so as to be clearly visible and easy to access. It should not obscure sight lines, or impede on pedestrian waiting and movement areas. In all cases materials should be vandal resistant and easy to maintain. Currently used Capital Metro bus stop signs are shown in Fig. 31.

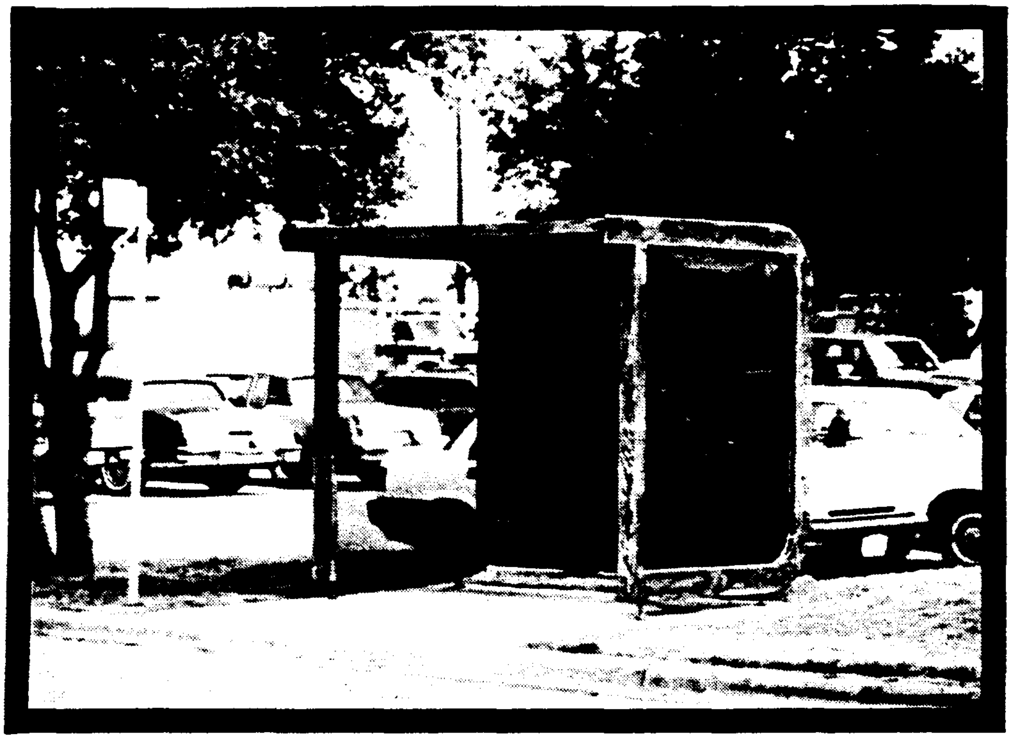


Figure 27 : Presently Used Capital Metro Bus Shelter

Figure 28 : Bus Shelter on The University of Texas Campus

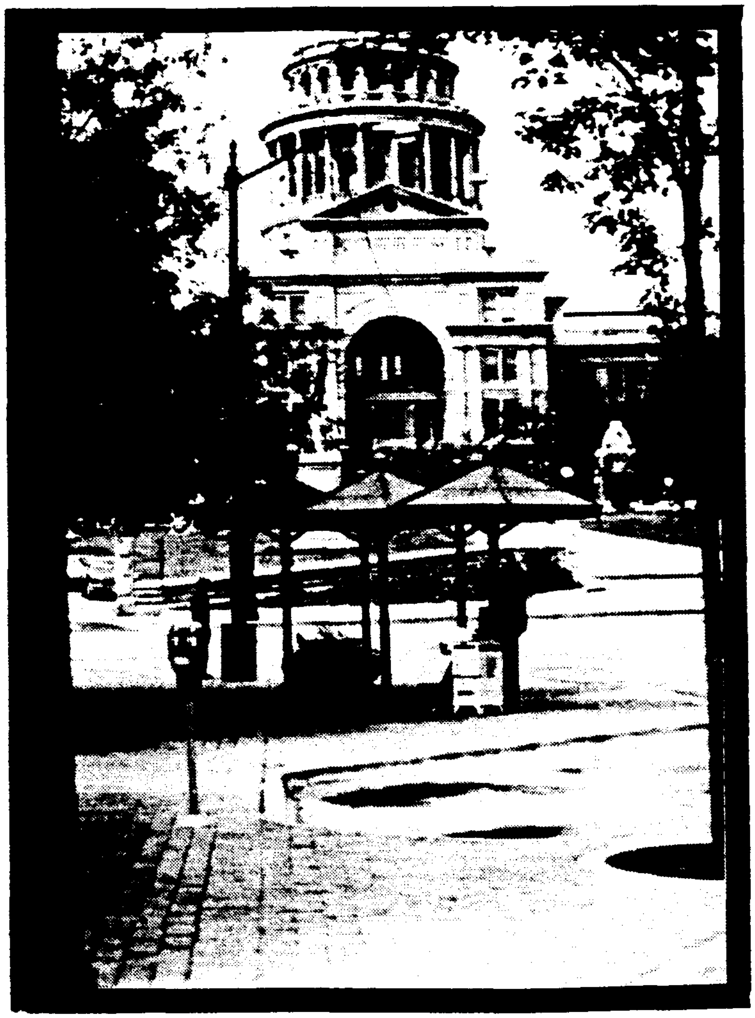


Figure 29 : Bus Shelter located at 11th Street and Congress

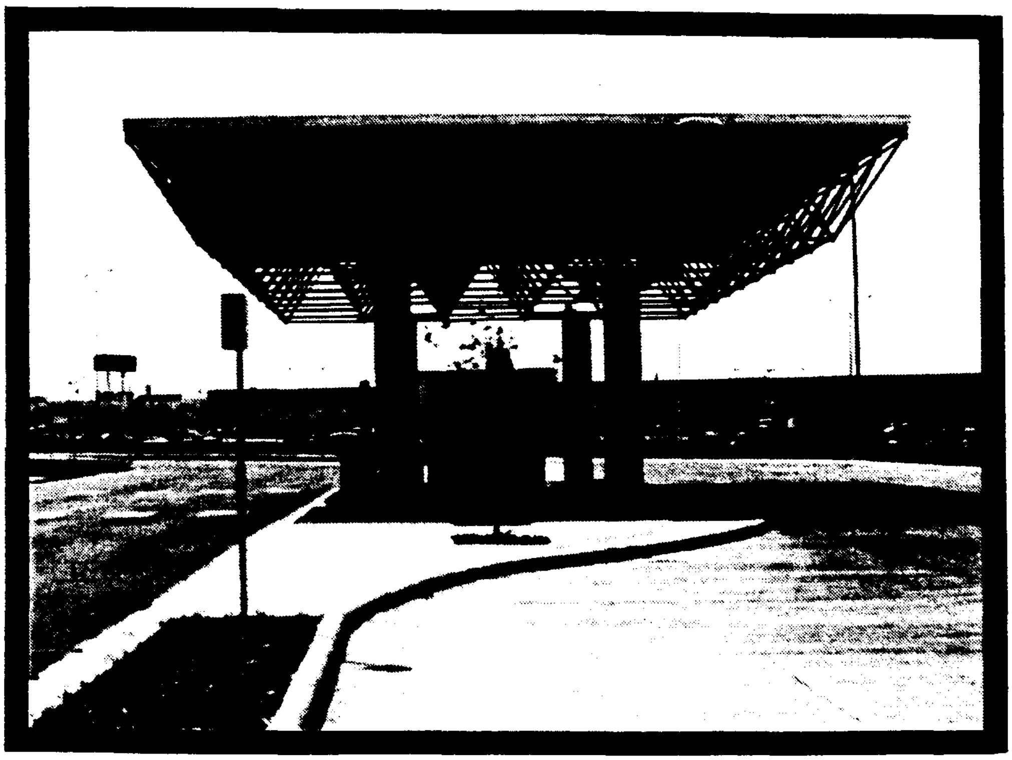


Figure 30 : Capital Metro Park-and-Ride Facility

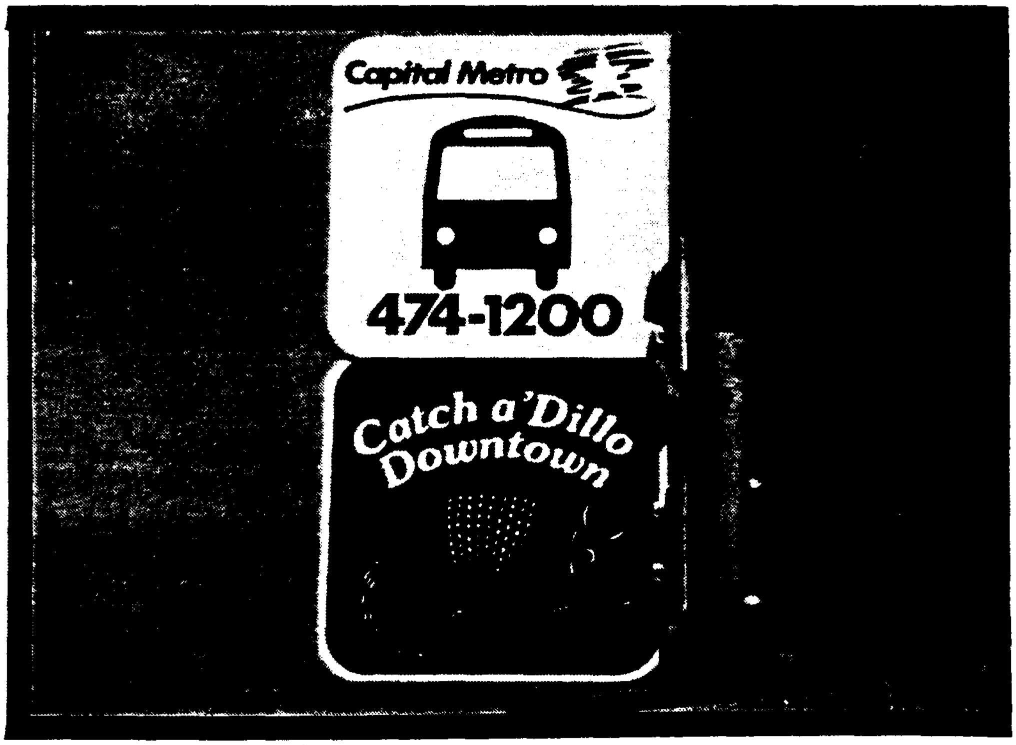


Figure 31 : Presently Used Capital Metro Bus Stop Signs

Lighting

The lighting of transit facilities provides security, comfort and visibility. Although the provision of illumination at all facilities is strongly recommended, it may not be practical or feasible in all cases. The following placement considerations are suggested:

- Illumination from nearby or integrated building can be taken into account when deciding on whether to provide lighting.
- Higher priority should be given to areas regarded as less safe and less secure and at locations frequented by children and senior citizens.
- Even if lighting is not initially provided, some provisions for future lighting should be made, such as to verify availability of electricity supply and provide ducting.

Vehicle Parking.

Passenger vehicle parking should be provided in transit trip origination areas such as Park-and-Ride facilities and transit centers, and can also be provided at high volume suburban bus stops. The size of the facility depends on the design volume, the available land area, and the size and number of other parking lots in the area. The facility should be designed for self-parking. The layout and design of the parking areas should conform to accepted standards and the requirements of the relevant local authority.

Bicycle Storage

Bicycle storage facilities should be provided at high volume suburban bus stops, Park-and-Ride facilities and at transit centers. Bicycle storage facilities can either be in the form of bicycle racks or bicycle lockers located on asphalt or concrete pads. Both cases require a minimum allowance of 9.5 ft. for maneuvering space. Figure 32 shows typical bicycle storage facilities.

Facilities for the Mobility Impaired

Requirements for providing ease of access for mobility impaired persons have largely been covered in previous sections of this chapter. In general, provision for the mobility impaired requires:

- the provision of skid resistant pavements,
- the provision of curb ramps,
- restriction to gradients to be below 4 %,

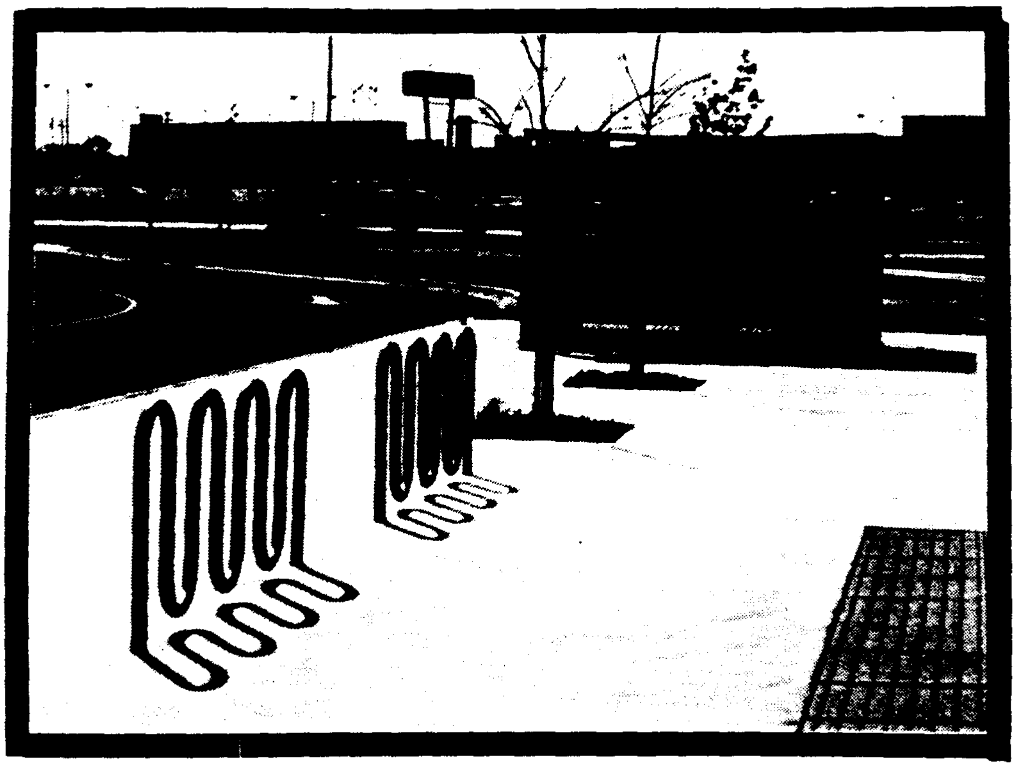


Figure 32 : Typical Bicycle Racks and Lockers

- barrier free areas,
- reservation of parking bays closest to the facility,
- adequate space to accommodate wheelchairs in all public areas, and
- information displays, such as maps or schedules should be placed low enough to be readable by a person in a wheel chair.

Additional information is available from Capital Metro's Special Transit Services Division.

Traffic Control Devices

All traffic signs associated with transit facilities, such as those to indicate parking restrictions, pedestrian crossings, warning signs, etc., should conform first to the Texas Manual of Uniform Traffic Control Devices (Ref. 26) and then to the national Manual of Uniform Traffic Control Devices (Ref. 32) and should be coordinated with the appropriate local authority.

Other Amenities

Amenities other than those already mentioned can also be used to enhance the comfort and safety of transit users, and make transit more attractive. Such amenities could include: rest rooms, newsstands, public phones, police and fire alarms, information kiosks and vending machines.

The decision to include such amenities will depend on the specific location, local needs, patronage, the proximity of similar amenities, security, and economic and operational considerations. Trash receptacles should be provided at all major transit stops and passenger waiting areas.

In all cases, the following should be considered when placing these amenities:

- adequate pedestrian waiting and circulation space as stated in past sections,
- adequate space for movement by mobility impaired persons,
- drainage requirements,
- clear sight lines for traffic,
- ease and economy of maintenance, and
- space clearance for passing vehicles, i.e., 3 ft. curb clearance.

FACILITY DEVELOPMENT

The process of planning and designing a transit facility will, in essence, comprise the selection and placement of the physical components discussed above, in a way to enhance the attractiveness, safety and efficiency of the total facility. Underlying this is the central concept of interaction between the transit vehicles and passengers and the separation of various modes of transport found in and around the transit facility. Modes in this context include transit vehicles, private automobiles, pedestrians and bicycles. Transit facilities may be areas of high activity and conflict between the modes, making careful planning essential.

Concept of Interaction / Separation of Modes

The location of interaction between buses and passengers is at the bus stop, discussed at length in previous sections. Transit patrons should be able to reach bus stops as unhindered as possible. In the same way buses should reach and depart from bus stops,while not causing a danger or impedance to other modes, and while operating at a high level of efficiency.

The following general guidelines apply to transit facilities incorporated into developments, whether retrofitted or planned from the outset:

- Bus stop areas should be located as close to streets as possible to minimize on-site travel and to minimize conflicts between modes.
- In heavily travelled areas the use of exclusive roadways and stopping areas for buses are highly recommended.
- Separate access points to developments for various modes should be provided to reduce conflict and enhance operational efficiency. Modes in this context include : automobiles, transit, pedestrians, and bicycles.
- Where access points from public streets to developments are separated by mode, they should be clearly designated and well spaced to avoid conflict and confusion. Points of egress onto public streets should be designed so as to avoid unnecessary obstruction of sight, conflict, and weaving maneuvers between modes.
- Transit facilities should be located so that pedestrians have direct access between the transit facility and the origin and destination of pedestrian trips (e.g. shopping center, employment, parking), and without unnecessarily having to cross roadways or areas used by transit vehicles. Where pedestrians do have to cross areas used by other modes it should only be at clearly demarcated locations, fitted with the necessary traffic control and warning devices, such as painted crosswalks, warning signs or traffic signals.
- Exclusive pedestrian walking ways should be provided as far as possible. A Coefficient of Directness (C = [designated walking path distance] / [straight line distance]) is often used to assist in the planning of Park-and-Ride and similar facilities. It is suggested that the coefficient of directness not exceed 1.2 , with 1.4 considered as a maximum (Ref. 36). In all cases the

distance to be traversed by mobility impaired persons should be minimized. This will, for instance, include the parking spaces closest to the transit facility being reserved for mobility impaired persons.

Some of the above concepts are illustrated in Fig. 33.

Park-and-Ride Facilities

Park-and-Ride facilities are special transit stations expressly for the use of patrons transferring from alternate transportation modes to the Capital Metro system. These parking facilities are provided primarily to encourage express bus ridership. They are usually located in the suburban residential community to attract daily commuters and to minimize access distances.

Placement Consideration. Park-and-Ride facilities should be located at sites that are highly visible and easily accessible to the commuter. These facilities should be located adjacent to major arterials and highways, outside points of significant urban congestion. Park-and-Ride facilities should be located more than 3 to 4 miles from the activity center being served, in order to make the bus part the major portion of the patron's trip (Ref. 36). The impact on the surrounding land uses and the availability of real estate will also impact the location of the Park-and-Ride facility.

Two general approaches can be used in designing Park-and-Ride facilities. One alternative is to provide new facilities specifically designed to serve exclusively as a Park-and-Ride terminal. The second alternative is to share unused portions of existing parking lots as the parking area for the Park-and-Ride service. Sites commonly used as joint-use arrangement are shopping centers, movie theaters, and sporting facilities.

Both of the alternatives listed above have their advantages and disadvantages. The shared lot option is faster to implement and less costly. Due to the low capital requirements, joint-use lots can be used to test travel demands. If demand is inadequate, the service can quickly be terminated. If the demand is substantial, a more extensive facility can be considered. The exclusive lot option, because it is planned in advance, can provide better access and circulation patterns. The planned facility will be able to incorporate space for future expansion and for excess parking needs.

Design Considerations. The potential demand for the Park-and-Ride facility will be the basic design criteria. The facility should be designed to accommodate a demand of approximately 10 percent greater than the estimated average daily demand (Ref. 36).

Certain operational and design features of the Park-and-Ride facility limit the desirable lot size. The minimum lot size must be justified by the level of demand experienced at the site. The maximum desirable lot size is constrained by walking distances, bus headways, and market-area characteristics. Maximum lot

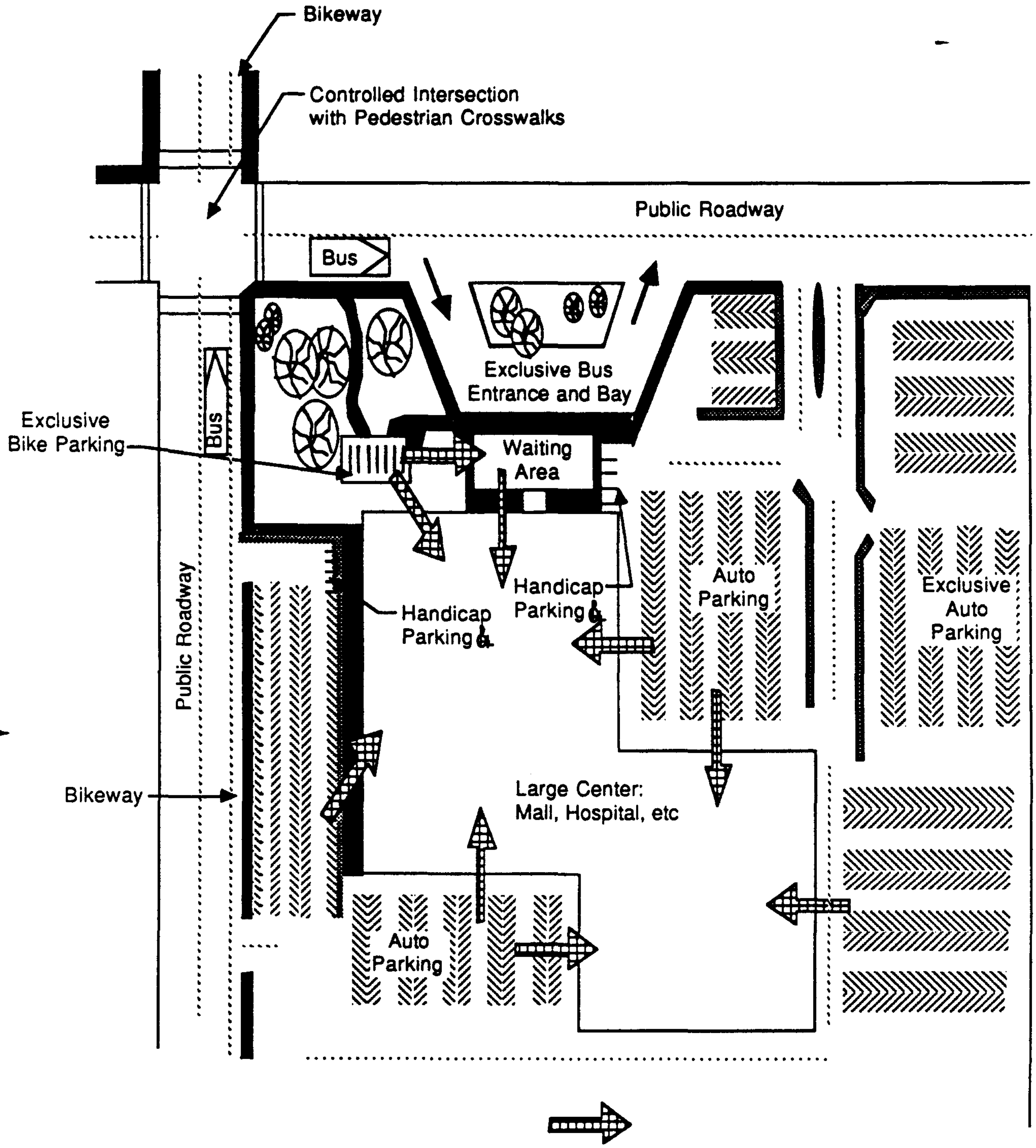


Figure 33 : Illustrated Concept of Separation and Interaction of Modes

sizes of 700 to 800 parking spaces and minimum lot sizes of 200 parking spaces are recommended (Ref. 36). To maximize the efficiency of the lot, right angle parking is recommended. Parking spaces should be 9 ft. by 20 ft. for full size cars. At least one parking space per 40, for the first 150 spaces, and for every 100 spaces thereafter, should be provided for the mobility impaired. The mobility impaired parking spaces should have a minimum width of 11 ft. (Ref. 4).

Park-and-Ride facilities are normally used by large numbers of patrons and vehicles and planning should be directed towards minimizing conflicts between vehicles and pedestrians. When planning internal site layout to minimize conflict, the following activities should be treated in the given priority order (Ref. 4):

- bus loading and unloading,
- other vehicles off-loading passengers,
- bicycle parking,
- mobility impaired parking, and
- all day parking.

Park-and-Ride entrance and exit lanes should be designed to minimize automobile and bus conflicts. Exclusive bus entrance and exit lanes are preferred but not essential if less than 12 buses serve the facility during the peak hour. An adequate number of traffic lanes should be provided at all entrance and exits to accommodate the expected number of vehicles, the local traffic conditions, and the site configuration.

The passenger loading area of the Park-and-Ride facility can be located either within or on the periphery of the lot. The loading location on the periphery will minimize the real estate requirements and reduce the number of conflicts between autos and buses. The time required for the bus to serve the facility may also be reduced. The average walking distance for patrons from parking slots to the loading area is, however, increased. The prime advantage of a loading area within the lot is that this average walking distance is greatly reduced. As a consequence, however the circulation of buses through the facility becomes much more complex. The potential for bus and auto conflicts will also increase as the buses must now circulate through the lot. Careful planning should be implemented when considering either of these designs. The design criteria should follow the standards for berthing areas described earlier in this chapter.

The "Kiss-and-Ride" patronage is represented by those persons who are dropped off by a driver at the Park-and-Ride facility in the morning and picked up again in the afternoon. Approximately 10 percent of the total number of vehicles using a Park-and-Ride lot could be Kiss-and-Ride vehicles. The average waiting time for a Kiss-and-Ride vehicle is from 6 to 10 minutes. Kiss-and-Ride spaces should be signed in a manner that will assure their use as short-duration parking spaces. Space for Kiss-and-Ride vehicles should be provided for approximately 1 to 1.5 percent of the lot capacity.

Principal passenger waiting areas should be provided with shelters, benches, route information, trash receptacles and, if possible, public telephones. Bicycle storage facilities may be provided and should be placed near the bus loading area. Amenities such as newsstands, vending machines, rest rooms and mailboxes can also be provided to increase the comfort of users. All lots should be provided with lighting. Park-and-Ride signs should be placed at the entrances to the facility so that they are clearly visible to approaching vehicles. For large Park-and-Ride facilities, information signs along highway ramps, arterial intersections and major feeder roads are recommended to adequately guide potential users.

Figure 34 shows a typical Park-and-Ride facility layout, while Fig.37 illustrates some placement considerations. Fig. 35 and 36 are examples of the bus and passenger shelter currently provided at the U.S. 183 and Lamar Blvd. Park-and-Ride facility in Austin.

Transit Centers

A transit center is a major transit facility which is designated to accommodate a variety of transit functions including passenger loading and unloading, transfers, driver breaks, bus layovers, Park-and-Ride operations, etc. Depending on the demand and level of service, a transit center may include an enclosed building , complete with restrooms, benches, phones and various other service amenities.

Usually transit centers are only appropriate for large scale developments like regional shopping centers, large office and commercial developments, universities and similar high activity centers. Bus access routes to and from the transit center should meet all geometrical design standards for bus design vehicles. Although transit needs and functions vary from location to location, a general design guideline for such a facility is to provide transit vehicles with ingress to and egress from the transit center, separated from automobile traffic. Passenger waiting areas should provide amenities similar to those at Park-and-Ride facilities. A typical Transit center layout is shown in Fig 38.

Facility Component Matrix

Table 4 summarizes what design components should be considered for specific types of transit facilities. This table should be helpful for the engineer designing transit facilities.

The Matrix is designed to provide a list of minimum design components required for each type of transit facility. It will be beneficial if components to be included and design criteria are confirmed with Capital Metro at an early stage in the planning process.

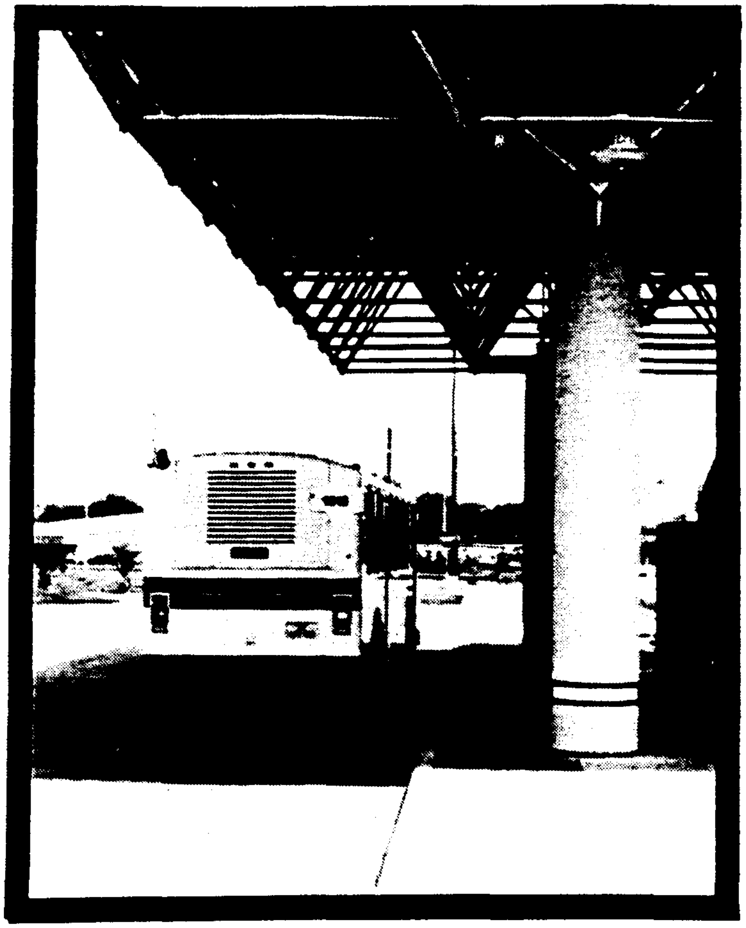


Figure 35 : Bus Awning at Capital Metro Park-and-Ride Facility: U.S. 183 and Lamar Blvd.

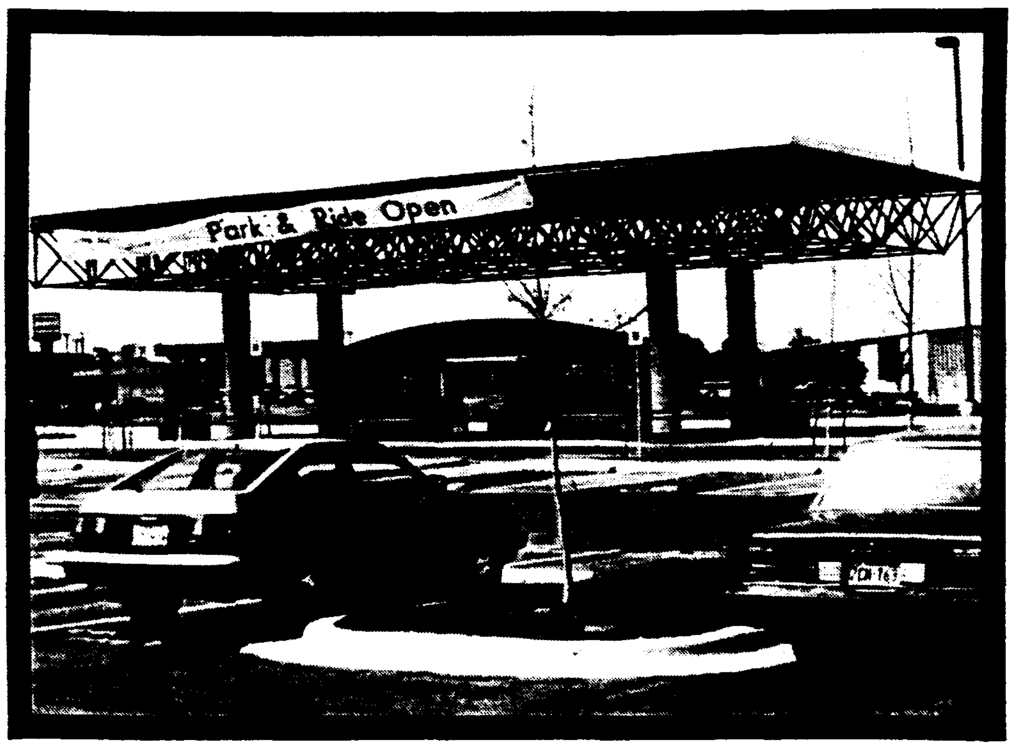


Figure 36 : Bus Passenger Shelter at Capital Metro Park-and-Ride Facility: U.S. 183 and Lamar Blvd.

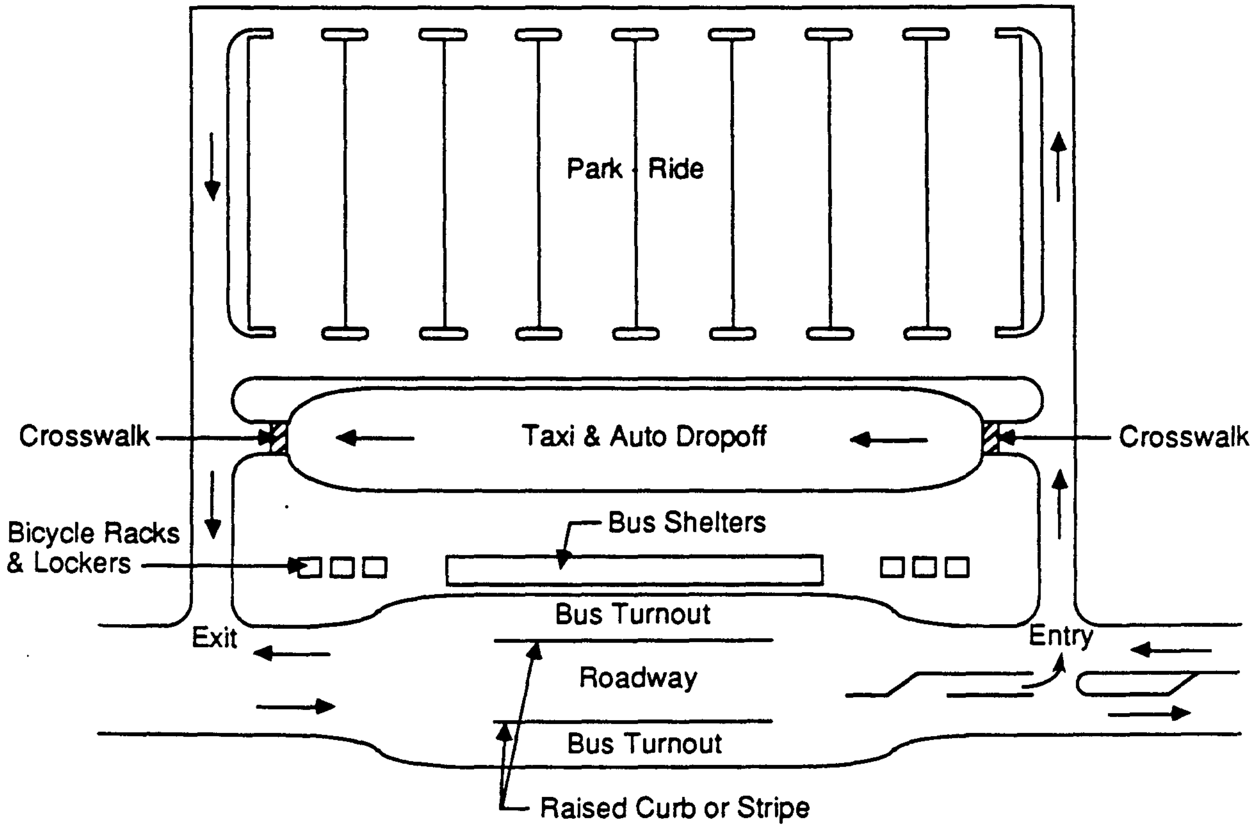


Figure 34 : Typical Park-and-Ride Layout

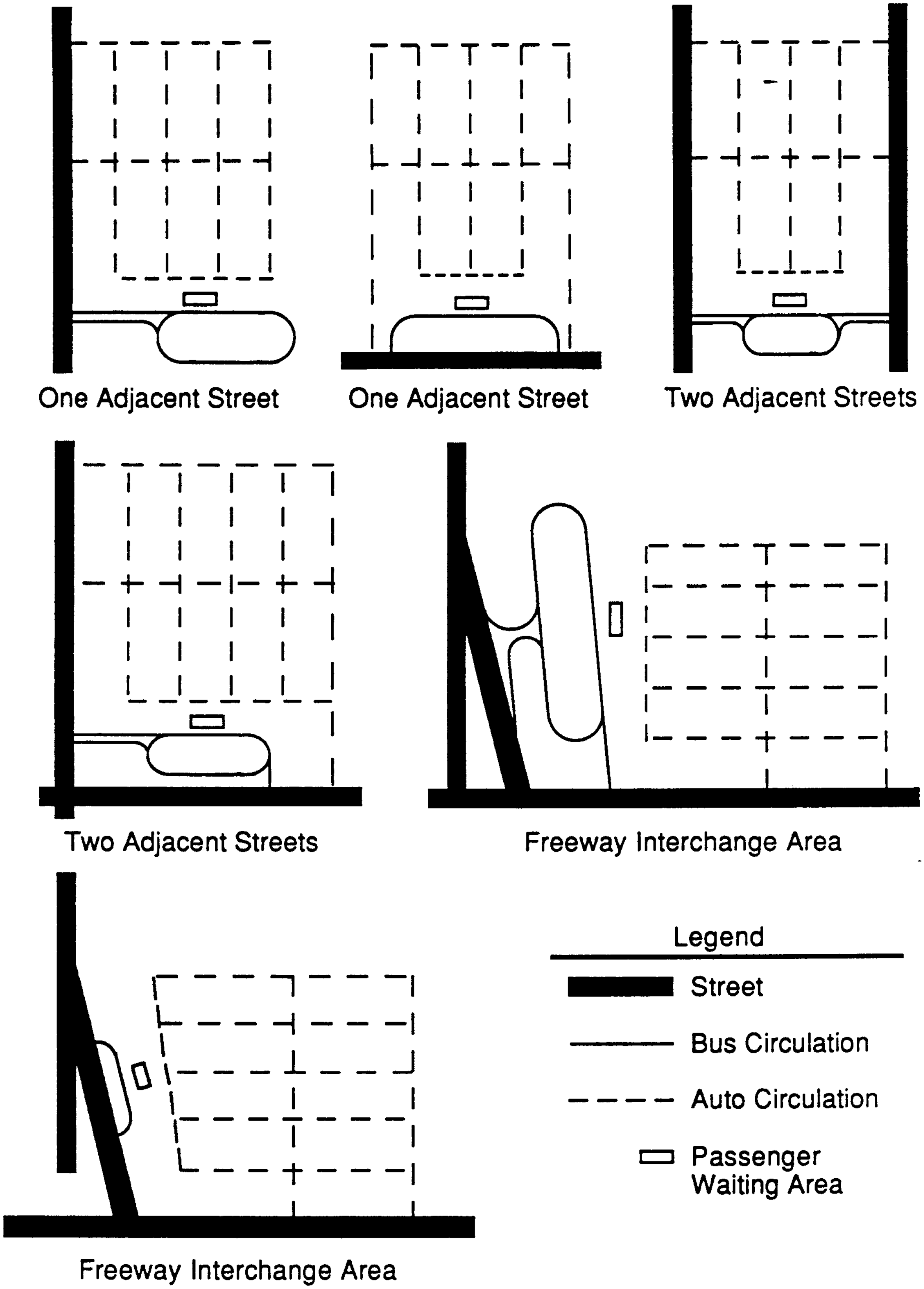


Figure 37 : Park-and-Ride Placement and Layout Design Options

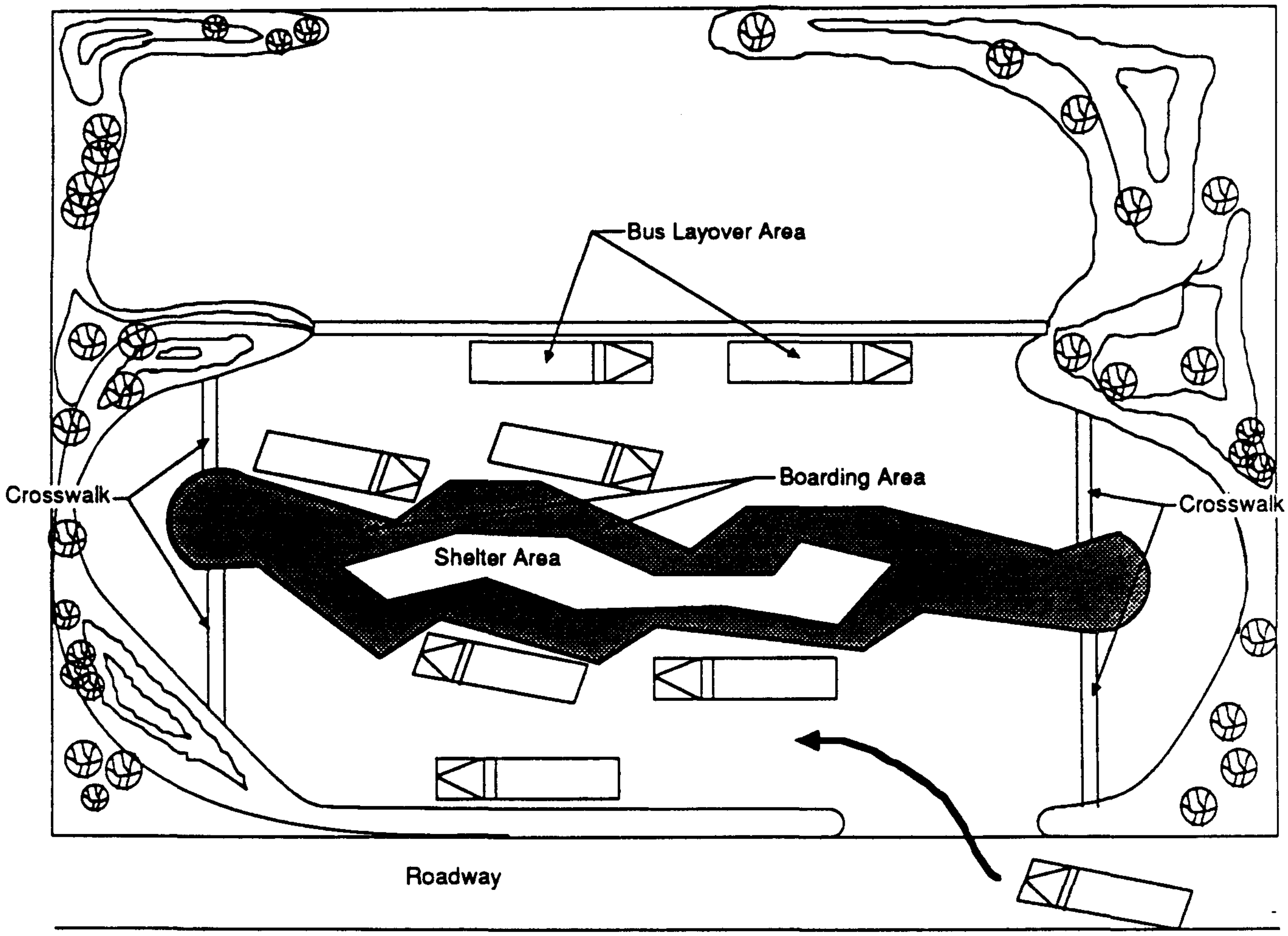


Figure 38 : A Typical Transit Center Site Layout

Facilities				
Bus Stops	Transfer Locations	Park and Ride	Transit Centers	Components
*	*			Turnouts
		O	O	Turnarounds
*	●	●	●	Berthing
●	●	●	●	Passenger Waiting Areas
O	O	●	●	Shelters
O	O	●	●	Benches
●	●	●	●	Information Devices
●	●	●	●	Handicapped Facilities
O	O	O	O	Bicycle Racks
O	O	●	●	Lighting
*	O	●	●	Vehicle Parking
O	O	O	●	Restrooms
O	O	O	O	Snackbars/Newsstands

● Essential
O Beneficial
* Beneficial in Some Situations

Table 4 : Facility Component Matrix

CONCLUSION

Capital Metro has the ability to coordinate the integration of public transit into new and existing development, but the actual integration of public transit can only result from active participation and cooperation among Capital Metro, city government, developers, and the citizens of the Capital Metro service area.

The key to successful transit integration is the inclusion of transit related planning into the initial phase of any project design. The analysis of transit integration feasibility during the initial phases of project planning permits the most comprehensive evaluation of whether transit integration can benefit a specific project and the community. If it is determined that transit integration is feasible, then the site plan and building design can incorporate the necessary design and construction elements from the preliminary design phase, and avoid the expensive process of retrofitting a development.

The "Transit Facility Design Guide" attempts to aid the process of transit integration by providing the appropriate facility design information necessary to assist the developer. While the transit handbook is comprehensive in scope, it is not intended to replace specific site design planning.

Site specific design should be developed in cooperation with city regulations and Capital Metro guidelines, and should take into account the potential for changes in vehicle design and project expansion, and site specific constraints. Project planners and developers are strongly encouraged to address questions to Capital Metro during the initial stages of planning a facility. The early discussions will enhance the opportunity to develop a successful transit related project. The greater the number of transit integration projects along a given corridor, the more likely that Capital Metro can provide efficient and economic public transportation for the entire Capital Metro service area.

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NOTE: Several of the references listed above are not specifically mentioned in the text.

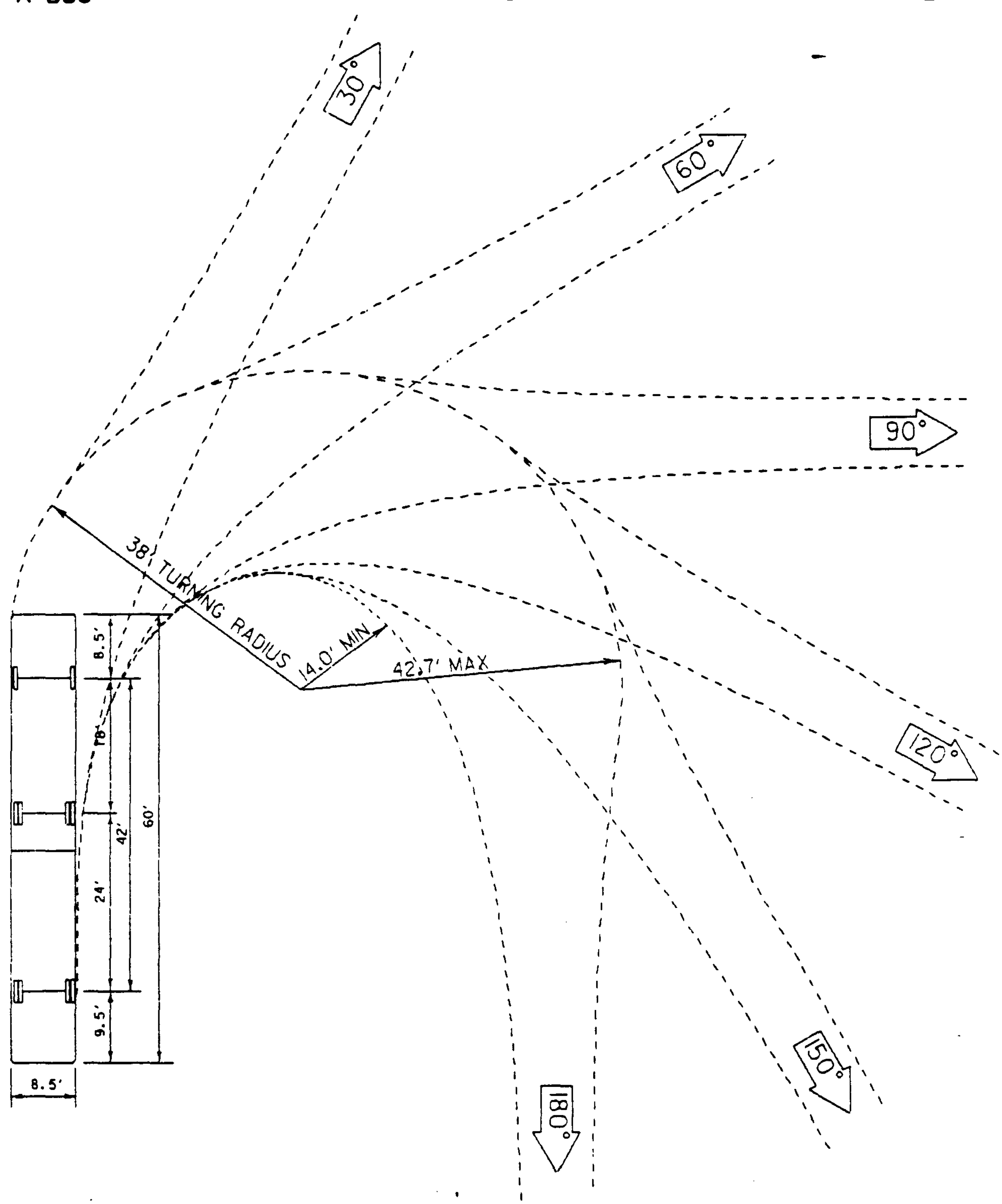
APPENDIX

DESIGN TURNING TEMPLATES
(Scales 1"=20'; 1"=40'; 1"=50'; 1"=100')

Articulated Bus*
40 ft. Bus*
30 ft. Bus or Truck*
'Dillo Bus**

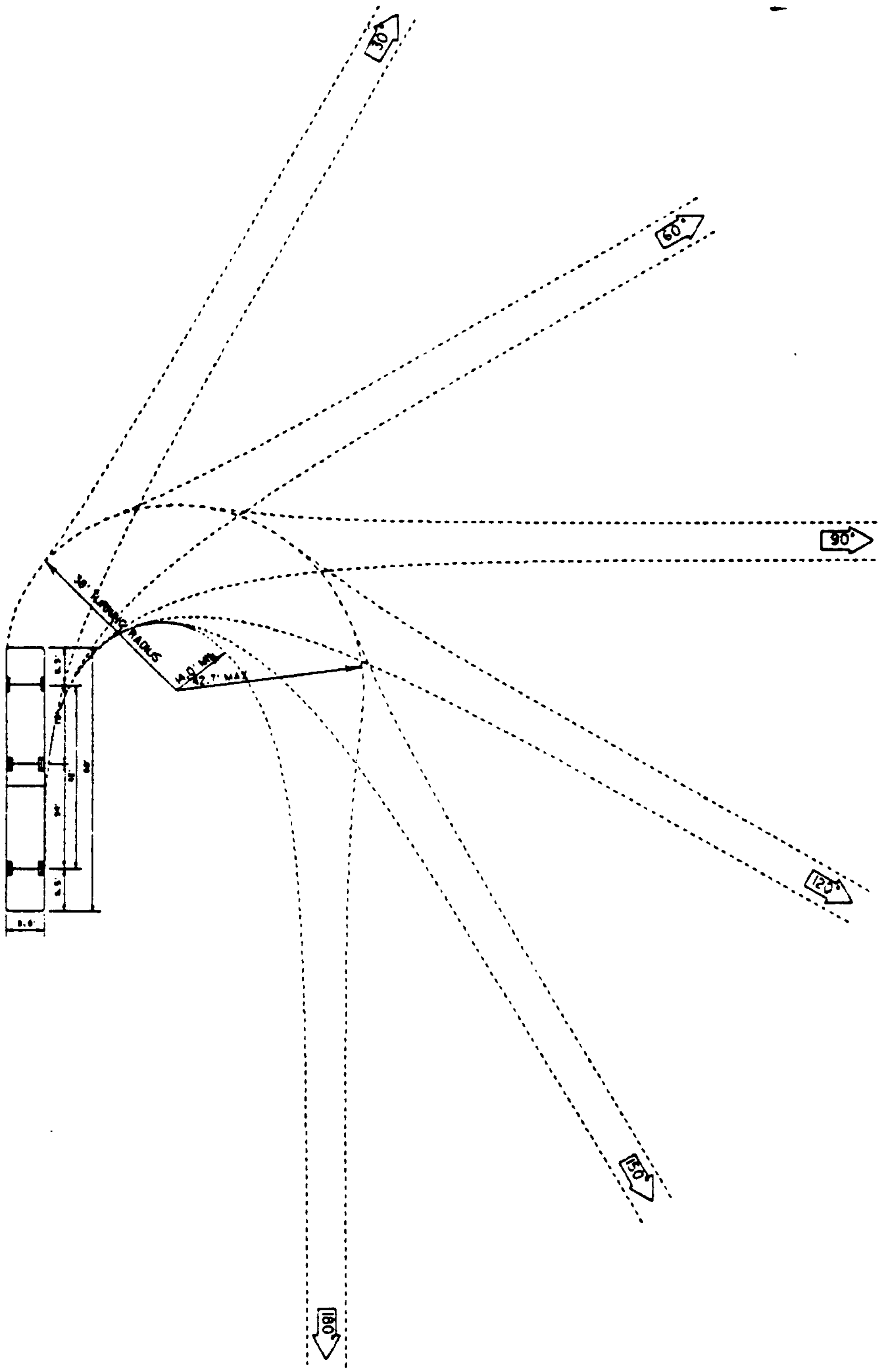
*Reprinted from Ref 27.
**Produced using the TXTOM computer program (Ref 27)

A-BUS R = 38' I" = 20'



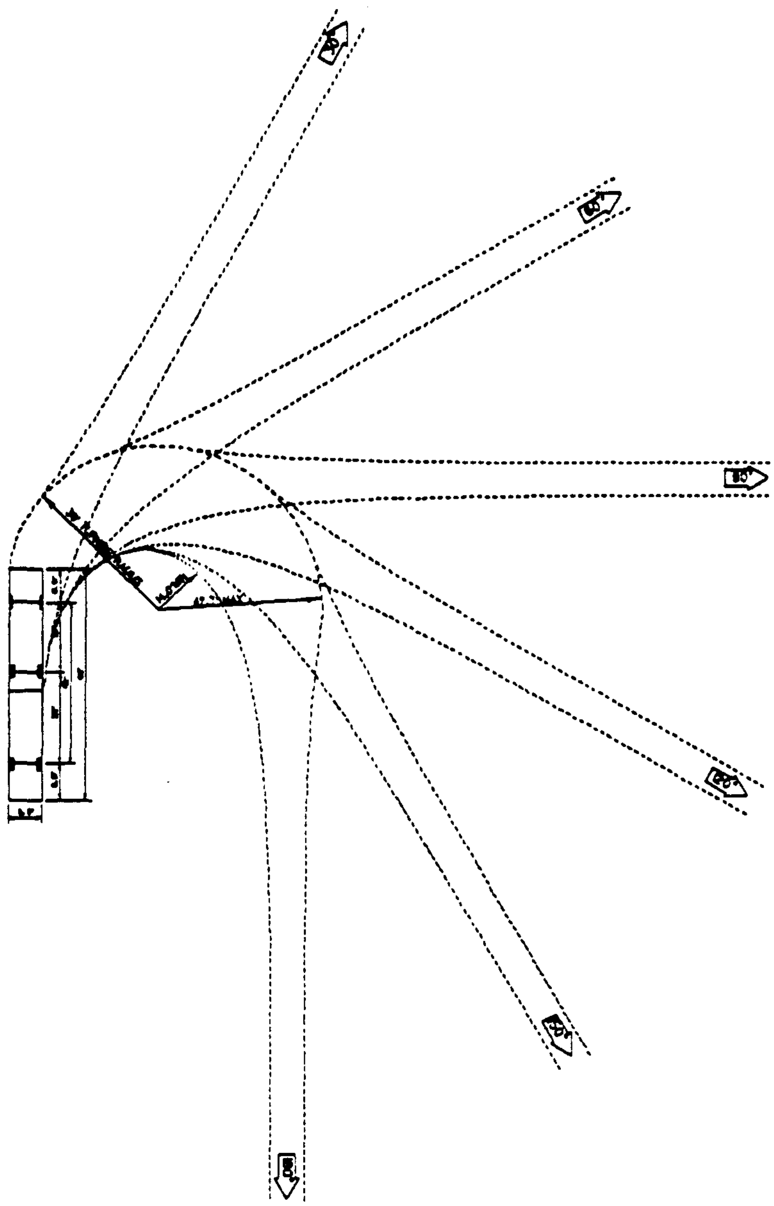
ARTICULATED BUS DESIGN VEHICLE
RADIUS = 38'
SCALE I" = 20'

A-BUS R = 38' 1" = 40'



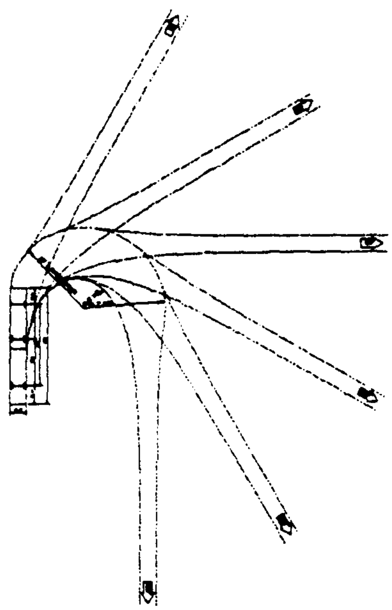
ARTICULATED BUS DESIGN VEHICLE
RADIUS = 38'
SCALE 1" = 40'

A-BUS R = 38' I" = 50'

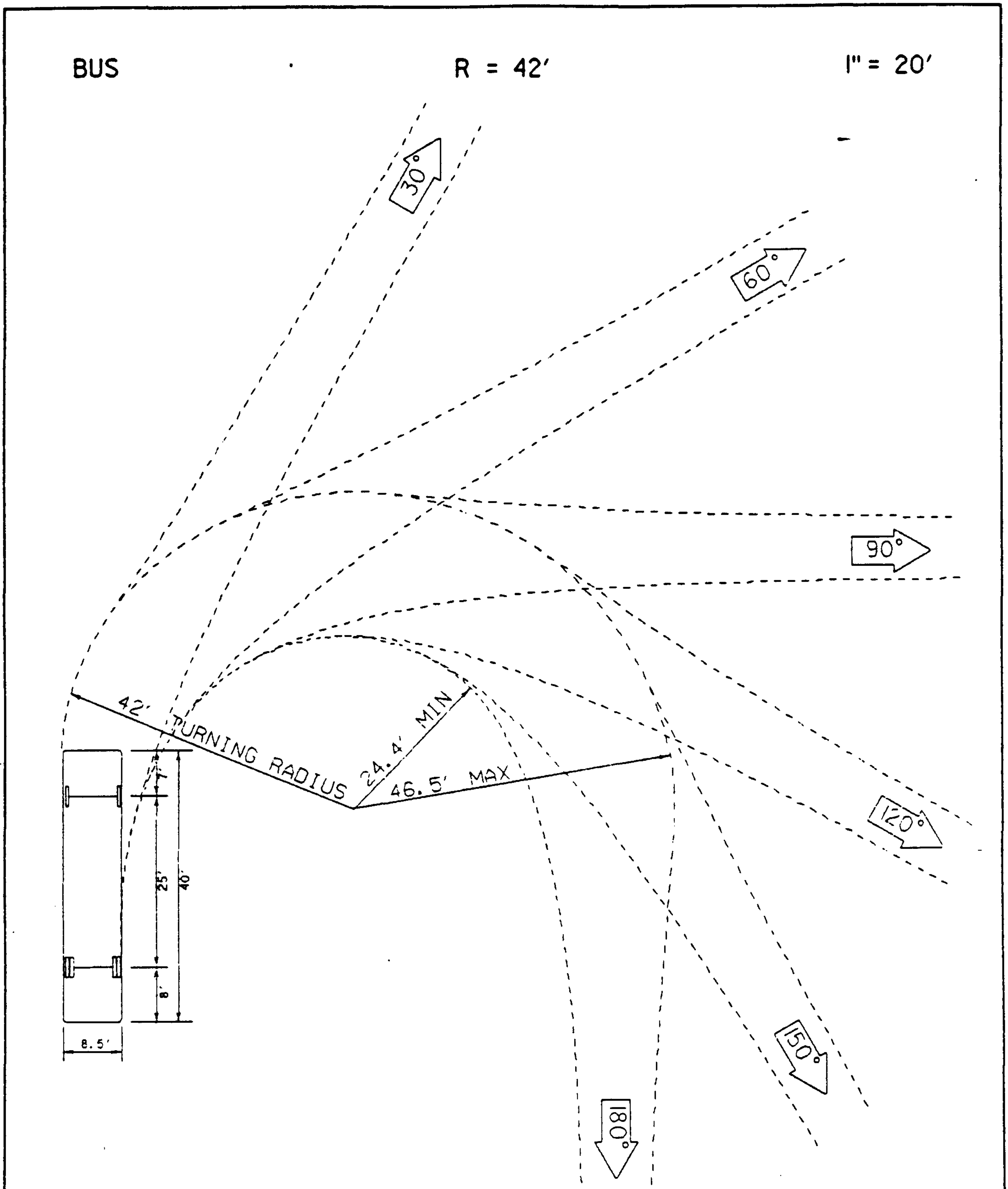


ARTICULATED BUS DESIGN VEHICLE
RADIUS = 38'
SCALE I" = 50'

A-BUS R = 38′ 1" = 100′

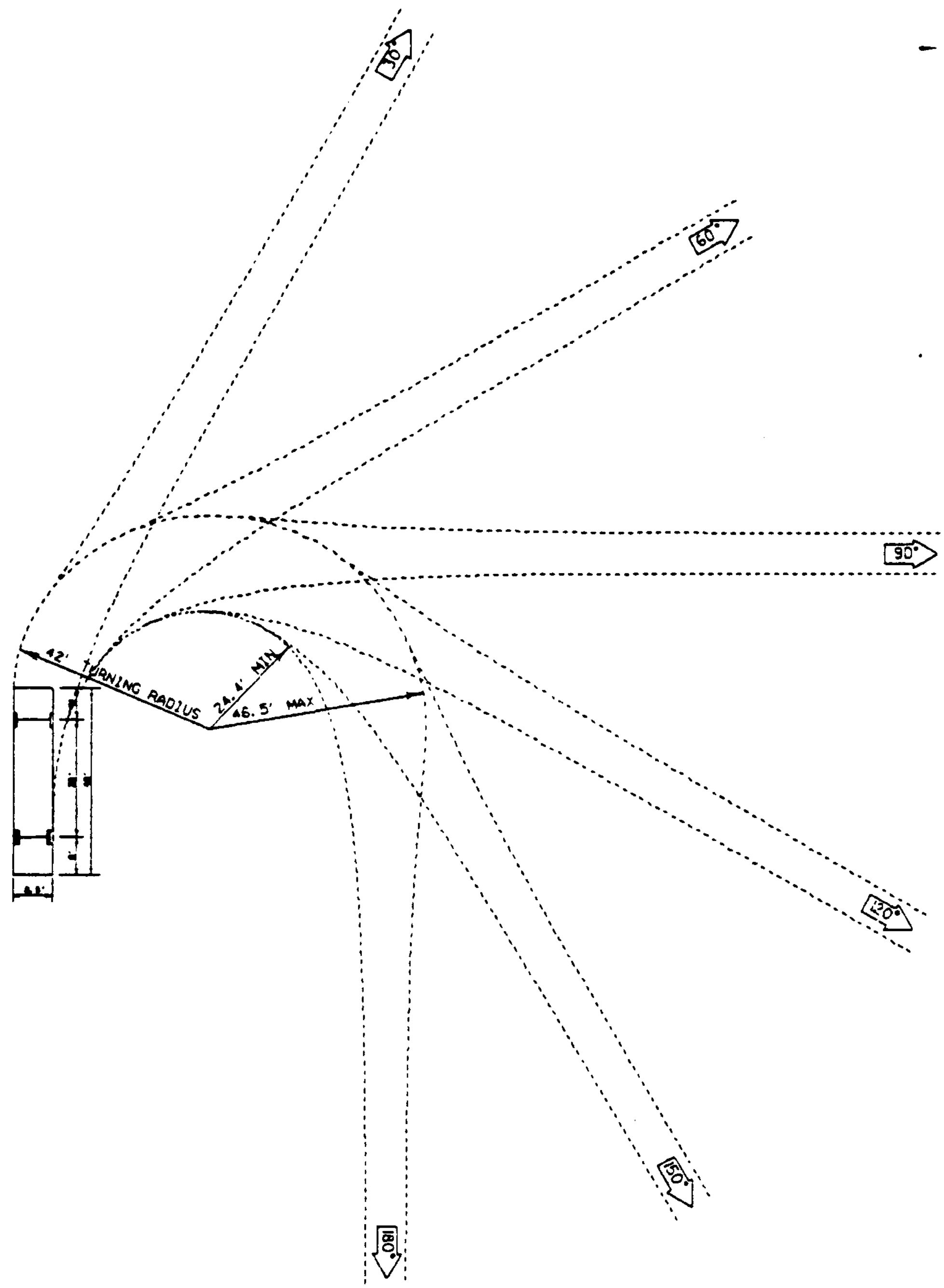


ARTICULATED BUS DESIGN VEHICLE
RADIUS = 38′
SCALE 1" = 100′



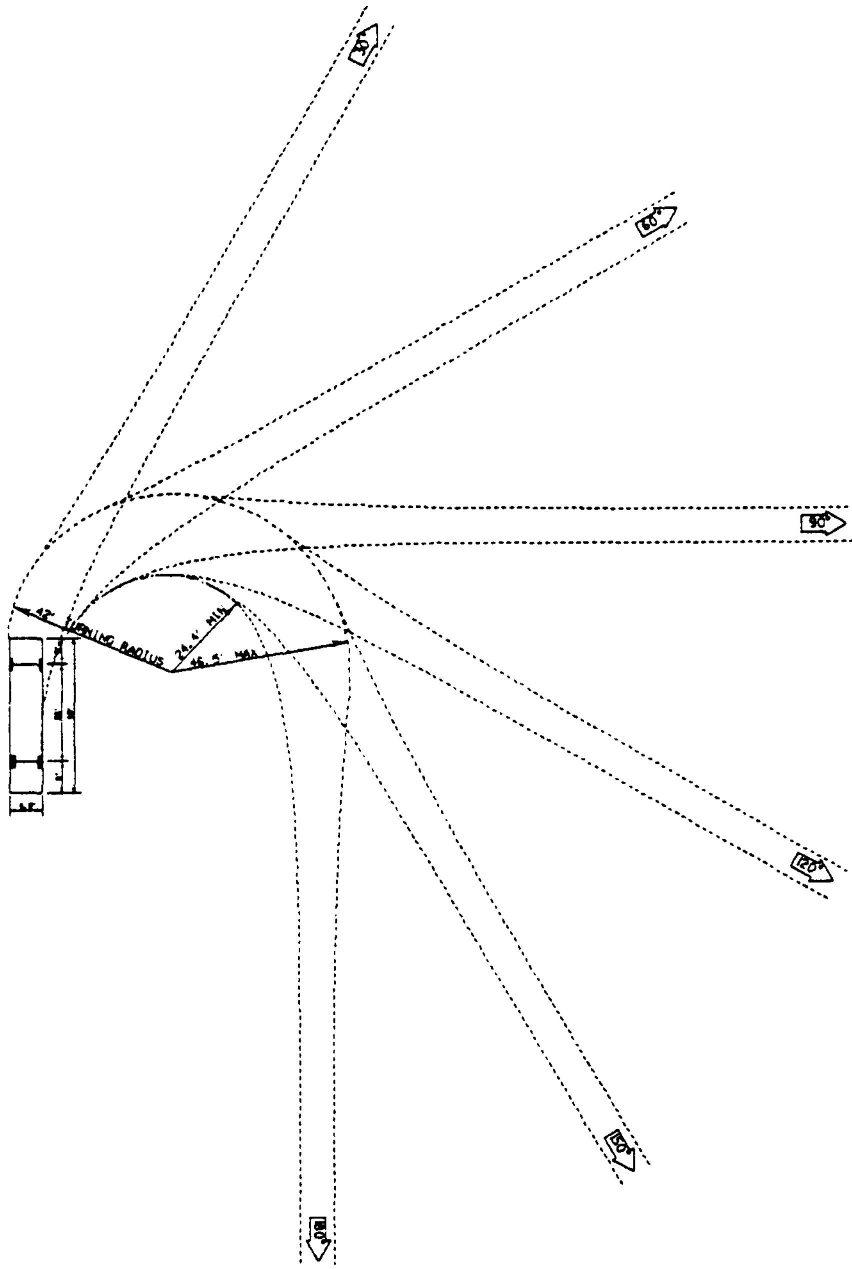
BUS DESIGN VEHICLE
RADIUS = 42′
SCALE 1" = 20′

BUS R = 42′ 1" = 40′



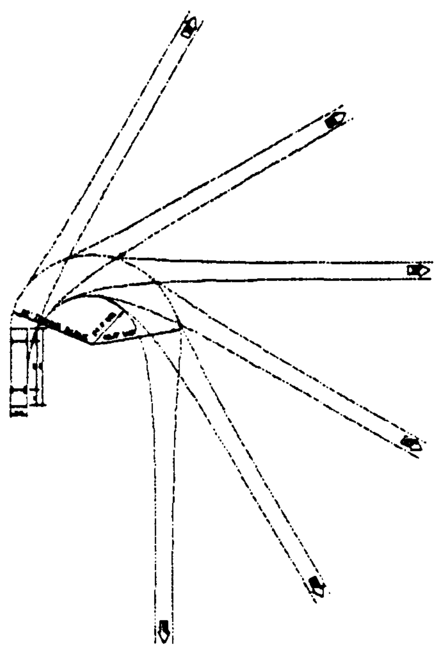
BUS DESIGN VEHICLE
RADIUS = 42′
SCALE 1" = 40′

BUS R = 42' 1" = 50'

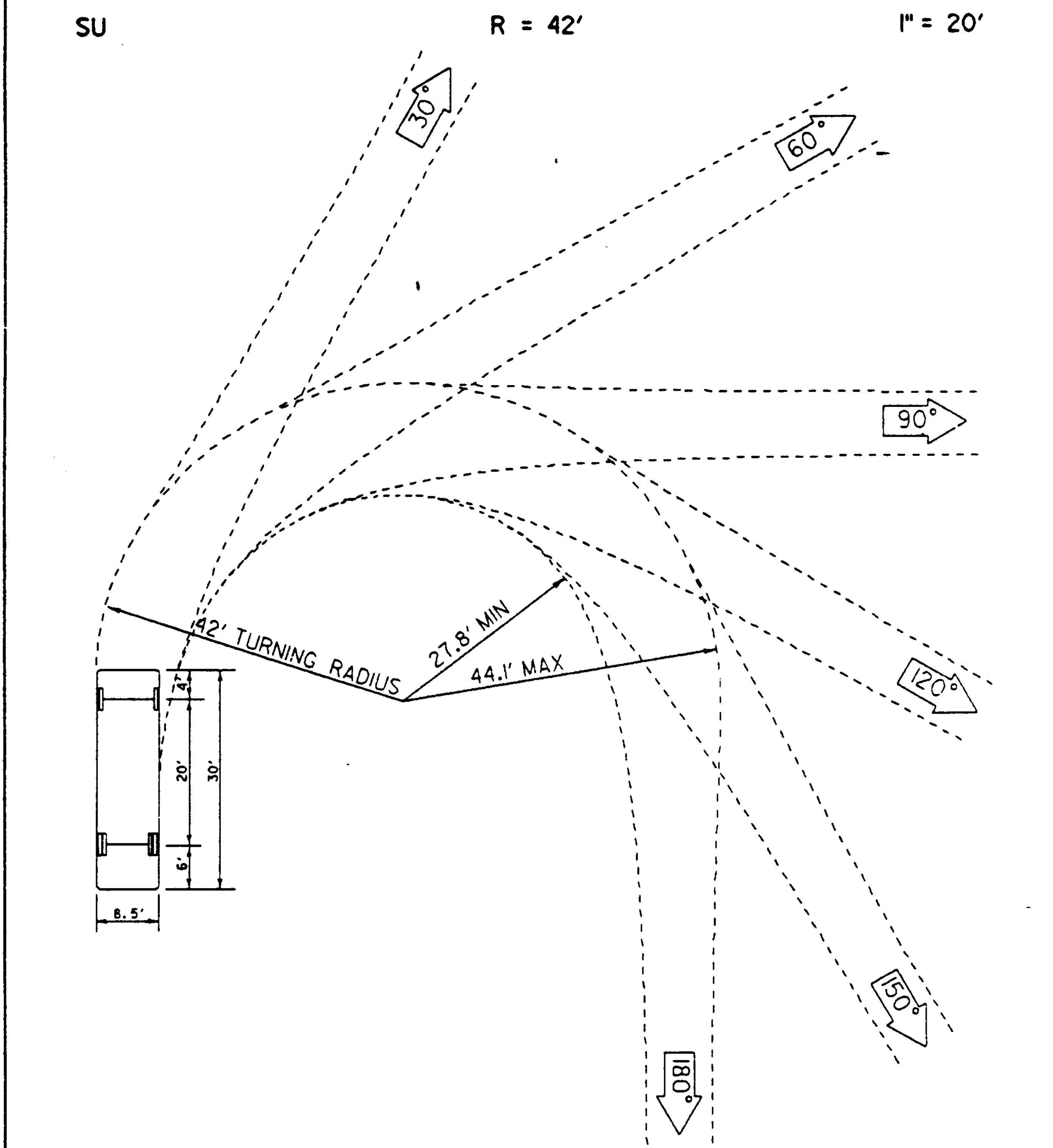


BUS DESIGN VEHICLE
RADIUS = 42'
SCALE 1" = 50'

BUS R = 42' 1" = 100'

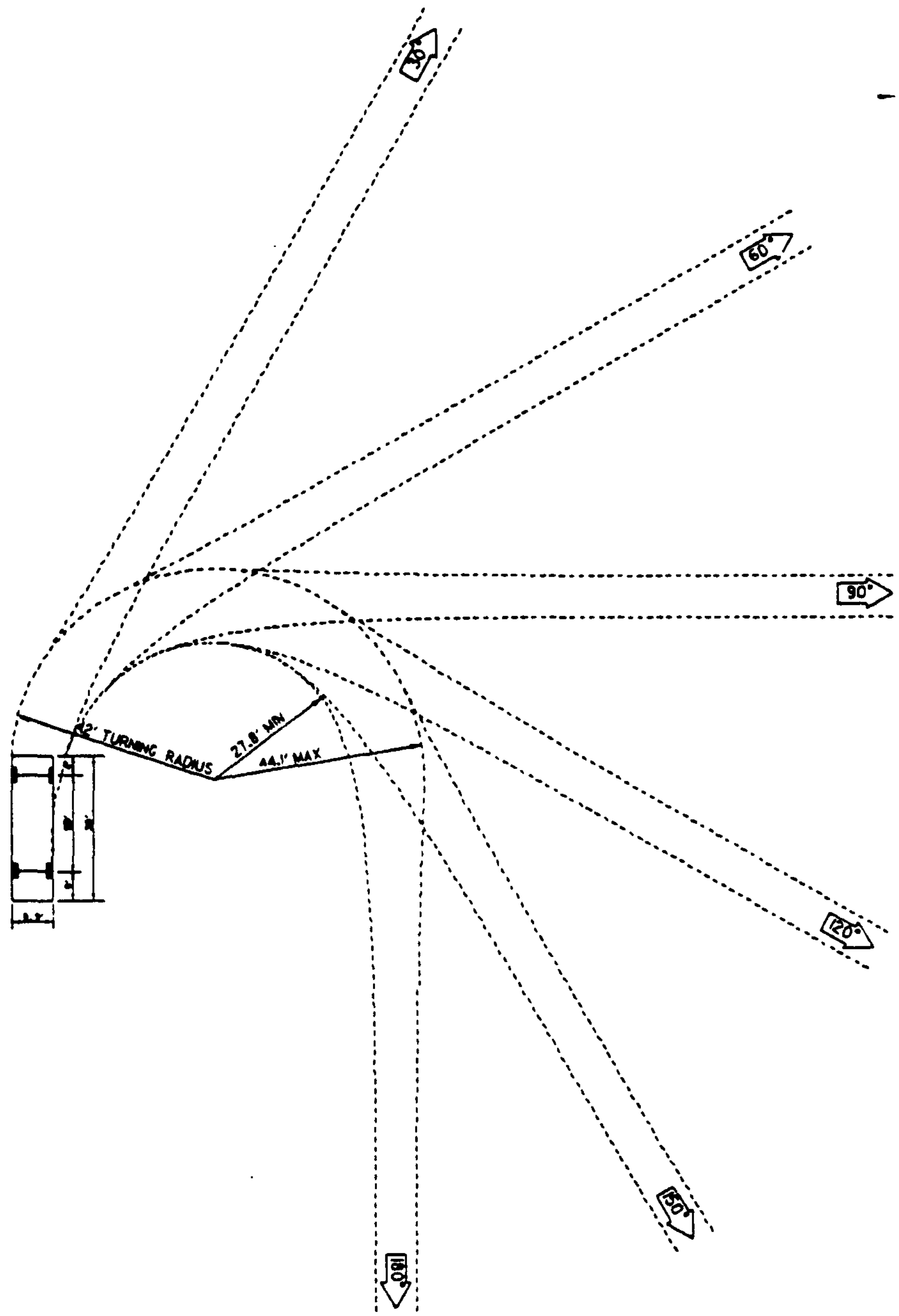


BUS DESIGN VEHICLE
RADIUS = 42'
SCALE 1" = 100'



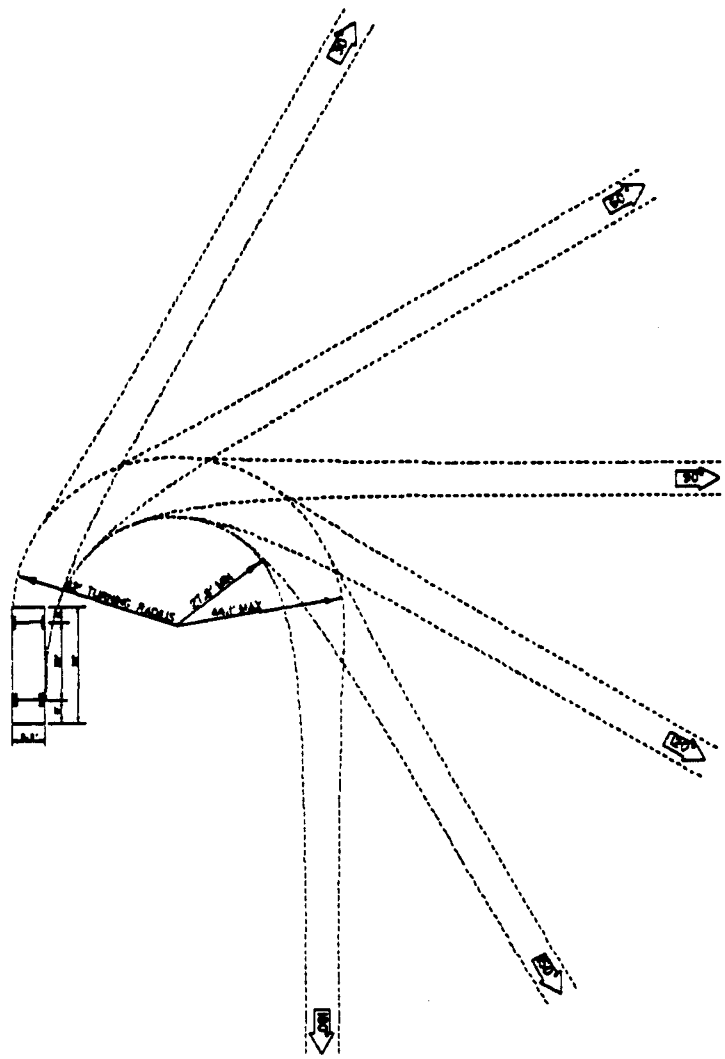
SINGLE UNIT TRUCK DESIGN VEHICLE
RADIUS = 42′
SCALE 1" = 20′

SU R = 42' I" = 40'



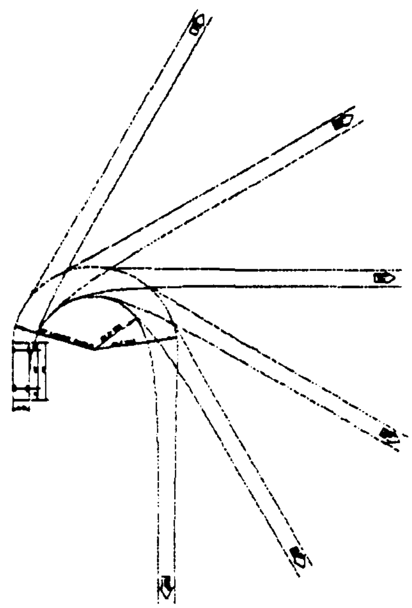
SINGLE UNIT TRUCK DESIGN VEHICLE
RADIUS = 42'
SCALE I" = 40'

SU R = 42′ 1" = 50′



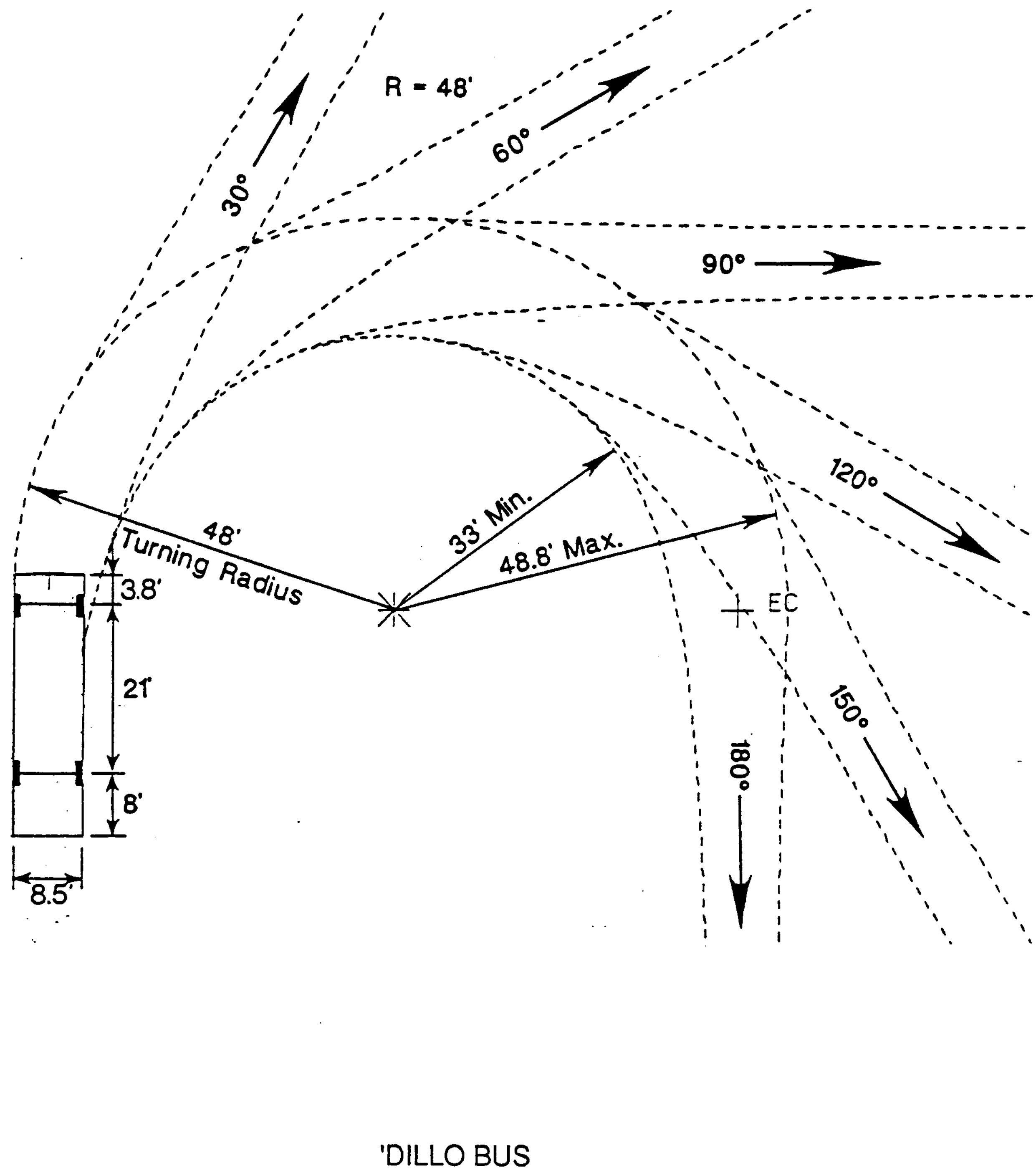
SINGLE UNIT TRUCK DESIGN VEHICLE
RADIUS = 42′
SCALE 1" = 50′

SU R = 42′ 1" = 100′



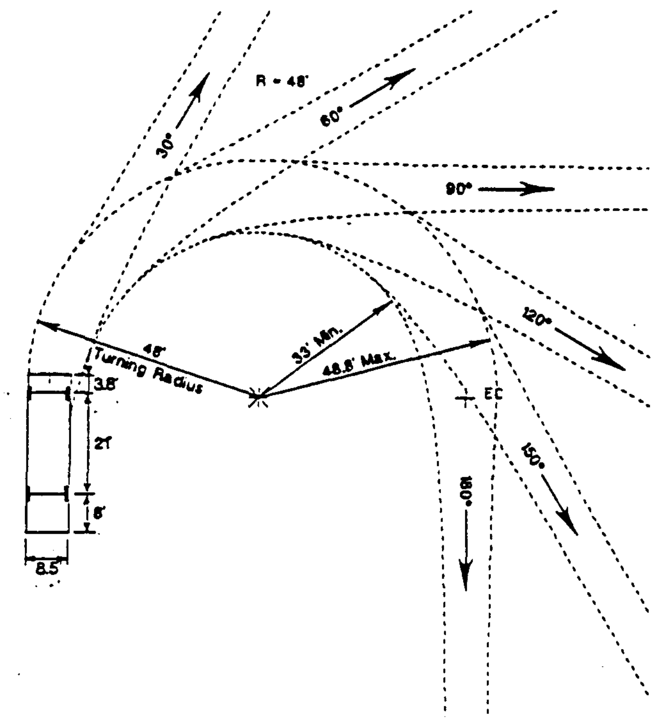
SINGLE UNIT TRUCK DESIGN VEHICLE
RADIUS = 42′
SCALE 1" = 100′

DILLO BUS R = 48' 1"= 20'



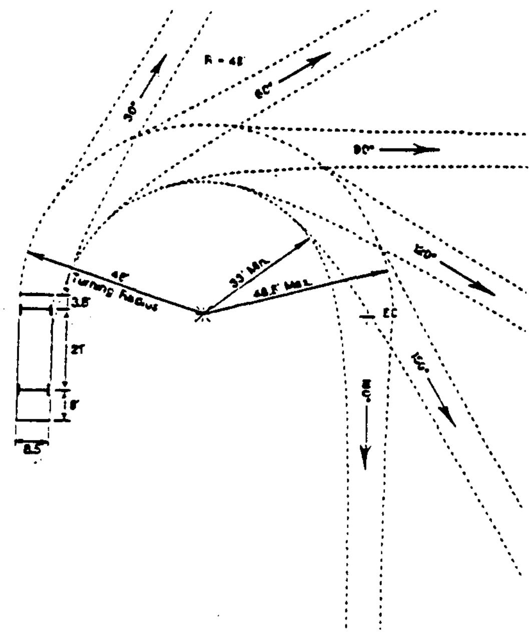
'DILLO BUS
RADIUS = 48'
SCALE 1"= 20'

DILLO BUS | R = 48' | 1"= 40'



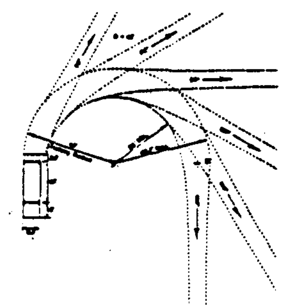
'DILLO BUS
RADIUS = 48'
SCALE 1"= 40'

DILLO BUS R = 48' 1"= 50'



'DILLO BUS
RADIUS = 48'
SCALE 1"= 50'

DILLO BUS R = 48' 1"= 100'



'DILLO BUS
RADIUS = 48'
SCALE 1"= 100'

GLOSSARY

Angle of Intersection- The angle or angles at which two or more streets meet to form an intersection.

Arterial Street- Streets that generally move high volumes of traffic for great distances, and at relatively high speeds.

Articulated Bus- An extended bus usually 60 to 70 feet in length which consists of two hinged or joined units.

Bus Encroachment- The movement of a bus into an adjacent or opposing lane of traffic during a turning maneuver.

Collector Streets- Collect traffic from other streets, serving as the most direct route to an arterial or another collector street. The five types are: residential, neighborhood, commercial, industrial, and primary.

Curb Return- The curved section of curb used at street intersections in joining straight sections of the curb.

Design Speed- The operating speed determined for the design of the specific physical features of a highway, street, or development.

Design Vehicle- A selected hypothetical motor vehicle, the dimensions and operating characteristics of which are used in highway and street development design.

Grades- The change in elevation between two points along the vertical alignment of a roadway. Usually expressed as the change per 100 feet or percent.

Inbound Lane- A lane of traffic leading into an intersection.

Local Street- Are intended primarily to serve traffic within a neighborhood or within a limited district. Local streets are not continuous through several districts.

Offtracking- The different path taken by the rear wheels in relation to the front wheels while turning. The line of this curve is closer to the curb return the curve made by the front wheels.

Outbound Lane- A lane of traffic leading away from an intersection

Queue- A line or file of waiting vehicles.

Swept Path- The area of the path covered by a vehicle making a turning maneuver. The radial distance between the turning paths of the outer front wheel and the inner rear wheel.

Travel Mode- The form of transportation used to accomplish a trip. In an urban commuter context the three primary travel modes are rail, bus, and private automobile.

Turnarounds- A area in which a vehicle can perform a 180 degree turn.

Turning Radius- The radius of the circle traced by the outer front wheel of a vehicle making a turn. The resulting measurement is strongly dependent on the steering characteristics, operating speed, and length of the wheelbase of a vehicle.

Turnouts- A special lane of limited length apart from through traffic lanes provided for the use of vehicles making stops of short duration.

Weaving Maneuvers-The crossing of traffic streams moving in the same general direction accomplished by merging and diverging.

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Typical designs are provided for the following facilities and amenities: 1) pedestrian accessways, 2) bus turnouts, 3) bus stops, 4) bus shelters, 5) bus benches, 6) bus stop signs, 7) park-and-ride facilities, and 8) transit centers. Current bus fleet dimensions are provided along with bus turning radii and recommended road grades.

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