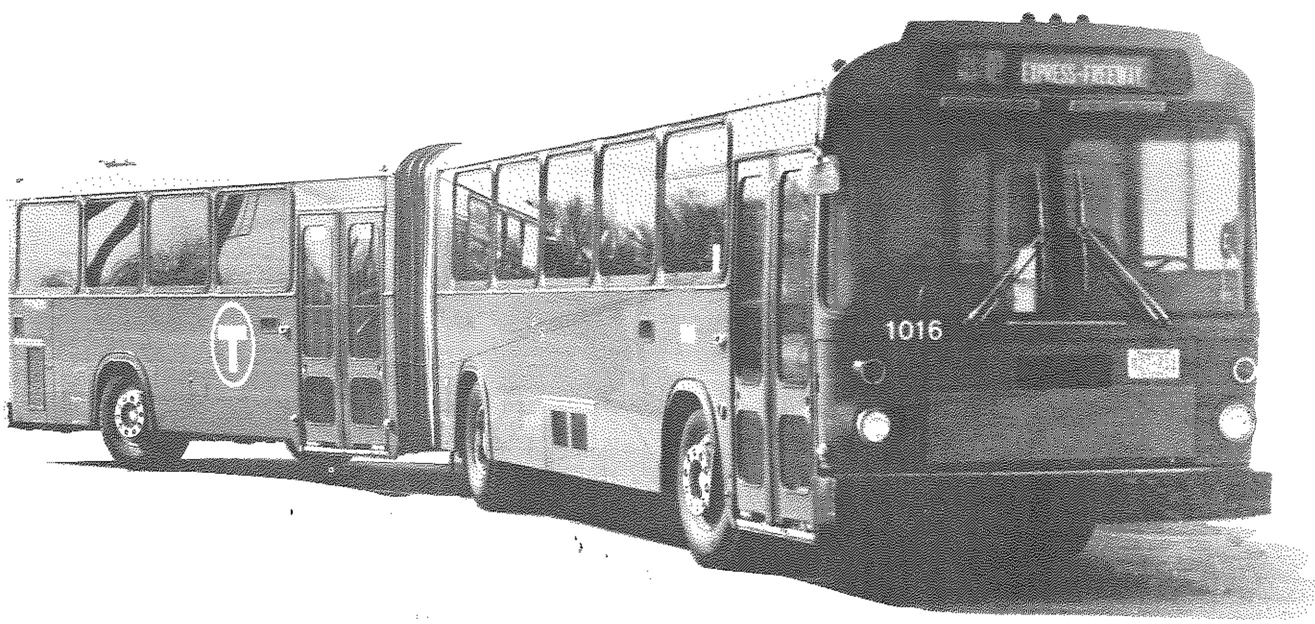
GUIDELINES FOR THE DESIGN OF TRANSIT RELATED ROADWAY IMPROVEMENTS



UMTA PROJECT NUMBERS: MN-09-0042 & MN-09-0048

METROPOLITAN TRANSIT COMMISSION
SAINT PAUL, MINNESOTA

MTC-TD-83-01

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
MTC-TD-83-01		

4. Title and Subtitle

GUIDELINES FOR THE DESIGN OF TRANSIT RELATED ROADWAY IMPROVEMENTS

5. Report Date

MAY 1983

6. Performing Organization Code

7. Author(s)

DAVID R. JESSUP (MTC) / GLENN VAN WORMER (SEH) / HOWARD PRESTON (SEH)

8. Performing Organization Report No.

MTC-TD-83-01

9. Performing Organization Name and Address

METROPOLITAN TRANSIT COMMISSION
801 AMERICAN CENTER BUILDING
150 EAST KELLOGG BOULEVARD
SAINT PAUL, MINNESOTA 55101

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

MN-09-0042 MN-09-0048

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Urban Mass Transportation Administration
400 Seventh Street, S.W.
Washington, D. C. 20590

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

Report prepared by the Metropolitan Transit Commission (MTC) and Short-Elliot-Hendrickson, Inc. (SEH)

16. Abstract

The GUIDELINES FOR THE DESIGN OF TRANSIT RELATED ROADWAY IMPROVEMENTS is a technical reference document which reflects the current transit related factors which traffic engineers, architects, planners and developers should consider during the design process for streets and highways, as well as residential, commercial and industrial developments.

The report covers several topic areas which include: design vehicle operating characteristics, roadway facilities, traffic control devices, park-and-ride lots, passenger shelters, bus stop design, handicapped transportation and ridesharing considerations.

In addition, the report identifies, by subject matter, the appropriate transit contact person to answer various transit related questions. It also references related design manuals and standards developed by the Minnesota Department of Transportation, American Association of State Highway and Transportation Officials and the Institute of Transportation Engineers.

17. Key Words

DESIGN GUIDELINES
TRANSIT RELATED ROADWAY IMPROVEMENTS

18. Distribution Statement

AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	118	

Form DOT F 1700.7 (8-72)

GUIDELINES FOR THE DESIGN OF TRANSIT RELATED ROADWAY IMPROVEMENTS

PREPARED FOR:
METROPOLITAN TRANSIT COMMISSION
ST. PAUL, MINNESOTA

PREPARED BY:
SHORT-ELLIOTT-HENDRICKSON, INC.
CONSULTING ENGINEERS
ST. PAUL, MINNESOTA

May 18, 1983

UMTA PROJECT NUMBERS: MN-09-0042
MN-09-0048

This report is the product of a project financed in part by the U.S. Department of Transportation, Urban Mass Transportation Administration.

TABLE OF CONTENTS

PAGE

PREFACE i

1. **INTRODUCTION** 1
   - 1.1 Purpose of Design Guides
   - 1.2 Application of Design Guides
   - 1.3 Method of Presentation

2. **DESIGN VEHICLE** 4
   - 2.1 Dimensions, Capacity and Weights
   - 2.2 Turning Paths
   - 2.3 Underbody and Vertical Clearances
   - 2.4 Acceleration and Deceleration
   - 2.5 Pull-in and Pull-Out
   - Figure 2.1.1. Articulated Design Vehicle Dimensions, Capacity and Weight
   - Figure 2.1.2. 40 Foot Design Vehicle Dimensions, Capacity and Weight
   - Figure 2.1.3. Small Design Vehicle Dimensions, Capacity and Weight
   - Figure 2.1.4. Van Design Vehicle Dimensions, Capacity and Weight
   - Figure 2.2.1. Articulated Design Vehicle Turning Template, Scale 1" = 20'
   - Figure 2.2.2. 40 Foot Design Vehicle Turning Template, Scale 1" = 20'
   - Figure 2.2.3. Small Bus Design Vehicle Turning Template, Scale 1" = 20'
   - Figure 2.3.1. Underbody Clearance for Driveway Design
   - Figure 2.5.1. Bus Pull-In and Pull-Out

3. **THE DESIGN OF TRANSIT RELATED ROADWAY FACILITIES** 29
   - 3.1 Corner Radii
   - 3.2 Lane Width
   - 3.3 Pavement Design
   - 3.4 Location and Designing On-Street Bus Stops
   - 3.5 Bus Pull-Outs
   - 3.6 Bus Turnarounds
   - 3.7 Driveways
   - 3.8 Other Transit Facilities
   - Figure 3.1.1. Recommended Corner Radii
   - Figure 3.3.1. Recommended Typical Concrete Sections
   - Figure 3.3.2. Recommended Typical Bituminous Sections
   - Figure 3.4.1. Recommended Onstreet Bus Stop Design
   - Figure 3.5.1. Basic Buss Pull Out Design
   - Figure 3.7.1. Preferential Treatment for High Occupancy Vehicles

PAGE

4. **TRAFFIC CONTROL DEVICES** 61
   4.1 Traffic Signals
   4.2 Traffic Signs
   4.3 Pavement Markings
   4.4 Regulations
   Figure 4.2.1. Standard Signs

5. **PARKING AREAS** 69
   5.1 Park and Ride Lots
   5.2 Exclusive Park and Ride Lots
   5.3 Joint-Use Park and Ride Lots
   Figure 5.2.1. Typical Park and Ride Lot (Exclusive)

6. **WAITING AREAS AND PASSENGER SHELTERS** 75
   6.1 Introduction
   6.2 Waiting Areas
   6.3 Passenger Shelters
   6.4 Shelter Design Guidelines
   6.5 Shelter Location Guidelines
   Figure 6.2.1. Waiting Area
   Figure 6.4.1. Conceptual Passenger Shelter Design (Four Sided)
   Figure 6.4.2. Conceptual Passenger Shelter Design (Three Sided)
   Figure 6.5.1. Typical Shelter Locations

7. **TRANSIT FACILITIES FOR THE HANDICAPPED** 91
   7.1 Service for the Handicapped
   7.2 Special Service Vehicles
   7.3 Design of Stop Areas
   7.4 Pedestrian Facilities
   7.5 References
   Figure 7.3.1. Recommended On-Street Bus Stop Design for Special Handicapped Service Vehicles

8. **RIDESHARING** 97
   8.1 Carpools and Vanpools
   8.2 Design of Stop Areas
   8.3 Preferential Treatment

9. **APPENDIX** 101
   9.1 Articulated Design Vehicle Turning Template
   Scale 1" = 30'
   Scale 1" = 40'
   Scale 1" = 50'

   9.2 40 Foot Design Vehicle Turning Template
   Scale 1" = 30'
   Scale 1" = 40'
   Scale 1" = 50'

   9.3 Small Bus Design Vehicle Turning Template
   Scale 1" = 30'
   Scale 1" = 40'
   Scale 1" = 50'

PREFACE

The Metropolitan Transit Commission has prepared these Guidelines for the Design of Transit Related Roadway Improvements to help engineers, architects and developers evaluate transit and rideshare service considerations during preparation of development plans or roadway plans.

We hope this guide will be useful both as a reminder to consider transit early in planning and to provide specific information about design features for transit service. Listed below are the appropriate contact persons who can readily answer your specific transit related questions.

Subject	Contact Person	Phone #
• State, county and municipal highway reviews, road improvements, private developments & vehicle operating characteristics	Transit Development Section, Senior Development Planner	221-0939
• Bus routes, schedules and service planning; joint-use park and ride facilities	Service Planning Section, Manager	221-0939
• Design and construction of exclusive park and ride lots, bus turn-arounds, shelter installations and relocations.	Engineering and Facilities Division, Civil Engineer	642-2675
• Daily on-street bus operations, bus stop signs, temporary detours and route information.	Transportation Division, Manager, Street Operations	827-4071

Subject	Contact Person	Phone #
• Shelter maintenance (MTC Owned)	Engineering and Facilities Division, Manager of Facility Maintenance	642-2674
• Shelter maintenance (Privately owned with advertising within Minneapolis)	Transtop Minnesota, Inc. One Appletree Square Suite 1026 Minneapolis, Mn. 55420	854-1900
• Ridesharing	Special Services Division, Manager, Minnesota Rideshare	297-3800
• Handicapped Services	Special Services Division, Manager, Metro Mobility	644-1119

Please direct all inquiries, comments and recommendations regarding the content of this document to: Metropolitan Transit Commission, Transit Development Section, 801 American Center Building, 150 East Kellogg Boulevard, Saint Paul, Minnesota, 55101 or call the Transit Development Section, (612) 221-0939.

INTRODUCTION

1.1 Purpose of Design Guides:

The purpose of this report is to provide a uniform guide for the development and design of various transit related roadway improvements. The guidelines contained in this report both update and expand the substance and coverage of the previous report, which was adopted by the Metropolitan Transit Commission (MTC) in July, 1975.

1.2 Application of Design Guides:

The contents of this report are intended to serve as guidelines for those responsible for the design of transit related roadway improvements. Dimensions, turning criteria, operating characteristics and typical layouts are provided. This information applies to regular scheduled transit service, special service for the handicapped and ridesharing. The guidelines also apply to Central Business District (CBD), urban and suburban service areas and to both freeways and arterial streets. Much of the information is also useful for school buses and other larger vehicles.

This information should not be used by the designer as standard details on which to base a final design, but rather as recommended criteria that are valuable in attaining good designs and which should be considered when designing transit facilities. It cannot be overemphasized that these guidelines must be used in conjunction with sound evaluation of the facts and engineering judgement. Each particular site must be examined and each particular project must be evaluated from the aspect of safety, operations, and cost-effectiveness. The guideline approach provides state of the art information on the development and design of transit facilities while allowing flexibility to adjust to existing conditions, local needs, or fiscal constraints.

1.3 Method of Presentation:

The design guidelines are presented in seven sections. The first section documents the dimensions and operating characteristics of the various types of vehicles in the MTC's transit fleet. This information provides the basis for the geometric guidelines developed in subsequent sections.

The remaining six sections deal with the following:

- Transit related roadway facilities
- Traffic control devices
- Parking areas
- Passenger waiting areas and shelters
- Transit facilities for the handicapped
- Ridesharing

Several of these sections contain discussions of subjects which are more highway related than transit related. Complete discussions of topics such as geometric design, pavement design and signing are not provided. An attempt was made to give designers an idea of what should be considered to accommodate transit operations. If more detailed information is required the following documents should be consulted.

1) Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers (1982).

2) A Policy on Design of Urban Highways and Arterial Streets, American Association of State Highway and Transportation Officials (1973).

3) Road Design Manual, Minnesota Department of Transportation (1982).

4) Minnesota Manual on Uniform Traffic Control Devices, Minnesota Department of Transportation (1973).

DESIGN VEHICLE

2.1 Dimensions, Capacity and Weights:

The current MTC bus and Minnesota Rideshare fleet consists of the following general categories of vehicles.

- 60-foot articulated transit buses
- 40-foot standard transit buses
- Small buses
- Vans

The 60-foot and 40-foot buses are both used for regular, scheduled transit service and the small buses are primarily used to provide special service for the handicapped. In addition, the MTC coordinates vanpool and paratransit operations through Minnesota Rideshare. However, the vans used in this operation are not owned by the MTC.

The dimensions, passenger capacity and axle weights for these vehicles are shown in Figures 2.1.1 through 2.1.4. In the case where there is more than one make or type of vehicle within the general category, the range of dimensions for all buses is given in addition to data for the "Design Vehicle". The "Design Vehicle" is a composite of the various vehicles and uses the appropriate maximum or minimum values in order to accommodate a "worst case" design.

The small buses and vans are less restrictive in terms of size and weight than the standard 40 foot or articulated transit buses. The physical characteristics of the small buses and vans would be appropriate only for the design of a facility which would be served exclusively by these vehicles.

2.2 Turning Paths:

The minimum recommended design turning paths for the 60 foot articulated bus, 40 foot standard transit bus and small bus are shown in Figures 2.2.1 through 2.2.3, respectively and in the Appendix. These turning paths include an allowance for the front overhang and for driver reaction. They should be used for design purposes where bus speeds are less than 10 miles per hour. For speeds greater than 10 miles per hour or for reverse turns and other complicated maneuvers, a greater turning radius than those shown in Figures 2.2.1 through 2.2.3 should be used.

Additional information and instructions regarding the design of higher speed turns can be found in a variety of design texts, such as those published by the Minnesota Department of Transportation (Mn/DOT) or the American Association of State Highway and Transportation Officials (AASHTO) (See Section 1.3). Using the procedures outlined in these publications will provide a turning roadway which will safely accommodate the vehicle. However, a standing passenger (the "worst case" or design condition) may be subject to side forces. Therefore, special care must be taken when designing a higher speed turn.

Mylar templates can be made from the figures showing the turning paths of the three design vehicles and can be stored in the pocket attached to the inside of the back cover. These templates could be used during the design process in order to identify required corner radii, pavement widths and possible vehicle encroachments. A turning template for the vans operated by the MTC is not included because these vehicles have wheelbases and turning characteristics similar to passenger cars. Radius templates for this class of vehicle are readily available from other sources.

2.3 Underbody and Vertical Clearances:

Underbody clearance is an important consideration primarily in the design of driveways and other off-street facilities. The grades on ramps and driveways should be set so that the transit vehicles will not "bottom out" when using the facility.

When designing specifically for transit vehicles, the following three factors must be considered: (See Figure 2.3.1)

1) The Approach Angle - a function of the distance from the front axle to the front bumper and the distance from the ground to the bottom of the front bumper.

2) The Rollover Angle - a function of the wheelbase and underbody clearance.

3) The Departure Angle - a function of the distance from the rear axle to the rear bumper and the distance from the ground to the bottom of the rear bumper.

The table in Figure 2.3.1 shows the worst case Approach, Rollover and Departure Angles for the three general categories of vehicles in the current MTC bus fleet. It should be noted that these values assume a four inch factor of safety in the underbody clearance. This takes into account body movement, due to the suspension system, when the vehicle is in motion.

If a situation occurs where driveway grades cannot be changed but an analysis of the underbody clearance indicates that vehicles may "bottom out", the use of vertical curves is recommended.

The vertical height of doorways and canopies under which transit vehicles must pass is also an important design factor. Consideration must be given to each type of vehicle which may use a facility to ensure that damage does not occur to the structure or the vehicle. The vertical heights of transit vehicles are shown in Figures 2.1.1 through 2.1.4. A factor of safety for snow covered roads or vertical vehicle "bounce" should be added.

2.4 Acceleration and Deceleration:

Information on vehicle acceleration and deceleration capabilities is needed to evaluate or design tapers at ramps, pull-outs and other transit related roadway facilites.

Typical average acceleration rates for urban transit buses on level roadways are as follows:

0-15 MPH: 3 ft/sec/sec
0-30 MPH: 2 ft/sec/sec
0-50 MPH: 1.5 ft/sec/sec

Typical deceleration rates range from 3 ft/sec/sec to 5 ft/sec/sec. The table below shows recommended stopping distances for velocities of between 10 and 55 miles per hour.

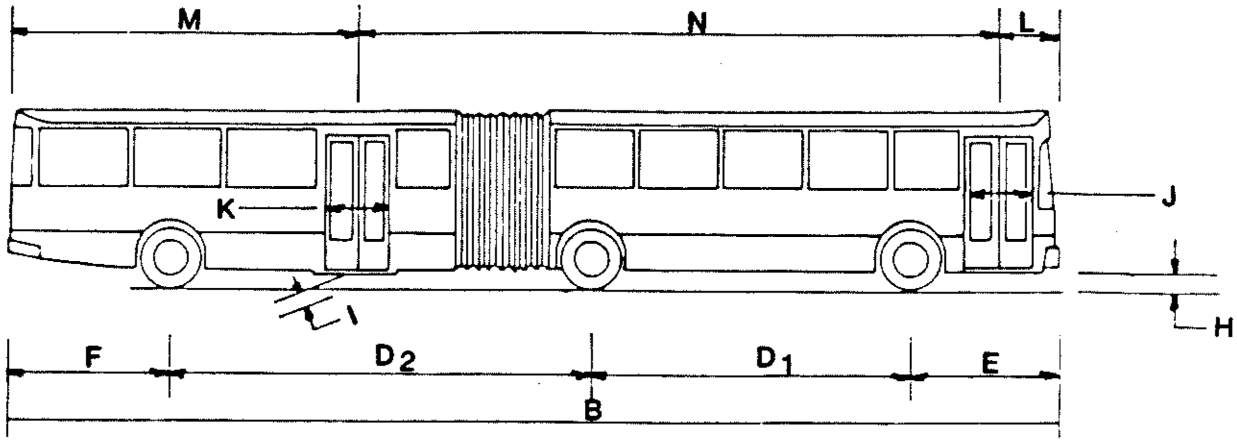
INITIAL VELOCITY	RECOMMENDED STOPPING DISTANCE
10 MPH	25 FT.
15 MPH	55 FT.
20 MPH	100 FT.
25 MPH	155 FT.
30 MPH	220 FT.
35 MPH	300 FT.
40 MPH	400 FT.
45 MPH	500 FT.
50 MPH	620 FT.
55 MPH	750 FT.

These rates are applicable for a vehicle with standing passengers.

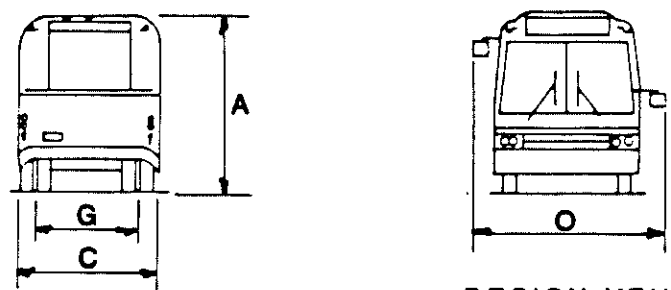
For specific designs, the effect of roadway grades and their impact on bus performance may have to be taken into account. The procedures for analyzing the impacts of truck operations on grades, found in the previously mentioned Mn/DOT and A.A.S.H.T.O. publications, should be used. The acceleration capability of buses and their weight to horsepower ratio are such that the procedures used for trucks will produce a satisfactory design for buses.

2.5 Pull-in and Pull-out

At exclusive bus layover areas, garages and other low speed (5 mph. or less) traffic conditions where several buses may be parked or waiting simultaneously, it is desireable to provide adequate longitudinal distance and width for buses to independently pull-in parallel to the curb and pull-out without encroaching on the adjacent lane or require the moving of adjacent vehicles. Figure 2.5.1 shows minimum dimensions of these maneuvers.



** M.A.N. SG 310



ITEM		DESIGN VEHICLE **
A	Overall Height	10'4"
B	Overall Length	60'0"
C	Overall Width	8'6"
D	Wheel Base (D_1 / D_2)	18'7"/24'0"
E	Front Axle to Bumper	8'8"
F	Rear Axle to Bumper	8'8"
G	Dist. Between Rear Wheels	7'1"
H	Step to Ground, Entrance	1'2"
I	Step to Ground, Exit	1'2"
J	Clr. Door Opening, Entrance	3'7"
K	Clr. Door Opening, Exit	4'2"
L	Centerline Door to Front	3'6"
M	Centerline Door to Rear	21'4"
N	Centerline Door to Door	35'0"
O	Edge Mirror to Mirror	9'9"
	Seating Capacity	67
	Standing Capacity	30
	Driver's Eye Height	91"
	Front Axle Wt. Net/Gross*	11,800/15,700
	Rear Axle Wt. Net/Gross*	12,130/18,430
	Center Axle Wt. Net/Gross*	14,970/19,320

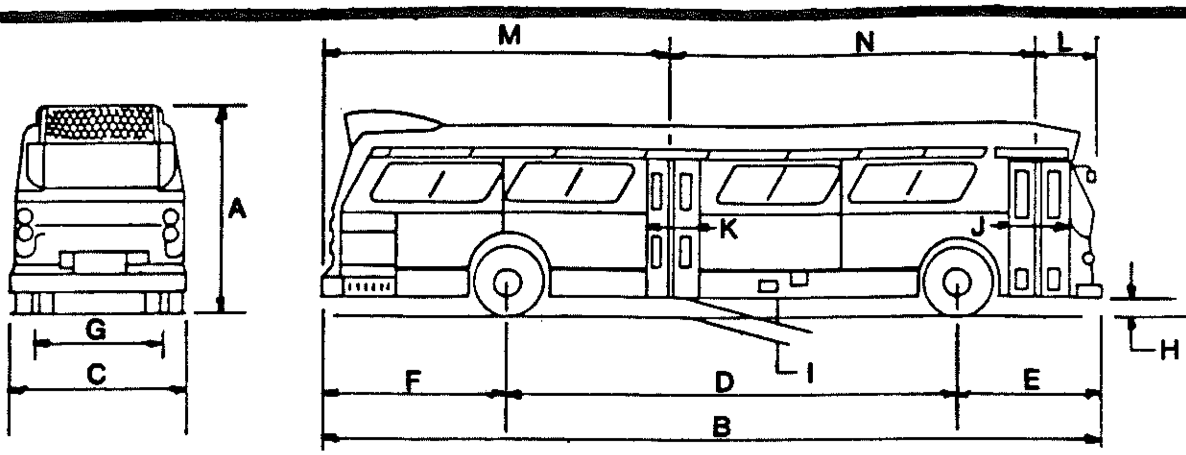
*Net Wt. is "road ready" without passengers, Gross includes passengers

TRANSIT RELATED ROADWAY IMPROVEMENTS

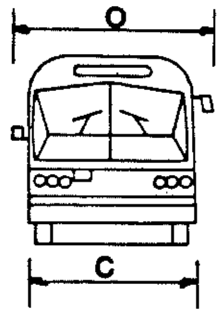
Articulated Design Vehicle Dimensions, Capacity, & Weight

FIGURE 2.1.1. MAY 1983

Metropolitan Transit Commission



**GMC 5303
FLXIBLE 111CC
FLXIBLE 53102
AM GENERAL 10240-B



	ITEM	DESIGN VEHICLE	RANGE FOR 40' BUSES**
A	Overall Height	10'9"	9'8-3/4" — 10'9"
B	Overall Length	40'0"	39'9" — 40'0"
C	Overall Width	8'6"	8'5" — 8'6"
D	Wheel Base	23'9"	23'5-3/4" — 23'9"
E	Front Axle to Bumper	7'3-3/4"	6'9" — 7'3-3/4"
F	Rear Axle to Bumper	9'4-3/4"	9'0" — 9'4-3/4"
G	Dist. Between Rear Wheels	6'9"	6'4-1/2" — 6'9"
H	Step to Ground, Entrance	1'5"	1'1-1/2" — 1'4-15/16"
I	Step to Ground, Exit	1'4-1/2"	1'2" — 1'4-7/16"
J	Clr. Door Opening, Entrance	2'6"	2'3" — 2'6"
K	Clr. Door Opening, Exit	2'2-1/2"	1'11-1/2" — 2'2-1/2"
L	Centerline Door to Front	3'0"	2'11-3/4" — 3'0"
M	Centerline Door to Rear	17'11-1/4"	17'2" — 17'11-1/4"
N	Centerline Door to Door	19'8"	19'1" — 19'8"
O	Edge Mirror to Mirror	10'2"	9'10" — 10'2"
	Seating Capacity	51	49 — 51
	Standing Capacity	25	25
	Driver's Eye Height	87"	87" — 91"
	Front Axle Wt. Net/Gross*	7,420/11,980	6,950/11,920-7,420/11,980
	Rear Axle Wt. Net/Gross*	18,060/24,660	16,550/23,070-18,060/24,660

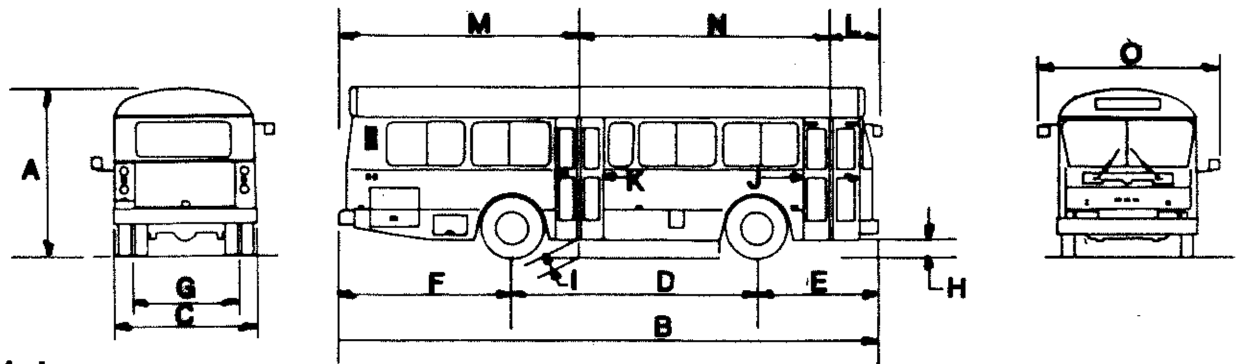
*Net Wt. is "road ready" without passengers, Gross includes passengers

TRANSIT RELATED ROADWAY IMPROVEMENTS

40 Foot Design Vehicle Dimensions, Capacity, & Weight

FIGURE 2.1.2. MAY 1983

Metropolitan Transit Commission



**** GRUMMAN M-500**
FORTIBUS E375A
CARPENTER CBW-300

	ITEM	DESIGN VEHICLE	RANGE** FOR MTC BUSES
A	Overall Height	10'2"	9'3"–10'2"
B	Overall Length	31'2"	21'1"–31'2"
C	Overall Width	8'	7'5"–8'
D	Wheel Base	14'9"	11'1"–14'9"
E	Front Axle to Bumper	7'3"	2'–7'3"
F	Rear Axle to Bumper	9'6"	6'–9'6"
G	Dist. Between Rear Wheels	7'11"	4'1"–7'9"
H	Step to Ground, Entrance	1'2"	1'–1'2"
I	Step to Ground, Exit	2'4"	1'2"–2'4"
J	Clr. Door Opening, Entrance	3'	2'4"–3'
K	Clr. Door Opening, Exit	3'1"	2'6"–3'1"
L	Centerline Door to Front	7'3"	2'11"–7'3"
M	Centerline Door to Rear	13'4"	10'4"–13'4"
N	Centerline Door to Door	14'3"	3'7"–14'3"
O	Edge Mirror to Mirror	10'4"	7'8"–10'4"
	Seating Capacity	18	10–18
	Wheelchair Capacity	5	4–5
	Driver's Eye Height	78	78–91
	Front Axle Wt. Net/Gross*	6360/7235	4200/4900–6360/7235
	Rear Axle Wt. Net/Gross*	14200/17231	4830/6605–14200/17231

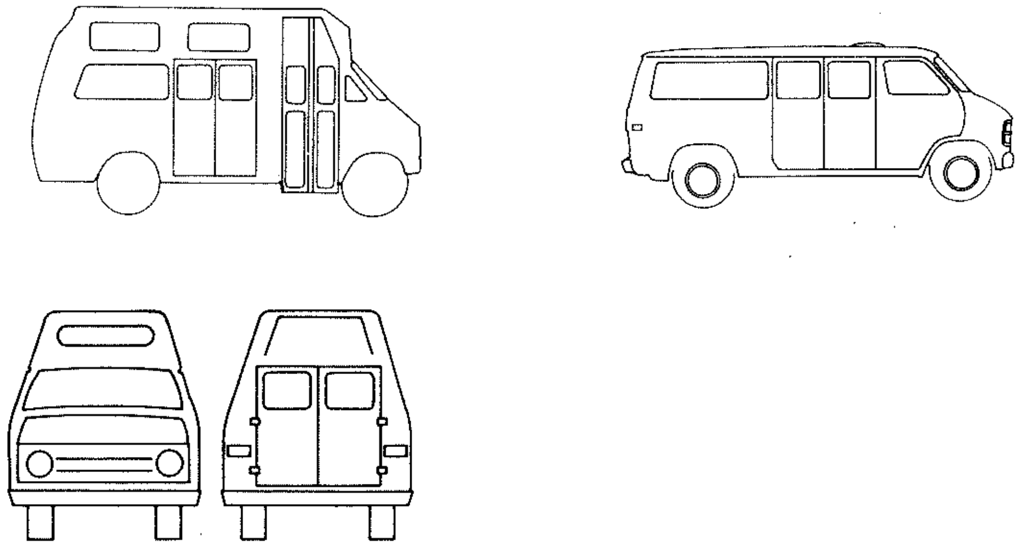
*Net Wt. is "road ready" without passengers, Gross includes passengers

TRANSIT RELATED ROADWAY IMPROVEMENTS

Small Design Vehicle Dimensions, Capacity, & Weight

FIGURE 2.1.3. **MAY 1983**

Metropolitan Transit Commission



	ITEM	TRAVEL EQUIPMENT CCTS VAN	MINNESOTA RIDE SHARE VAN
A	Overall Height	8' 4"	6' 8"
B	Overall Length	18'	16' 4"–18' 6"
C	Overall Width	6' 8"	6' 6"
D	Wheel Base	10' 6"	10' 7"
E	Front Axle to Bumper	2'	2'
F	Rear Axle to Bumper	5' 2"	5'
G	Dist. Between Rear Wheels	5' 6"	5' 4"
H	Step to Ground, Entrance	10'	10'
I	Step to Ground, Exit	N/A	N/A
J	Clr. Door Opening, Entrance	2'	3' 4"
K	Clr. Door Opening, Exit	N/A	N/A
L	Centerline Door to Front	5' 7"	7' 10"
M	Centerline Door to Rear	4' 3"	8' 4"
N	Centerline Door to Door	N/A	N/A
O	Edge Mirror to Mirror	7' 7"	7' 5"
	Seating Capacity	11	12–15
	Standing Capacity	0	0
	Front Axle Wt. Net/Gross*	3,020/3,320	3,600/4,350
	Rear Axle Wt. Net/Gross*	3,240/3,690	5,500/7000

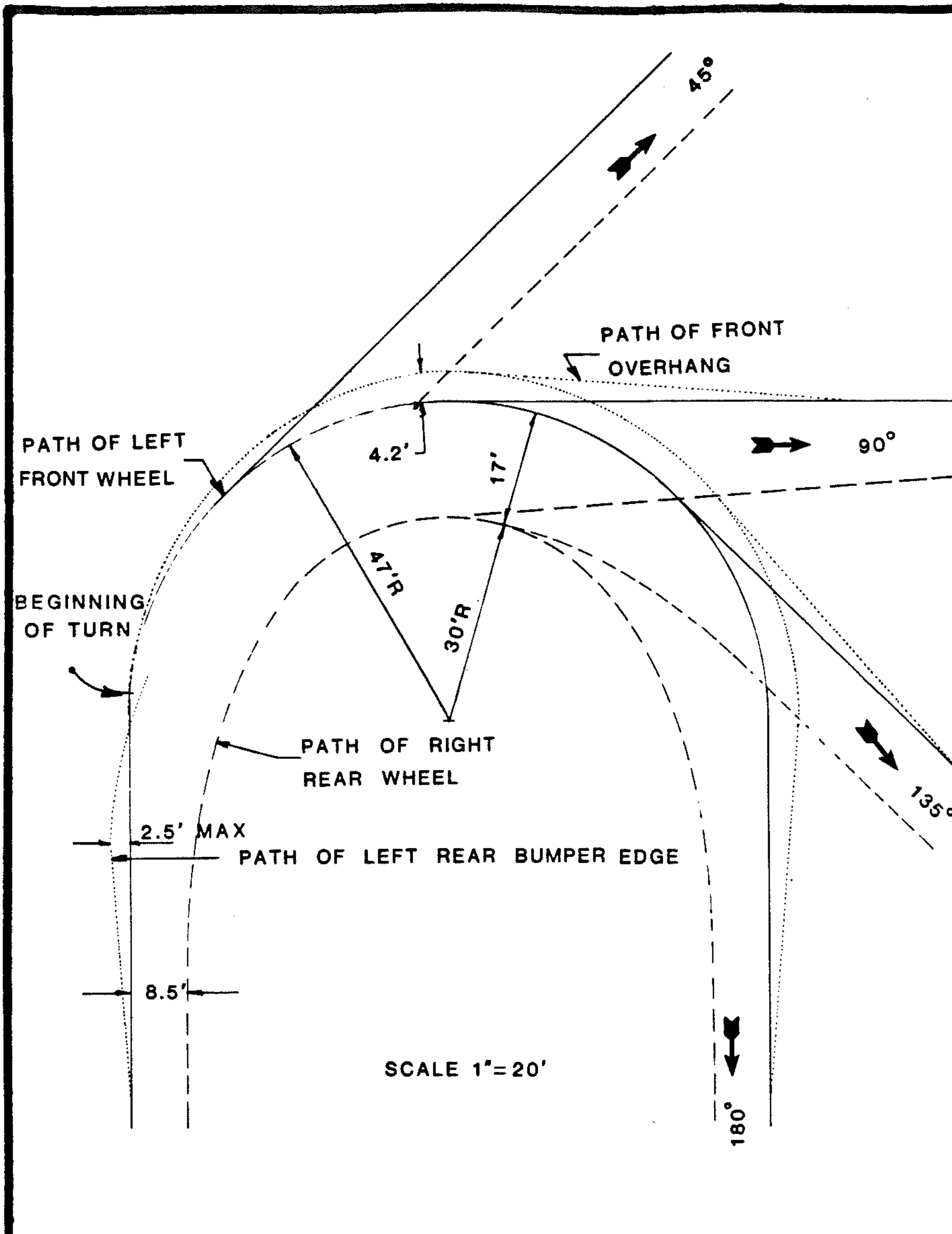
*Net Wt. is "road ready" without passengers, Gross includes passengers

TRANSIT RELATED ROADWAY IMPROVEMENTS

Van Design Vehicle
Dimensions, Capacity, & Weight

FIGURE 2.1.4. MAY 1983

Metropolitan Transit Commission

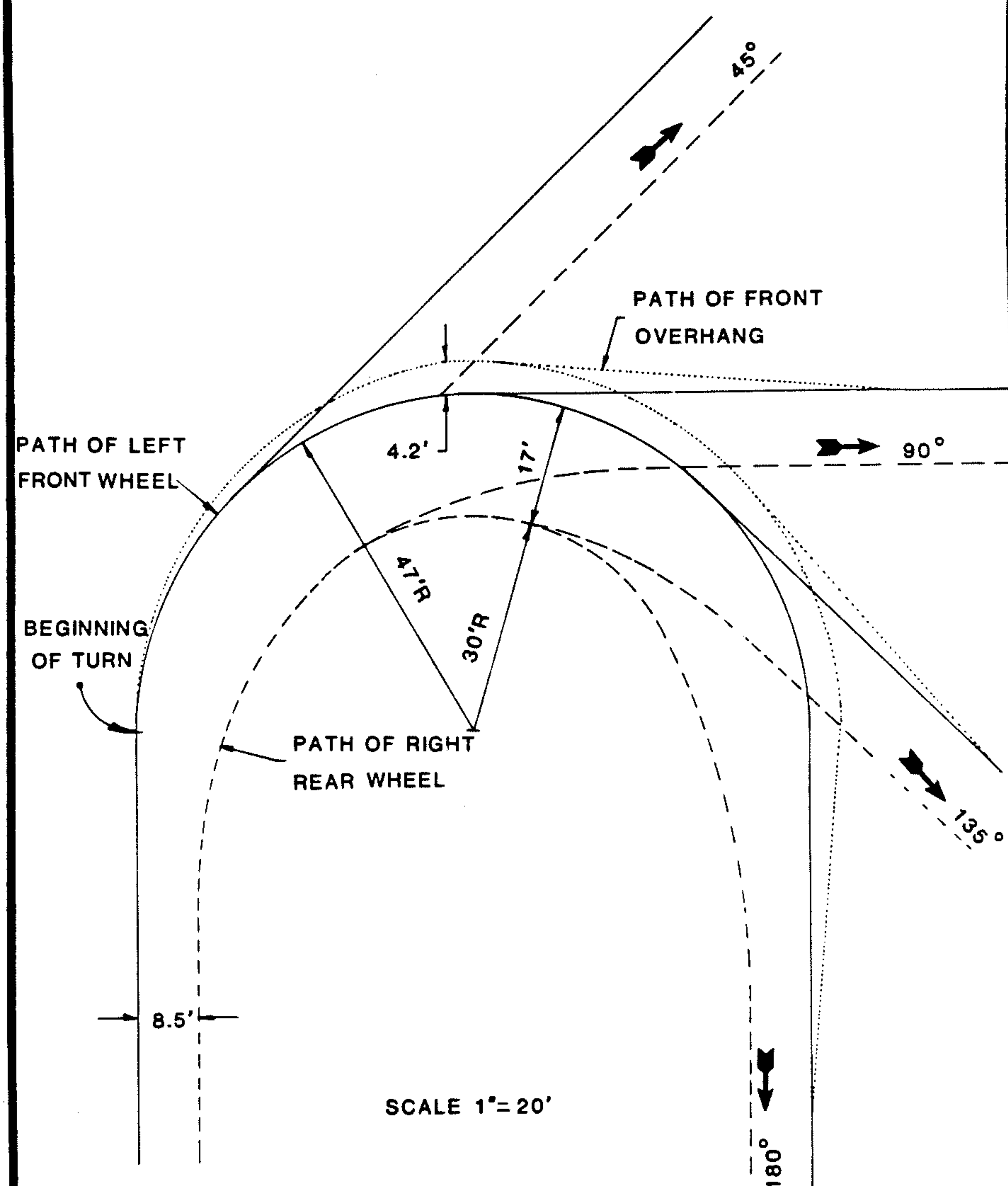


TRANSIT RELATED ROADWAY IMPROVEMENTS

Articulated Design Vehicle
Recommended Design Turning Template

FIGURE 2.2.1. MAY 1983

Metropolitan
Transit Commission

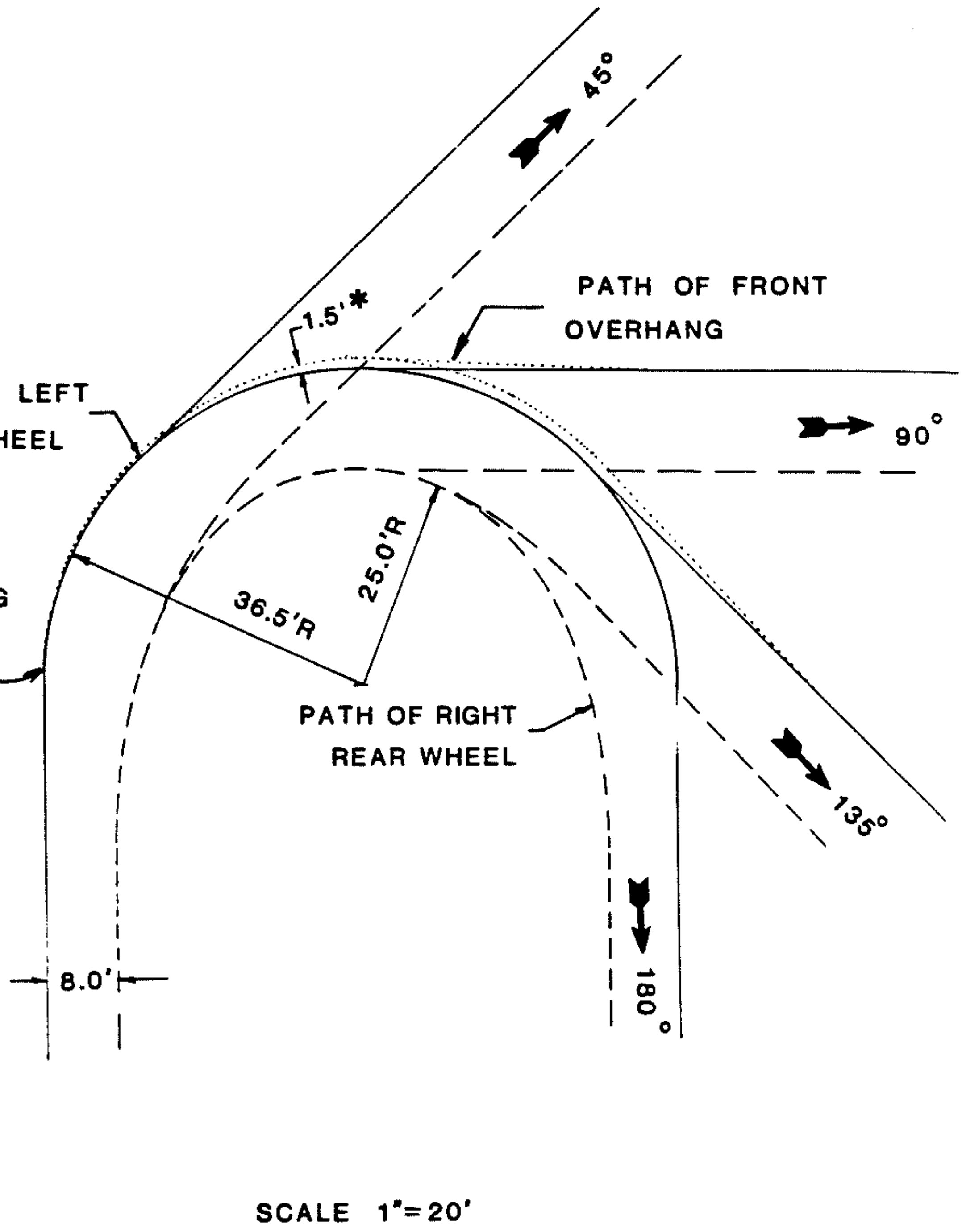


TRANSIT RELATED ROADWAY IMPROVEMENTS

40 Foot Design Vehicle
Recommended Design Turning Template

FIGURE 2.2.2. MAY 1983

Metropolitan Transit Commission



* SOME SMALL BUS VEHICLES HAVE A LARGER FRONT OVERHANG BUT SMALLER TURNING RADIUS

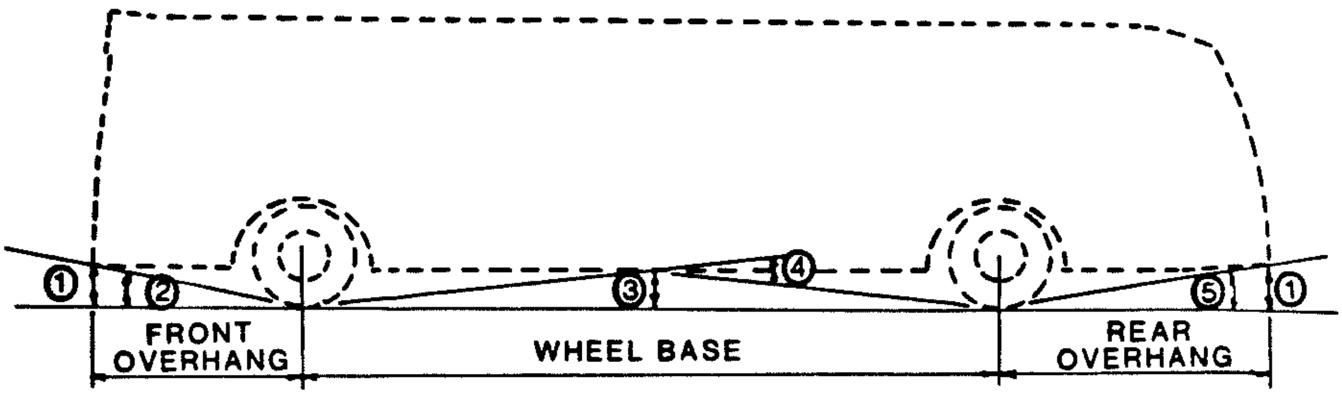
TRANSIT RELATED ROADWAY IMPROVEMENTS

Small Bus Design Vehicle

Recommended Design Turning Template

FIGURE 2.2. 3. MAY 1983

Metropolitan Transit Commission



① GROUND TO BUMPER CLEARANCE

② APPROACH ANGLE

③ UNDERBODY CLEARANCE

④ ROLLOVER ANGLE

⑤ DEPARTURE ANGLE

VEHICLE CLASS	APPROACH ∡ %/o	ROLLOVER ∡ %/o	DEPARTURE ∡ %/o
60' ARTICULATED TRANSIT BUS	9.6% / 5.5°	6.2%* / 3.6°*	9.1% / 5.2°
40' STANDARD TRANSIT BUS	12,3% / 7.0°	9.8% / 5.6°	6.3% / 3.6°
SMALL BUS	10.9% / 6.2°	11.4% / 6.4°	9.0% / 5.1°

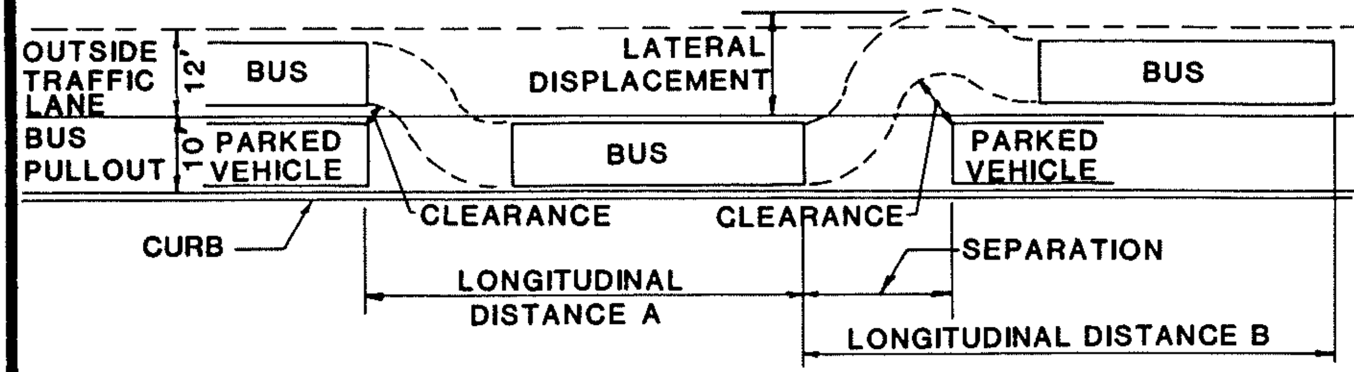
* ON THE ARTICULATED BUS THE CRITICAL ROLLOVER OCCURS ON THE TRAILER SECTION

TRANSIT RELATED ROADWAY IMPROVEMENTS

Underbody Clearance for Driveway Design

FIGURE 2.3.1. MAY 1983

Metropolitan Transit Commission



TYPE OF BUS	LONGITUDINAL DISTANCE A	SEPARATION	LATERAL DISPLACEMENT	LONGITUDINAL DISTANCE B	CLEARANCE
40' DESIGN VEHICLE	80 FT	10 FT 20 FT 30 FT	14.25 FT 13.25 FT 12 FT	70 FT 60 FT 60 FT	1 FT 1 FT 1 FT
60' ARTICULATED VEHICLE	110 FT	10 FT 20 FT 30 FT	13.75 FT 12.25 FT 12 FT	80 FT 75 FT 70 FT	1 FT 1 FT 1 FT

MINIMUM DISTANCES REQUIRED AT
5 MPH OR LESS IN EXCLUSIVE TRANSIT FACILITY

TRANSIT RELATED ROADWAY IMPROVEMENTS

BUS PULL IN AND PULL OUT

FIGURE 2.5.1 MAY 1983

Metropolitan
Transit Commission

THE DESIGN OF TRANSIT RELATED ROADWAY FACILITIES

3.1 Corner Radii:

An important element in the design of transit related roadway facilities is the corner radius. The selection of a corner radius for a street intersection or driveway should be based on the turning capabilities of the design vehicle, the widths of the intersecting roadways or driveway involved, and the amount of encroachment into adjacent lanes which can be tolerated.

If the facility being designed is intended to be used exclusively by transit vehicles, a bus would be an appropriate choice for a design vehicle. If, however, the facility is to be used by general traffic, the selection of either a single unit truck or a tractor-semitrailer may be more appropriate. In the latter case, a design based on the operating characteristics of a truck should be checked to ensure that a bus would also be satisfactorily accommodated.

The width of the roadways involved enters into the design because as the width increases, the length of the radius required to accommodate the turning vehicle decreases. For example, if the width of both roadways is 12 feet, a single curve with a radius of approximately 50 feet is required in order to accommodate a 90° turn by a bus with no encroachment outside the 12 foot lanes. If the width of both roadways is increased to 16 feet, the length of the radius required in order to accommodate the bus with no encroachment outside the 16 foot lanes decreases to 40 feet.

The final element of corner radii design is the amount of lane encroachment which can be tolerated. This tends to be a subjective decision made by the designer based on an evaluation of the speed and volume of the vehicles involved and the functional classification of the roadways. In general, there should be no encroachment. However, in low speed, low volume situations, some encroachment into adjacent lanes may be acceptable.

One additional item should also be evaluated. At intersections, as the size of the corner radius increases, the walking distance across the intersection increases. Designers should be aware of this pedestrian factor and be prepared to accommodate the pedestrians if the length of one particular crossing increases to the point where it may create operational problems.

When designing a new facility, the designer should select the design vehicle, the roadway widths, and determine the amount of encroachment which can be tolerated. Figure 3.1.1 shows appropriate corner radii for transit vehicles and various combinations of lane widths. These figures may be used as a starting point but should be checked with an appropriate turning radius template before being incorporated in a final design.

If an existing intersection or driveway is to be evaluated for transit operations, a layout showing existing lane widths and corner radii should be prepared. The layout should then be checked with the appropriate turning radius template and the resulting encroachment, if any, determined. This can then be compared to the amount of encroachment that can be tolerated and potential remedial efforts such as increases in lane width or corner radii evaluated.

The simple curve is the most common corner radius which will be encountered in typical urban designs. However, in some special situations such as skewed intersections or when it is desirable to allow turns at speeds greater than 10 miles per hour, the designer should consider using a compound curve. Compound curves consist of more than one curve or a simple curve with taper offsets. Compound curves have an advantage over simple curves because they more closely fit the natural turning paths of design vehicles.

Design procedures using compound curves and the channelization which frequently accompanies them can be found in the previously mentioned A.A.S.H.T.O. or Mn/DOT design publications.

3.2 Lane Width:

The width of the roadway over which a bus must travel has a significant impact on the overall transit operation. If the width is very narrow, a bus must travel very slowly in order to safely negotiate the roadway. As lane widths increase, the operating speed of the bus will also increase, up to a reasonable limit.

On public streets, the traveled lanes are typically 10 to 12 feet wide. While buses can satisfactorily operate within these widths, the 12 foot width is recommended because it provides a more appropriate area for driver reaction.

When a roadway is being designed exclusively for transit operations (such as driveways, approaches to park and ride facilities or exclusive bus lanes) the recommended minimum width for the roadway is as follows:

One-way operation: 20 feet
Two-way operation: 28 feet

These values do not include the width of gutters when a curbed section is used.

3.3 Pavement Design:

The basic requirement of a pavement section is to provide a durable travel surface which will withstand the repeated wheel loads of transit vehicles.

The two types of pavements recommended for use at transit facilities are rigid (concrete) and flexible (bituminous) surfaces. Each of these surfaces has advantages and disadvantages. The designer should select the pavement type which will result in the most favorable combination of economic and engineering factors.

Concrete pavements are generally more expensive than bituminous pavements. However, the concrete pavement provides better resistance to rutting and shoving caused by the repeated starting and stopping of buses. In addition, the concrete pavement is more resistant to deterioration from spilled petroleum products. Therefore, the concrete pavement tends to hold up better under transit use and requires less maintenance than a bituminous pavement.

Pavement design for transit usage is similar to the normal pavement design procedures for streets and highways. The recommended pavement thickness is a function of subsurface soil conditions and the number and weight of the vehicles expected to use the facility during its design life.

Pavement Design Recommendations

1) The subsurface soils should be uniform and granular in order to minimize moisture problems and provide an adequate base for the pavement surface.

If the inplace soils do not meet this requirement, they should be excavated and replaced with at least 24 inches of a suitable material. A detailed soils investigation is recommended prior to actually designing the pavement.

2) Areas such as bus pads which are subject to repeated starting and stopping should have a concrete surface. Figure 3.3.1 shows recommended typical sections for concrete pavement. These sections assume plastic subsurface soils (clay or silt) with 24 inches of granular material subbase and 6 inches of crushed rock base.

3) Areas such as driveways, parking lots, and turnarounds which are not subject to repeated starting or stopping could have a bituminous surface. Figure 3.3.2 shows recommended typical sections for bituminous pavements. These sections assume plastic subsurface soils (clay or silt) with 24 inches of granular material subbase and a minimum of 6 inches of crushed rock base.

The typical concrete and bituminous sections shown in Figures 3.3.1 and 3.3.2 utilize Mn/DOT design methods and are for facilities to be used exclusively by buses. When designing a pavement for a facility which will be used by a variety of vehicles, the pavement design procedures outlined in the

Mn/DOT Road Design Manual should be utilized and the expected number of buses reflected in the calculations.

3.4 Locating and Designing On-Street Bus Stops

The most common roadway related transit facility a designer will encounter is locating and designing on-street bus stops.

Locations

On-street bus stops may be near side, far side and mid-block. The decision as to which type of stop is appropriate for a particular situation should be based on an engineering investigation. No one type of stop can be recommended for all stop locations.

The three types of bus stops have the following general characteristics (See Figure 3.4.1):

- Near Side Bus Stops
  Located in advance of the intersection using an area just before the crosswalk.

- Far Side Bus Stops
  Located on the far side of the intersection just beyond the crosswalk.

- Mid-Block Bus Stops
  Located between intersections usually near a major pedestrian generator.

Location Factors

The engineering investigation which is required in order to select the most appropriate type of stop should consider the following factors:

1) Traffic Volumes and Turning Movements

   A differential volume of traffic on the near side or far side of the intersection could allow less bus-vehicle conflicts with the stop on the lower volume side.

   A near side bus stop will conflict with right turning traffic. Traffic must either turn right, crossing in front of the stopped bus, or wait behind the bus potentially blocking a through lane.

   The near side bus stop can operate as a right turn lane when buses are not present.

   High vehicle turning movement volumes can cause more bus-vehicle conflicts at the bus stop. A far side bus stop can conflict with right turns from the cross street onto the bus route.

2) Bus Volumes and Turning Movements

   The turning of buses within an intersection will somewhat dictate bus stop locations. A left turn will require a far side stop or mid-block stop.

   The volume of buses will have a bearing on total space required for the bus stop, amount of parking removed and potential for vehicle backup.

3) Traffic Control

A near side bus stop puts a bus in a potential position of obscuring stop signs, traffic signals and other traffic signs on the approach to the intersection.

A far side bus stop at a stop sign controlled intersection would require the bus to make two stops while a near side bus stop would allow a single dual purpose stop.

A near side stop at a traffic signal controlled intersection could allow a bus to stop, unload and load passengers during the red phase of the signal, depending on when the bus arrived. However, it could also delay the bus if it changed to the red phase just as the loading of passengers was completed. Refer to Section 4.1 for a further discussion of traffic signal operation and bus stops.

If the cross street is one way from right to left, a near side bus stop will have little traffic interference. Similarly, a far side bus stop will have less interference where the cross street is one way from left to right.

4) Parking

Bus stops generally will require removal of some parking. A mid-block bus stop generally will require the greatest amount of parking to be removed. A far side bus stop generally requires the least parking removal, if there are no parking prohibitions in effect for other purposes.

A near side bus stop can be used as a right turn lane when buses are not present. Thus a low bus volume route can use a right turn lane for a near side bus stop with little or no extra parking removal.

The importance of parking on various corners of the interection might vary. A heavy demand for short term parking could lead to frequent use of the bus stop for illegal parking.

5) Intersection Characteristics
Variations in roadway width or number of lanes could permit bus stops to interfere less with traffic in one location than another.

Stopped buses at near side bus stops could create sight distance restrictions to cross street traffic while buses at far side bus stops could create similar restrictions for traffic entering the street from driveways or alleys.

6) Pedestrian Movements
Near side bus stops permit pedestrians to cross in front of a bus, with very limited sight distance. Far side bus stops have pedestrians crossing behind the bus with improved sight distance. Mid-block bus stops invite pedestrians to cross the street at the mid-block location.

The origins and destinations of transit patrons should be considered and the bus stop location coordinated with them to reduce the total number of streets the pedestrians must cross.

A mid-block crosswalk can often be located close to the pedestrian and passenger generators.

Transfers of passengers from one bus to another can be made without crossing a street if both stops are in the same quadrant of the intersection. Bus drivers at near side stops have greater visibility of passengers transferring from other buses.

7) Pedestrian-Passenger Facilities
Bus stops should be coordinated with lighting, sidewalks and waiting facilities whether they are already inplace or possible future installations.

The bus stop location should allow loading and unloading of passengers without interference from landscaping, street hardware, signs, etc.

Bus stop locations should reflect existing and proposed street lights.

The bus stop location should provide a safe waiting area, away from vehicle conflicts or movements. One quadrant might offer more security and safety. Refer to Section 6.2 for more information on waiting areas.

8) Other Factors

A far side bus stop could cause traffic to back up into the intersection. This could be caused by a stop located in a lane of traffic, illegal parking in the bus stop, turning traffic or more than one bus in the bus stop.

A bus stop for a low volume bus route could be coordinated with a vanpool or carpool pickup location.

A bus stop served only by peak period buses could be coordinated with a non-peak period loading zone.

Designs

Once the location for the on-street bus stop has been selected, the stop area must be properly designed in order to safely and conveniently accommodate both the design vehicle and bus passengers. Sufficient room must be provided so the bus can pull in, park parallel to the curb, and pull out with a minimum of disruption to through traffic. In addition, appropriate traffic control devices must be provided so that the stop area is delineated and parking is restricted.

Figure 3.4.1 shows typical near side, far side and mid-block stops with recommended dimensions. These recommended designs will allow a bus to pull into and out of the stop area with sufficient clearances from parked vehicles and without encroaching on more than one lane of traffic. The recommended designs provide for stopping and storing a single bus. If more than one bus is to use the stop at the same time, an additional 65 feet should be added for each extra bus.

The recommended traffic control devices for these stops are discussed in Sections 4.2. and 4.3.

After locating the bus stop and providing for the transit vehicle, provisions must also be made for accommodating the passengers. In general, an all-weather surface should be provided adjacent to the stopped vehicle at all stops. Details and designs for passenger waiting areas and shelters are found in Chapter 6.

Special considerations for bus stops and transit facilities for the handicapped can be found in Chapter 7. Ridesharing stop locations, loading and unloading details, and related considerations can be found in Chapter 8.

3.5 Bus Pull-Outs: A bus pull-out is a specially constructed area for bus loading and unloading which is completely off the through lanes of a roadway. Pull-outs are provided primarily on high volume or high speed roadways in order to improve the safety and efficiency of bus operations and to minimize disruption to through traffic.

The basic design of a bus pull-out (see Figure 3.5.1) consists of three parts:

1) A deceleration area
2) A full-width stopping area
3) An acceleration area

The lengths of the deceleration and acceleration areas are functions of the operating speeds on the adjacent roadway, the operating characteristics of the bus and the amount of force which can be tolerated by a standing passenger. Figure 3.5.1 also shows the recommended taper lengths for a variety of roadway operating speeds.

The stopping area should be minimum of 10 feet wide for operating speeds less than or equal to 30 miles per hour and 12 feet wide for speeds greater than 30 miles per hour. The length of the stopping area should be a minimum of 80 feet. If two or more buses are expected to stop in the pull out at the same time the length should be increased by 65 feet for each additional bus.

It should be noted that the recommended pull-out designs assume that a considerable amount of speed change will take place when the bus is still occupying at least a portion of the outside through lane. If this situation cannot be tolerated because of the operating characteristics of the roadway (for example on expressways and freeways), the designer should refer to the recommended procedures for designing parallel acceleration and deceleration lanes in the Mn/DOT Road Design Manual.

The use of the Mn/DOT recommended design meets the criteria for bus operations and tolerable forces on standing passengers. It will also result in design uniformity. The resulting speed change lanes for buses will look like and operate in a fashion similar to the rest of the speed change lanes on the Metropolitan area system of high speed arterial roadways.

In recent years, bus service has been extended into the suburban and rural areas surrounding the Twin Cities. As a result, buses are sometimes routed over low volume (less than 5,000 vehicles per day) rural design roadways. In these cases, occasional stops along the roadway by transit vehicles are not critical. However, it is recommended that a minimum 10' wide paved stopping area be provided for the bus. Lengthy tapers, as previously recommended, are not often necessary because the speed change can be accommodated in the through lanes without a significant impact due to the low traffic volume.

Regardless of the type of roadway, provisions for pedestrians should be provided. As a minimum, an all-weather surface adjacent to the entire length of the stopping area should be provided. For additional information regarding passenger waiting areas, see Chapter 6.

3.6 Bus Turnarounds

Bus turnarounds are special facilities designed for exclusive use by buses. The purpose of the bus turnaround is to provide a location in which buses may layover and reverse route direction. They may be provided as part of a roadway facility or may be provided as an exclusive transit facility.

The reason for providing a bus turnaround at any particular site may be based upon one or more the following reasons:

- The on-street bus terminal cannot be tolerated because the roadway does not allow for vehicle parking.
- The intersecting minor streets cannot accommodate the axle weights of a bus.
- The neighboring environment is sensitive to bus operations.
- The on-street routing necessary for the bus to reverse direction requires an unacceptable amount of unproductive mileage.
- The current layover or route reversal maneuver, once acceptable, has become hazardous due to increases in traffic or due to other changes which have been made in the roadway system.

Factors to be considered in designing a bus turnaround include:

- Number of buses using the facility.
- Number of buses simultaneously at the site.
- Passenger amenities
- Lighting
- Safety
- Maintenance Activities

The physical and operating characteristics of buses contained in Chapters 2 and 3 should provide sufficient information to develop a plan for a bus turnaround.

3.7 Driveways:

The MTC frequently serves facilities such as nursing homes, senior citizen highrise apartments, and hospitals picking up passengers at locations off the public street system. In such cases a driveway or access road would be required.

Special care must be taken when designing such a driveway or access road to ensure reasonable bus operations. The designer should consider the following factors:

- Corner radii
- Driveway width
- Horizontal alignment
- Vertical alignment
- Horizontal and vertical clearances
- Pavement structural design
- Stopping and pick-up area.

No driveway or access road should be designed as a dead end which requires the bus to back up in order to exit. Due to the size of the bus, drivers have extremely limited vision to the rear and all backing maneuvers should be avoided.

An adequately designed driveway will be based on an evaluation of the previously mentioned factors and should consist of the following:

1) Corner radii - Encroachment in the driveway is usually acceptable, therefore the size of the radius will be dictated by the width and parking condition on the approaching street. The final design should be checked with the appropriate turning radius template.

2) Driveway width - A one-way driveway should be a minimum of 20 feet wide plus gutters and a two-way drive should be a minimum of 28 feet wide plus gutters.

3) Horizontal alignment - The horizontal alignment should not contain curves with radii shorter than 50 feet.

4) Vertical alignment - The grades on driveways should be less than 6%. In addition, the recommended change in grades, as indicated in Section 2.3, should not be exceeded.

5) Horizontal and vertical clearances - Landscape material as well as highway and utility hardware should be set back sufficiently far from the edge of the driveway in order to clear the body overhang while the bus is maneuvering. In addition, there must be sufficient vertical clearance under all canopies, gates, and other structures in order to accommodate the approximate 11 foot height of the bus. A 12.5 foot vertical clearance is recommended.

6) Stopping and pickup area - The stopping area should be relatively flat with grades and cross slopes less than 4%. In addition, a loading and passenger waiting area at least 12 feet wide should be provided and it should be on the same profile grade as the stopping area. This last feature must be provided in order to facilitate the loading and unloading of handicapped individuals on vehicles fitted with wheelchair lifts.

3.8 Other Transit Facilities

In recent years, improvements in transit operations have been achieved through the preferential treatment of buses and high occupancy vehicles on both freeways and arterial streets.

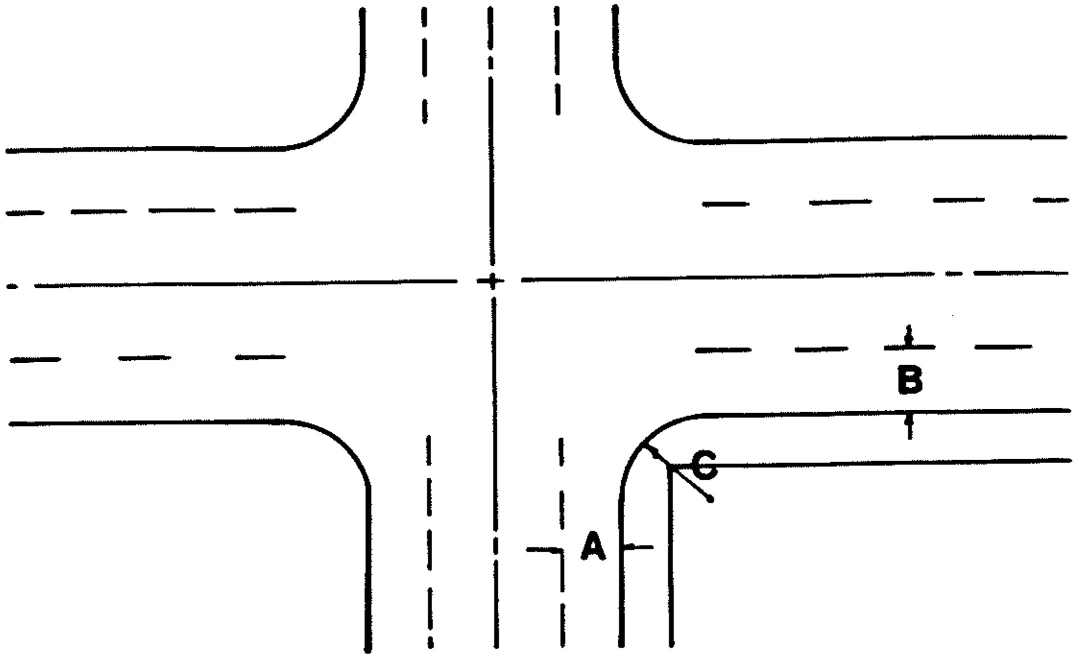
Examples of preferential treatment of bus and high occupancy vehicles include the following: (See Figure 3.7.1)

1) High occupancy vehicle (HOV) lanes on expressways or freeways - these are exclusive lanes reserved for buses or buses, carpools and vanpools.

2) Bypass lanes at freeway ramps - these lanes allow buses, carpools and vanpools to bypass queues of vehicles at metered on-ramps.

3) Exclusive lanes on arterial streets - these lanes are reserved exclusively for buses or buses and vanpools. These lanes may provide for transit operation in either the same or opposite direction as general traffic on one-way streets.

The application and design of preferential transit improvements is beyond the scope of this guide. Questions regarding possible projects should be directed to the MTC.



A LEAVING LEG WIDTH	B ENTERING LEG WIDTH	C RADII*
12′	12′	50′
	16′	45′
	20′	35′
	24′	30′
16′	12′	40′
	16′	32′
	20′	25′
	24′	20′
20′	12′	35′
	16′	25′
	20′	20′
	24′	10′
24′	16′	30′
	12′	20′
	20′	12′
	24′	10′

*ASSUMES NO PARKING AND NO LANE ENCROACHMENT

TRANSIT RELATED ROADWAY IMPROVEMENTS

Recommended Corner Radii

FIGURE 3.1.1. MAY 1983

Metropolitan Transit Commission

NUMBER OF BUSES PER DAY*	PAVEMENT THICKNESS (INCHES)
5	6" NON-REINFORCED
15	6 1/2" NON-REINFORCED
25	7" NON-REINFORCED
40	7 1/2" NON-REINFORCED
100	8" NON-REINFORCED
200	8" REINFORCED
750	9" REINFORCED
1,000	10" REINFORCED

*1 WAY, DESIGN LANE 20 YEAR PROJECTED ADT

ASSUMES PLASTIC SUBSURFACE SOILS (CLAY OR SILT) WITH 24 INCHES OF GRANULAR MATERIAL AND A MINIMUM OF 6 INCHES OF CRUSHED ROCK. SEE MN/DOT ROAD DESIGN MANUAL FOR FURTHER PAVEMENT DESIGN PROCEDURES.

NUMBER OF BUSES PER DAY*	PAVEMENT THICKNESS** (INCHES)
0-10	2" 2341 WEAR 2" 2331 BASE 2" 2331 BINDER 6" CLASS 5
10-20	2" 2341 WEAR 3" 2331 BASE 3" 2331 BINDER 9" CLASS 5
20-50	3" 2341 WEAR 3" 2331 BASE 3" 2331 BINDER 12" CLASS 5
50-100	3" 2341 WEAR 4" 2331 BASE 4" 2331 BINDER 12" CLASS 5
> 100	4" 2341 WEAR 6" 2331 BASE 6" 2331 BINDER 12" CLASS 5

*1WAY, DESIGN LANE, 20 YEAR PROJECTED ADT

**SEE MN/DOT SPECIFICATIONS FOR EXPLANATION OF WEAR, BASE AND BINDER COURSES.

ASSUMES PLASTIC SUBSURFACE SOILS(CLAY OR SILT) WITH 24 INCHES OF GRANULAR MATERIAL AND A MINIMUM OF 6 INCHES OF CRUSHED ROCK. SEE MN/DOT ROAD DESIGN MANUAL FOR FURTHER PAVEMENT DESIGN PROCEDURES.

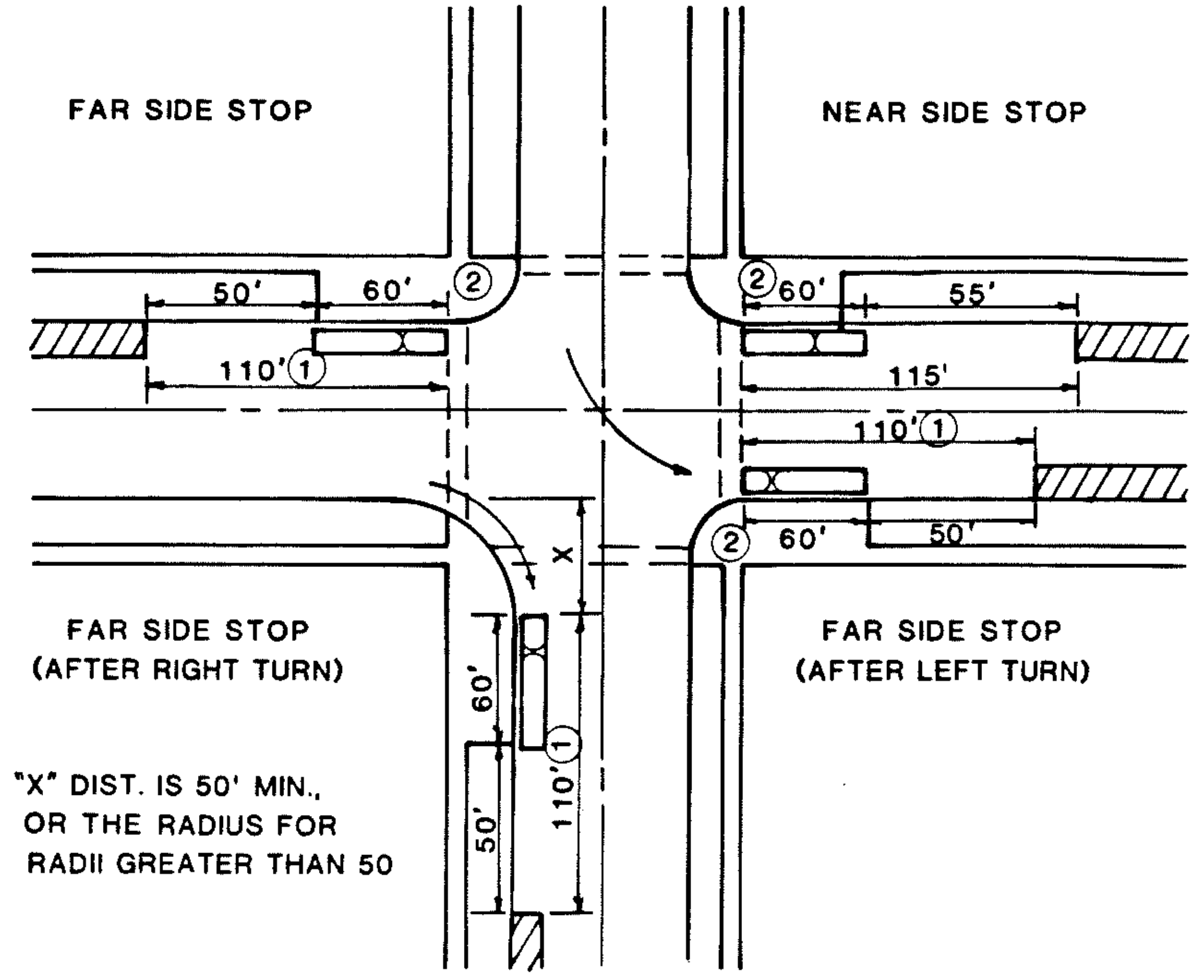
TRANSIT RELATED ROADWAY IMPROVEMENTS

Recommmended Typical Bituminous Sections

FIGURE 3.3.2.

MAY 1983

Metropolitan Transit Commission



① MINIMUM DISTANCE OF NO PARKING ZONE SEE NOTE ②

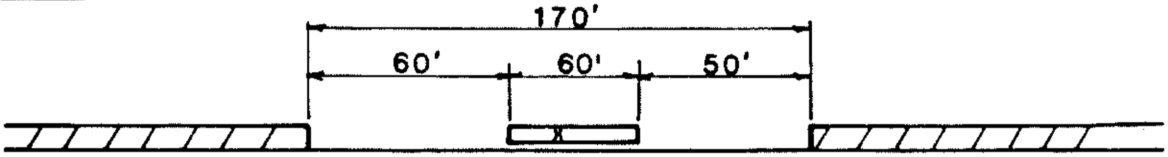
② MEASURE FROM 5 FEET FROM EDGE OF CROSSWALK OR END OF RADIUS, WHICHEVER IS FURTHER FROM INTERSECTION.

ADD 65 FEET FOR EACH ADDITIONAL BUS WHICH WILL SIMULTANEOUSLY BE AT THE STOP.

SYMBOLS:

BUS

PARKING



MID BLOCK STOP ③

③

FOR ENTERING SPEEDS OF 15 MPH OR LESS, SEE FIGURE 3.5.1. FOR HIGHER SPEEDS

NOT TO SCALE

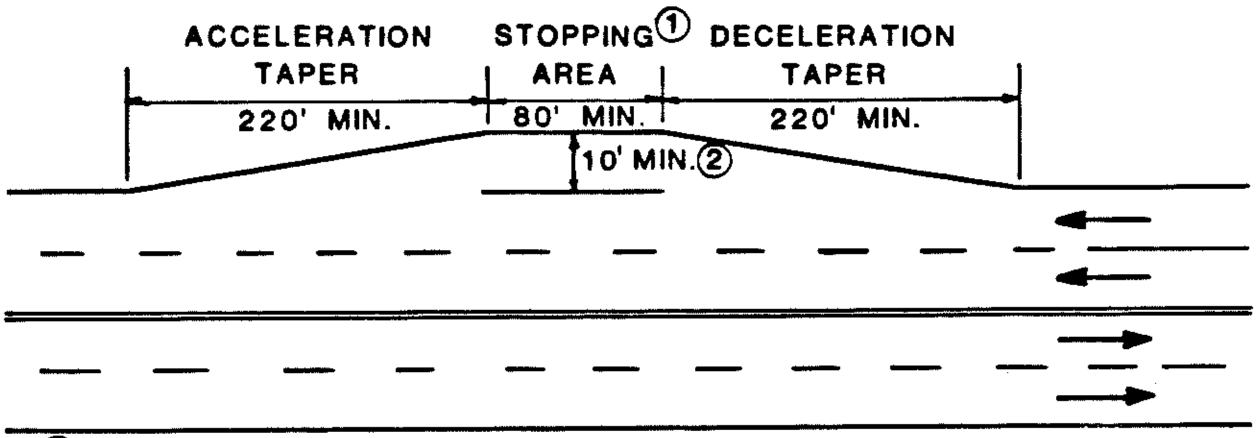
TRANSIT RELATED ROADWAY IMPROVEMENTS

Recommended Onstreet Bus Stop Design

FIGURE 3.4.1.

MAY 1983

Metropolitan Transit Commission



① ADD 65 FEET FOR EACH ADDITIONAL BUS WHICH WILL SIMULTANEOUSLY BE AT THE STOP

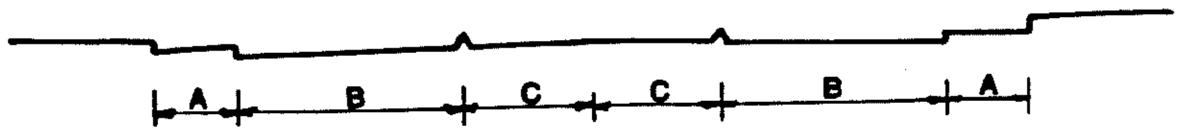
② DOES NOT INCLUDE GUTTER WIDTH. FOR SPEEDS OVER 30 MPH, A 12' MINIMUM IS RECOMMENDED

Recommended Acceleration & Deceleration Lengths	
DESIGN SPEED (MPH)	TAPER LENGTH (FEET)
30	220
35	300
40	400
45	500
50	620
55	750

TRANSIT RELATED ROADWAY IMPROVEMENTS

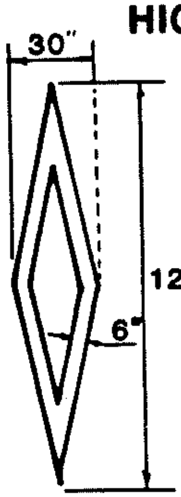
Basic Bus Pull Out Design

Metropolitan Transit Commission

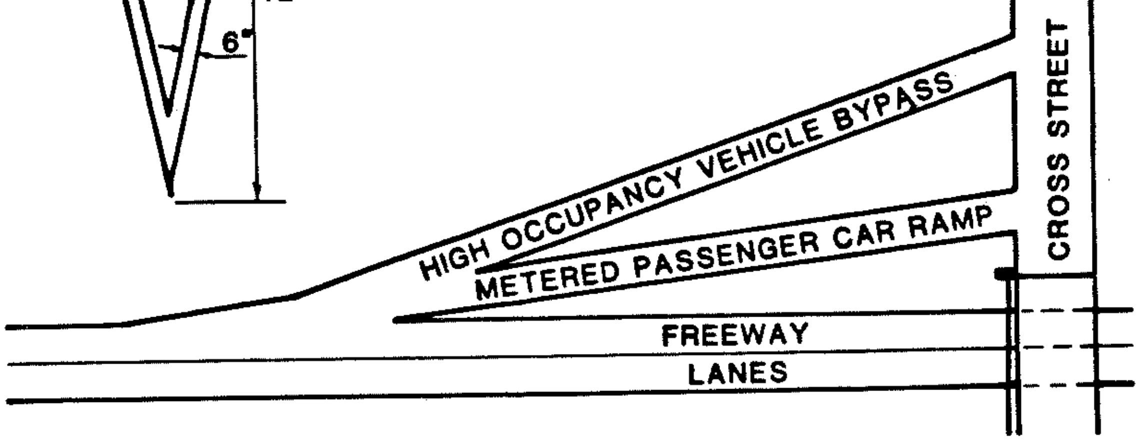


A- SHOULDER
B- FREEWAY LANES
C- HIGH OCCUPANCY VEHICLE LANES AND SHOULDERS

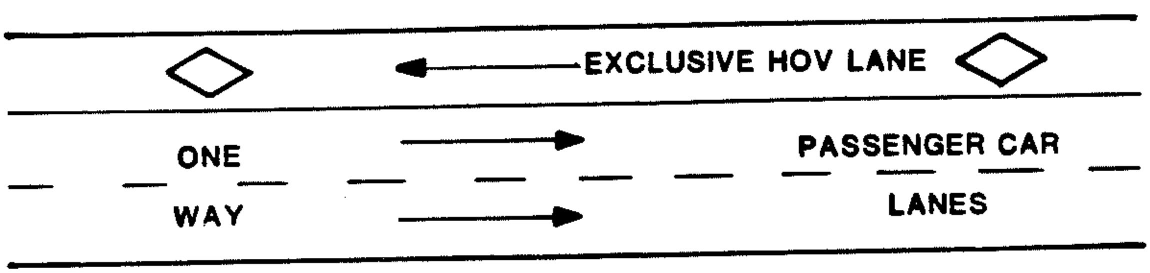
HIGH OCCUPANCY VEHICLE LANE ON A FREEWAY



TYPICAL MARKING FOR HOV LANE



BYPASS LANE AT FREEWAY ON-RAMP



EXCLUSIVE HIGH OCCUPANCY VEHICLE (HOV) LANE (REVERSED ON AN ARTERIAL ROADWAY)

TRANSIT RELATED ROADWAY IMPROVEMENTS

Preferential Treatment for High Occupancy Vehicles

FIGURE 3.7.1. MAY 1983

Metropolitan Transit Commission

TRAFFIC CONTROL DEVICES

4.1 Traffic Signals: Bus stops frequently are located at intersections with traffic signals. Generally the intersections are of two major streets with the potential for transfers of passengers between buses or for larger accumulations of passengers. Traffic signal design must accommodate buses and bus passengers.

Location of bus stops must be coordinated with traffic signal pole and head location. Bus stops should be located so that buses do not totally restrict visibility of traffic signals from other vehicles. Likewise, the design of traffic signals should take into account buses at the designated bus stop.

All bus passengers become pedestrians upon leaving the bus. It is very desirable that WALK and DON'T WALK indications be in place at signalized intersections at bus stops.

When traffic actuated signals are installed, pedestrian push buttons must also be installed to activate the WALK and DON'T WALK lights. Without push buttons, pedestrians are totally dependent upon vehicles for actuating the signal. Push buttons should be mounted on signal poles and pedestals or on separate push button stations convenient to crosswalks and the bus stop locations. Traffic actuated signals utilize vehicle detectors. These detectors can be calling, extending, or both. Calling detectors merely place a call into the traffic signal controller which ultimately will provide a green light for that direction of approach. Extending detectors will only extend the amount of green time once the green indication has been displayed for that approach. Combination calling and extending detectors are normally used to both call and extend the green light.

Bus stop areas often are between the advance detectors for a traffic signal and the crosswalk. Generally some secondary detection is desirable or else the particular phase should be placed on the recall mode of operation. Location of a detector at the bus stop will enable the bus to actuate the detector and the signal controller to obtain or extend the green light. Lack of a detector will force a bus to wait until other traffic approaches from the same direction and actuates the signal controller.

An extending detector placed at a bus stop will cause a loading or unloading bus to extend the green light even without the presence of other traffic. This can produce a somewhat inefficient intersection operation. A calling detector at a bus stop will provide a green light ultimately, but the bus may wait for a cycle of the signal.

For overall operating efficiency at the intersection, a calling detector is generally used. In some instances, the right lane will be designated for right turns only and detection either not provided or provided on a delayed basis. Buses stopping in this lane will then be either undetected or delayed before being detected.

Timing of traffic signals should also reflect the specific needs of buses. Clearance intervals should be designed to reflect the deceleration characteristics of loaded buses as well as trucks and passenger vehicles. Longer clearance intervals may be required on higher speed roadways with significant bus traffic. Vehicle passage times must provide adequate time for a bus to accelerate from the bus stop into the intersection. Intersections adjacent to railroad tracks should have timing and detection reflect the need for buses to stop at the railroad crossings.

Preemption of traffic signals by buses is technically possible. The buses may either call for a green light for its direction of approach or may extend the green light to enable the bus to proceed through without stopping. Obviously either of these preemption systems will have a significant impact on the overall operation of the traffic signal and must be carefully coordinated and designed with the authorities responsible for signal operation.

4.2 Traffic Signs:

Signs normally associated with bus stops include the regulatory NO PARKING BUS STOP signs, informational bus stop signs (T signs), and other guide signs such as trail blazers and park-ride signs. (See Figure 4.2.1).

No parking signs are normally located at the beginning or end of a no parking zone as shown in Figure 6.2.1. While a single no parking sign may be sufficient in most instances, long restricted zones or midblock locations may require additional signs. No parking zones may be reinforced by painting the curbs yellow.

Bus stop signs should be located at the front of the bus when in its normal stopped position. The bus stop signs are furnished by the MTC. Local road authorities install and maintain the bus stop signs. Replacement signs are available from the MTC. They will also provide spare signs to local authorities as a ready reserve for replacements.

The general provisions of the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD) requires that signs be mounted not less than seven feet above the road in business or residential districts and five feet in rural districts. Because of pedestrian activities near bus stops, it is recommended that all signs be mounted seven feet above the road. The lateral location varies from two feet to twelve feet in the two types of districts, respectively. More details and requirements can be found in the MMUTCD.

All regulatory signs, such as no parking signs, are furnished, installed and maintained by local authorities. All signs are subject to the policies and ordinances of the local agencies.

4.3 Pavement Markings: Pavement markings associated with bus stops are generally installed and maintained by local authorities. The most common is the yellow painted curb at bus stops. Stop lines and/or crosswalks are also desirable as most bus stop locations are at intersections.

Pavement markings for priority lanes, such as for high occupancy vehicles or buses, should be installed by local authorities.

4.4 Regulations: The most common regulations associated with bus stops are the necessary resolutions and ordinances required of local governments for establishment of no parking zones. No parking signs generally require official action by a local governmental agency having jurisdication over the road or over regulation of parking before they are legal.

Symbol: Ⓣ

MTC TRANSIT LOGO SIGN

WHITE CIRCLE AND "T"
TRANSIT ORANGE BACKGROUND

D4-2

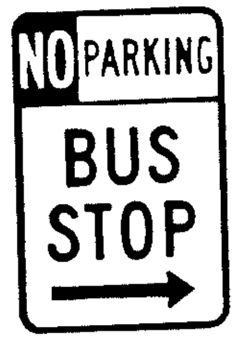
PARK AND RIDE SIGN

White Legend, Green Background

R3-11

PREFERENTIAL LANE SIGN

Black Legend, White Background



R7-107

NO PARKING BUS STOP SIGN

Red Legend, White Background

NOTES:

1) Minimum mounting post should be 2.0 lb/ft channel. Refer to Mn/DOT standard specifications 3401.

2) For more information on sign use, refer to Minnesota Manual on Uniform Traffic Control Devices.

3) Arrow direction should be changed to meet specific needs.

4) All signs to be mounted 7' from roadway to bottom of sign.

PARKING AREAS

5.1 Park and Ride Lots: Park and ride lots are an integral part of the Metropolitan area's public transportation system, as evidenced by the fact that the MTC currently provides bus service to approximately 115 such lots. These lots consist of two general categories; lots used exclusively by transit and rideshare patrons and joint-use lots where transit patrons use excess space at such locations as shopping centers, movie theaters and churches. The overwhelming majority of the park and ride lots now in service are in the latter category, under a contractual arrangement through the MTC.

The recommendations which follow may be applied to the development of both exclusive and joint-use park and ride lots. However, they do have greater application in the design of the exclusive type lot since the joint-use lots are, for the most part, used "as is" and do not require any significant design effort.

5.2 Exclusive Park and Ride Lots: The exclusive type park and ride lots should incorporate as many of the following location and design features as possible in order to provide safe and efficient bus operations:

1) Bus, auto and pedestrian traffic should be separated.

2) The bus stop area should be located on the portion of the site closest to the street.

3) Preferred automobile parking area design should have ninety degree (90°) parking stalls and two-way aisles which are perpendicular to the passenger waiting areas. One-way aisles and other angle parking is appropriate if properly designed for circulation and pedestrians.

4) The design of driveway widths, roadway widths, and corner radii should be based on the operating characteristics of transit vehicles.

5) The pavement structural section should be based on the actual soil conditions and the anticipated bus and auto volume.

6) A pick up/drop off area should be provided.

7) A passenger waiting area should be provided near the bus stop area. This area should be lighted and include a shelter. Additional recommendations for pedestrian ammenities are found in Chapter 6.

8) Handicapped parking stalls must be provided. These stalls should be located adjacent to the waiting area and there should be no physical barriers

between the parking and waiting areas. The number of handicapped stalls which must be provided is a function of the overall size of the lot. One handicapped stall should be provided for the first 25 parking spaces; one additional handicapped stall for the next 25 parking spaces; and one more handicapped stall for each 50 additional spaces.

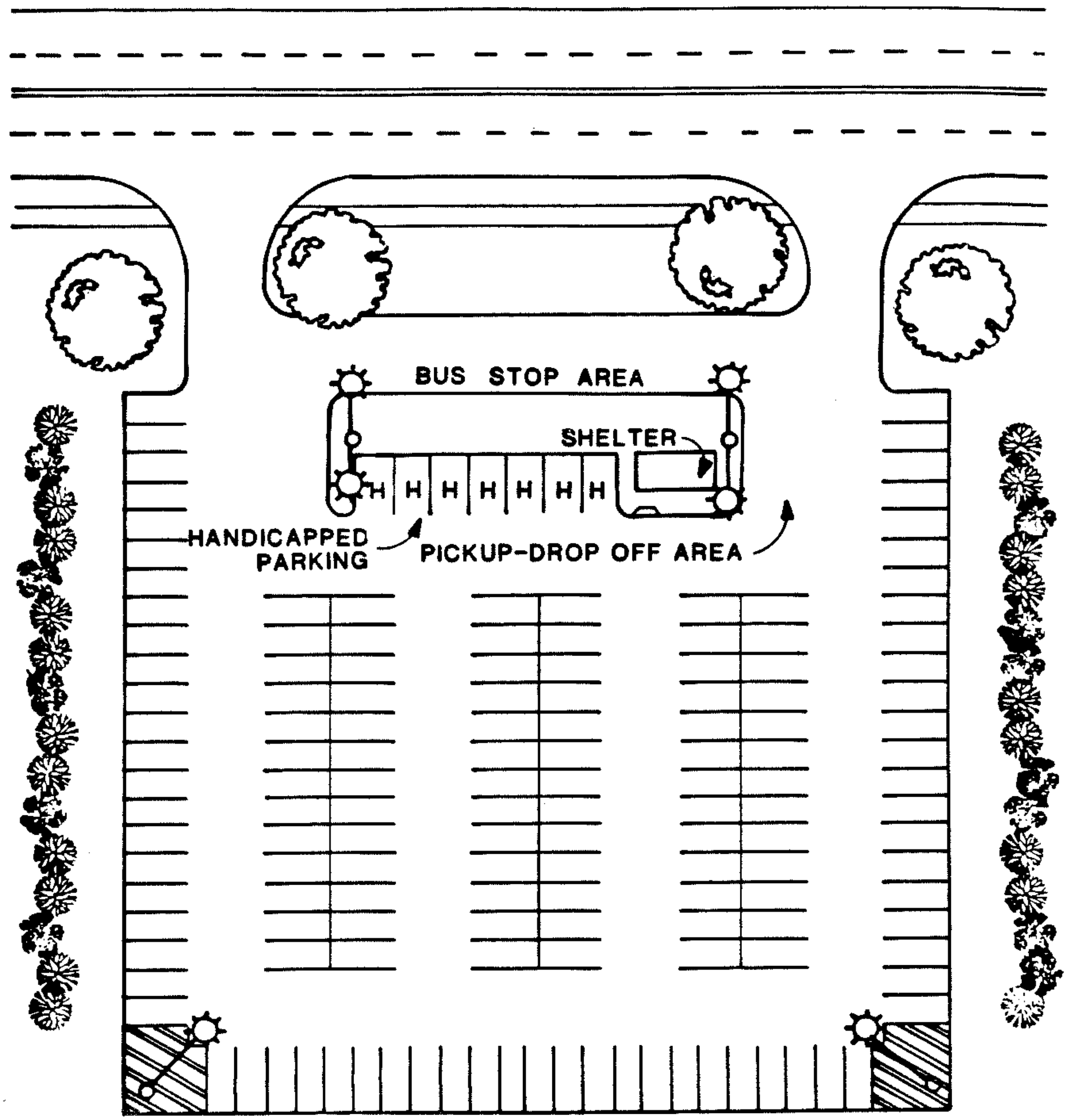
Figure 5.2.1 shows a design for a park and ride lot which incorporates the recommended design features.

5.3 Joint-Use Park and Ride Lots:

Even though the development of a joint-use lot does not require a significant design effort, a potential site should be evaluated in order to determine its operating efficiently and any changes which may be desired. The previously recommended design features can be used as a basis for the evaluation.

The two most important features which should be taken into consideration are the geometric design and the pavement structural section of both the access roads or driveways and the parking area. Buses will be allowed to circulate through the site only if these features have been originally designed to accommodate either transit or heavy commercial vehicles. If either geometric design or pavement section are found to be deficient, buses will remain on the public street system and the transit patrons will be picked up at the most convenient location.

The bus stop location, whether within a public lot or adjacent to a public street, must take into account pedestrian safety. Pedestrian ammenities such as waiting areas and shelters should be provided in accordance with the recommendations in Chapter 6.



TRANSIT RELATED ROADWAY IMPROVEMENTS

Typical Park & Ride Lot (Exclusive)

FIGURE 5.2.1.

MAY 1983

Metropolitan Transit Commission

WAITING AREAS AND PASSENGER SHELTERS

6.1 Introduction:

The design of waiting areas and passenger shelters can play a significant role in a person's decision to use public transportation. Their design can greatly affect a person's actual and perceived sense of safety, comfort and convenience. The following sections will identify the factors which should be considered in locationing and designing waiting areas and passenger shelters.

6.2 Waiting Areas:

The following factors which should be considered in the selection of the location and design of waiting areas:

- Sidewalk availability
- Space requirements
- Accessibility for elderly and handicapped individuals
- Safety and security
- Sign placement and requirements
- Maintenance requirements

Figure 6.2.1 presents a typical waiting area with the recommended accommodations for pedestrians.

When possible, a bus stop and waiting area should be located in an area with sidewalks. If no sidewalk exists, or a non-paved boulevard is present, a concrete pad, similar in design to a sidewalk, should be provided. This pad should be long enough to extend beyond the rear door of the bus, taking into consideration the maximum number of buses which may be at the stop simultaneously. It should also be large enough to hold all waiting passengers and unloading passengers.

At those stops which are served by buses equipped with lifts for handicapped individuals, a clear sidewalk width of 12 feet should be provided. This will be adequate to permit the maneuvering and loading of a wheelchair without leaving the sidewalk area. Curb heights of zero (0) to ten (10) inches can normally be tolerated by the mechanical lifts installed on special vehicles. However, to function properly, the slope of the roadway and the slope of the sidewalk should be identical and should not exceed 4% cross slope. In addition, curb ramps, nonskid textured surfaces and other design features should be incorporated as appropriate to ensure accessibility for all individuals.

It is important that the waiting area be designed to provide a sense of security and safety. Near the front of the bus stop, the sidewalk should be widened to the maximum extent practical to provide a safe lateral distance between waiting pedestrians and passing vehicles. Where feasible, street lighting should be provided. Landscaping at waiting areas should be designed in a way which does not afford areas in which a person could hide. The landscaping features, signs, etc. should not obstruct the sight line between the pedestrian and approaching drivers.

The transit sign normally indicates the point at which the front of the bus will be when it is stopped to pick up or discharge riders. The sign should be placed in a location which is clearly visible to an approaching bus driver. Other regulatory and informational signs may be necessary to ensure that the bus stop is not used for other purposes and to provide desired information to pedestrians. Refer to Section 4.2.

The design of the waiting area should take into consideration maintenance activities which must be performed. Of particular concern is the placement of facilities which will hinder the plowing of snow. Snow must either be removed or adequate storage space provided to ensure the sidewalks and curbs can be kept free of windrows of snow.

6.3 Passenger Shelters: Passenger shelters are provided to enhance the safety, security and comfort of transit patrons. They may be provided in many ways and can take almost any form and appearance. Most often, passenger shelters are separate free standing structures. However, there are passenger waiting shelters which have been incorporated into other buildings or are freestanding but of a special design to complement their environment.

When considering the development of a passenger shelter, there are three basic considerations:

- Under what conditions should a passenger shelter be provided?
- What guidelines should be used to determine the specific location of a shelter?
- What guidelines should be used for the design?

A passenger shelter should be provided wherever a significant number of persons gather to board transit vehicles. The exact number of persons needed to justify a shelter varies from location to location. Historically, the MTC has used 40 persons/day as a minimum threshold. However, special consideration should be given to locations frequented by elderly and handicapped individuals. Other factors which should be considered are the presence of alternative locations where pedestrians can find protection from the weather and the proximity to other shelters.

6.4 Shelter Design Guidelines:

Based upon the MTC experience, the following features should be incorporated into a shelter:

- Complete roof.
- Three walls plus windscreen, (partial wall), transparent with minimum visual obstructions.
- Inside bench with outside bench if site conditions permit.
- Lighting, both interior and exterior.
- Display area for route and schedule information.
- Concrete base.

In determining the size of a shelter, approximately 2.5 square feet per person should be provided for the peak five minute usage. At locations where a large number of persons wait at various hours, up to five square feet per person should be considered. In all cases, the shelter should be a minimum of fifty (50) square feet.

Where site conditions restrict the use of a four-sided shelter, a three-sided shelter, may be appropriate. Figures 6.4.1 and 6.4.2 show conceptual passenger shelter designs developed by the MTC.

Provision for a telephone may deserve consideration depending upon the number of persons using the shelter and the surrounding conditions. In all cases, the location of other street furniture, such as waste recepticals, information kiosks, newspaper dispensers and postal boxes shall be coordinated with the location and design of the shelter.

The user's safety and security should be a primary design element of the shelter. Safety and security can be enhanced by providing transparent walls and carefully landscaping to ensure good visibility of the shelter and to minimize the possibility of a person hiding in the shelter or surrounding area. Where practical, lighting of the shelter should be provided (2.0 foot candles interior, .8 foot candles exterior as a minimum).

Care should be taken that all aspects of the shelter design and site improvements are fully accessible to elderly and handicapped persons.

Particular attention should be given to the materials used to construct the shelter. To the extent it is practical, shelters should compliment the architecture and style of the surrounding area. However, care must be taken to use materials, finishes, etc., which are easy to maintain and vandal resistant.

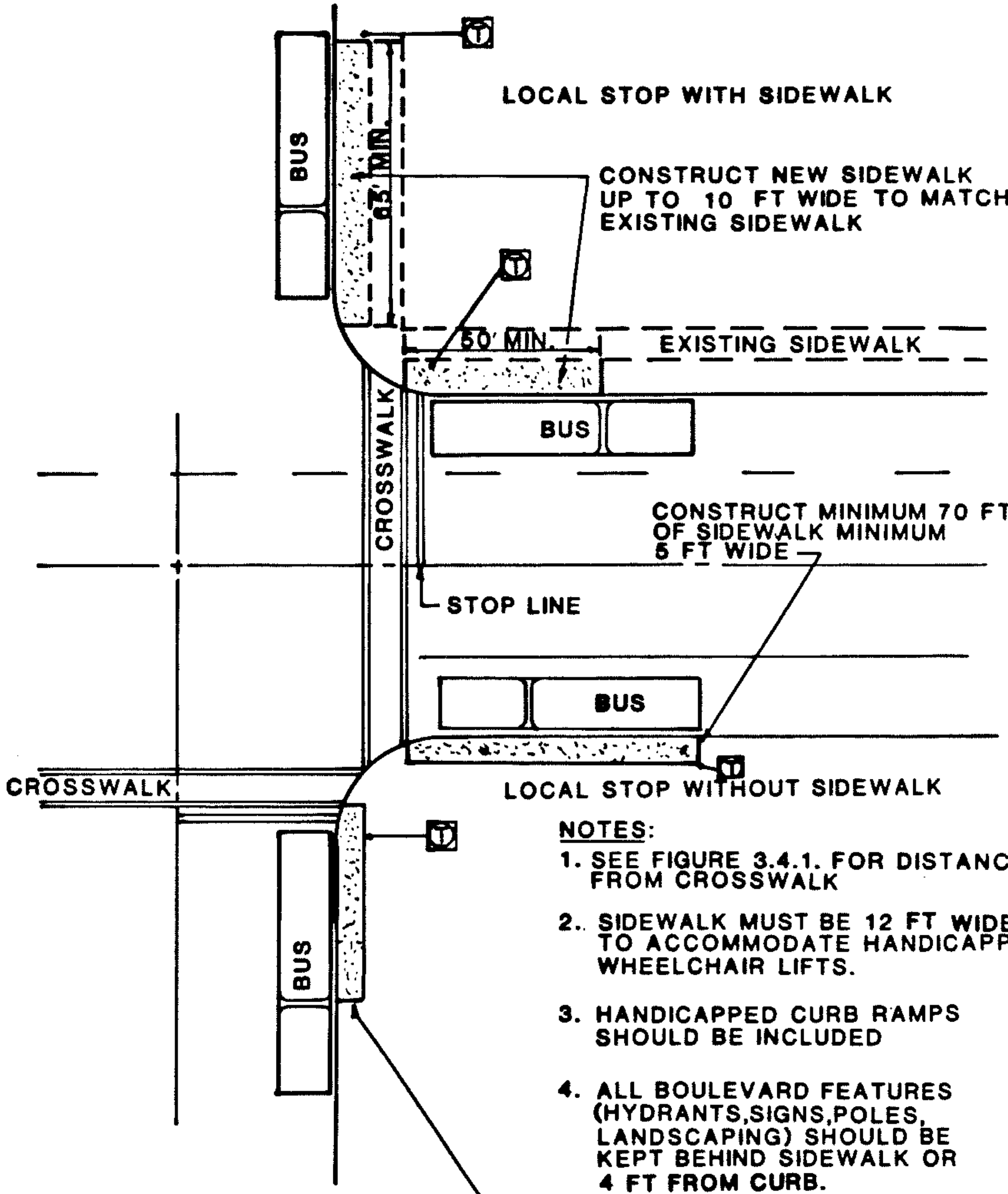
6.5 Shelter Location Guidelines:

The location of a passenger shelter at a specific site can have a great impact upon how well the shelter serves its intended function and how it impacts upon other facilities in the immediate area. The following factors should be considered in establishing the specific locations of a shelter.

- Adjacent land use.
- Sidewalk condition and location
- Pedestrian circulation
- Location of bus entrance and exit doors
- Visibility
- Safety of pedestrians
- Location of other street furniture
- Sightlines for traffic
- Drainage
- Electrical service
- Availability of right-of-way
- Concurrence of municipal jurisdiction and review by adjacent property owners and utility companies
- Accessibility for elderly and handicapped persons
- Snow removal and other maintenace procedures

In general, a passenger shelter should be located near the front end of the bus stop. Where possible, it should be located more than four feet from the face of the curb and the doorways should be oriented away from the prevailing winds. A shelter should be located so it does not interfere with sightlines of drivers. The impact the shelter may have will vary depending upon the type of traffic control at the intersection and the adjacent land use. In situations where the overhang of vehicles using adjacent parking areas of roadways could possibly damage the shelters or cause personal injury, a plate beam guard rail or guard posts, should be installed adjacent to the shelter.

Figure 6.5.1 shows locations for a freestanding passenger shelter under typical circumstances.



NOTES:

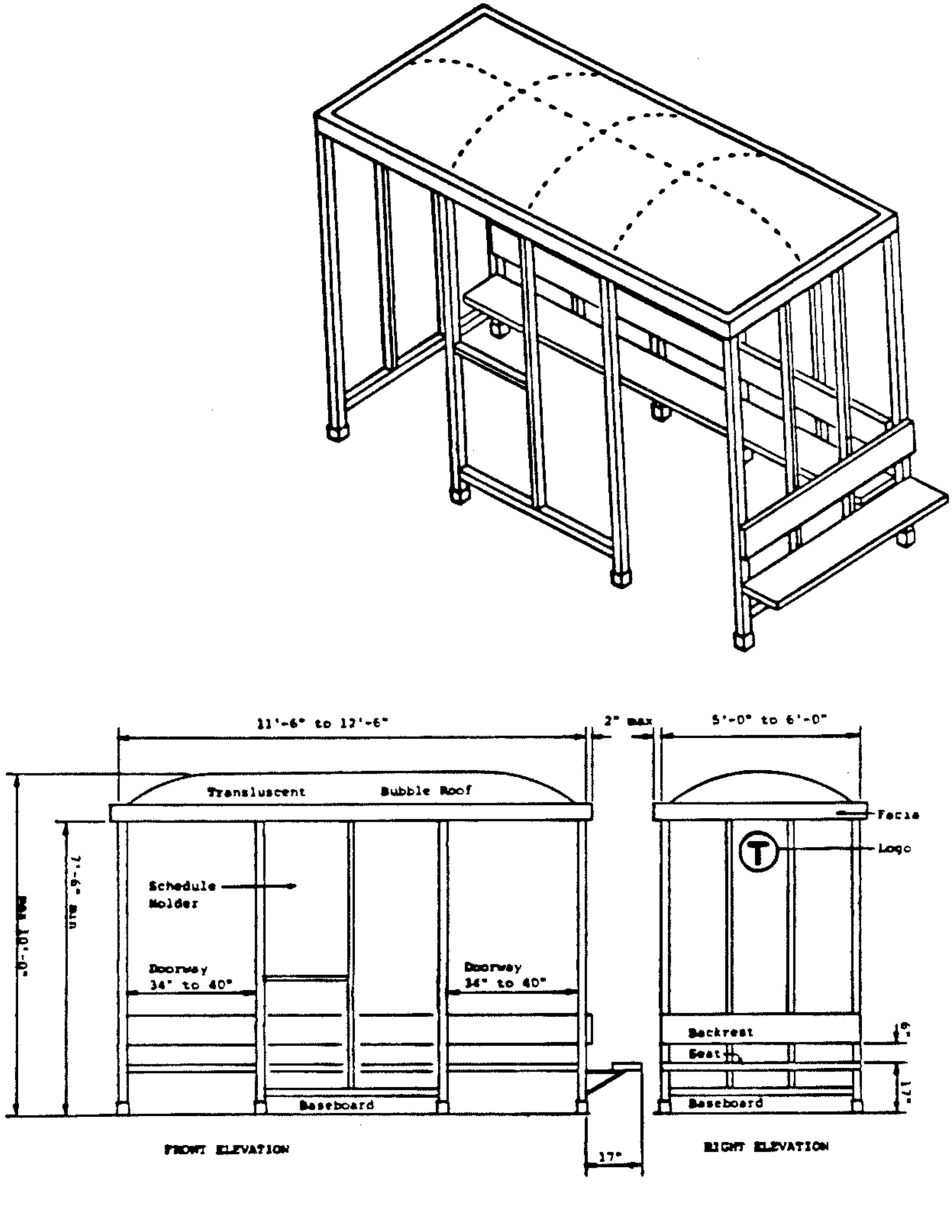
1. SEE FIGURE 3.4.1. FOR DISTANCES FROM CROSSWALK
2. SIDEWALK MUST BE 12 FT WIDE TO ACCOMMODATE HANDICAPPED WHEELCHAIR LIFTS.
3. HANDICAPPED CURB RAMPS SHOULD BE INCLUDED
4. ALL BOULEVARD FEATURES (HYDRANTS,SIGNS,POLES, LANDSCAPING) SHOULD BE KEPT BEHIND SIDEWALK OR 4 FT FROM CURB.
5. STREET LIGHTING SHOULD BE PROVIDED TO ILLUMINATE INTERSECTION AND WAITING AREA.
6. AN ADDITIONAL 65'OF SIDEWALK IS NEEDED FOR EACH ADDITIONAL BUS SIMULTANEOUSLY PRESENT.

TRANSIT RELATED ROADWAY IMPROVEMENTS

Waiting Area

FIGURE 6.2.1. MAY 1983

Metropolitan Transit Commission

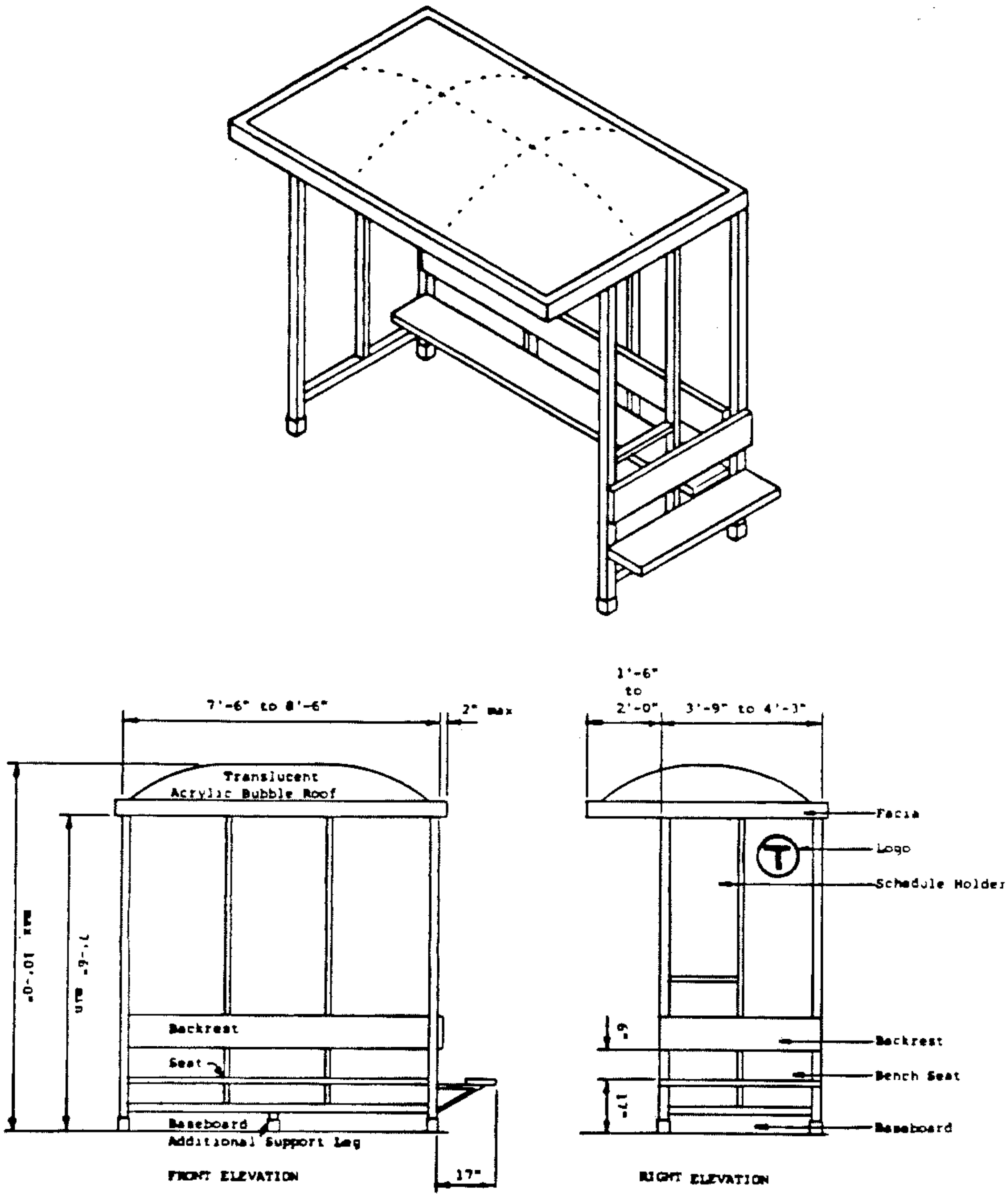


TRANSIT RELATED ROADWAY IMPROVEMENTS

Conceptual Passenger Shelter Design
Four Sided

FIGURE 6.4.1 MAY 1983

Metropolitan Transit Commission

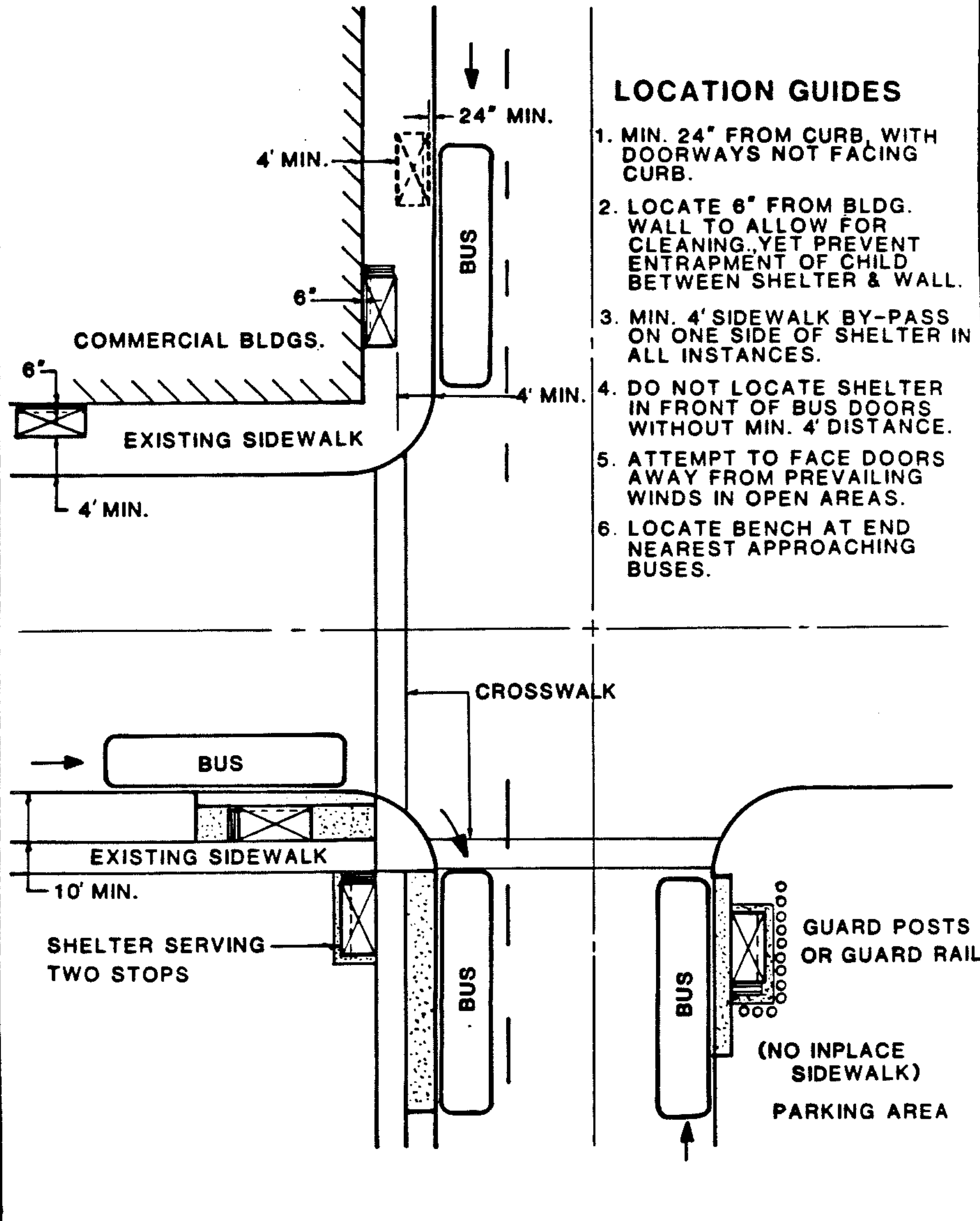


TRANSIT RELATED ROADWAY IMPROVEMENTS

Conceptual Passenger Shelter Design
Three Sided

FIGURE 6.4.2. MAY 1983

Metropolitan
Transit Commission



LOCATION GUIDES

1. MIN. 24" FROM CURB, WITH DOORWAYS NOT FACING CURB.
2. LOCATE 6" FROM BLDG. WALL TO ALLOW FOR CLEANING, YET PREVENT ENTRAPMENT OF CHILD BETWEEN SHELTER & WALL.
3. MIN. 4' SIDEWALK BY-PASS ON ONE SIDE OF SHELTER IN ALL INSTANCES.
4. DO NOT LOCATE SHELTER IN FRONT OF BUS DOORS WITHOUT MIN. 4' DISTANCE.
5. ATTEMPT TO FACE DOORS AWAY FROM PREVAILING WINDS IN OPEN AREAS.
6. LOCATE BENCH AT END NEAREST APPROACHING BUSES.

TRANSIT RELATED ROADWAY IMPROVEMENTS

Typical Shelter Locations

FIGURE 6.5.1. MAY 1983

Metropolitan Transit Commission

TRANSIT FACILITIES FOR THE HANDICAPPED

7.1 Service for the Handicapped:

The MTC participates in the operation of special transportation services, such as demand responsive transit, lift equipped service and shared ride taxi, to meet the travel needs of handicapped individuals in the Metropolitan Area. Providing these special services for the handicapped requires that designers consider the accessibility needs of these individuals. Specific attention must be given to facilities for vehicles providing the service and to handicapped patrons.

7.2 Special Service Vehicles:

The MTC provides service to the handicapped with a fleet of small buses equipped with wheelchair lifts. The dimensions and operating characteristics of these vehicles are provided in Chapter 2.

Since this service is frequently "door to door", these vehicles must often use off-road facilities, such as driveways, which may not have originally been intended to be used by large vehicles. Designers should pay particular attention to the width and turning path requirements for these vehicles and make certain there is adequate vertical clearance under all structures, canopies, etc. (11 feet minimum is suggested).

7.3 Design of Stop Areas:

One of the most important features of a stop area for handicapped service is to have it physically separated from a regular transit bus stop. The two types of services are different in both operating characteristics and loading times and are not compatible operations under most circumstances.

Other important considerations for locating stops for the handicapped include the following:

1) A location close to the origin or destination of the handicapped individual.

2) A location which is visible from the origin or destination of the handicapped individual.

3) Accessibility to a telephone.

4) Dimensions of the stop area consistent for the vehicle being used. (See Figure 7.3.1)

5) Preferential parking for the handicapped.

6) Traffic control devices, and informational signs adapted to the handicapped individuals.

7.4 Pedestrian Facilities:

The design of waiting areas and shelters for regular transit services is discussed in detail in Chapter 6. All of the recommendations also apply to pedestrian facilities for the handicapped, although some are more important than others.

The following design features must be provided in order to adequately accommodate the handicapped.

1) Pick up area must be 12 feet wide in order to satisfactorily accommodate the wheelchair lift on the special buses and to provide enough room for the loading operation.

2) Sidewalk grades and cross slope must be less than 4% in order to allow safe usage of the wheelchair lift. In addition, the profile grade of the sidewalk and pick up area must be the same as the street grade.

3) Curb ramps must be provided so that the handicapped are not confronted with impassible barriers. Curb heights of zero (0) to ten (10) inches can normally be tolerated by mechanical lifts.

4) Non-skid textured surfaces and other design features should be incorporated.

5) Waiting areas and access ways must be free from steps and other obstacles which could impede wheelchair movements or walking.

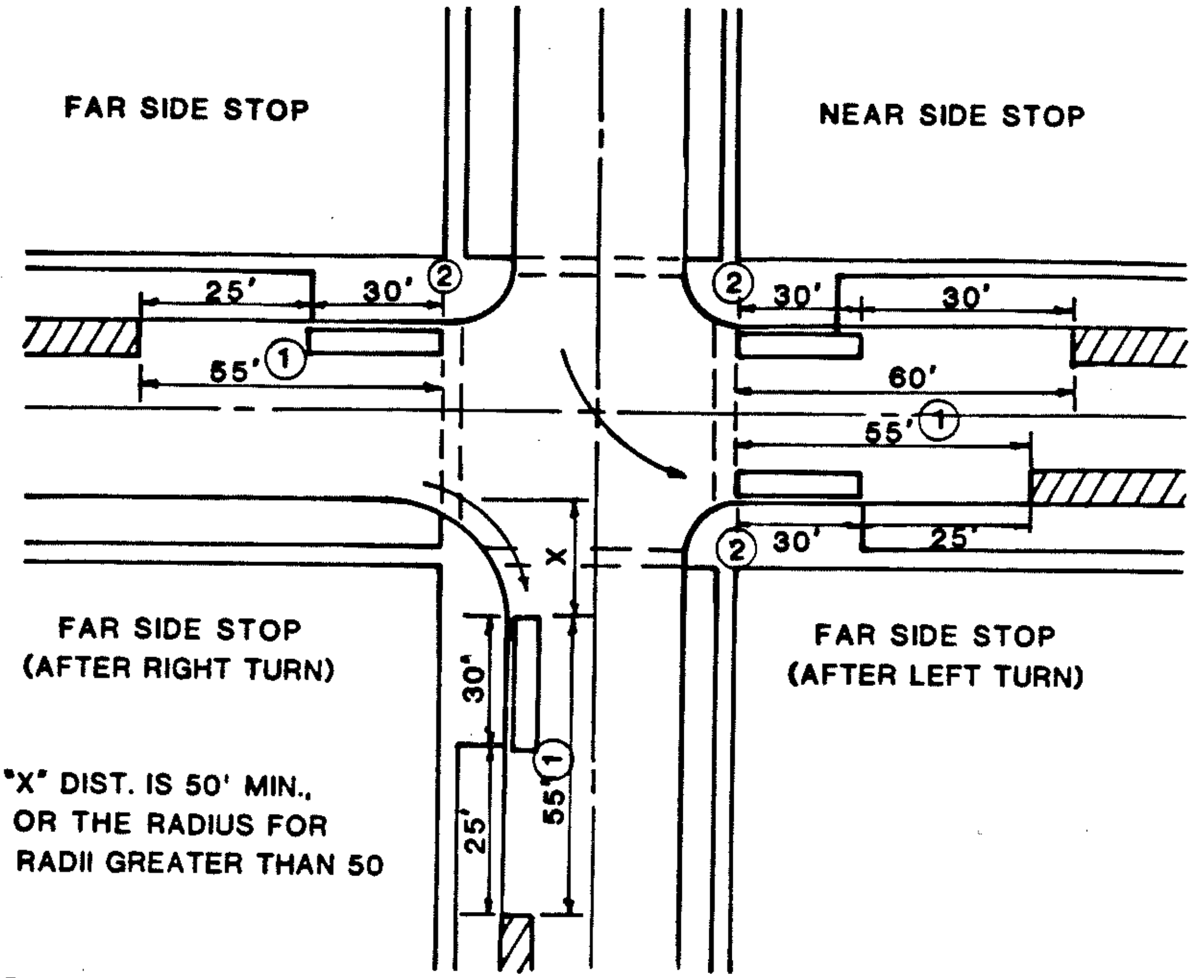
7.5 References:

Additional information regarding planning and designing facilities for the handicapped can be found in the following reference materials:

1) Guidelines for Handicapped Architectural & Transportation Barriers, U.S. Federal Register, August 4, 1982.

2) Handicapped Accessibility in Urban Areas, National Cooperative Highway Research Program Synthesis of Highway Practice No. 83, Transportation Research Board, October, 1981.

3) Accessible Architecture: Minnesota Building Code Chapter 55, The Minnesota State Council for the Handicapped Document No. 10-86, 1977.

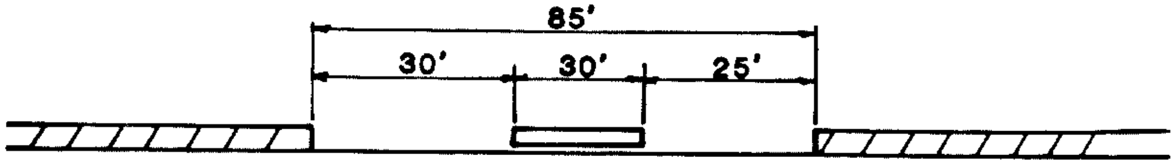


(1) MINIMUM DISTANCE OF NO PARKING ZONE. SEE NOTE (2)

(2) MEASURE FROM 5 FEET FROM EDGE OF CROSSWALK OR END OF RADIUS, WHICHEVER IS FURTHER FROM INTERSECTION.

SYMBOLS:

- BUS
- PARKING



MID BLOCK STOP

NOT TO SCALE

TRANSIT RELATED ROADWAY IMPROVEMENTS

Recommended Onstreet Bus Stop Design For Special Handicapped Service Vehicles

FIGURE 7.3.1. MAY 1983

Metropolitan Transit Commission

RIDESHARING

8.1 Carpools and Vanpools:

The MTC participates in ridesharing by providing services to the seven county Metropolitan area. This program helps coordinate carpool and vanpool operations in the Metropolitan area. The most commonly used vehicle for this type of operation, other than private passenger vehicles, is a van which seats twelve to fifteen passengers. Typical dimensions for this type of vehicle are found in Chapter 2.

8.2 Design of Stop, Loading and Unloading Areas:

The design of stop areas for regular transit service is discussed in Chapter 3. Most of the location and design features for the regular stops can also be applied to paratransit stops. However, there are some important differences.

Carpool and vanpool stop areas should be physically separated from regular transit stops because of the differences in operating characteristics. Other important design features include the following:

- Stop locations close to the origin and destination of the patrons.

- A stop area of sufficient length for the rideshare vehicle to pull in parallel to the curb and pull back into the traffic lanes without backing up. A stop area for a single vehicle generally will require 32 to 36 feet.

- Signs and traffic control devices clearly defining the stop area.

The stop areas need not be set aside exclusively for the carpool/vanpool operation. Based on the specific characteristics of the rideshare service provided, it may be possible to designate the space as a stop area for only the peak periods in the morning and afternoon. During the remaining hours of the day the space could be used for parking, a loading zone, or some other compatible use. The time restrictions must be rigidly enforced however.

8.3 Preferential Treatment:

The MTC encourages the use of preferential treatment for carpools and vanpools because of the overall benefits associated with this type of operation. Preferential treatment could include, but is not limited to the following:

- Parking adequate for the individual passenger cars at the origin of the trip, permitting formation of carpools and vanpools, parking for the rideshare vehicle at the priority access and the desired destination. Designers must remember to take into account the type of vehicle being used to provide the service. Vans frequently have different heights and widths, than passenger cars and the parking areas must reflect these differences.

- Exclusive lanes on both arterial streets and freeways.

- High occupany vehicle bypasses at freeway on ramps.

- Designated pick up and drop off stops on streets.

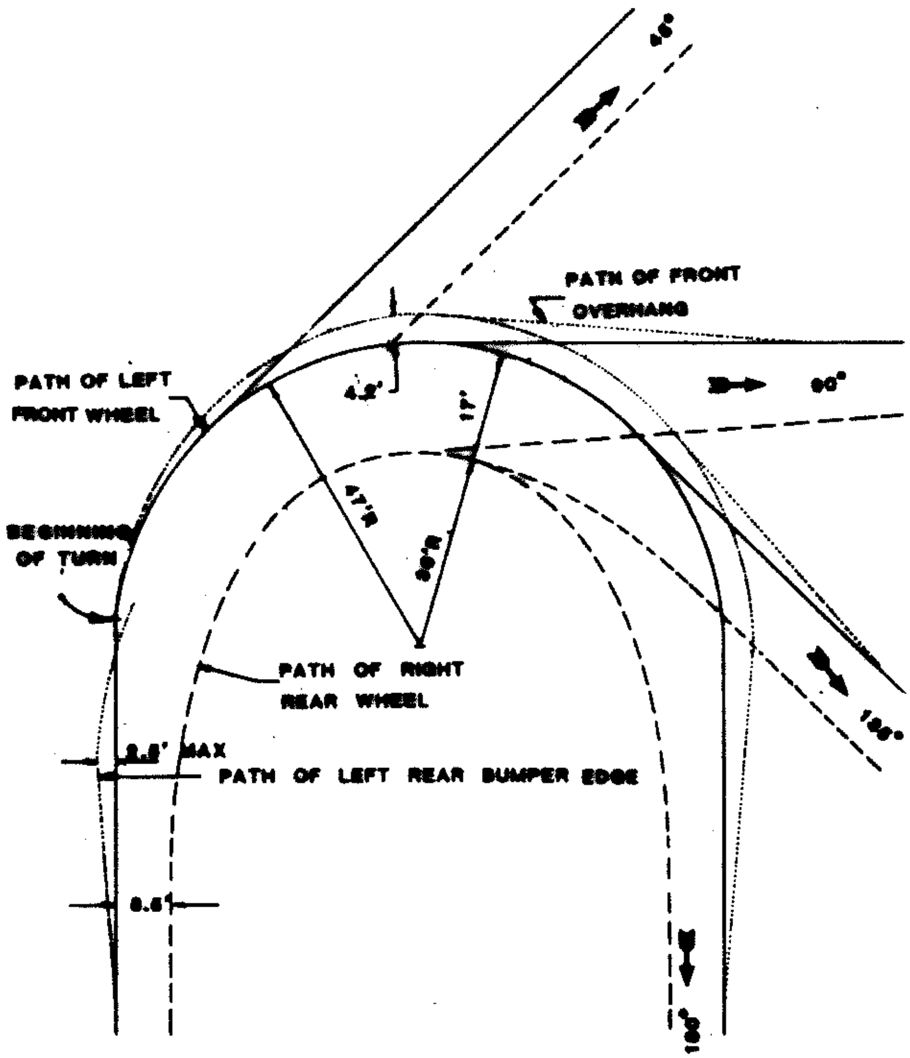
- Reduced parking rates, preferential parking spaces and priority fee payment techniques.

APPENDIX

9.1 Articulated Design Vehicle Turning Template
Scale 1" = 30'
Scale 1" = 40'
Scale 1" = 50'

9.2 40 Foot Design Vehicle Turning Template
Scale 1" = 30'
Scale 1" = 40'
Scale 1" = 50'

9.3 Small Bus Design Vehicle Turning Template
Scale 1" = 30'
Scale 1" = 40'
Scale 1" = 50'



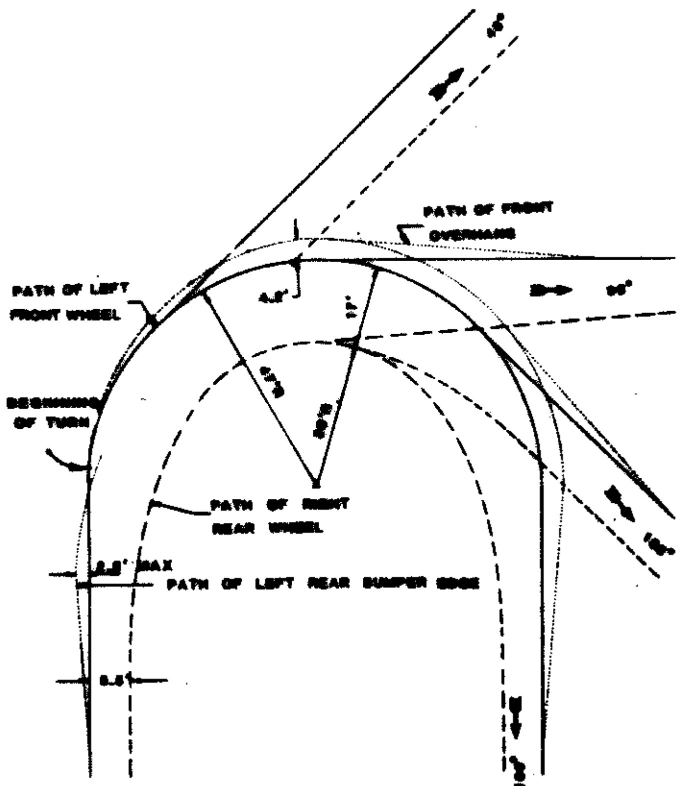
SCALE 1"=30'

TRANSIT RELATED ROADWAY IMPROVEMENTS

**Articulated Design Vehicle
Recommended Design Turning Template**

FIGURE 9.1.1 **MAY 1983**

Metropolitan Transit Commission



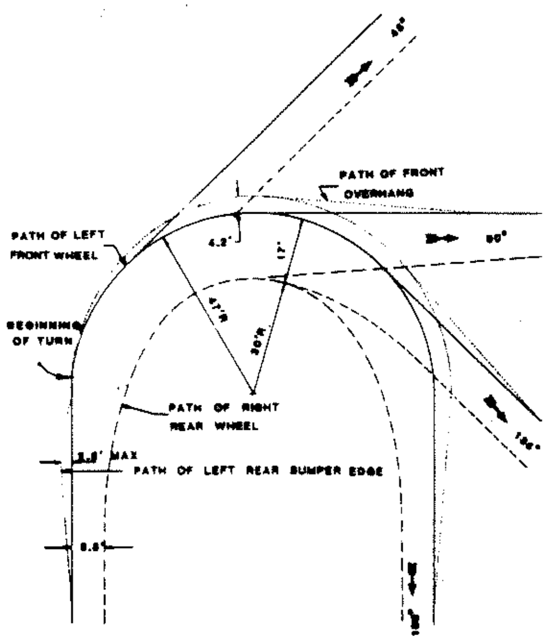
SCALE 1"= 40'

TRANSIT RELATED ROADWAY IMPROVEMENTS

Articulated Design Vehicle Recommended Design Turning Template

FIGURE 9.1.2. **MAY 1983**

Metropolitan Transit Commission



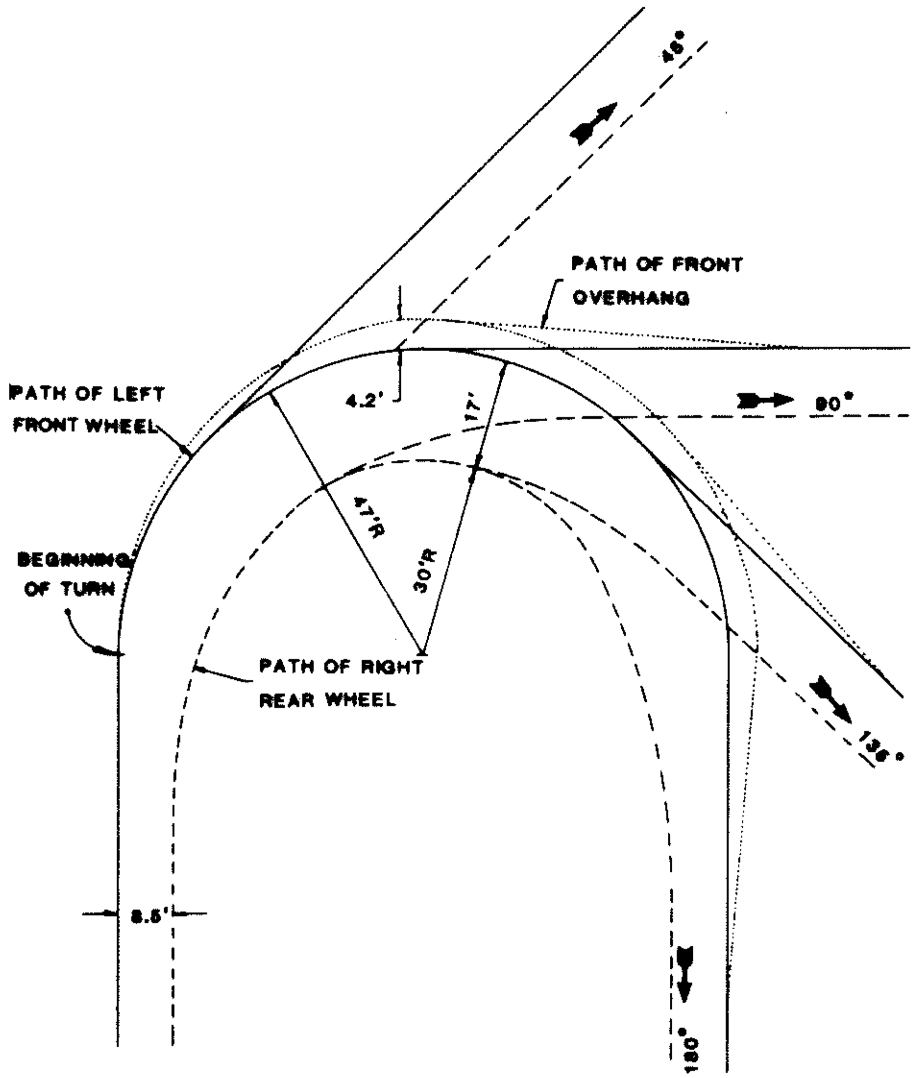
SCALE 1"=50'

TRANSIT RELATED ROADWAY IMPROVEMENTS

Articulated Design Vehicle
Recommended Design Turning Template

FIGURE 9.1.3 **MAY 1983**

Metropolitan
Transit Commission



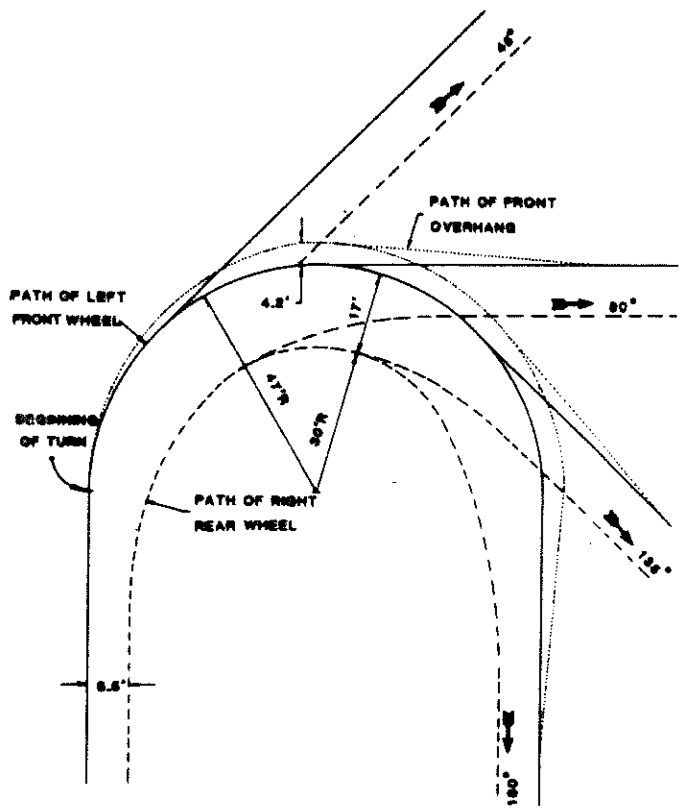
SCALE 1"= 30'

TRANSIT RELATED ROADWAY IMPROVEMENTS

40 Foot Design Vehicle
Recommended Design Turning Template

FIGURE 9.2.1 -109- **MAY 1983**

Metropolitan
Transit Commission



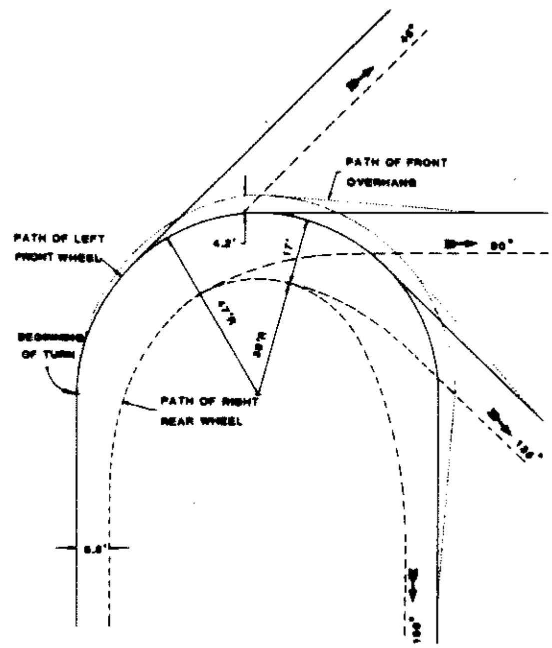
SCALE 1"= 40'

TRANSIT RELATED ROADWAY IMPROVEMENTS

40 Foot Design Vehicle
Recommended Design Turning Template

FIGURE 9.2.2 MAY 1983

Metropolitan
Transit Commission



SCALE 1"= 50'

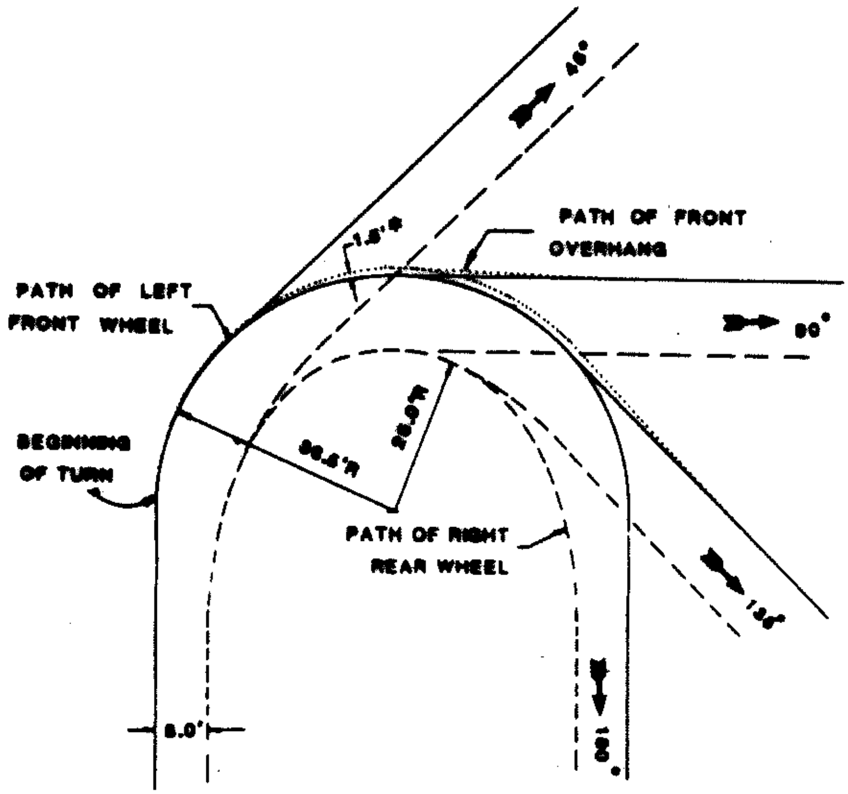
TRANSIT RELATED ROADWAY IMPROVEMENTS

40 Foot Design Vehicle Recommended Design Turning Template

FIGURE 9.2.3

MAY 1983

Metropolitan Transit Commission



SCALE 1"=30'

* SOME SMALL BUS VEHICLES HAVE A LARGER FRONT OVERHANG BUT SMALLER TURNING RADIUS

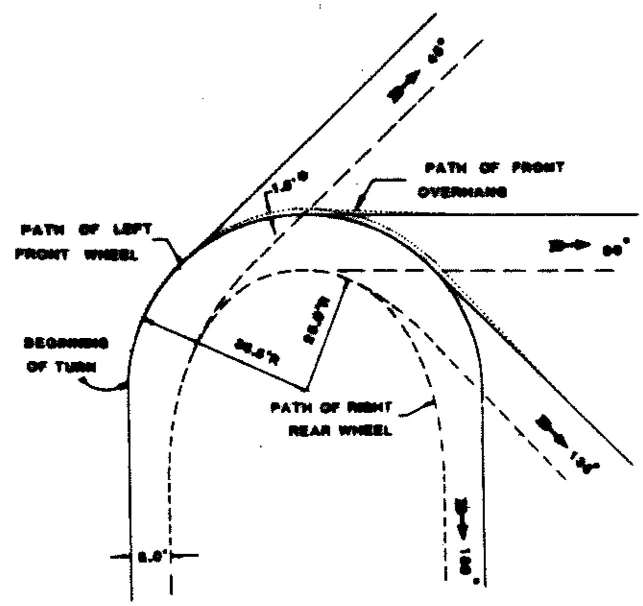
TRANSIT RELATED ROADWAY IMPROVEMENTS

Small Bus Design Vehicle

Recommended Design Turning Template

FIGURE 9.3.1 MAY 1983

Metropolitan Transit Commission



SCALE 1"=40'

* SOME SMALL BUS VEHICLES HAVE A LARGER FRONT OVERHANG BUT SMALLER TURNING RADIUS

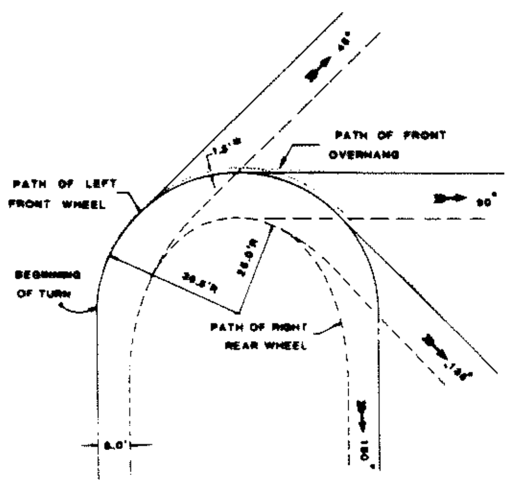
TRANSIT RELATED ROADWAY IMPROVEMENTS

Small Bus Design Vehicle

Recommended Design Turning Template

FIGURE 9.3.2 **MAY 1983**

Metropolitan Transit Commission



SCALE 1"= 50'

* SOME SMALL BUS VEHICLES HAVE A LARGER FRONT OVERHANG BUT SMALLER TURNING RADIUS

TRANSIT RELATED ROADWAY IMPROVEMENTS

Small Bus Design Vehicle

Recommended Design Turning Template

FIGURE 9.3.3 **MAY 1983**

Metropolitan
Transit Commission