Excerpt

- A city transit bus may be used in the design of state highway intersections with city streets that are designated bus routes and that have relatively few large trucks using them.
- Depending on expected usage, a large school bus (84 passengers) or a conventional school bus (65 passengers) may be used for the design of intersections of highways with low-volume county highways and township/local roads under 400 ADT. The school bus may also be appropriate for the design of some subdivision street intersections.
- The WB-20 [WB-65 or 67] truck should generally be the minimum size design vehicle considered for intersections of freeway ramp terminals with arterial crossroads and for other intersections on state highways and industrialized streets that carry high volumes of traffic and/or that provide local access for large trucks.

In addition to the 19 design vehicles, dimensions for a typical farm tractor are shown in Exhibit 2-1, and the minimum turning radius for a farm tractor with one wagon is shown in Exhibit 2-2. Turning paths of design vehicles can be determined from the dimensions shown in Exhibits 2-1 and 2-2 and through the use of commercially available computer programs.

Minimum Turning Paths of Design Vehicles

Exhibits 2-3 through 2-23 present the minimum turning paths for 19 typical design vehicles. The principal dimensions affecting design are the minimum centerline turning radius (CTR), the out-to-out track width, the wheelbase, and the path of the inner rear tire. Effects of driver characteristics (such as the speed at which the driver makes a turn) and of the slip angles of wheels are minimized by assuming that the speed of the vehicle for the minimum turning radius is less than 15 km/h [10 mph].

The boundaries of the turning paths of each design vehicle for its sharpest turns are established by the outer trace of the front overhang and the path of the inner rear wheel. This turn assumes that the outer front wheel follows the circular arc defining the minimum centerline turning radius as determined by the vehicle steering mechanism. The minimum radii of the outside and inside wheel paths and the centerline turning radii (CTR) for specific design vehicles are given in Exhibit 2-2.

Trucks and buses generally require more generous geometric designs than do passenger vehicles. This is largely because trucks and buses are wider and have longer wheelbases and greater minimum turning radii, which are the principal vehicle dimensions affecting horizontal alignment and cross section. Single-unit trucks and buses have smaller minimum turning radii than most combination vehicles, but because of their greater offtracking, the longer combination vehicles need greater turning path widths. Exhibit 2-11 defines the turning characteristics of a typical tractor/semitrailer combination. Exhibit 2-12 defines the lengths of tractors commonly used in tractor/semitrailer combinations.

A combination truck is a single-unit truck with a full trailer, a truck tractor with a semitrailer, or a truck tractor with a semitrailer and one or more full trailers. Because combination truck sizes and turning characteristics vary widely, there are several combination truck design

Metric

Design Vehicle Type	Passenger Car	Single-Unit Truck	Intercity Bus (Motor Coach)		City Transit Bus	Conventional School Bus (65 pass.)	Large[2] School Bus (84 pass.)	Articulated Bus	Intermediate Semitrailer	Intermediate Semitrailer
Symbol	P	SU	BUS-12	BUS-14	CITY-BUS	S-BUS11	S-BUS12	A-BUS	WB-12	WB-15
Minimum Design Turning Radius (m)	7.3	12.8	13.7	13.7	12.8	11.9	12.0	12.1	12.2	13.7
Centerline[1] Turning Radius (CTR) (m)	6.4	11.6	12.4	12.4	11.5	10.6	10.8	10.8	11.0	12.5
Minimum Inside Radius (m)	4.4	8.6	8.4	7.8	7.5	7.3	7.7	6.5	5.9	5.2

Design Vehicle Type	Interstate Semitrailer		"Double Bottom" Combination	Triple Semitrailer/ trailers	Turnpike Double Semitrailer/ trailer	Motor Home	Car and Camper Trailer	Car and Boat Trailer	Motor Home and Boat Trailer	Farm Tractor w/One Wagon
Symbol	WB-19*	WB-20**	WB-20D	WB-30T	WB-33D*	MH	P/T	P/B	MH/B	TR/W
Minimum Design Turning Radius (m)	13.7	13.7	13.7	13.7	18.3	12.2	10.1	7.3	15.2	5.5
Centerline[1] Turning Radius (CTR) (m)	12.5	12.5	12.5	12.5	17.1	11.0	9.1	6.4	14.0	4.3
Minimum Inside Radius (m)	2.4	1.3	5.9	3.0	4.5	7.9	5.3	2.4	10.7	3.2

Note: Numbers in table have been rounded to the nearest tenth of a meter.

* = Design vehicle with 14.63-m trailer as adopted in 1982 Surface Transportation Assistance Act (STAA).

** = Design vehicle with 16.16-m trailer as grandfathered in with 1982 Surface Transportation Assistance Act (STAA).

[1] = The turning radius assumed by a designer when investigating possible turning paths and is set at the centerline of the front axle of a vehicle. If the minimum turning path is assumed, the CTR approximately equals the minimum design turning radius minus one-half the front width of the vehicle.

[2] = School buses are manufactured from 42-passenger to 84-passenger sizes. This corresponds to wheelbase lengths of 3.35 m to 6.1 m, respectively. For these different sizes, the minimum design turning radii vary from 8.78 m to 12.01 m and the minimum inside radii vary from 4.27 m to 7.74 m.

[3] = Turning radius is for 150–200 hp tractor with one 5.64 m long wagon attached to hitch point. Front wheel drive is disengaged and without brakes being applied.

Exhibit 2-2. Minimum Turning Radii of Design Vehicles

US Customary

Design Vehicle Type	Passenger Car	Single-Unit Truck	Intercity Bus (Motor Coach)		City Transit Bus	Conventional School Bus (65 pass.)	Large[2] School Bus (84 pass.)	Articulated Bus	Intermediate Semi-trailer	Intermediate Semi-trailer
Symbol	P	SU	BUS-40	BUS-45	CITY-BUS	S-BUS36	S-BUS40	A-BUS	WB-40	WB-50
Minimum Design Turning Radius (ft)	24	42	45	45	42.0	38.9	39.4	39.8	40	45
Centerline[1] Turning Radius (CTR) (ft)	21	38	40.8	40.8	37.8	34.9	35.4	35.5	36	41
Minimum Inside Radius (ft)	14.4	28.3	27.6	25.5	24.5	23.8	25.4	21.3	19.3	17.0

Design Vehicle Type	Interstate Semitrailer		"Double Bottom" Combination	Triple Semi-trailer/ trailers	Turnpike Double Semi-trailer/ trailer	Motor Home	Car and Camper Trailer	Car and Boat Trailer	Motor Home and Boat Trailer	Farm[3] Tractor w/One Wagon
Symbol	WB-62*	WB-65** or WB-67	WB-67D	WB-100T	WB-109D*	MH	P/T	P/B	MH/B	TR/W
Minimum Design Turning Radius (ft)	45	45	45	45	60	40	33	24	50	18
Centerline[1] Turning Radius (CTR) (ft)	41	41	41	41	56	36	30	21	46	14
Minimum Inside Radius (ft)	7.9	4.4	19.3	9.9	14.9	25.9	17.4	8.0	35.1	10.5

* = Design vehicle with 48-ft trailer as adopted in 1982 Surface Transportation Assistance Act (STAA).

** = Design vehicle with 53-ft trailer as grandfathered in with 1982 Surface Transportation Assistance Act (STAA).

1 = The turning radius assumed by a designer when investigating possible turning paths and is set at the centerline of the front axle of a vehicle. If the minimum turning path is assumed, the CTR approximately equals the minimum design turning radius minus one-half the front width of the vehicle.

2 = School buses are manufactured from 42-passenger to 84-passenger sizes. This corresponds to wheelbase lengths of 11.0 ft to 20.0 ft, respectively. For these different sizes, the minimum design turning radii vary from 28.8 ft to 39.4 ft and the minimum inside radii vary from 14.0 ft to 25.4 ft.

3 = Turning radius is for 150–200 hp tractor with one 18.5 ft long wagon attached to hitch point. Front wheel drive is disengaged and without brakes being applied.

Exhibit 2-2. Minimum Turning Radii of Design Vehicles (Continued)

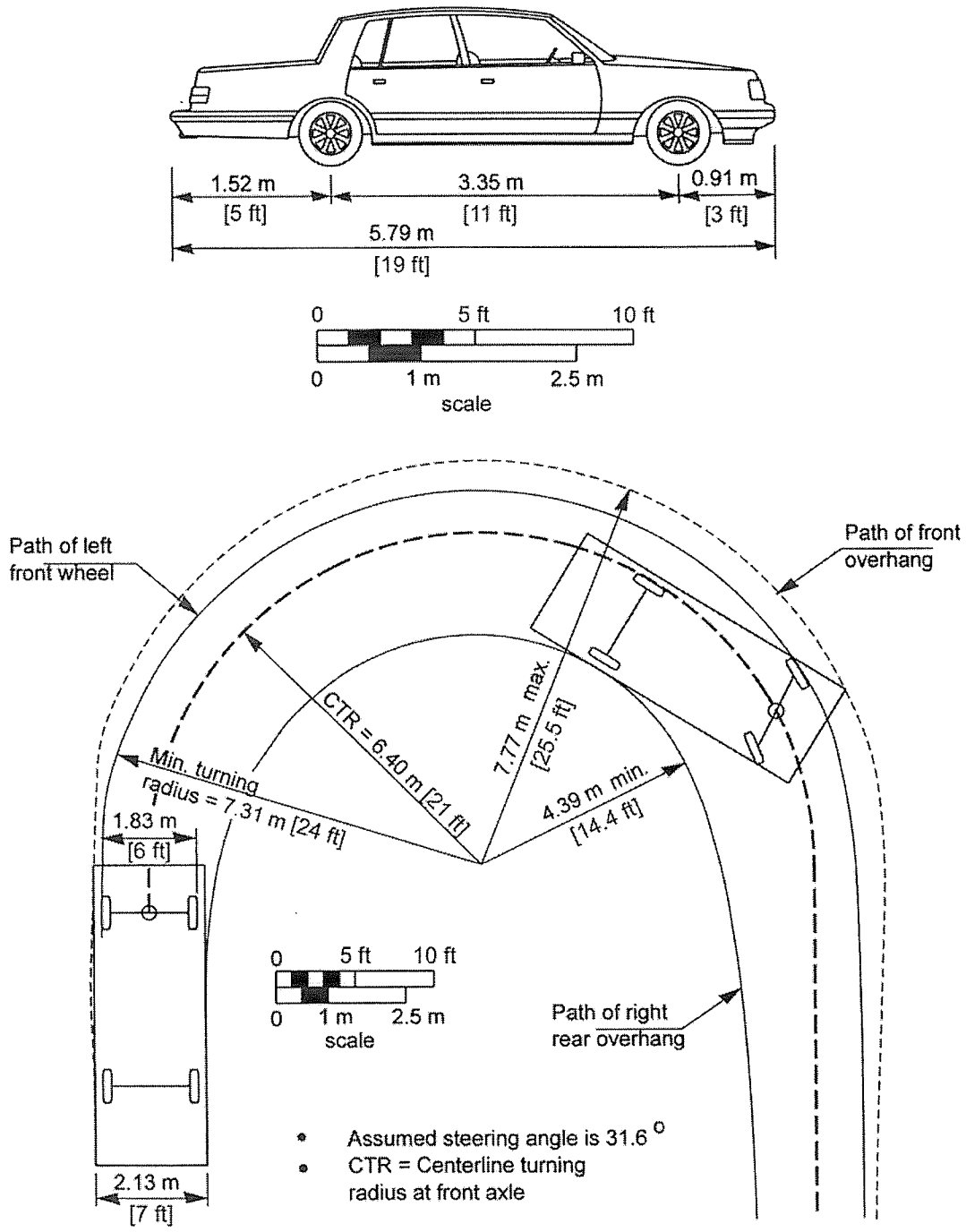
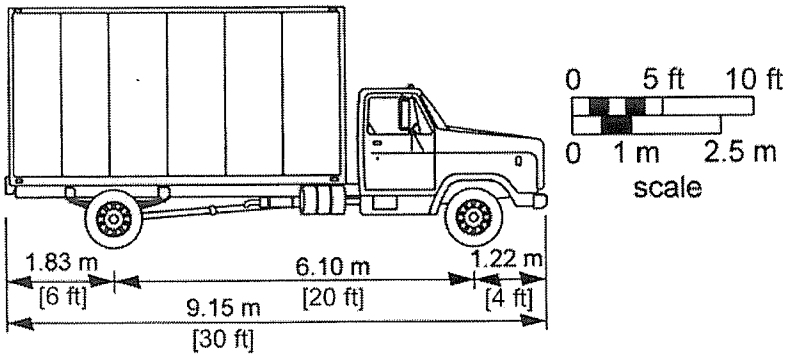


Exhibit 2-3. Minimum Turning Path for Passenger Car (P) Design Vehicle



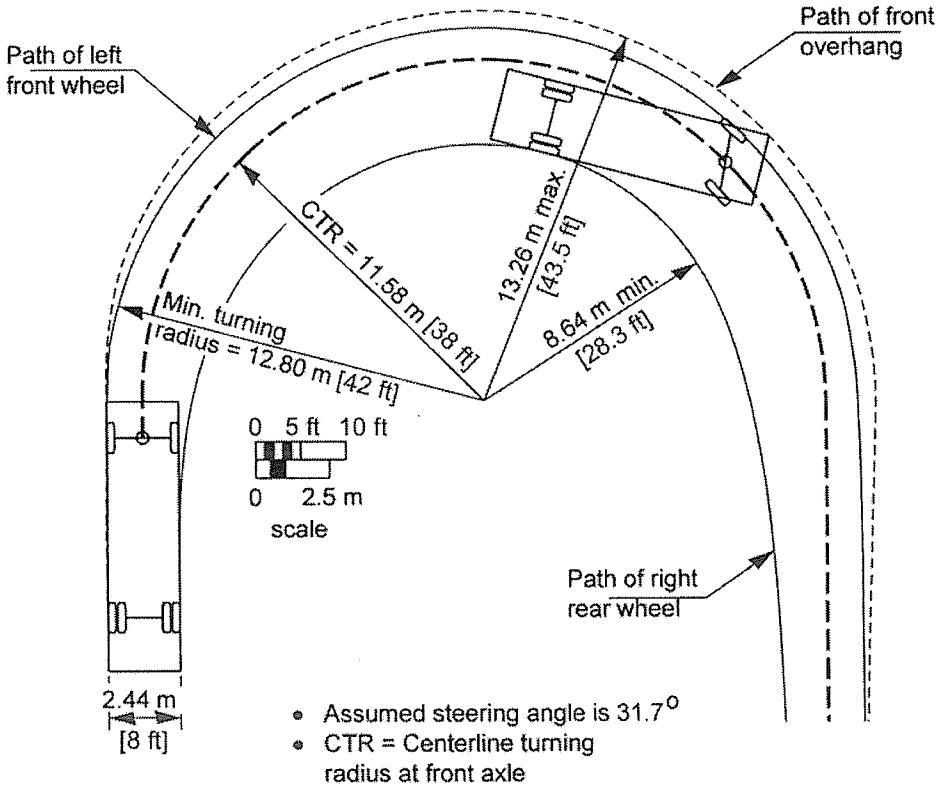


Exhibit 2-4. Minimum Turning Path for Single-Unit (SU) Truck Design Vehicle

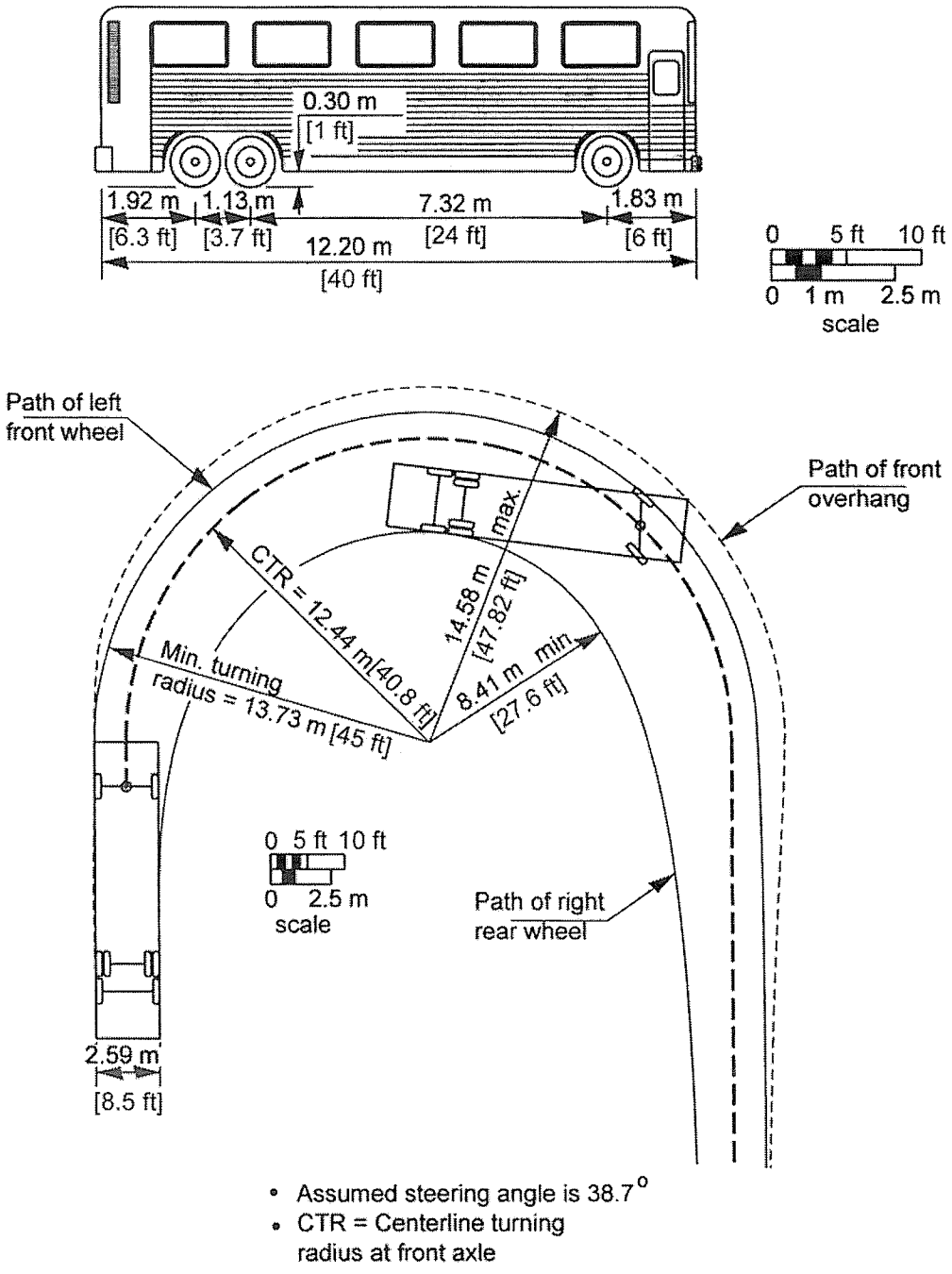


Exhibit 2-5. Minimum Turning Path for Intercity Bus (BUS-12 [BUS-40]) Design Vehicle

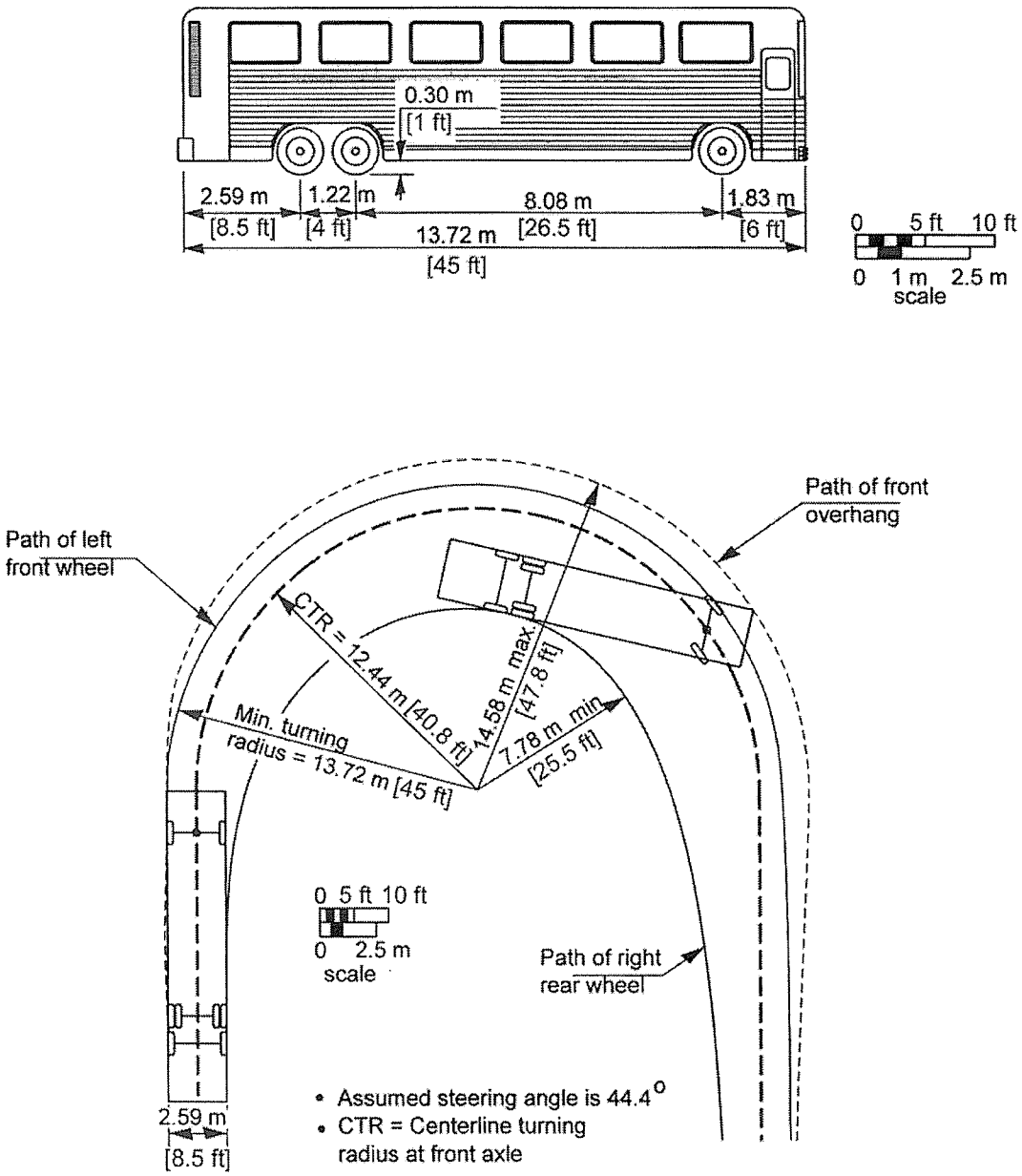


Exhibit 2-6. Minimum Turning Path for Intercity Bus (BUS-14 [BUS-45]) Design Vehicle

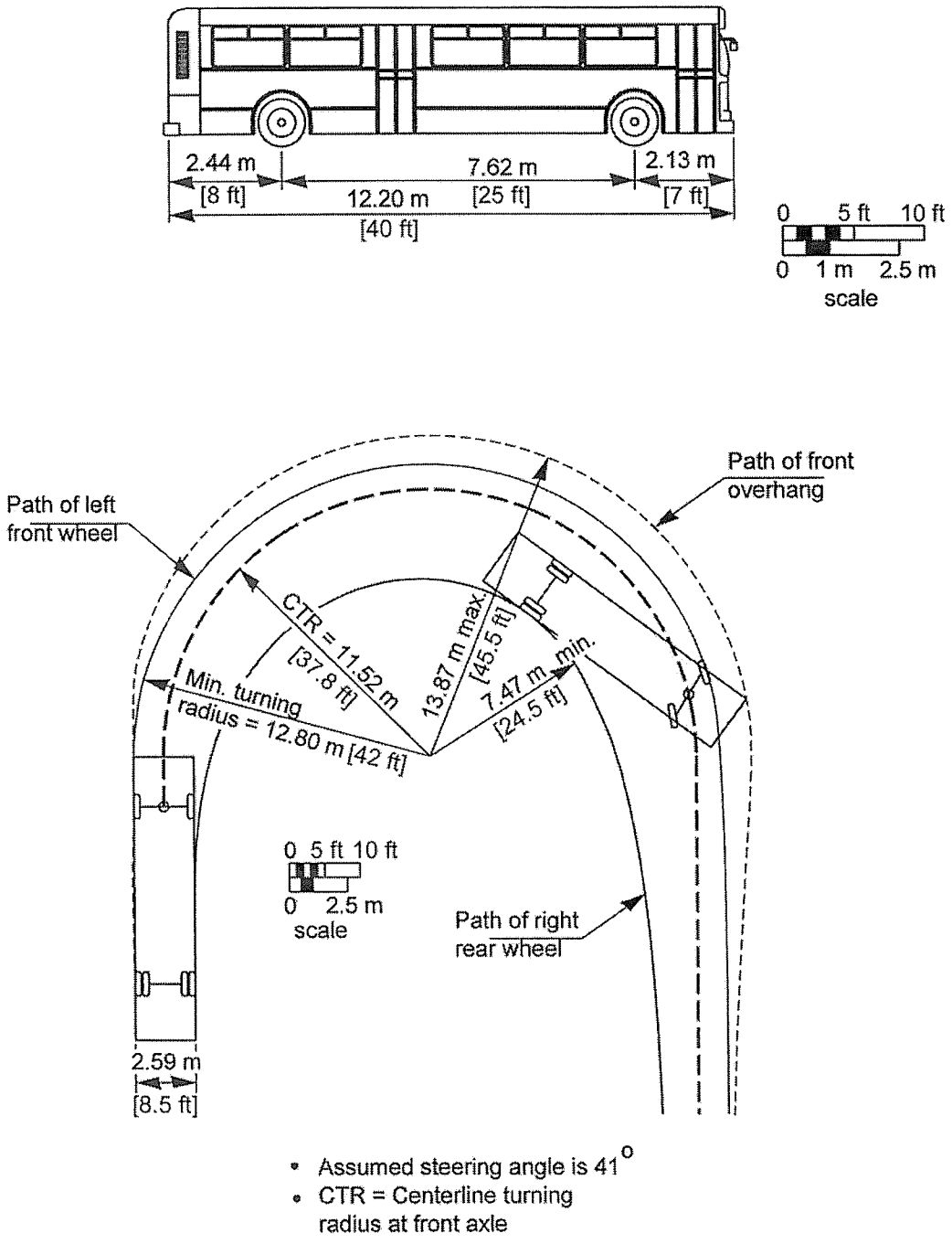
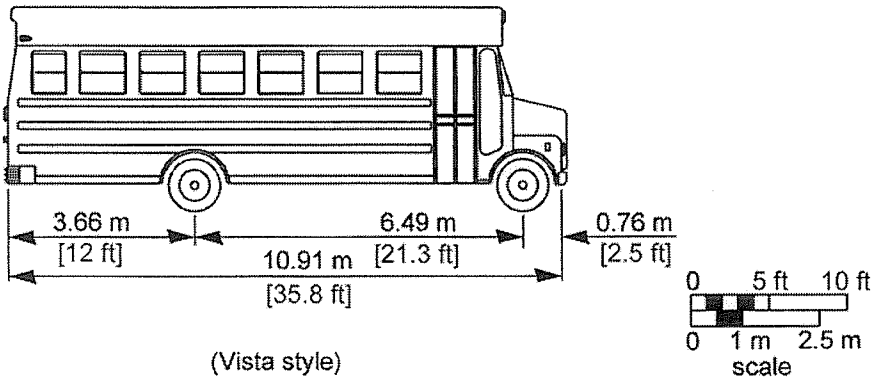


Exhibit 2-7. Minimum Turning Path for City Transit Bus (CITY-BUS) Design Vehicle



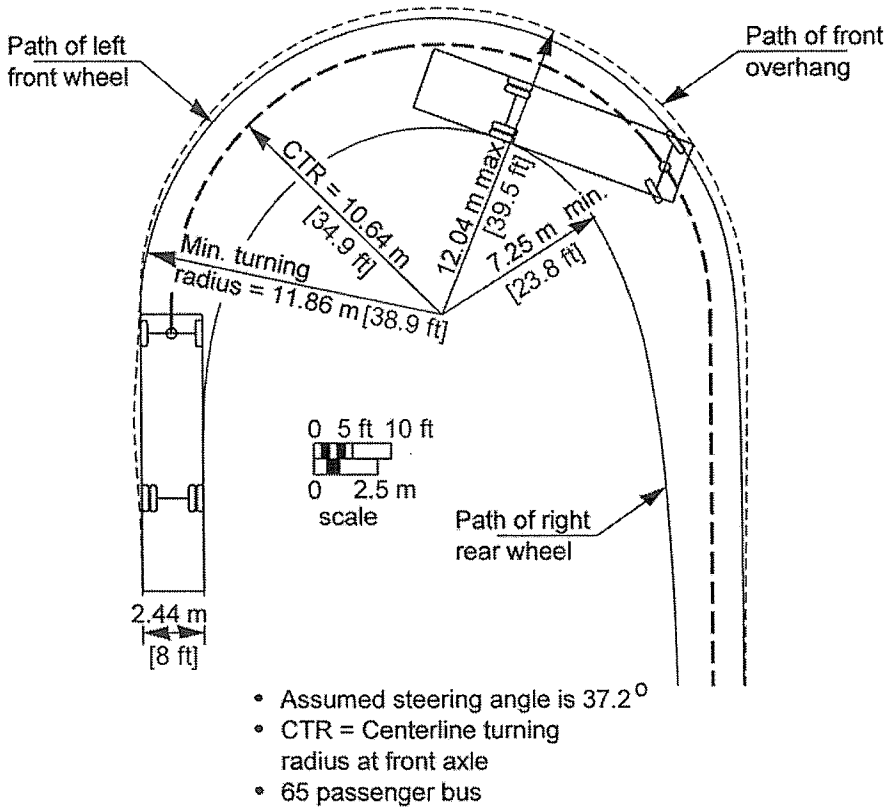


Exhibit 2-8. Minimum Turning Path for Conventional School Bus (S-BUS-11 [S-BUS-36]) Design Vehicle

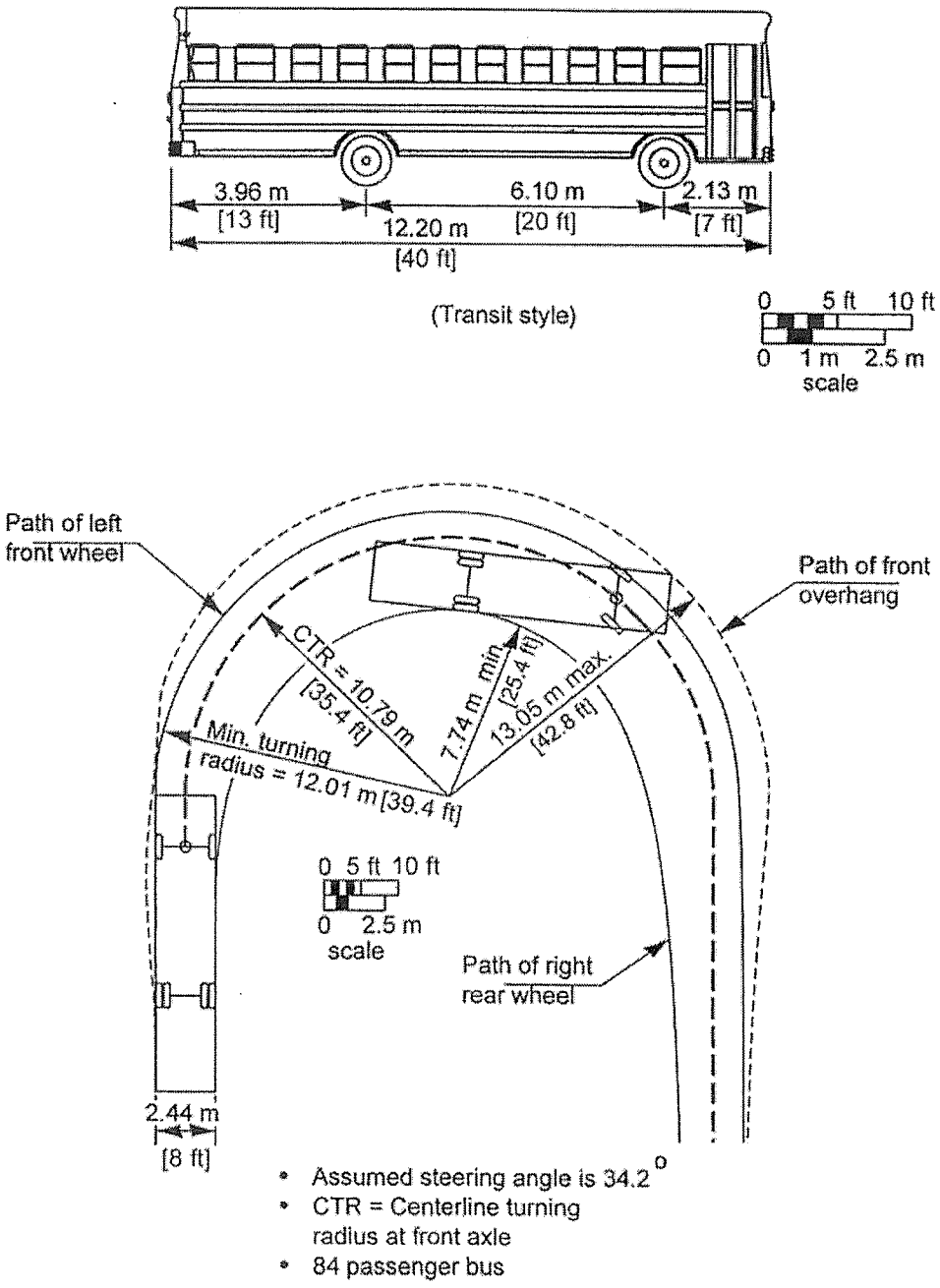


Exhibit 2-9. Minimum Turning Path for Large School Bus (S-BUS-12 [S-BUS-40]) Design Vehicle

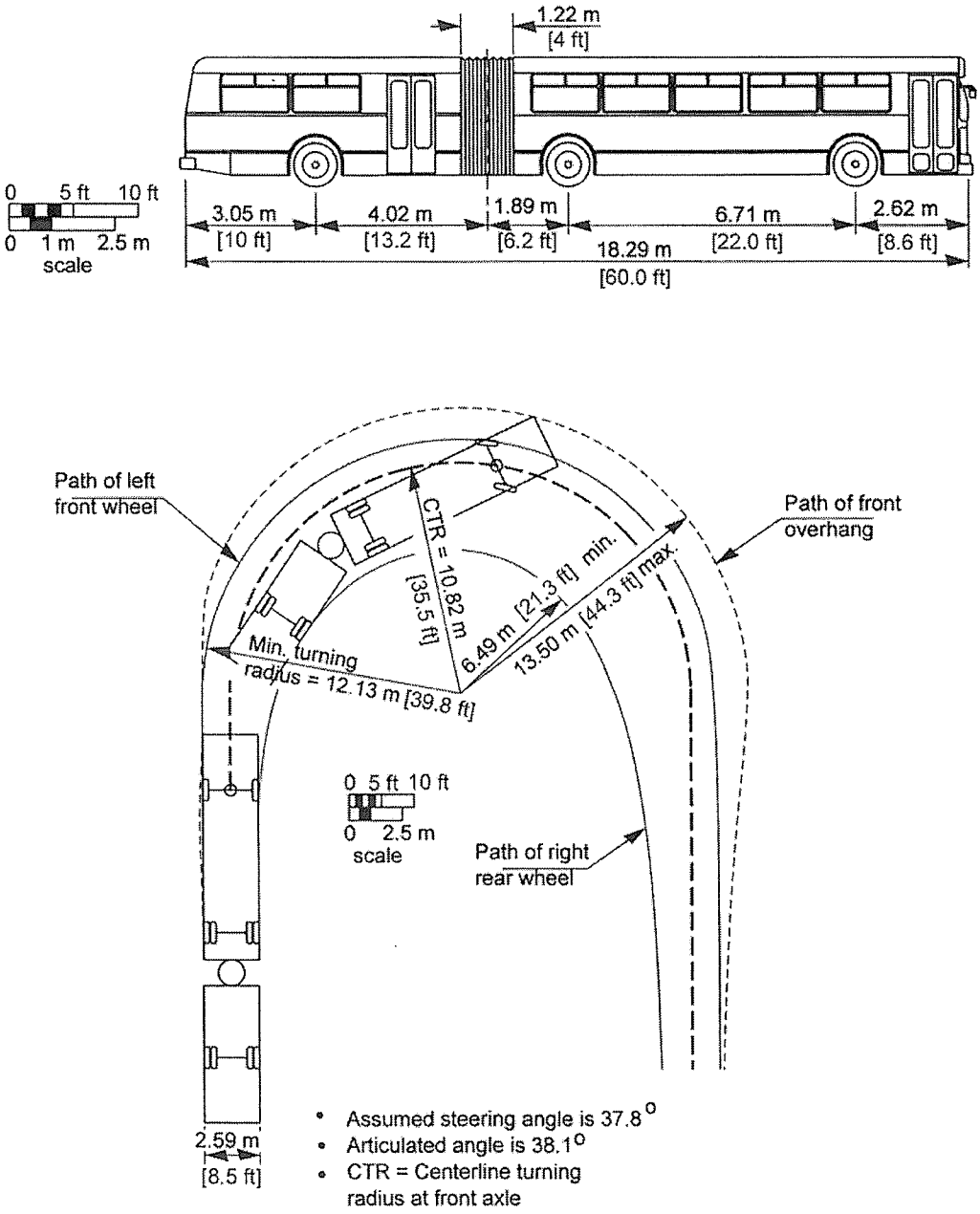
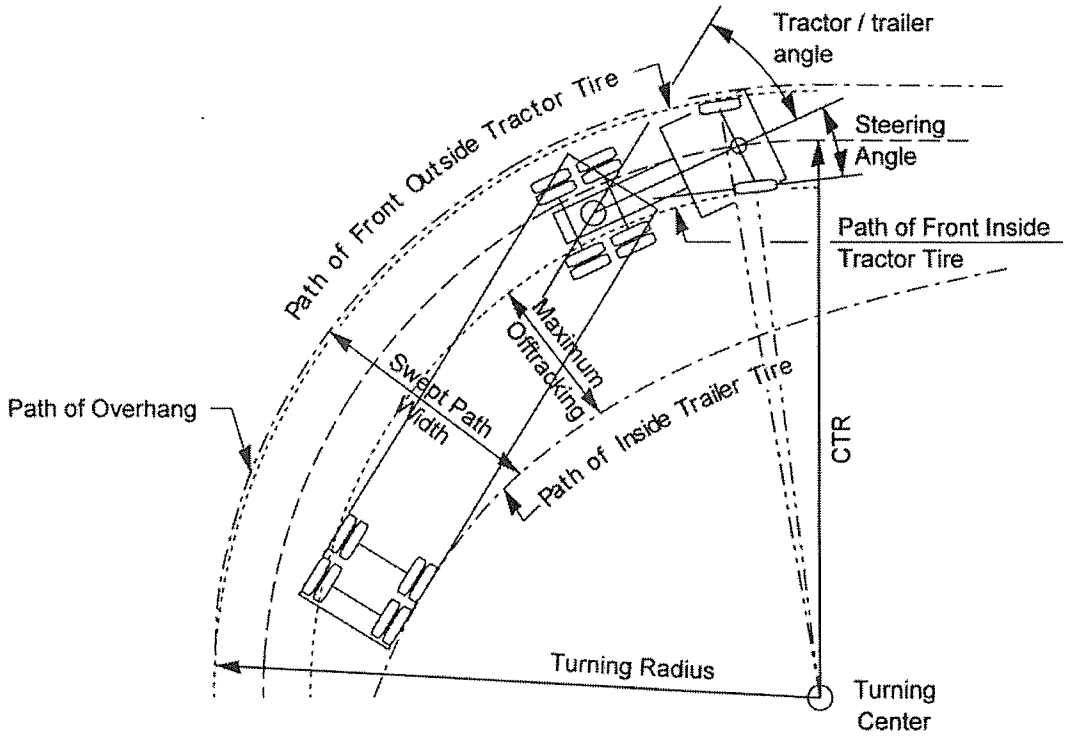


Exhibit 2-10. Minimum Turning Path for Articulated Bus (A-BUS) Design Vehicle



Definitions:

1. Turning radius—The circular arc formed by the turning path radius of the front outside tire of a vehicle. This radius is also described by vehicle manufacturers as the "turning curb radius."
2. CTR—The turning radius of the centerline of the front axle of a vehicle.
3. Offtracking—The difference in the paths of the front and rear wheels of a tractor/semitrailer as it negotiates a turn. The path of the rear tires of a turning truck does not coincide with that of the front tires, and this effect is shown in the drawing above.
4. Swept path width—The amount of roadway width that a truck covers in negotiating a turn and is equal to the amount of offtracking plus the width of the tractor unit. The most significant dimension affecting the swept path width of a tractor/semitrailer is the distance from the kingpin to the rear trailer axle or axles. The greater this distance is, the greater the swept path width.
5. Steering angle—The maximum angle of turn built into the steering mechanism of the front wheels of a vehicle. This maximum angle controls the minimum turning radius of the vehicle.
6. Tractor/trailer angle—The angle between adjoining units of a tractor/semitrailer when the combination unit is placed into a turn; this angle is measured between the longitudinal axes of the tractor and trailer as the vehicle turns. The maximum tractor/trailer angle occurs when a vehicle makes a 180° turn at the minimum turning radius; this angle is reached slightly beyond the point where maximum swept path width is achieved.

Exhibit 2-11. Turning Characteristics of a Typical Tractor-Semitrailer Combination Truck

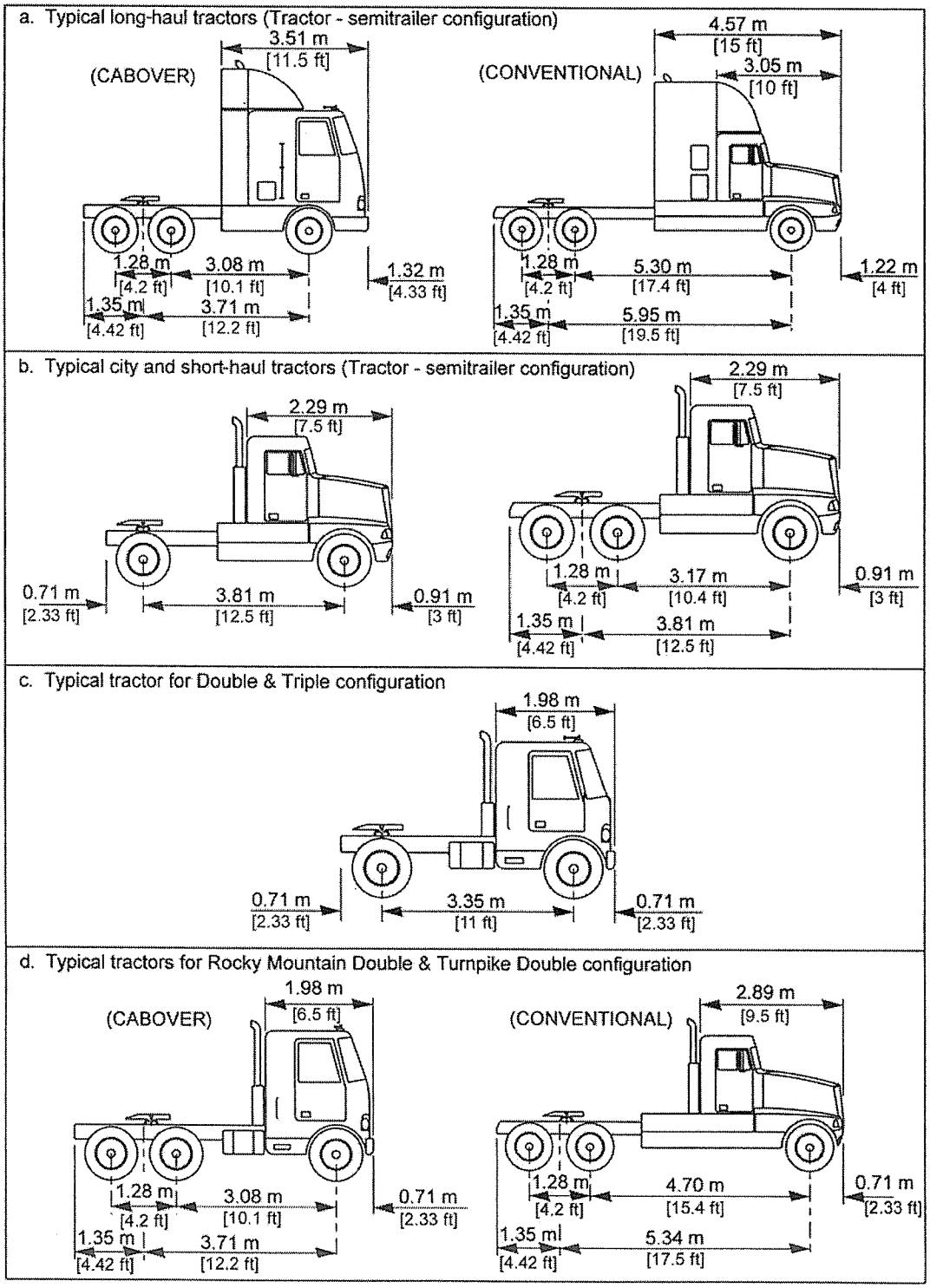
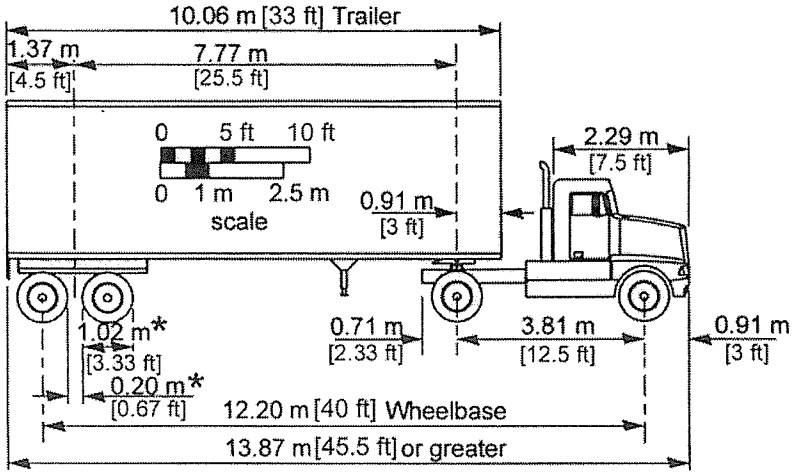


Exhibit 2-12. Lengths of Commonly Used Truck Tractors



* Typical tire size and space between tires applies to all trailers.

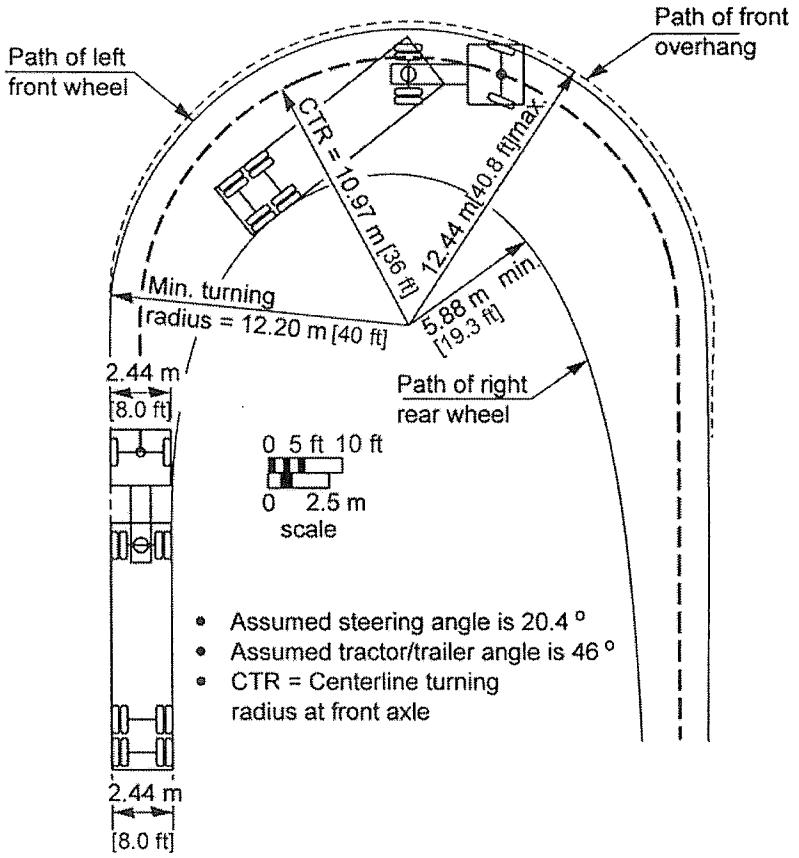


Exhibit 2-13. Minimum Turning Path for Intermediate Semitrailer (WB-12 [WB-40]) Design Vehicle

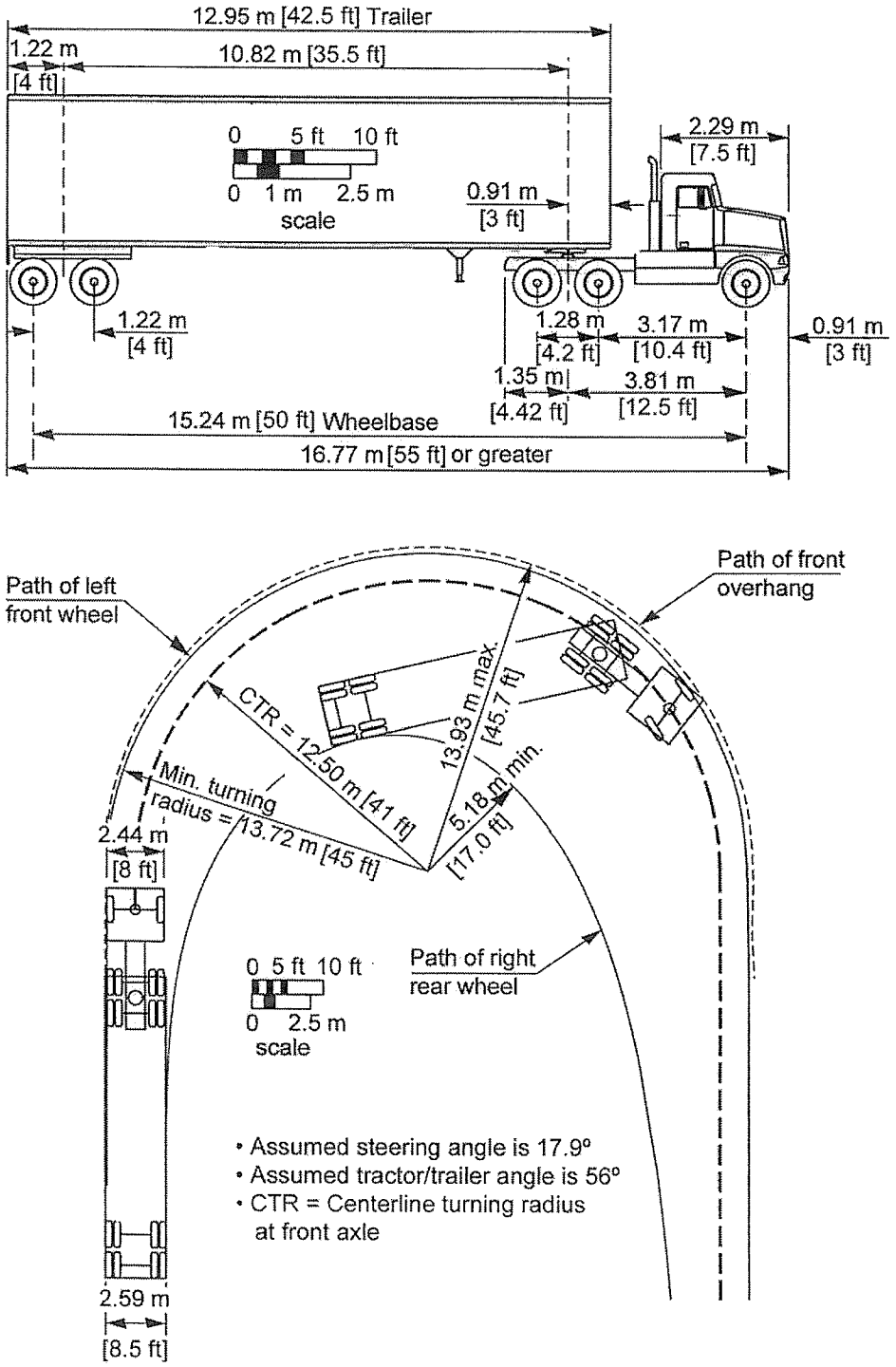


Exhibit 2-14. Minimum Turning Path for Intermediate Semitrailer (WB-15 [WB-50]) Design Vehicle

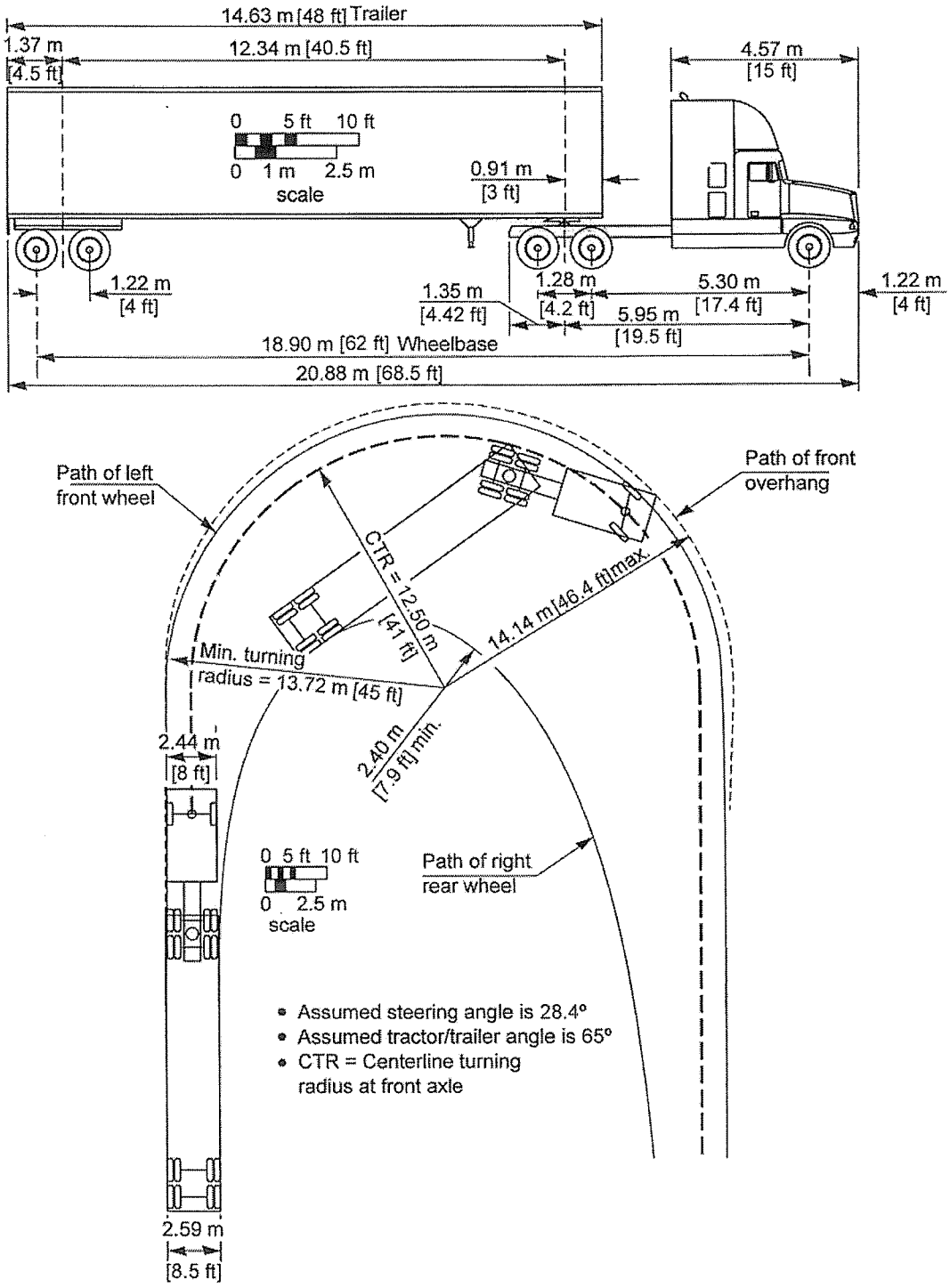


Exhibit 2-15. Minimum Turning Path for Interstate Semitrailer (WB-19 [WB-62]) Design Vehicle

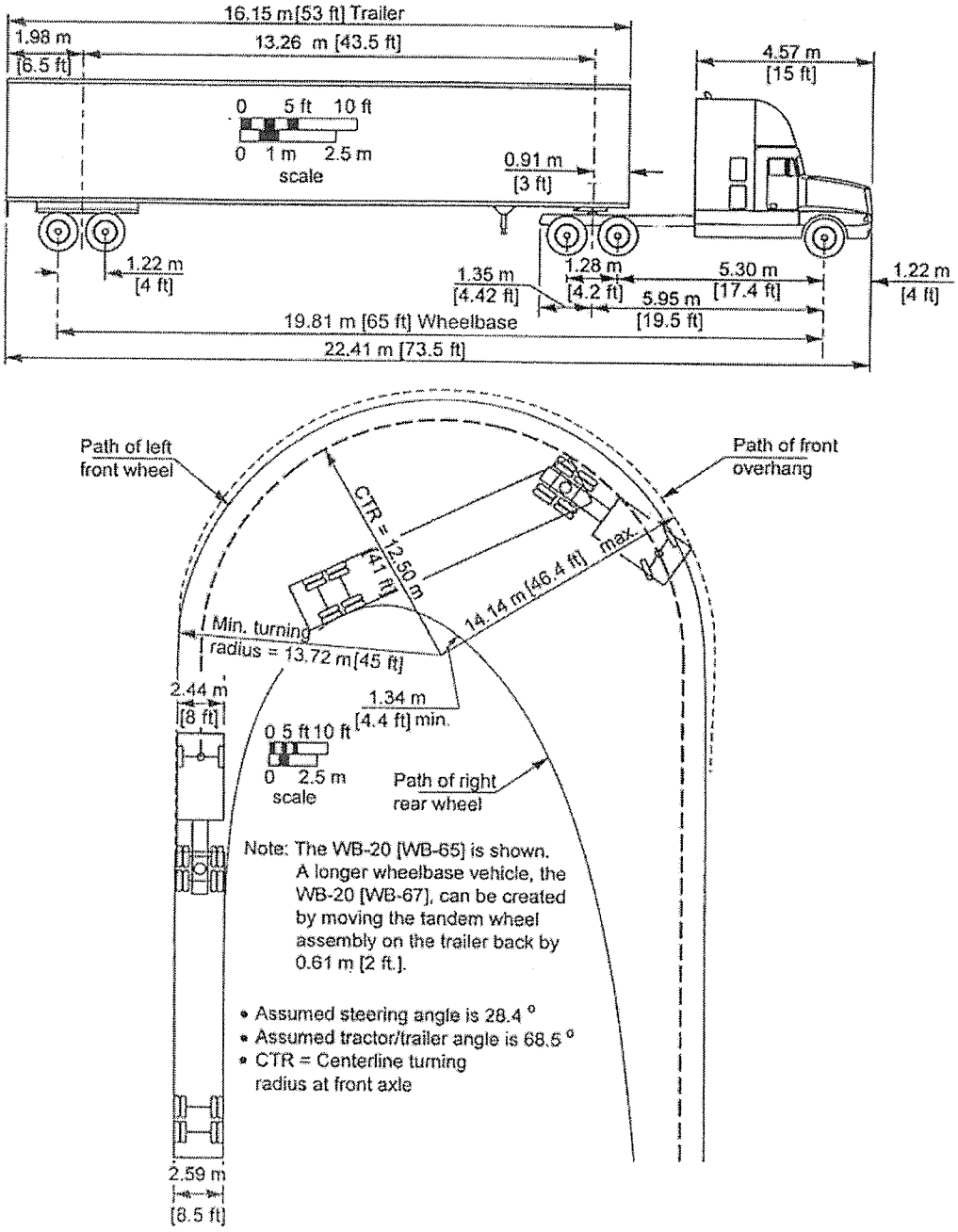


Exhibit 2-16. Minimum Turning Path for Interstate Semitrailer (WB-20 [WB-65 and WB-67]) Design Vehicle

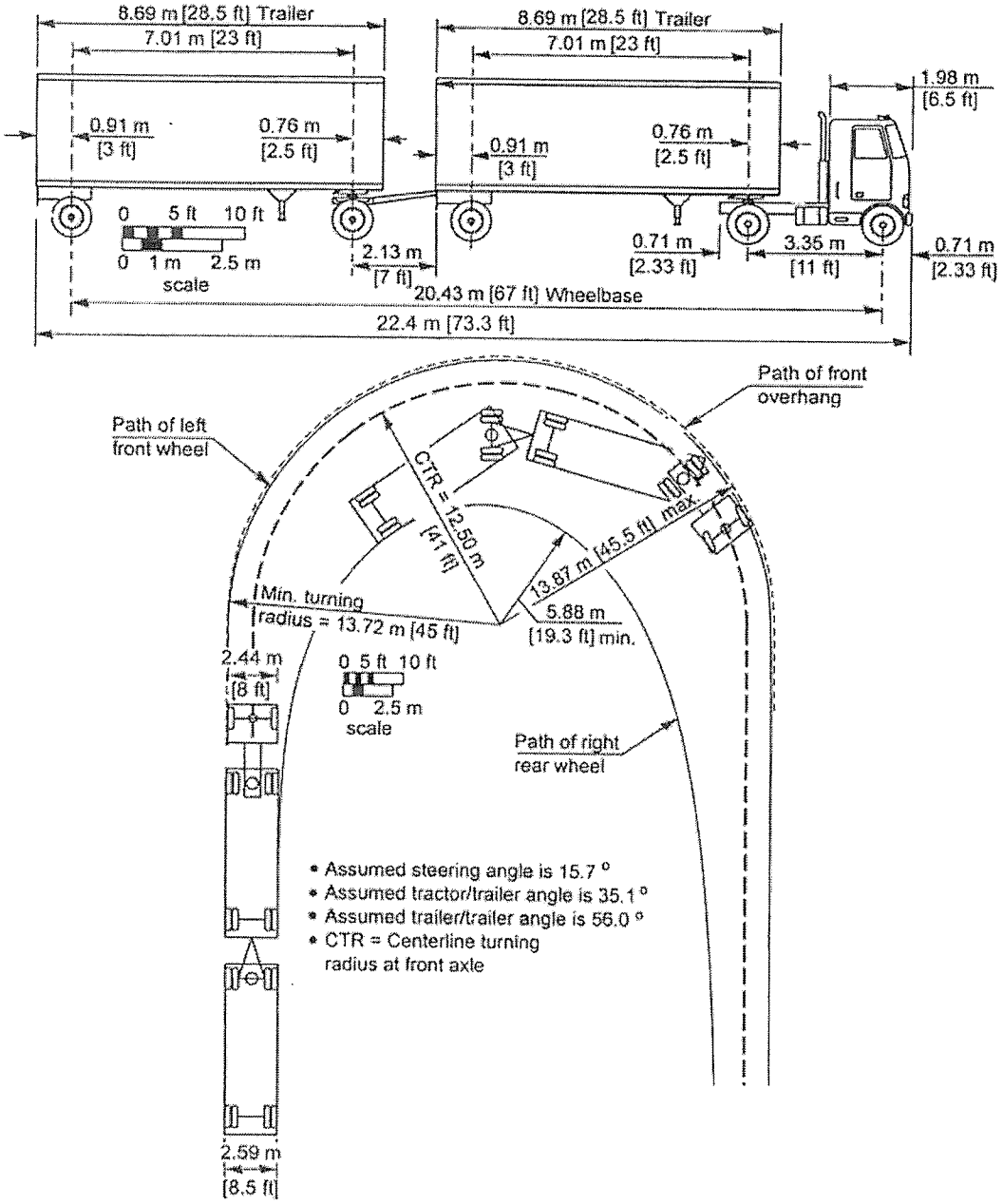


Exhibit 2-17. Minimum Turning Path for Double-Trailer Combination (WB-20D [WB-67D]) Design Vehicle

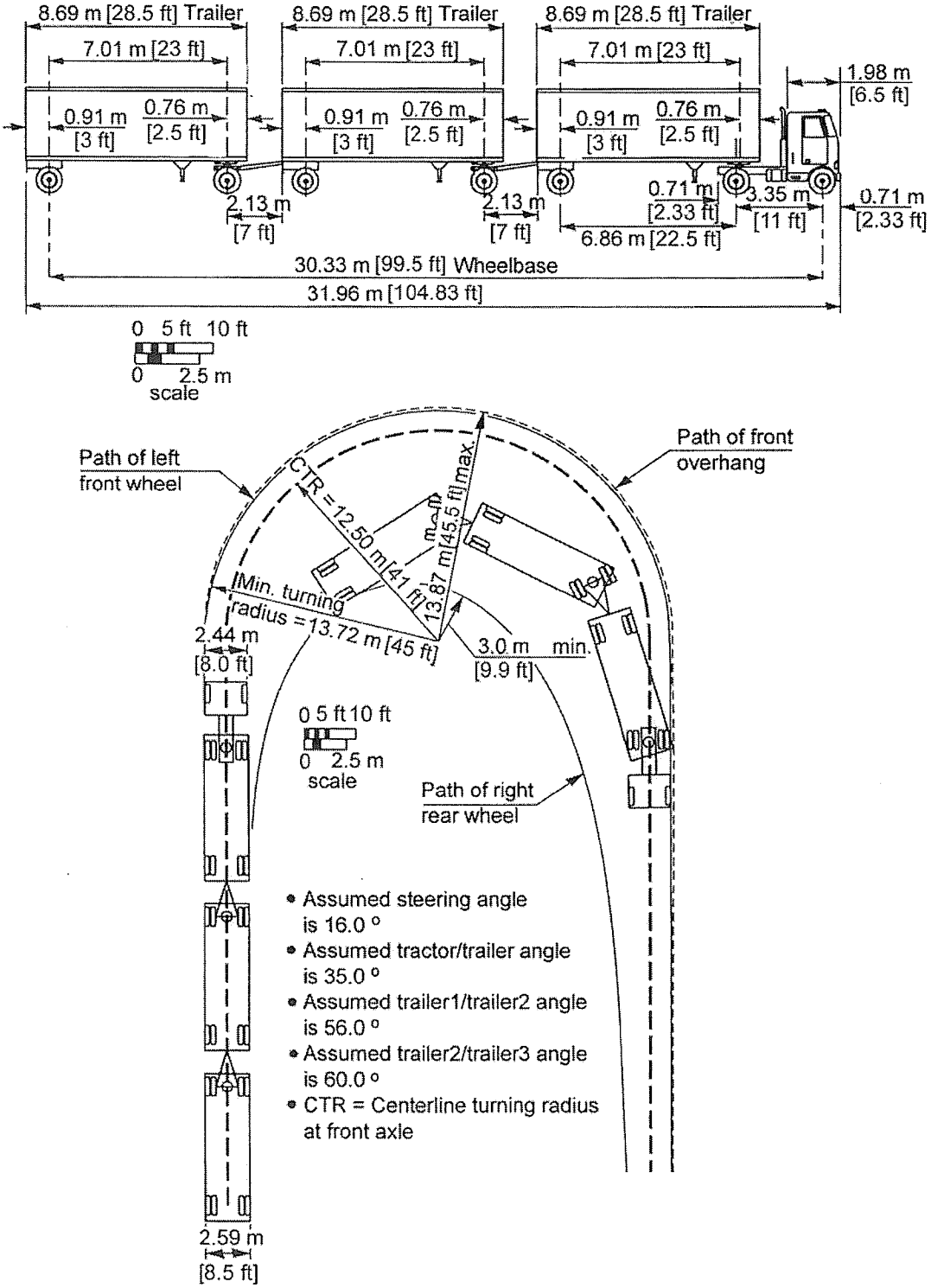
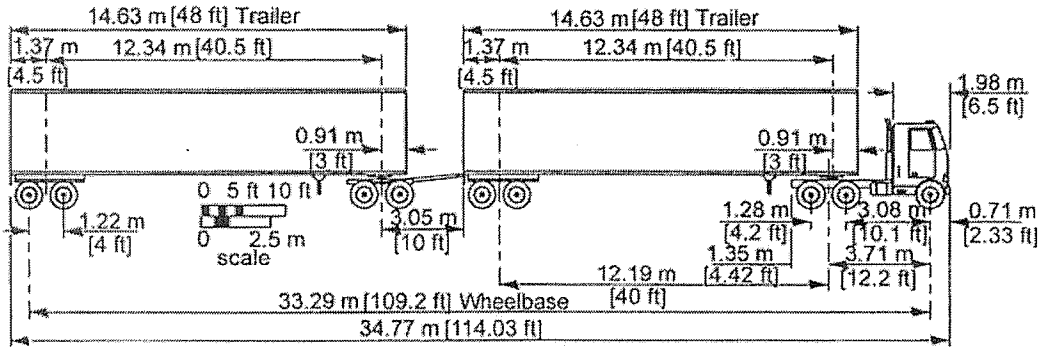


Exhibit 2-18. Minimum Turning Path for Triple-Trailer Combination (WB-30T [WB-100T]) Design Vehicle



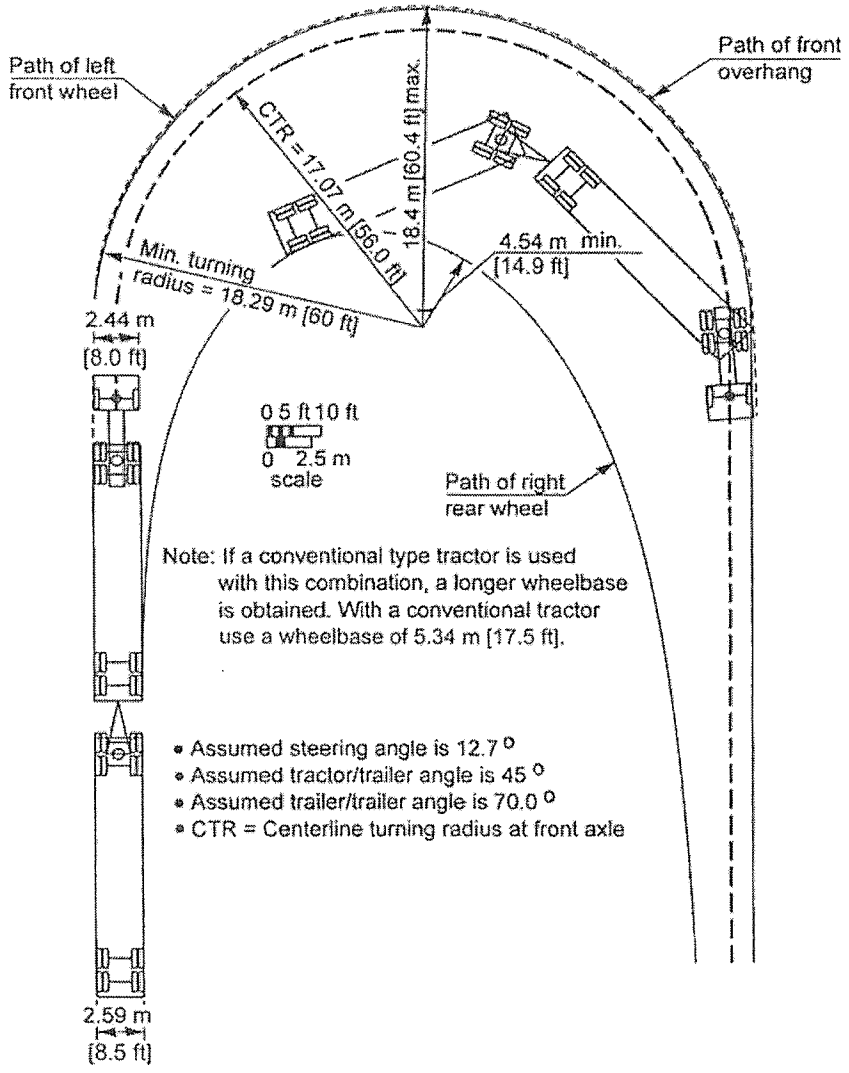
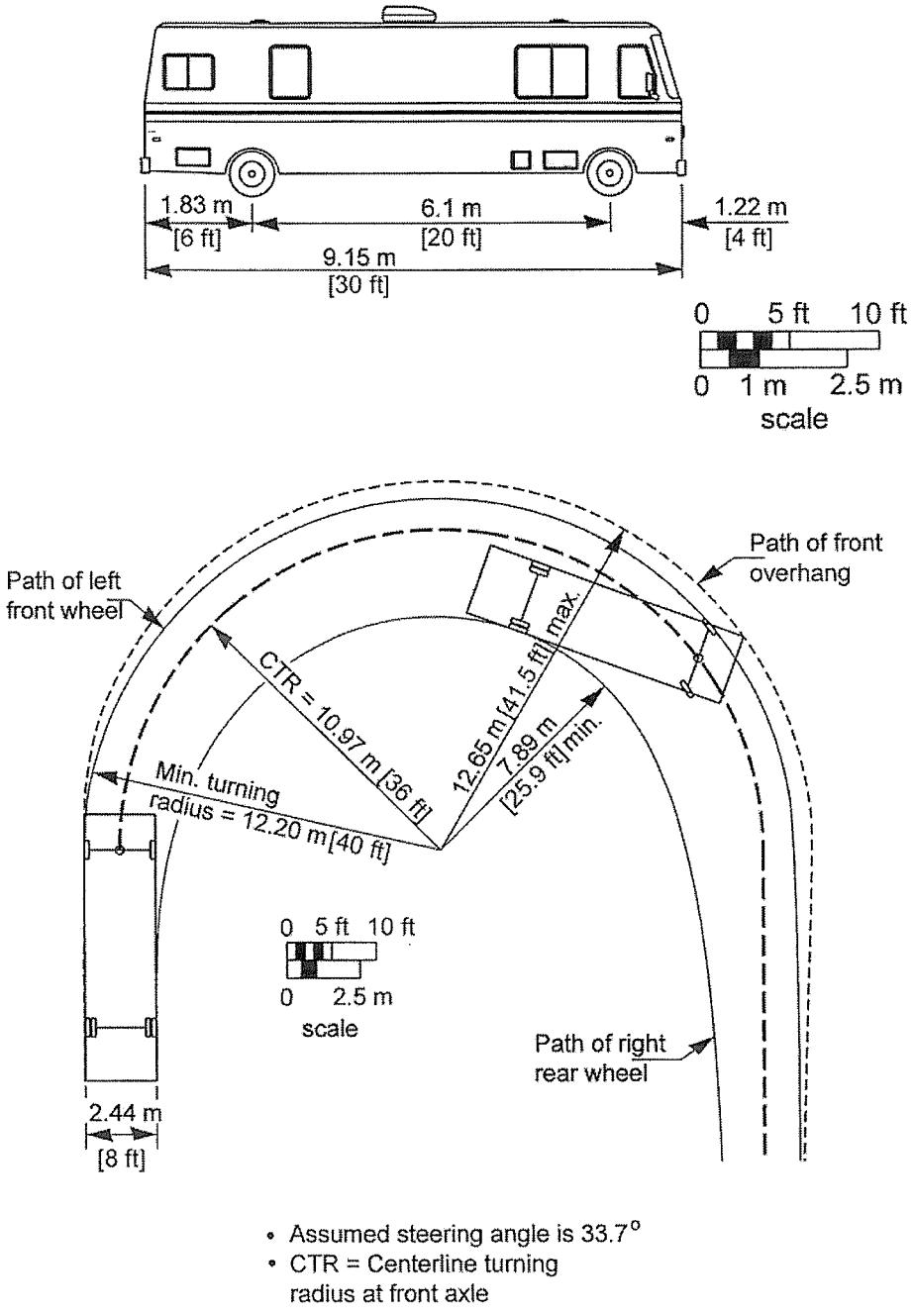


Exhibit 2-19. Minimum Turning Path for Turnpike-Double Combination (WB-33D [WB-109D]) Design Vehicle



- Assumed steering angle is 33.7°
- CTR = Centerline turning radius at front axle

Exhibit 2-20. Minimum Turning Path for Motor Home (MH) Design Vehicle

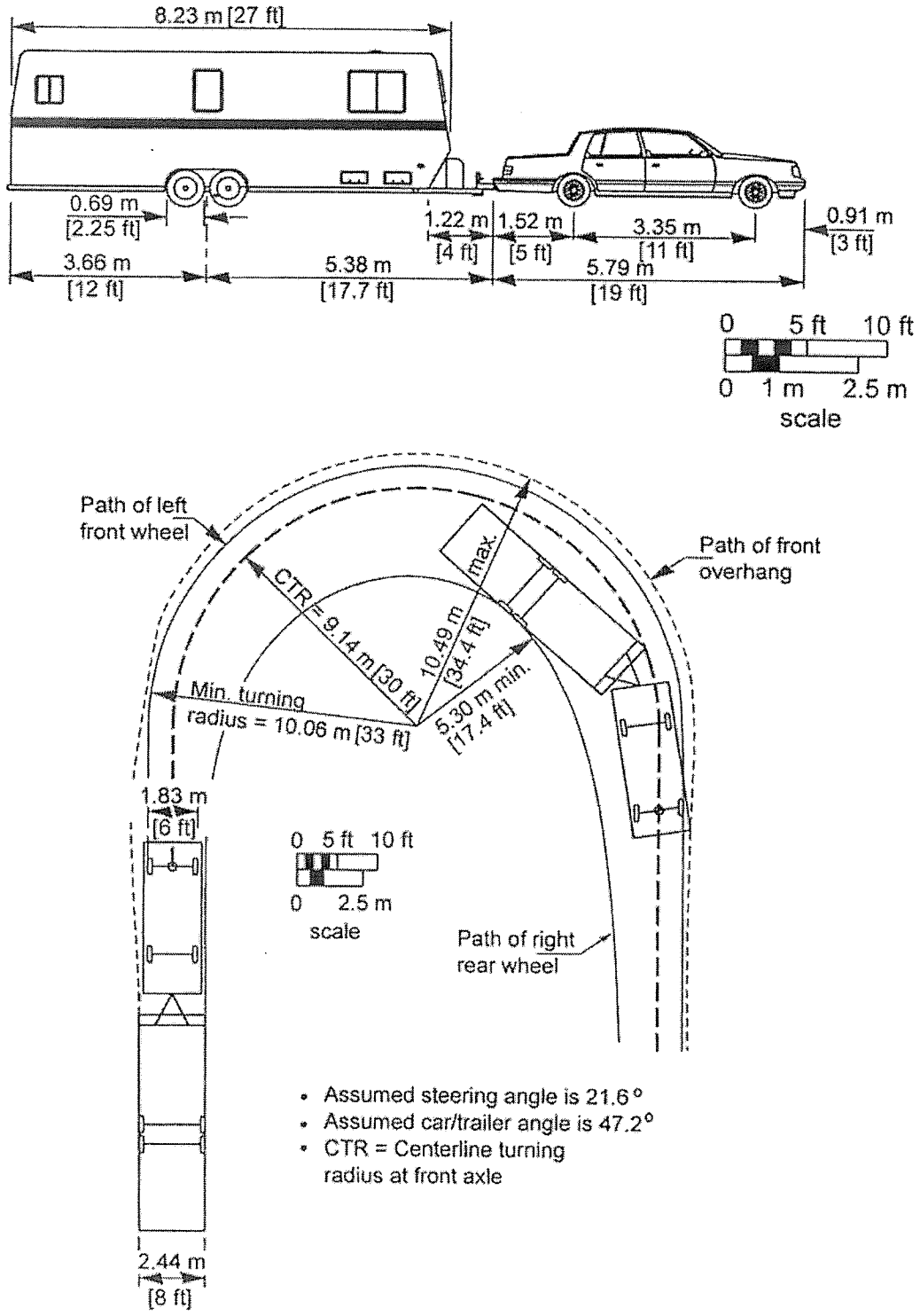


Exhibit 2-21. Minimum Turning Path for Passenger Car and Camper Trailer (P/T) Design Vehicle

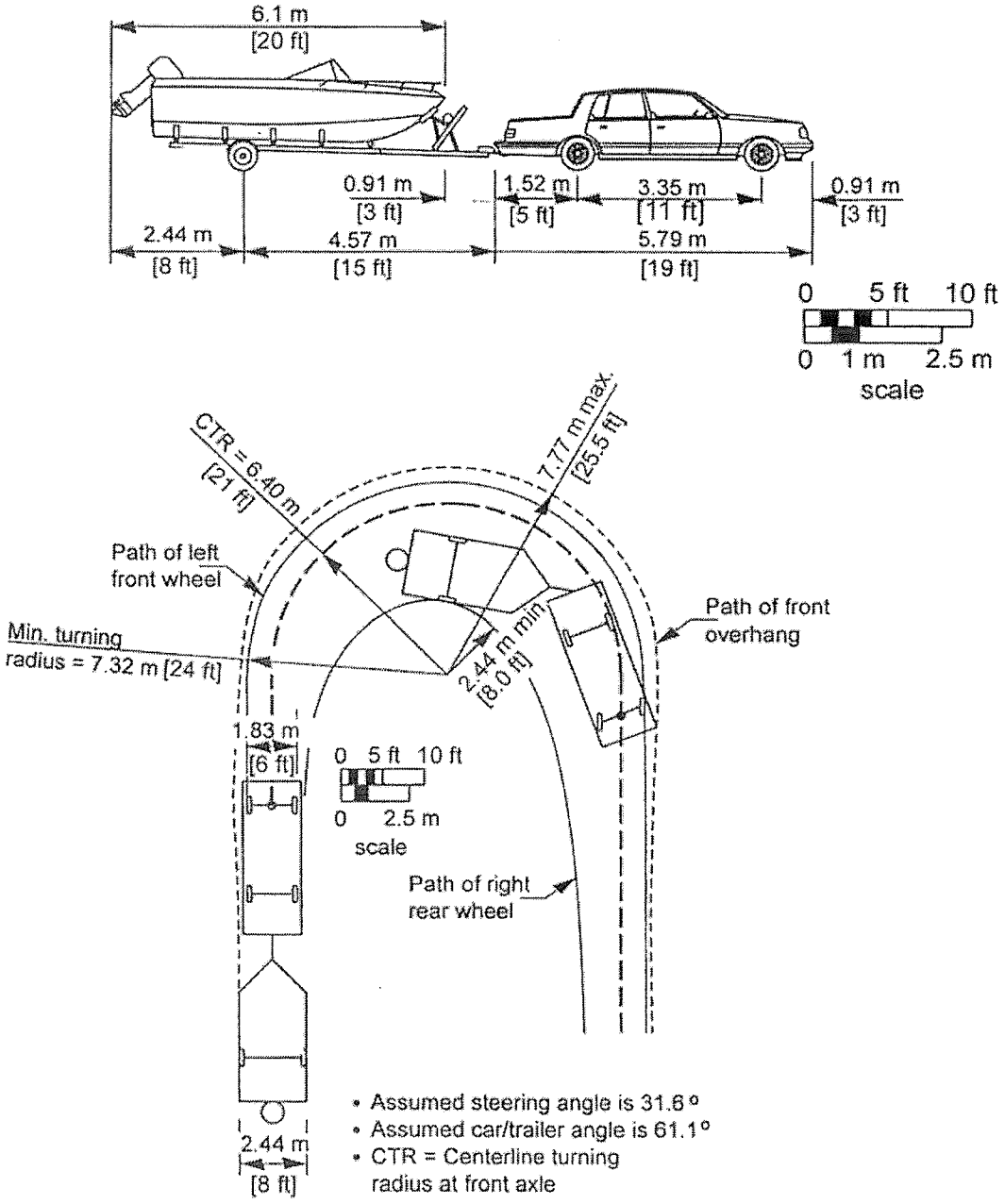


Exhibit 2-22. Minimum Turning Path for Passenger Car and Boat Trailer (P/B) Design Vehicle

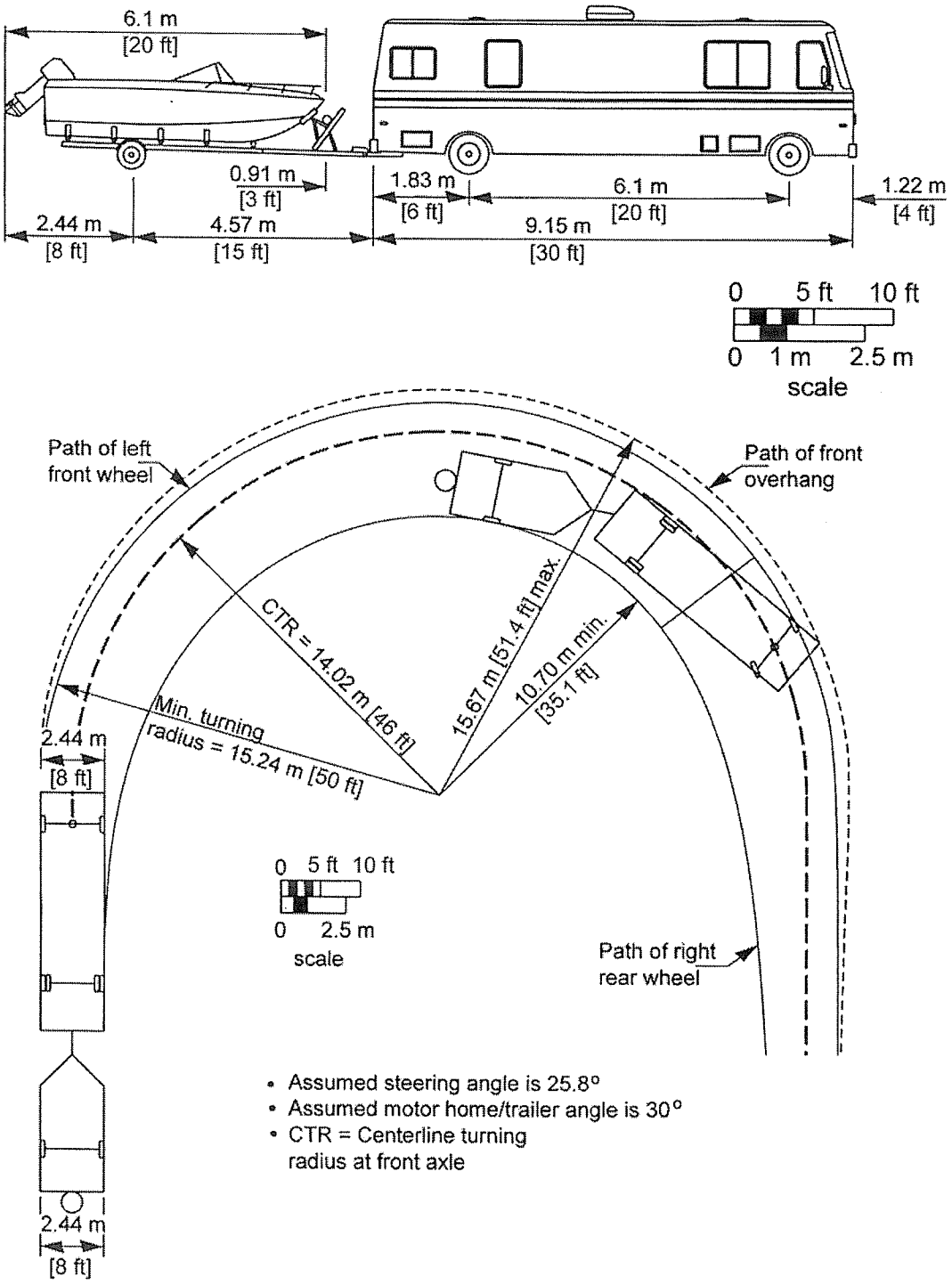


Exhibit 2-23. Minimum Turning Path for Motor Home and Boat Trailer (MH/B) Design Vehicle

vehicles. These combination trucks are identified by the designation WB, together with the wheel base or another length dimension in both metric and U.S. customary units. The combination truck design vehicles are: (1) the WB-12 [WB-40] design vehicle representative of intermediate size tractor-semitrailer combinations, (2) the WB-15 [WB-50] design vehicle representative of a slightly larger intermediate size tractor-semitrailer combination commonly in use, (3) the WB-19 [WB-62] design vehicle representative of larger tractor semitrailer combinations allowed on selected highways by the Surface Transportation Assistance Act of 1982, (4) the WB-20 [WB-65 or WB-67] design vehicle representative of a larger tractor-semitrailer allowed to operate on selected highways by "grandfather" rights under the Surface Transportation Assistance Act of 1982, (5) the WB-20D [WB-67D] design vehicle representative of a tractor-semitrailer/full trailer (doubles or twin trailer) combination commonly in use, (6) the WB-30T [WB-100T] design vehicle representative of tractor-semitrailer/full trailer/full trailer combinations (triples) selectively in use, and (7) the WB-33D [WB-109D] design vehicle representative of larger tractor-semitrailer/full trailer combinations (turnpike double) selectively in use. Although turnpike doubles and triple trailers are not permitted on many highways, their occurrence does warrant inclusion in this publication.

The minimum turning radii and transition lengths shown in the exhibits are for turns at less than 15 km/h [10 mph]. Longer transition curves and larger curve radii are needed for roadways with higher speeds. The radii shown are considered appropriate minimum values for use in design, although skilled drivers might be able to turn with a slightly smaller radius.

The dimensions of the design vehicles take into account recent trends in motor vehicle sizes manufactured in the United States and represent a composite of vehicles currently in operation. However, the design vehicle dimensions are intended to represent vehicle sizes that are critical to geometric design and thus are larger than nearly all vehicles belonging to their corresponding vehicle classes.

The turning paths shown in Exhibits 2-3 through 2-10 and Exhibits 2-13 through 2-23 were derived by using commercially available computer programs.

The P design vehicle, with the dimensions and turning characteristics shown in Exhibit 2-3, represents a larger passenger car.

The SU design vehicle represents a larger single-unit truck. The control dimensions indicate the minimum turning path for most single-unit trucks now in operation (see Exhibit 2-4). On long-distance facilities serving large over-the-road truck traffic or intercity buses (motor coaches), the design vehicle should generally be either a combination truck or an intercity bus (see Exhibit 2-5 or Exhibit 2-6).

For intracity or city transit buses, a design vehicle designated as CITY-BUS is shown in Exhibit 2-7. This design vehicle has a wheel base of 7.62 m [25 ft] and an overall length of 12.20 m [40 ft]. Buses serving particular urban areas may not conform to the dimensions shown in Exhibit 2-7. For example, articulated buses, which are now used in certain cities, are longer than a conventional bus, with a permanent hinge near the vehicle's center that allows more maneuverability. Exhibit 2-10 displays the critical dimensions for the A-BUS design vehicle.

Also, due to the importance of school buses, two design vehicles designated as S-BUS 11 [S-BUS 36] and S-BUS 12 [S-BUS 40] are shown in Exhibits 2-8 and 2-9, respectively. The larger design vehicle is an 84-passenger bus and the smaller design vehicle is a 65-passenger bus. The highway designer should also be aware that for certain buses the combination of ground clearance, overhang, and vertical curvature of the roadway may present problems in hilly areas.

Exhibits 2-13 through 2-19 show dimensions and the minimum turning paths of the design vehicles that represent various combination trucks. For local roads and streets, the WB-15 [WB-50] or WB-12 [WB-40] is often considered an appropriate design vehicle. The larger combination trucks are appropriate for design of facilities that serve over-the-road trucks.

Exhibits 2-20 through 2-23 indicate minimum turning paths for typical recreational vehicles.

In addition to the vehicles shown in Exhibits 2-3 through 2-10 and Exhibits 2-13 through 2-23, other vehicles may be used for selected design applications, as appropriate. With the advent of computer programs that can derive turning path plots, the designer can determine the path characteristics of any selected vehicle if it differs from those shown (**1**).

Vehicle Performance

Acceleration and deceleration rates of vehicles are often critical parameters in determining highway design. These rates often govern the dimensions of such design features as intersections, freeway ramps, climbing or passing lanes, and turnout bays for buses. The following data are not meant to depict average performance for specific vehicle classes but rather lower performance vehicles suitable for design application, such as a low-powered (compact) car and a loaded truck or bus.

Based on its acceleration and deceleration performance, the passenger car seldom controls design. From Exhibits 2-24 and 2-25, it is obvious that relatively rapid accelerations and decelerations are possible, although they may be uncomfortable for the vehicle's passengers. Also, due to the rapid changes being made in vehicle operating characteristics, current data on acceleration and deceleration may soon become outdated. In addition, refer to the NCHRP Report 400, *Determination of Stopping Sight Distances* (**2**). Exhibit 2-24 is based on NCHRP Report 270 (**3**).

When a highway is located in a recreational area, the performance characteristics of recreational vehicles should be considered.

Vehicular Pollution

Pollutants emitted from motor vehicles and their impact on land uses adjacent to highways are factors affecting the highway design process. As each vehicle travels along the highway, it emits pollutants into the atmosphere and transmits noise to the surrounding area. The highway