Bus Concepts

Types of Service

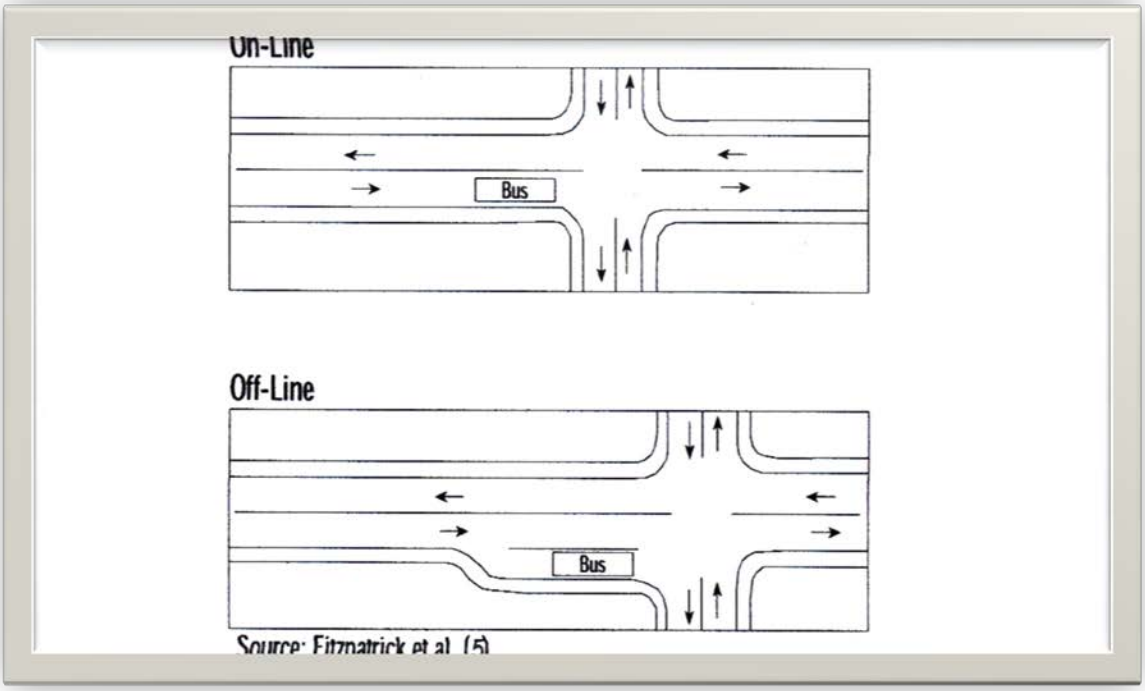
Bus transit service can be either fixed route or demand responsive:

- Fixed-route service is ideal for large, densely populated urban areas. In less dense areas, which cannot support fixed -route.
- demand -responsive transit that can be an essential part of transportation for the non driving population. With this type of service, the passenger calls dispatcher, who then radios the caller's location to a driver. Generally taxicabs or vans provide this type door-to-door service.

Bus Capacity Concepts

Loading Areas

A loading areas, or bus berth, is a space for buses to stop to pick up and discharge passengers. Bus stops, discussed below, contain one or more loading areas. The most common form of loading area is a linear bus stop along a street curb. In this case, loading areas either can be provided in the travel lane (i.e. on- line); so that following buses cannot pass the stopped bus; or they can be pullouts out of the travel lane (i.e. off-line), so that following buses may pass. See Figure(1) below:



a) Off-Line b) On-Line

Figure 1: On-Line and Off-Line Loading Areas.

Loading areas in bus terminals may be linear or may take other forms. Angle berths are limited to one bus per berth and require the buses to back out. Drive -through berths are also feasible and may accommodate multiple vehicles. Shallow saw tooth berths are popular in urban transit centers, because they permit independent movements into and out of each berth. See Figure (2) below:

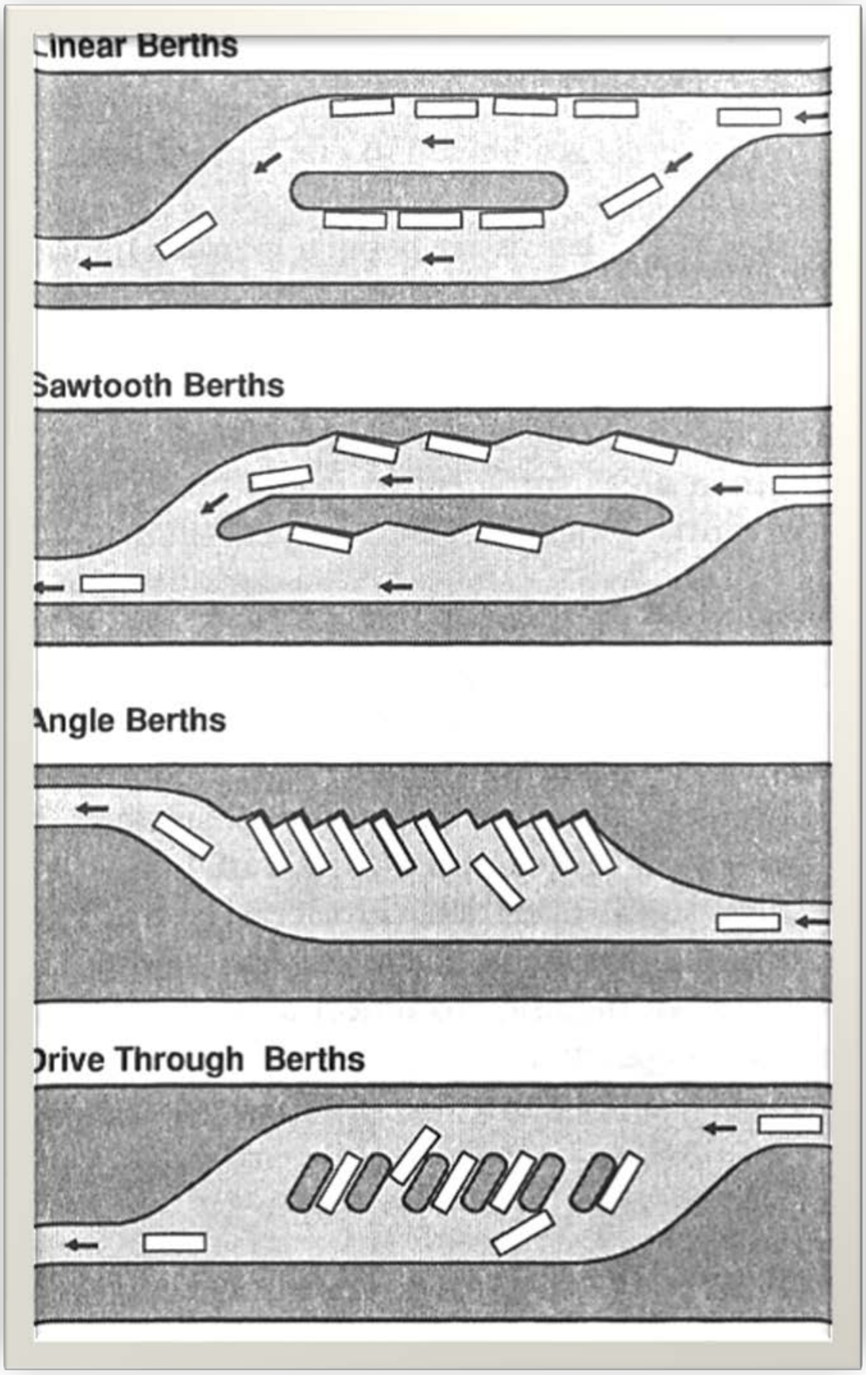


Figure 2: Bus Loading Areas (Berth) Design.

- Linear (curb-side): These bays can operate in series and have capacity characteristics similar to on-street bus stops.
- Sawtooth: This loading configuration is popular in urban transit centers, and designed to permit independent movements into and out of each bay.
- Angle: This loading type is limited to one bus per bay, and requires buses to back out. This is often used for inter-city coach terminals, with long dwell times, single-door entry, and luggage loading requirements.

- ❖ Drive Through: Drive-through angle bays do not require buses to back out of the bay and may accommodate multiple vehicles.

a) Linear.

b) Sawtooth.

c) Derive -Through.

d) Angle.

Figure 3: Bus Loading Area (Berth) Examples.

Bus Stops

A bus stop is an area where one or more buses load and unload passengers. It consists of one or more loading areas. **Bus stop capacity is related to the following** :

- capacity of the individual loading areas at the stop,
- loading area design (linear or nonlinear), and
- the number of loading areas.

Off-line bus stops provide greater capacity than on-line stops for loading areas, but in mixed traffic, bus speeds may be reduced if heavy volumes delay the buses exiting a stop. On the other hand, skip-stop operations are possible with offline stops, but not with on-line stops.
Bus stop design for bus terminals must consider passengers and take into account longer loading area occupancies by buses.

Bus Terminals

The design of off-street bus terminals and transfer centers involves additional considerations—not only estimates of passenger service times of buses, but also a clear understanding of how each bus route will operate. Therefore, schedule recovery times, driver relief times, and layovers to meet scheduled departure times become key in establishing loading area requirements and in sizing the facility.

In addition, good operating practice suggests that each bus route, or geographically compatible groups of routes, should have a separate loading position clearly distinguished for passengers.

Loading-area space requirements should recognize the following :

- specific type of transit operations,
- fare collection practices,
- bus door configurations,
- passenger arrival patterns,
- amount of baggage,
- driver layover-recovery times,
- terminal design,
- loading area configuration.

They should reflect both scheduled and actual peak-period bus arrivals and departures, since intercity bus services regularly run extra vehicles during the busiest travel periods. Bus routes and service patterns also influence loading area requirements.

Under good operating practices a maximum of two distinct routes (i.e., services) share a loading position.

On-Street Bus Stops

On-street bus stops typically are located curbside in one of three locations as shown in Figure (4) below :

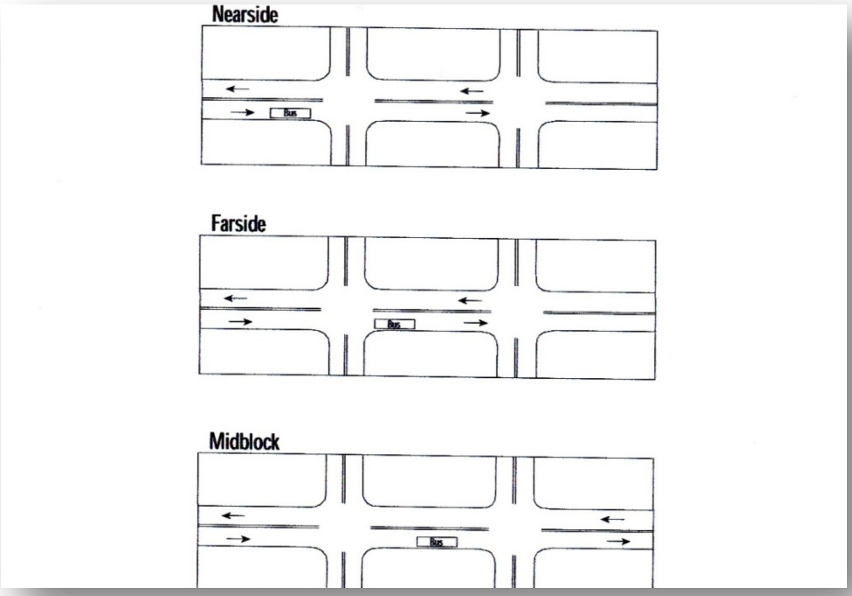


Figure 4: On-Street Bus Stop Location.

(a) nearside, when the bus stops immediately before an intersection;

(b) far side, when the bus stops immediately after an intersection; and

(c) midblock, when the bus stops in the middle of a block, between intersections.

Under certain circumstances, such as when buses share a stop with streetcars running in the center of the street, or when exclusive bus lanes are located in the center of the street, a bus stop may be located on a boarding island within the street rather than curbside. When boarding islands are used, pedestrian safety and Americans with Disabilities Act (ADA) accessibility issues should be carefully considered. Figure (4) depicts typical on-street bus stop locations.

The bus stop location influences capacity, particularly when passenger vehicles are allowed to make right turns from the curb lane (as is the case in most situations, except for certain kinds of exclusive bus lanes). Far side stops have the least effect on capacity (when buses are able to use an adjacent lane to avoid right-turn queues), followed by midblock stops, and nearside stops.

Bus Stop Loading-Area Requirements

The key factors influencing the number of loading areas required at a bus stop are the following:

- **Bus volumes**. The number of buses scheduled to use a bus stop during an hour directly affects the number of buses that may need to use the stop. If loading areas are insufficient, buses will queue behind the stop, decreasing its vehicle capacity. This increases passenger travel times and decreases on-time reliability, negatively affecting quality of service.

- **Probability of queue formation**. The failure rate—the probability that queues of buses will form at a bus stop—is a design factor that should be considered when sizing a bus stop.
- **Loading area design**. With the exception of the linear model, loading area designs—such as sawtooth and drive through—are 100 percent effective: the bus-stop vehicle capacity equals the number of loading areas times the vehicle capacity of each loading area, since buses are able to maneuver in and out of the loading areas independently of other buses. Linear loading areas, on the other hand, decrease in effectiveness as the number of loading areas increases, because it is not likely that the loading areas will be used equally. Buses entering or leaving a linear loading area also may be blocked and delayed by buses stopped in adjacent loading areas.

  Linear loading areas are less efficient than other loading area designs.

- **Traffic signal timing.** The amount of green signal time provided to a street that buses operate on affects the maximum number of buses that potentially can arrive at a bus stop during an hour. The amount of red signal time influences how much additional time a bus occupies a stop after passenger movements are completed.

Bus Lanes

For the purpose of determining capacity, a bus lane is any lane on a roadway in which buses operate. It may be used exclusively by buses, or it may be shared with other traffic. The vehicle capacity of a bus lane is influenced by the capacity of the critical bus stop located along the lane, typically the stop with the highest volume of passengers.

However, the critical stop also might have an insufficient number of loading areas. Bus lane capacity also is influenced by the following:

- Bus lane type. The vehicle capacity procedures identify three types of bus lanes. Type 1 bus lanes have no use of the adjacent lane; Type 2 bus lanes have partial use of the adjacent lane, which is shared with other traffic; and Type 3 bus lanes provide for exclusive use of two lanes by buses. The curb lane of Type 1 and 2 lanes may or may not be shared with other traffic. When the lane is primarily for mixed traffic, typically there is no formal designation of a bus lane either with signing or with pavement markings. The greater the degree of exclusivity of the bus lane and the greater the number of lanes available for buses to maneuver, the greater the bus lane capacity.
- Skip-stop operation. Bus lane capacity can be increased by dispersing bus stops, so that only a portion of the buses use the bus lane stop at a particular set of stops. This block-skipping pattern allows for a faster trip and reduces the number of buses stopping at each stop, although it also increases the complexity of the bus system for new riders and may increase passenger walking distances to bus stops.
- Platooning. When skip stops are used, gathering buses into platoons at the beginning of the skip-stop section maximizes the efficiency of the operation. Each platoon is assigned a group of stops, and the platooned buses travel as trains past the skip stop

section. The number of buses in each group ideally should equal the number of loading areas at each stop.

- Bus stop location. Far side stops provide the highest bus lane capacity, but other factors, such as conflicts with other vehicles, transfer opportunities, and traffic signal timing, also must be considered when siting bus stops.

Figure (5) below show a brief description of the main elements that determine the bus vehicle capacity of loading areas, stops, and lanes.

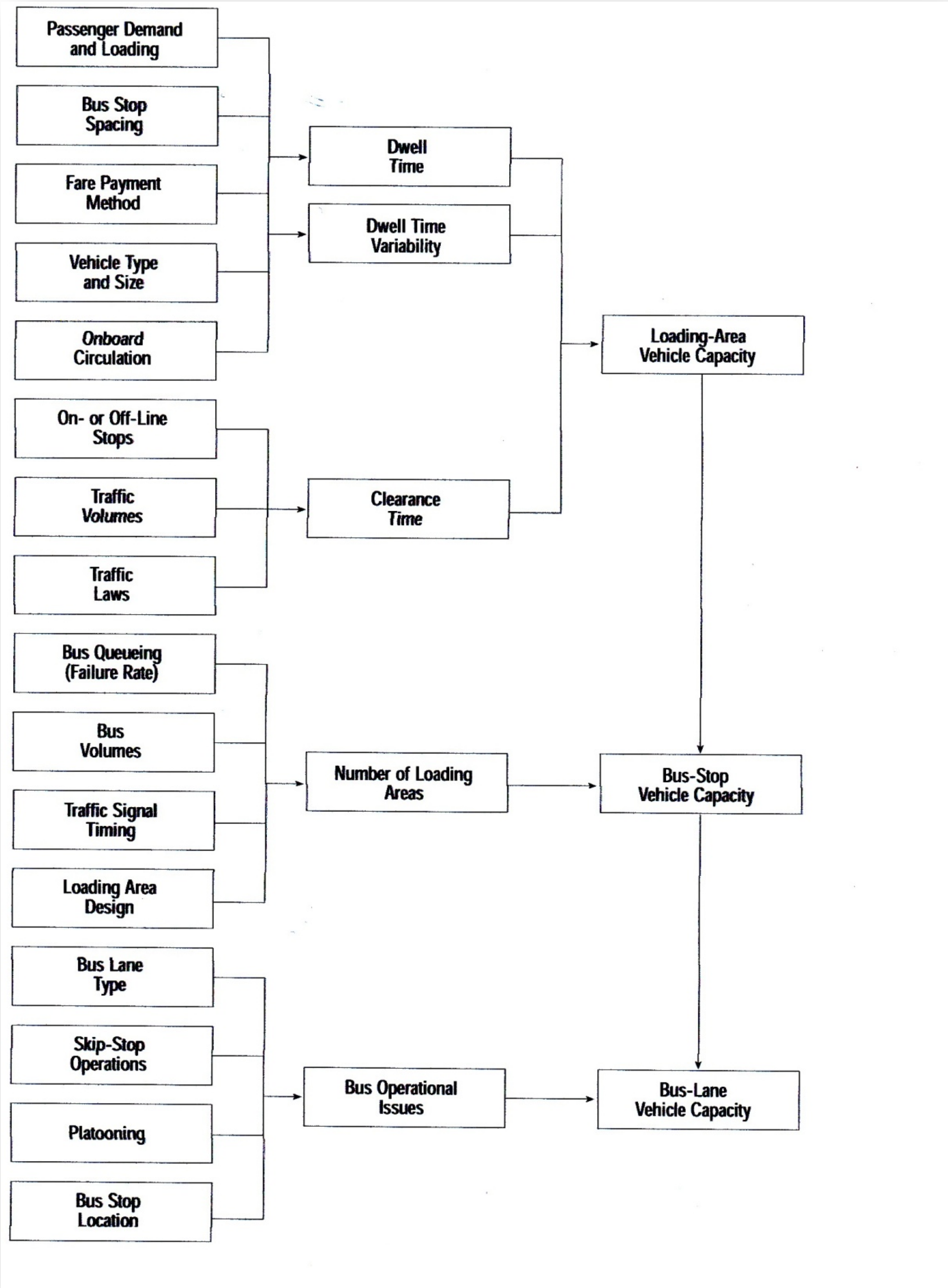


Figure 5: Influences on Bus Vehicle Capacity.

Loading Areas

Table (1) identifies the estimated bus vehicle capacity at loading areas, based on various values of dwell time and the ratio of green traffic signal time to total cycle length (g/C ratio). Other values not provided in the exhibit may be interpolated.

Table 1: Estimated Vehicle Capacity of On- Street Loading Areas.

Dwell Time (s)	Capacity (buses/h) g/C = 0.50	g/C = 1.00
15	63	100
30	43	63
45	32	46
60	26	36
75	22	30
90	19	25
105	16	22
120	15	20

Bus Stops

Table (2) lists estimated vehicle capacities of on-line linear bus stops. Note that increasing the number of loading areas at a linear bus stop has an ever-decreasing effect on capacity as the number of loading areas increases (i.e., doubling the number of loading areas at a linear bus stop does not double capacity). Nonlinear designs are 100 percent efficient, since doubling the number of loading areas also doubles the capacity of the stop.

Table 2:Estimated Capacity of On-Line Bus Stops.

	Capacity (buses/h)									
	g/C 0.50	g/C 1.00	g/C 0.50	g/C 1.00	g/C 0.50	g/C 1.00	g/C 0.50	g/C 1.00	g/C 0.50	g/C 1.00
	Number of On-Line Linear Loading Areas									
Dwell Time (s)	1		2		3		4		5	
30	43	63	79	117	105	154	113	167	115	170
60	26	36	48	67	64	89	69	96	70	98
90	19	25	35	47	46	62	49	67	50	69
120	15	20	27	36	36	48	39	52	39	53

Note:
Assumes 15-s clearance time, 25 percent queue probability, and 60 percent coefficient of variation of dwell times. To obtain the vehicle capacity of nonlinear on-line bus stops, multiply the single loading area values by the number of loading areas provided.

Busways

If a busway extends into the CBD and has a limited number of stations in the downtown area, the passenger distribution characteristics will be similar to those of a subway or other rail line. A reasonable design assumption is that 50 percent of the maximum load-point volume is served at the heaviest CBD busway station, assuming a minimum of three stops in the downtown area.

Busway vehicle and person capacities for central areas are given in Table (3) for a variety of bus types and service conditions. The key assumptions used in Table (3) are:

Table 3: Examples of CBD Busway Capacity.

	Loading Condition							
	A		B		C		D	
Stations: On-Line/Off-Line	On	Off	On	Off	On	Off	On	Off
	Passengers Boarding at Heaviest Station							
Boarding passengers per bus	20	20	20	20	20	20	30	30
Boarding time per passenger (s)	2.0	2.0	1.2	1.2	0.7	0.7	0.5	0.5
Dwell time (s)	40.0	40.0	24.0	24.0	14.0	14.0	15.0	15.0
	Vehicle Capacity							
Loading area capacity (bus/h)	42	42	65	65	100	100	95	95
Effective loading areas	2.45	2.60	2.45	2.60	2.45	2.60	2.45	2.60
Station capacity (bus/h)	103	109	159	169	245	260	233	247
	Passengers/Hour - Maximum Load Point							
Peak-flow rate (15 min • 4)	4120	4360	6360	6760	9800	10,400	13,980	14,820
Average peak hour (with PHF)	2760	2920	4260	4530	6570	6970	9370	9930

Notes:
Loading Condition A: single-door conventional bus, simultaneously loading and unloading.
Loading Condition B: two-door conventional bus, both doors loading or double-stream doors simultaneously loading and unloading.
Loading Condition C: four-door conventional bus, all double-stream doors loading.
Loading Condition D: six-door articulated bus, all doors loading.
Assumes 10-s clearance time, 7.5 percent failure rate, 60 percent coefficient of variation of dwell times, 3 linear loading areas, g/C = 1.0, PHF = 0.67, 50 percent of passengers board at heaviest CBD station, 40 seats per conventional bus, 60 seats per articulated bus, no standees allowed.

- Fares are prepaid at busway stations. This allows all doors to be used for loading, which greatly decreases the service time per passenger, since several passengers may board at the same time.
- Fifty percent of the maximum load-point passengers board at the heaviest stop. A PHF of 0.67 is assumed.
- No delays are due to signals (i.e., it is a grade-separated busway).

- The clearance time is 10 s. The design failure rate is 7.5 percent and a 60 percent coefficient of variation is assumed.
- Three linear loading areas are provided at each station.
- The maximum load-point passenger volume is limited to 40 passengers per bus for standard buses and 60 passengers per bus for articulated buses; this provides a seat for all passengers

Exclusive Arterial- Street Bus Lanes

Figure (6) illustrates the effects of dwell time, right-turning volume from the bus lane, and conflicting pedestrian volumes on bus-lane vehicle capacity. It assumes conflicting pedestrian volumes ranging from 100 to 800/h, dwell times of 30 or 60 s, and right-turning volumes of 0 to 400 vehicles, as well as other assumptions, held constant, that are listed in the exhibit. Buses are assumed to stop at every bus stop in the CBD.

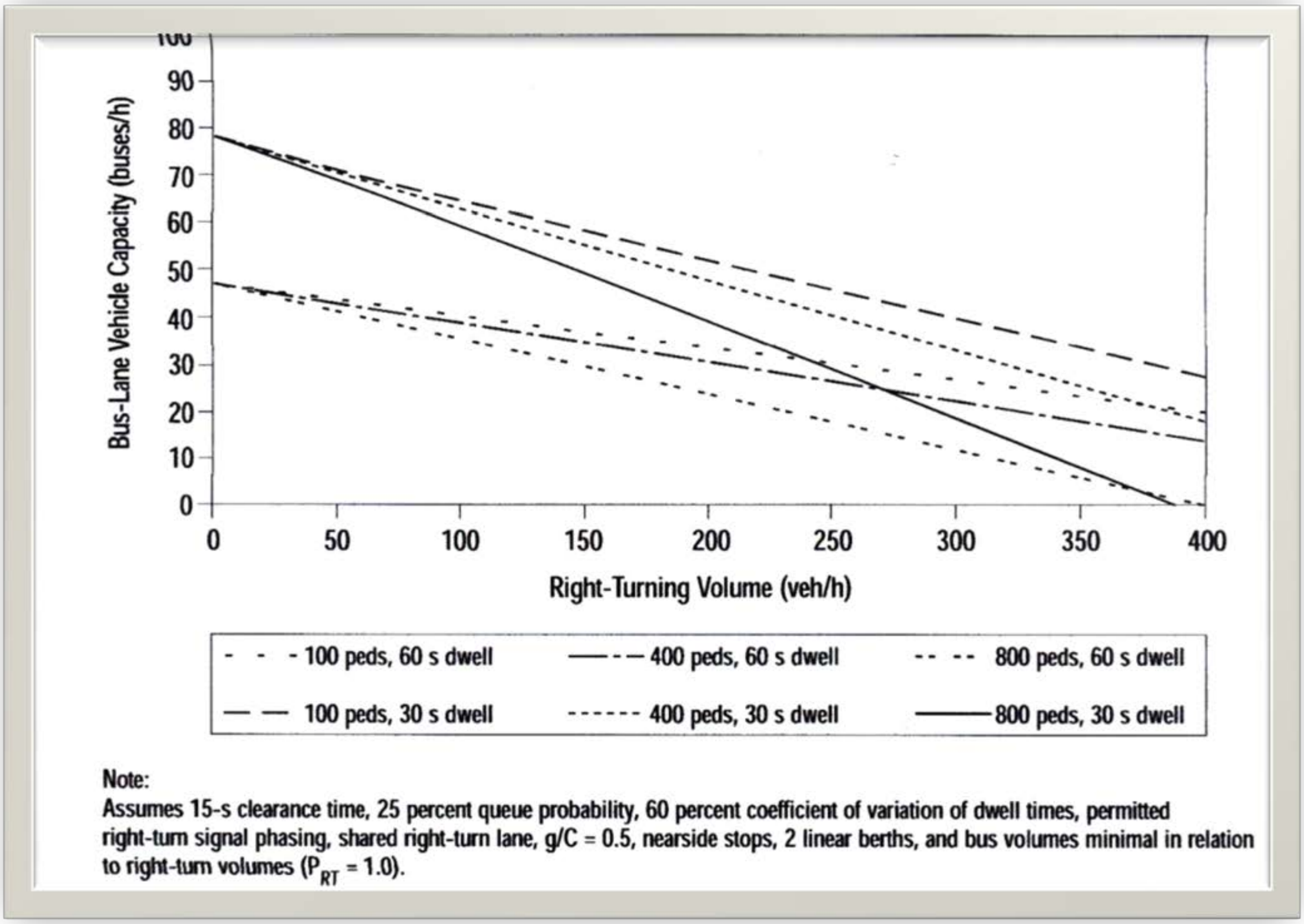


Figure 6: Exclusive Bus -Lane Vehicle Capacity: Non-skip- -stop Operation.

It can be seen that as dwell time decreases, bus vehicle capacity increases. Conflicting pedestrian volumes under 200/h have little effect on bus vehicle capacity, but have substantial effects at higher conflicting volumes, especially as right-turning volumes increase. However, when there are no right-turn conflicts, pedestrian volumes have no impact on vehicle capacity, and the lines for a given dwell time converge to a single point. It also can be seen that the lines for a given pedestrian volume converge toward a point at which the right-turn capacity is exceeded and the bus-lane vehicle capacity drops to zero. Between these two extremes, bus vehicle capacity steadily declines as right turning volumes increase.

Mixed -Traffic Lanes

Figure (7) depicts the decline in bus vehicle capacity in mixed traffic when curb lane volumes increase, as well as the variation in bus vehicle capacity by bus stop location. In mixed traffic, off-line linear stops may provide less bus vehicle capacity than on-line stops with identical dwell times, since the benefits of additional loading areas at off-line stops can be outweighed by the additional delay as buses reenter traffic. In mixed traffic, on-line stops may provide greater capacity than off-line stops, depending on traffic volumes and the number of loading areas.

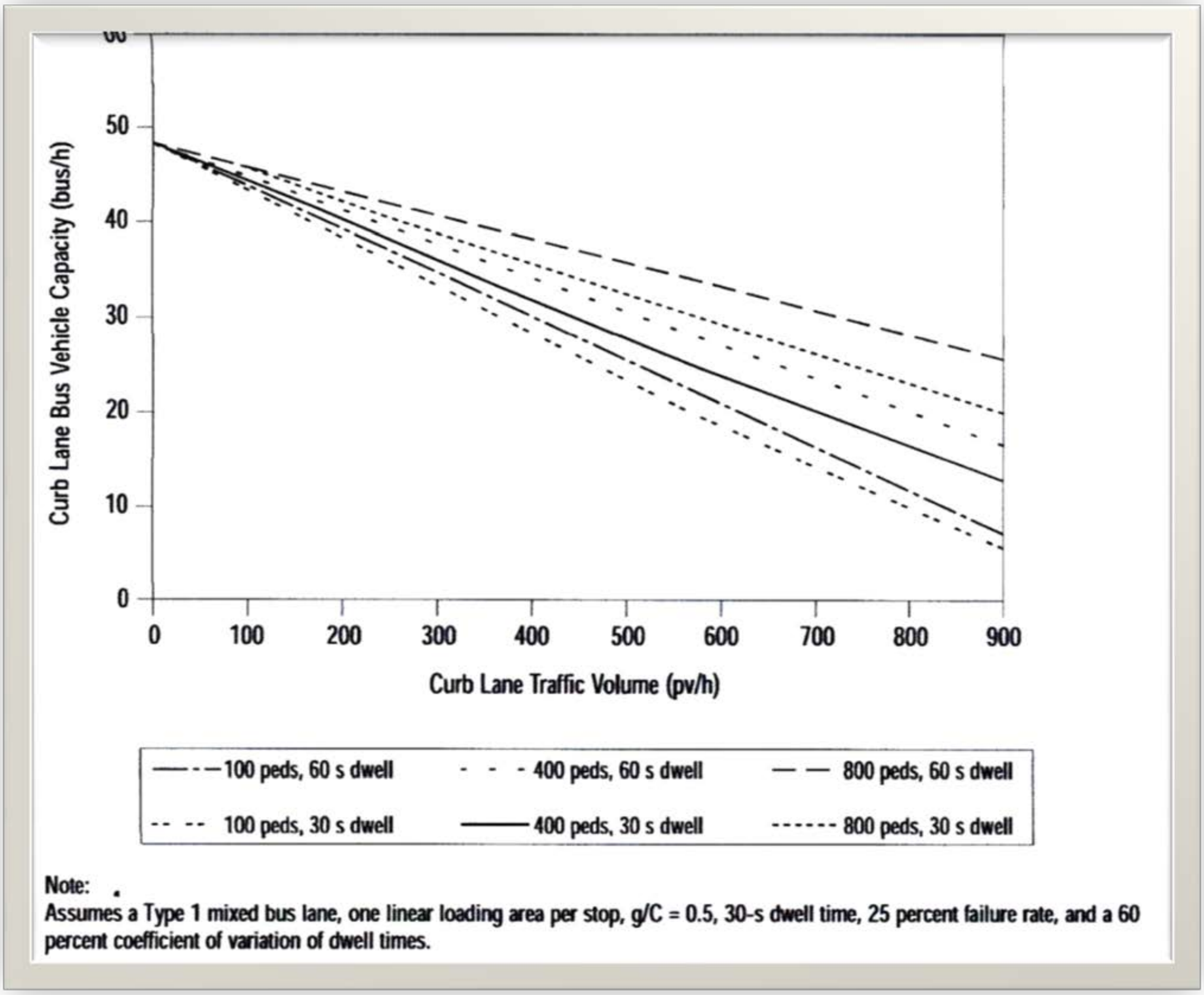


Figure 7: Mixed - Traffic- lane Bus Vehicle Capacity.