PART 4
TERMINAL CAPACITY

CONTENTS

LIST OF EXHIBITS

1. INTRODUCTION

This chapter contains procedures for estimating the capacities of various elements of transit terminals. For bus stops, procedures are provided for sizing passenger waiting areas at stops, and the provision of passenger amenities within these areas. For bus and rail stations, procedures are provided for sizing outside transfer facilities, such as bus transfer, park-and-ride, and kiss-and-ride areas, as well as the various inside terminal elements, such as walkways, stairways, escalators, elevators, turnstiles, ticket machines, and platforms.

Although previous efforts have involved designing terminal facilities based on maximum pedestrian capacity; research has shown that a breakdown in pedestrian flow occurs when there is a dense crowding of pedestrians, causing restricted and uncomfortable movement. For this reason, many of the procedures contained in this chapter for sizing terminal elements are based on maintaining a desirable pedestrian level of service, and utilize the pedestrian level of service analysis procedures also documented in the *Highway Capacity Manual*.

Pedestrian level of service procedures derived from the Highway Capacity Manual.

For larger terminals, the different pedestrian spaces interact with one another such that capacity and level of service might better be evaluated from a systems perspective. The use of simulation models to assess the impact of queue spillback on downstream facilities has application in assisting to size overall internal spaces within a terminal facility, and thus their application is discussed in this part of the manual.

Appendix A provides substitute exhibits in U.S. customary units for those Part 4 exhibits that use metric units.

Exhibits appearing in Appendix A are indicated by a marginal note such as this.

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2. BUS STOPS

PASSENGER WAITING AREAS

The recommended procedures for computing the size of passenger waiting areas at bus stops is based on maintaining a desirable level of service. The concept of pedestrian level of service is presented in the *Highway Capacity Manual*.(R5) The primary measure of effectiveness for defining pedestrian level of service is the average space available to each pedestrian. The level of service for a pedestrian waiting area is based not only on space but also the degree of mobility allowed. In dense standing crowds, there is little room to move, but limited circulation is possible as the average space per pedestrian increases.

Studies have shown that pedestrians keep as much as an 0.4-meter (18-inch) buffer between themselves and the edge of curb. This suggests that the effective width of a typical bus stop should be computed as the total width minus 0.4 meters (18 inches).

Level of Service Standards

Level-of-service descriptions for passenger waiting areas are shown in Exhibit 4-1. The standards were developed based on average pedestrian space, personal comfort, and degrees of internal mobility. The standards are presented in terms of average area per person and average interpersonal space (distance between people).

Passenger waiting area LOS utilizes concepts from the Highway Capacity Manual.

The level of service required for waiting within a facility is a function of the amount of time spent waiting and the number of people waiting. Typically, the longer the wait, the greater the space per person required. Also, the required space per person may vary over time. For example, those waiting in the beginning will want a certain amount of space initially, but will be willing to accept less space as additional people arrive later.(R5)

A person's acceptance of close interpersonal spacing will also depend on the characteristics of the population, the weather conditions, and the type of facility. For example, commuters may be willing to accept higher levels or longer periods of crowding than intercity and recreational travelers.(R5)

Determining Required Passenger Waiting Area

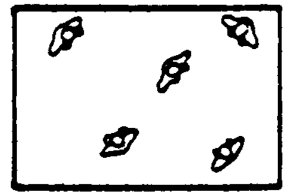
As discussed above, the procedures to determine passenger waiting area at bus stops are based on maintaining a desirable pedestrian level of service. For most bus stops, the design level of service should be C to D or better. Following is a list of steps recommended for determining the desired bus stop size:

1. Based on the desired level of service, choose the average pedestrian space from Exhibit 4-1.
2. Estimate the maximum demand of passengers waiting for a bus at a given time.
3. Calculate the effective waiting area required by multiplying the average pedestrian space by the maximum pedestrian demand.

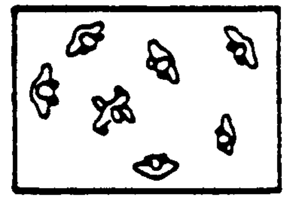
Calculate the total required waiting area by adding an 0.4-meter (18-inch) buffer width (next to the roadway) to the effective waiting area.

Exhibit 4-1
Levels of Service for Queuing Areas[R5]

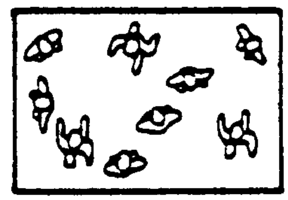
LEVEL OF SERVICE A
Average Pedestrian Area: ≥ 1.2 m^2 (13 ft^2) per person
Average Inter-Person Spacing: ≥ 1.2 m (4 ft)
Description: Standing and free circulation through the queuing area possible without disturbing others within the queue.



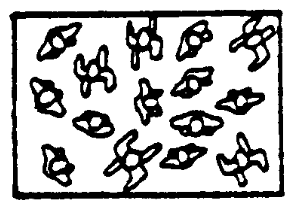
LEVEL OF SERVICE B
Average Pedestrian Area: 0.9-1.2 m^2 (10-13 ft^2) per person
Average Inter-Person Spacing: 1.1-1.2 m (3.5-4 ft)
Description: Standing and partially restricted circulation to avoid disturbing others within the queue is possible.



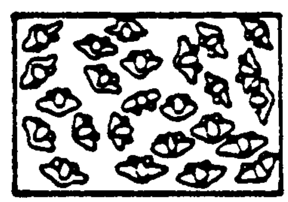
LEVEL OF SERVICE C
Average Pedestrian Area: 0.7-0.9 m^2 (7-10 ft^2) per person
Average Inter-Person Spacing: 0.9-1.1 m (3-3.5 ft)
Description: Standing and restricted circulation through the queuing area by disturbing others is possible; this density is within the range of personal comfort.



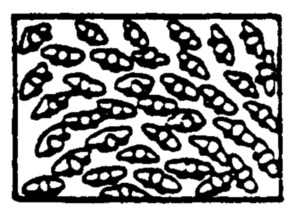
LEVEL OF SERVICE D
Average Pedestrian Area: 0.3–0.7 m^2 (3-7 ft^2) per person
Average Inter-Person Spacing: 0.6–0.9 m (2-3 ft)
Description: Standing without touching is impossible; circulation is severely restricted within the queue and forward movement is only possible as a group; long term waiting at this density is discomforting.



LEVEL OF SERVICE E
Average Pedestrian Area: 0.2- 0.3 m^2 (2-3 ft^2) per person
Average Inter-Person Spacing: ≤ 0.6 m (2 ft)
Description: Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can only be sustained for a short period without serious discomfort.



LEVEL OF SERVICE F
Average Pedestrian Area: ≤ 0.2 m^2 (2 ft^2) per person
Average Inter-Person Spacing: Close contact
Description: Virtually all persons within the queue are standing in direct physical contact with others; this density is extremely discomforting; no movement is possible within the queue; the potential for panic exists.



IMPACT OF PASSENGER AMENITIES

Placement of passenger amenities at bus stops impacts space requirements for waiting areas.

Passenger amenities are those elements provided at a bus stop to enhance comfort, convenience, and security for the transit patron. Amenities include such items as shelters, benches, vending machines, trash receptacles, phone booths, information signs or kiosks, bike racks, lighting, and landscaping. The effects that particular amenities have on transit ridership and passenger waiting area capacity is unclear. Amenities at most bus stops are placed in response to a human need or a need to address an environmental condition. The advantages and disadvantages of different passenger amenities at bus stops are summarized in Exhibit 4-2. An example of providing pedestrian amenities at a typical bus stop is illustrated in Exhibit 4-3.

Overall required passenger waiting areas at bus stops should account for space taken up by shelters, benches, information signs and other amenities, with appropriate shy distances.

Exhibit 4-2
Examples of Passenger Amenities at Bus Stops(R12)

Amenity	Advantages	Disadvantages
Shelters	• Provide comfort for waiting passengers • Provide protection from climate-related elements (sun, glare, wind, rain, snow) • Help identify the stop	• Require maintenance, trash collection • May be used by graffiti artists
Benches	• Provide comfort for waiting passengers • Help identify the stop • Low-cost when compared to installing a shelter	• Require maintenance • May be used by graffiti artists
Vending Machines	• Provide reading material for waiting passengers	• Increase trash accumulation • May have poor visual appearance • Reduce circulation space • Can be vandalized
Lighting	• Increases visibility • Increases perceptions of comfort and security • Discourages “after hours” use of bus stop facilities by indigents	• Requires maintenance • Can be costly
Trash Receptacles	• Provide place to discard trash • Keep bus stop clean	• May be costly to maintain • May be used by customers of nearby land use (i.e., fast food restaurant) • May have a bad odor
Telephones	• Convenient for bus patrons • Provide access to transit information	• May encourage loitering at bus stop • May encourage illegal activities at bus stop
Route or Schedule Information	• Useful for first-time riders • Helps identify bus stop • Can communicate general system information	• Must by maintained to provide current information • May be used by graffiti artists

Exhibit 4-3
Typical Transit Stop and Station Amenities

Shelter & Bench (Denver)

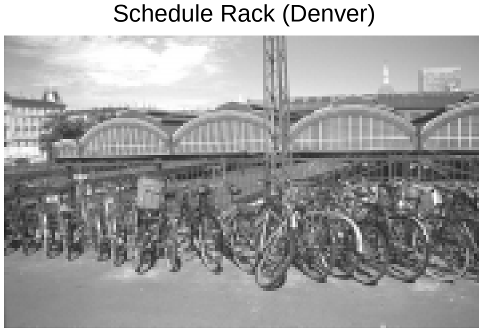
Telephones (Denver)

General Transit Information (San Diego)

Posted Bus Schedules (San Diego)

Schedule Rack (Denver)

Bus Arrival Times (Denver)



Bicycle Racks (Copenhagen, Denmark)

Bicycle Lockers (San Jose)

Retail Sales (Denver)

Landscaping (San Diego)

Art (Portland, OR)

3. RAIL AND BUS STATIONS

OUTSIDE TRANSFER FACILITIES

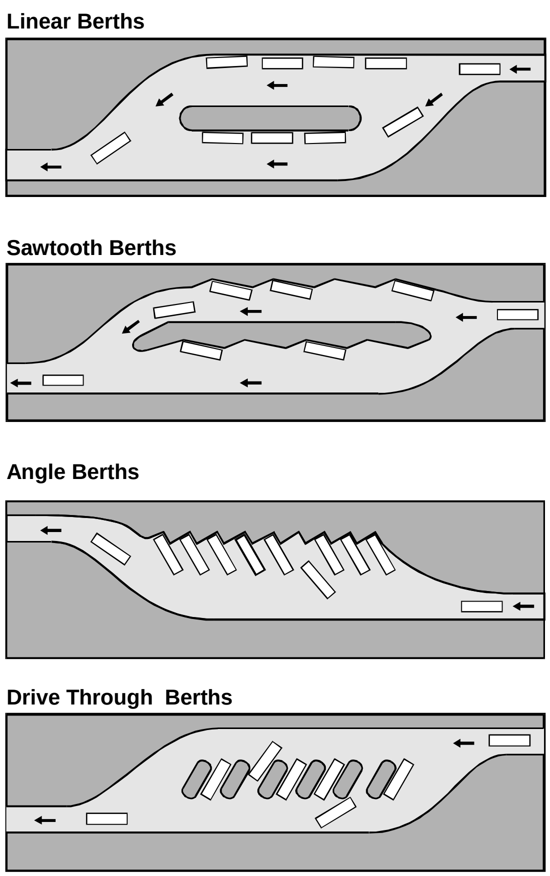
Bus Berths

A critical component at major bus and rail stations is the provision of bus transfer areas where buses serving the station can board and alight passengers. For most stations, the bus transfer area consists of an off-street bus berthing area near or adjacent to the station building or platform area. For small transit stations, the number of berths (loading areas) is small with a fairly simple access and layout configuration. For larger terminals, numerous berths and more sophisticated designs are applied. Before BART was opened, the Transbay Bus Terminal in San Francisco, for example, had 37 berths, serving 13,000 peak-hour passengers.

Exhibit 4-4 and Exhibit 4-6 illustrate the different types of bus berths integrated into station design. Four types of bus berthing are typically applied:

- linear,
- sawtooth,
- angle, and
- drive-through.

Exhibit 4-4
Bus Loading Area (Berth) Designs



Linear berths are not as efficient as other berth types and are usually used when buses will use the berth for only a short time (for example, at an on-street bus stop).

Sawtooth berths allow independent movements by buses into and out of berths and are commonly used at bus transfer centers.

Angle berths require buses to back out. They are typically used when a bus will occupy the berth for a long time (for example, at an intercity bus terminal).

Drive-through berths allow bus stops to be located in a compact area, and also can allow all buses to wait with their front destination sign facing the direction passengers will arrive from (e.g., from a rail station exit).

Sawtooth, drive-through, and angle loading area designs should include provisions for positive protection (such as bollards) to protect pedestrians from errant buses.

Exhibit 4-5
Bus Loading Area (Berth) Examples

Linear (Miami)

Sawtooth (San Diego)

Drive-Through (Copenhagen, Denmark)

Angle (Newark Airport)

Linear berths can operate in series and have capacity characteristics similar to on-street bus stops. Angle berths are limited to one bus per berth, and they require buses to back out. Drive-through angle berths are also feasible, and may accommodate multiple vehicles. Shallow “sawtooth” berths are popular in urban transit centers and are designed to permit independent movements into and out of each berth. The National Transportation Safety Board recommends that transit facility designs incorporating sawtooth berths, or other types of berths that may direct errant buses towards pedestrian-occupied areas, include provisions for positive separation (such as bollards) between the roadway and pedestrian areas sufficient to stop a bus operating under normal parking area speed conditions from progressing into the pedestrian area.[R9]

Capacity Characteristics

For bus and rail stations, the bus berth capacity estimation procedures identified in Part 2 (related to on-street bus stops) are only applicable for relatively low bus dwell times (3 minutes or less). This is typically the case of thorough-routed buses that do not layover at the station, or buses that might coordinate their arrival times with certain express or train arrivals. In this case, a g/C ratio of 1.00 is applicable as buses are not restricted by on-street signal operations in accessing the off-street bus berthing area. Exhibit 4-6 identifies the maximum linear berthing capacity under this condition. The capacity figures have been modified to reflect a lower clearance time for buses exiting the stop due to off-street operation.

Exhibit 4-6
Estimated Maximum Vehicle Capacity of Station Linear Bus Berths Under Low Dwell Time Conditions

Dwell Time (s)	Bus/h
15	116
30	69
45	49
60	38
75	31
90	26
105	23
120	20

NOTE: Assumes 10-second clearance time, 25% queue probability, and 60% coefficient of variation.

For larger bus stations, and for bus routes laying over or terminating at a station, typical design practice is to provide for individual berths for each route. In this case, bus dwell times are typically longer than the 2-minute ceiling applicable to Exhibit 4-6 , and the number of berths required per route will be driven by the longer dwell time.

As indicated in Part 2 of the manual, providing additional space within a linear bus berth configuration increases the overall berth capacity, but at a decreasing rate as the number of loading areas increases. Each loading area at a multiple-berth stop does not have the same capacity as a single-berth stop, because it is not likely that the loading areas at a multiple-berth stop will be equally used, or that passengers will distribute equally among loading positions. Moreover, where stops are designated for specific routes, bus schedules may not permit an even distribution of buses among loading positions. Buses may also be delayed in entering or leaving a berth by buses in adjacent loading positions.

Suggested berth efficiency factors are given in Exhibit 4-7 for off-line linear berths at bus terminals. This is similar to the off-line berth scenario for on-street bus stops in Exhibit 2-16. These factors are based on experience at the Port Authority of New York and New Jersey's Midtown Bus Terminal. The exhibit suggests that four or five on-line positions could have a maximum efficiency of 2.5 berths. Five off-line positions would have an efficiency of about 3.75 berths.

Exhibit 4-7
Efficiency of Multiple Linear Off-Line Bus Berths at Bus Terminals[R6,R7,R8]

Berth No.	Efficiency (%)	No. of Cumulative Effective Linear Berths
1	100	1.00
2	85	1.85
3	75	2.60
4	65	3.25
5	50	3.75

Note that to provide two "effective" berths, *three* physical berths would need to be provided, since partial berths are never built. All other types of multiple berths are 100% efficient—the number of effective berths equals the number of physical berths.

Park-and-ride facilities are sized based on estimated demand.

The capacity of a linear bus berth at an off-street terminal is given by Equation 4-1:

$$B_s = N_{eb} \frac{3{,}600}{t_c + t_d + Z_a c_v t_d}$$

Equation 4-1

where:

B_s	=	maximum number of buses per bus stop per hour;
N_{eb}	=	number of effective berths, from Exhibit 4-;
t_c	=	clearance time between successive buses (s);
t_d	=	average (mean) dwell time (s);
Z_a	=	one-tail normal variate corresponding to the probability that queues will not form behind the bus stop, from Exhibit 2-15; and
c_v	=	coefficient of variation of dwell times.

Park-and-Ride Facilities

At selected transit stations, park-and-ride facilities for autos are provided. Park-and-ride facilities are primarily located at the outer portions of a rail line or busway, in the outer portions of central cities, and in the suburbs in urban areas. At most locations, these facilities are integrated with bus transfer facilities. The size of park-and-ride facilities can vary from as low as 10-20 spaces at minor stations to over 1,000 spaces at major stations. Exhibit 4-8 illustrates different degrees of park-and-ride facilities. The design of these facilities is similar to other off-street parking facilities. Most park-and-ride facilities are surface lots, with pedestrian connections to the transit station. Parking structures are used where land is a premium and where a substantial number of parking spaces are required.

Exhibit 4-8
Examples of Park-and-Ride Facilities at Transit Stations

Los Angeles

Houston

The required number of park-and-ride spaces at a transit station typically involves identifying the demand for such parking, and then relating the space demand to the ability to physically provide such a facility within cost constraints. Parking spaces in park-and-ride facilities typically have a low turnover during the day, as most persons parking at transit stations are commuters gone most of the day. In larger urban areas, the regional transportation model will have a mode split component which will allow the identification of park-and-ride demand at transit station locations, particularly applicable related to identifying park-and-ride needs for new rail line or busway development. Where the regional model does not have the level of sophistication to provide such demand estimates, then park-and-ride demand estimation through user surveys and an assessment of the ridership sheds for different station areas would be appropriate. In summary, park-and-ride capacity is driven by the demand for the facility.

Kiss-and-Ride Facilities

Kiss-and-ride facility capacity is governed by space required for passenger pick-ups.

Kiss-and-ride facilities are auto pickup and dropoff areas provided at transit stations, where transit patrons are dropped off and picked up by another person in a vehicle. Parking needs associated with this concept are associated with vehicles waiting to pick up transit riders, with the dropoff requiring no parking maneuver (though curb space is needed to handle the dropoff). As for park-and-ride facilities, the sizing of kiss-and-ride facilities is reflective of the demand and site physical constraints. Many larger transit stations provide dedicated kiss-and-ride facilities. In Toronto, an innovative "carousel" design has been applied at several stations where a separate inside terminal facility has been developed for transit riders to wait to be picked up, with direct access to the rail station. Exhibit 4-9 illustrates two kiss-and-ride facilities.

Exhibit 4-9
Examples of Kiss-and-Ride Facilities at Transit Stations

Toronto Denver

INSIDE TERMINAL ELEMENTS

An important objective of a transit station is to provide adequate space and appropriate facilities to accommodate projected peak pedestrian demands while ensuring pedestrian safety and convenience. Previous efforts have involved designing transit stations based on maximum pedestrian capacity without consideration of pedestrian convenience. Recent research has shown, however, that capacity is reached when there is a dense crowding of pedestrians, causing restricted and uncomfortable movement.[R3]

The capacity procedures presented in this section are based on a relative scale of pedestrian convenience. Procedures for evaluating pedestrian capacity and level of service are contained in Fruin's *Pedestrian Planning and Design*[R3] and in the 1997 *Highway Capacity Manual*.[R5] Those procedures that relate to transit station design are summarized in the following sections.

Pedestrian Capacity Terminology

Terms used in this chapter for evaluating pedestrian capacity are defined as follows:

Pedestrian speed: average pedestrian walking speed, generally expressed in units of meters or feet per second.

Pedestrian flow rate: number of pedestrians passing a point per unit time, expressed as pedestrians per 15 minutes or pedestrians per minute; "point" refers to a perpendicular line of sight across the width of roadway.

Unit width flow: average flow of pedestrians per unit of effective walkway width, expressed as pedestrians per minute per meter or foot.

Pedestrian density: average number of pedestrians per unit of area within a walkway or queuing area, expressed as pedestrians per square meter or foot.

Pedestrian space: average area provided for each pedestrian in a walkway or queuing area, expressed in terms of square meters or feet per pedestrian; this is the inverse of density, but is a more practical unit for the analysis of pedestrian facilities.

Pedestrian Level of Service

Level-of-service standards provide a useful means of determining the environmental quality of a pedestrian space. Pedestrian service standards related to walking are based on the freedom to select desired walking speeds and the ability to bypass slower-moving pedestrians. Other measures related to pedestrian flow include the ability to cross a pedestrian traffic stream, to walk in the reverse direction of a major pedestrian flow, and to maneuver without conflicts and changes in walking speed.

Level of service standards for queuing areas are based on available standing space and the ability to maneuver from one location to another. Since pedestrian level of service standards are based on the amount of pedestrian space available, these standards can be used to determine desirable design features such as platform size, number of stairs, corridor width, etc.

Principles of Pedestrian Flow

The relationship between density, speed, and flow for pedestrians is described in the following formula:

$$v = S \times D$$

Equation 4-2

where:

v = flow (pedestrians per minute per m or ft);
S = speed (m/min or ft/min); and
D = density (peds/m^2 or peds/ft^2).

The flow variable used in this expression is the “unit width flow” defined earlier. An alternative and more useful expression can be developed using the reciprocal of density, or *space*, as follows:

$$v = S / M$$

Equation 4-3

where:

M = pedestrian space (m^2 or ft^2 per pedestrian).

Pedestrian System Requirements

An initial step in evaluating a transit station design is to outline the pedestrian system requirements. Determining system requirements begins with a detailed description of the pedestrian flow process through a terminal in the form of a flow chart (see Exhibit 4-10). Properly done, the system diagram serves as a checklist and a constant reminder of the interrelationship of the various functional elements of the station. Exhibit 4-11 lists examples of elements and components to be included in a system diagram for the evaluation of pedestrian flows off of a transit platform at a rail or bus station.

Exhibit 4-10
Pedestrian Flow Diagram Through a Transit Terminal(R2)

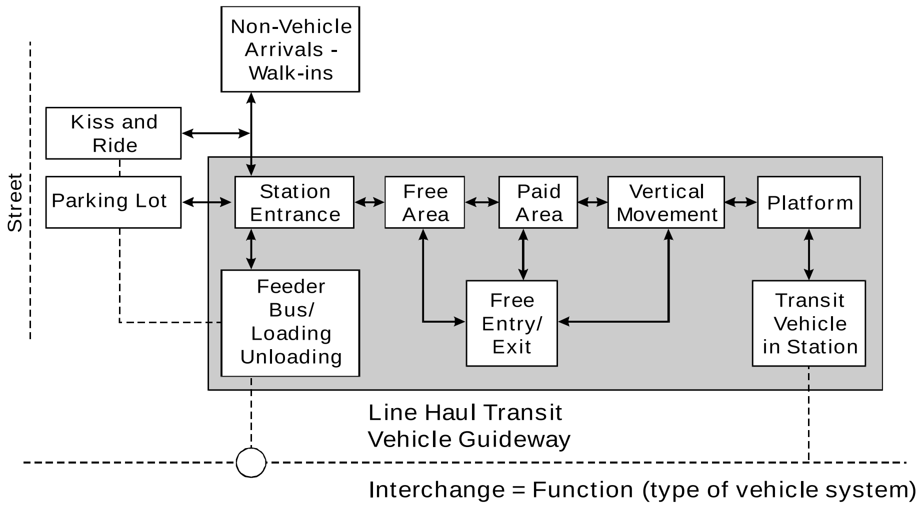


Exhibit 4-11
System Description of Transit Platform for Arriving Passengers(R3)

Element	Components
Train Arrival	On or off schedule; train length; number and locations of doors
Passengers	Number arriving; type; baggage; others boarding; discharge rates
Platform	Length, width and effective area; locations of columns and obstructions; system coherence: stair and escalator orientation, lines of sight, signs, maps and other visual statements
Pedestrians	Walking distance and time; numbers arriving and waiting; effective area per pedestrian; levels of service
Stairs	Location; width; riser height and tread; traffic volume and direction; queue size; possibility of escalator breakdown
Escalators	Location; width; direction and speed; traffic volume and queue size; maintainability
Elevators	Location; size and speed; traffic volume and queue size; maintainability; alternate provisions for ADA passengers when elevator is non-functioning

After the system requirements have been described schematically, they should be described quantitatively. Often this can be done following the same basic format and sequence as the system description. Pedestrian volumes can be scaled to size and plotted graphically, to illustrate volume and direction. Pedestrian walking times, distances, and waiting and service times can also be entered into this diagram.

WALKWAYS

Design Factors

The capacity of a walkway is controlled by the following factors:

- pedestrian walking speed,
- pedestrian traffic density, and
- walkway width.

Speed

Normal walking speeds of pedestrians may vary over a wide range, depending on many factors. Studies have shown that male walking speeds are typically faster than female walking speeds. Walking speeds have also been found to decline with age. Other factors influencing a pedestrian's selected walking speed include the following:

- time of day,
- temperature,
- traffic composition,
- trip purpose, and
- reaction to environment.

Free-flow walking speeds have been shown to range from 48 m/min (145 ft/min) to 155 m/min (470 ft/min). On this basis, speeds below 48 m/min (145 ft/min) would constitute restricted, shuffling locomotion, and speeds greater than 155 m/min (470 ft/min) would be considered as running. A pedestrian walking speed typically used for design is 83 m/min (250 ft/min).

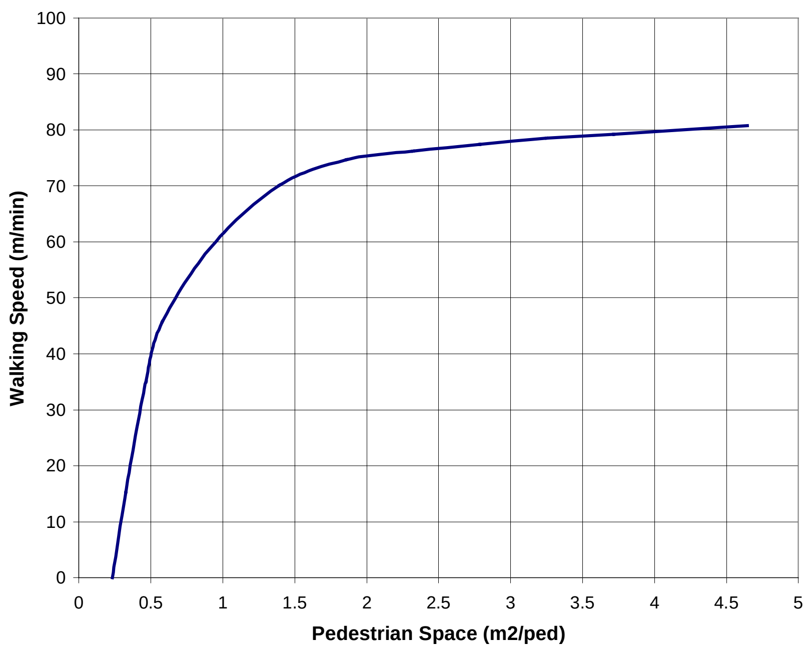
Density

Perhaps the most significant factor influencing pedestrian walking speed is traffic density. Normal walking requires sufficient space for unrestricted pacing, sensory recognition, and reaction to potential obstacles. Increasing density reduces the available space for walking, and therefore, reduces walking speed.

Exhibit 4-12 shows the relationship between walking speed and average pedestrian space (inverse of density). Observing this exhibit, pedestrian speeds are free-flow up to an average pedestrian space of 8.25 m^2 (25 ft^2) per person. For average spaces below this value, walking speeds begin to decline rapidly. Walking speeds approach zero at an average pedestrian space of approximately one sq. m (3 ft^2) per person.

An alternative figure using U.S. customary units appears in Appendix A.

Exhibit 4-12
Pedestrian Speed on Walkways(R3)



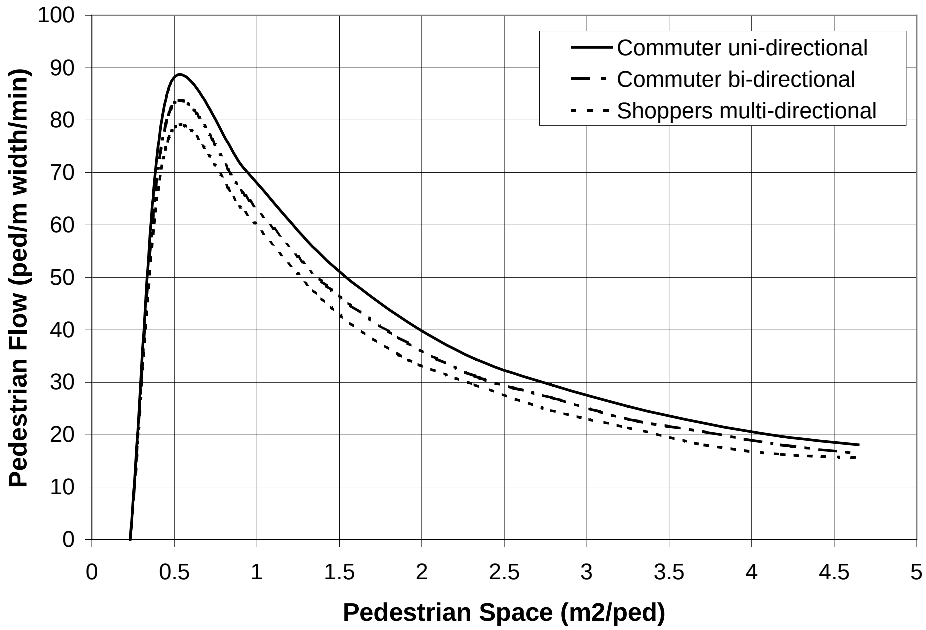
Effective Walkway Width

The final factor affecting the capacity of a walkway is the effective width available. Studies have shown that pedestrians keep as much as a 0.4-meter (18-inch) buffer between themselves and the edge of curb or the edge of passageway. This suggests that the effective width of a typical terminal corridor should be computed as the total width minus one meter (3 ft), with 0.5 meter (18 inches) on each side.

Exhibit 4-13 shows the relationship between pedestrian flow per unit width of effective walkway and average pedestrian occupancy. Curves are shown for uni-directional, bi-directional, and multi-directional (cross-flow) pedestrian traffic. As this exhibit shows, there is a relatively small range in variation between the three curves. This finding suggests that reverse and cross-flow traffic do not significantly reduce pedestrian flow rates.

Exhibit 4-13
Pedestrian Unit Width Flow on Walkways[R3]

An alternative figure using U.S. customary units appears in Appendix A.



As shown in Exhibit 4-, the maximum average peak flow rates (86.0, 81.0, and 76.4 persons/m, or 26.2, 24.7, and 23.3 persons/ft, of walkway for uni-directional, bi-directional, and multi-directional flow, respectively) occur at an average occupancy of 1.65 m^2 (5 ft^2) per person. Many authorities have used these maximum flow rates as a basis for design. This practice, however, may result in a limited walkway section that operates at capacity and restricts normal locomotion. The following section presents procedures for designing walkways based on level-of-service design standards.

Design walkways based on a desired pedestrian level of service, not capacity.

Level of Service Standards

As discussed in the previous section, it is not desirable to design walkways based on capacity, but on a desired pedestrian level of service. The desirable pedestrian environment allows sufficient space for the pedestrian to:

- walk at a relaxed walking speed,
- bypass slower pedestrians,
- avoid conflicts with oncoming or crossing pedestrians, and
- interact visually with surroundings.

The following level-of-service standards are given as a relative scale based on achieving this desirable pedestrian environment.

Pedestrian Demand

When estimating the pedestrian demand for a particular facility, it is important to consider short peak periods and surges within the peak. For design purposes, a 15-minute peak period is recommended. However, because micro-peaking (temporary higher volumes) are likely to occur, consequences of these surges within the peak should be considered. Micro-peaking may result in restricted space for a given time period, but the short duration and the fact that most users are knowledgeable of the transit facilities may justify the temporary lower level of service.

Level of Service

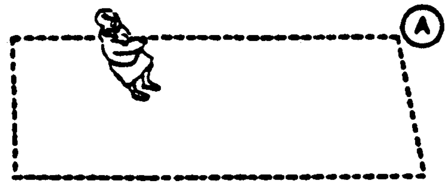
Exhibit 4-14 lists the criteria for pedestrian level of service on walkways. These level of service standards are based on average pedestrian space and average flow rate. Average speed and volume-to-capacity ratio are shown as supplementary criteria. Graphical illustrations and descriptions of walkway levels of service are shown in Exhibit 4-15. Capacity is taken to be 7.6 pedestrians per minute per meter (25 pedestrians per minute per foot) (level of service E).

Exhibit 4-14
Pedestrian Level of Service on Walkways[R5]

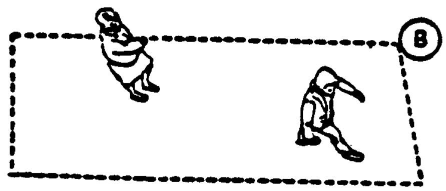
Pedestrian Level of Service	Space (m^2/ped)	Expected Flows and Speeds		
		Avg. Speed, *S* (m/min)	Unit Width Flow, *v* (ped/min/m)	Vol/Capacity Ratio
A	≥ 12.1	≥ 79.2	≤ 6.1	≤ 0.08
B	≥ 3.7	≥ 76.2	≤ 21.3	≤ 0.28
C	≥ 2.2	≥ 73.2	≤ 30.5	≤ 0.40
D	≥ 1.4	≥ 68.6	≤ 45.7	≤ 0.60
E	≥ 0.6	≥ 45.7	≤ 76.2	≤ 1.00
F	< 0.6	< 45.7	*Variable*	

Pedestrian Level of Service	Space (ft^2/ped)	Expected Flows and Speeds		
		Avg. Speed, *S* (ft/min)	Unit Width Flow, *v* (ped/min/ft)	Vol/Capacity Ratio
A	≥ 130	≥ 260	≤ 2	≤ 0.08
B	≥ 40	≥ 250	≤ 7	≤ 0.28
C	≥ 24	≥ 240	≤ 10	≤ 0.40
D	≥ 15	≥ 225	≤ 15	≤ 0.60
E	≥ 6	≥ 150	≤ 25	≤ 1.00
F	< 6	< 150	*Variable*	

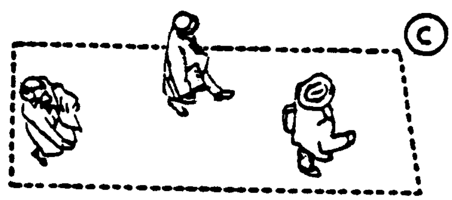
Exhibit 4-15
Illustration of Walkway Levels of Service(R5)



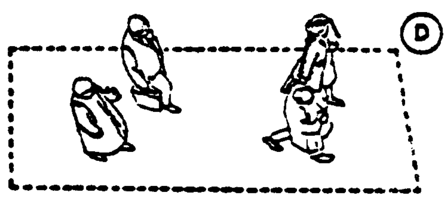
LEVEL OF SERVICE A
Pedestrian Space: ≥ 12.1 m^2/ped (130 ft^2/ped)
Unit Width Flow: ≤ 6.1 ped/min/m (2 ped/min/ft)
Description: Walking speeds are freely selected; conflicts with other pedestrians are unlikely.



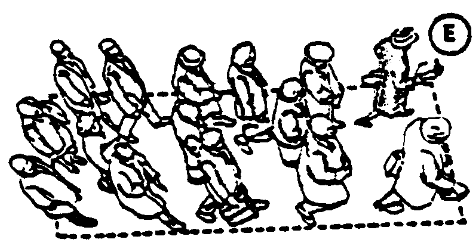
LEVEL OF SERVICE B
Pedestrian Space: ≥ 3.7 m^2/ ped (40 ft^2/ped)
Unit Width Flow: ≤ 21.3 ped/min/m (7 ped/min/ft)
Description: Walking speeds are freely selected; pedestrians become aware of others and respond to their presence.



LEVEL OF SERVICE C
Pedestrian Space: ≥ 2.2 m^2/ped (24 ft^2/ped)
Unit Width Flow: ≤ 30.5 ped/min/m (10 ped/min/ft)
Description: Walking speeds are freely selected; passing is possible in unidirectional streams; minor conflicts will exist for reverse or crossing movements.



LEVEL OF SERVICE D
Pedestrian Space: ≥ 1.4 m^2/ped (15 ft^2/ped)
Unit Width Flow: ≤ 45.7 ped/min/m (15 ped/min/ft)
Description: Freedom to select desired walking speeds and to pass others is restricted; high probability of conflicts for reverse or crossing movements.



LEVEL OF SERVICE E
Pedestrian Space: ≥ 0.6 m^2/ped (6 ft^2/ped)
Unit Width Flow: ≤ 76.2 ped/min/m (25 ped/min/ft)
Description: Walking speeds and passing ability are restricted for all pedestrians; foreword movement is possible only by shuffling; reverse or cross movements are possible only with extreme difficulties; traffic volumes approach limit of walking capacity.

LEVEL OF SERVICE F
Pedestrian Space: ≤ 0.6 m^2/ped (6 ft^2/ped)
Unit Width Flow: variable
Description: Walking speeds are severely restricted; frequent, unavoidable contact with others; reverse or cross movements are virtually impossible; flow is sporadic and unstable.

Evaluation Procedures

Determining Required Walkway Width

The procedures to determine the required walkway width for a transit terminal corridor are based on maintaining a desirable pedestrian level of service. It is desirable for pedestrian flows at most transit facilities to operate at or above level of service C or D. Following is a list of steps recommended for determining the required walkway width:

1. Based on the desired level of service, choose the maximum pedestrian flow rate (pedestrians/min/m or pedestrians/min/ft) from Exhibit 4-15.
2. Estimate the peak 15-minute pedestrian demand for the walkway.
3. Compute the design pedestrian flow (pedestrians/min) by dividing the 15-min demand by 15.
4. Compute the required effective width of walkway (in meters or feet) by dividing the design pedestrian flow by the maximum pedestrian flow rate.
5. Compute the total width of walkway (in meters or feet) by adding one meter (3 ft), with an 0.4-meter (18-inch) buffer on each side to the effective width of walkway.

Determining Walkway Capacity

As discussed above, the capacity of a walkway is taken to be 25 pedestrians/min/m (8.25 pedestrians/min/ ft) (level of service E). Therefore, for a given walkway width, the following steps may be used to compute the capacity:

1. Compute the effective width of walkway (in ft) by subtracting one meter (3 ft) from the total walkway width.
2. Compute the design pedestrian flow (pedestrians per minute) by multiplying the effective width of walkway by 8.25 pedestrians/min/m (25 pedestrians/min/ft).
3. Compute the pedestrian capacity (pedestrians per hour) by multiplying the design pedestrian flow by 60.

TICKET MACHINES

Design Factors

Prior to entering a platform area at a transit station, ticket machines or pay booths are located for transit passengers to pay their fare. Exhibit 4-18 illustrates different ticket machine/booth configurations at transit stations. At larger heavy rail stations, several ticket machines are typically provided to handle peak passenger demand for tickets. At most light rail stations, a single ticket machine on each platform is provided. Ticket booths are used at older heavy rail stations and at many commuter rail stations.

Level of Service Standards

There is no information currently available in the literature on passenger processing times nor level of service standards for different types of ticket machines, as an aid in identifying the number of machines required. The per passenger processing time can substantially vary, depending on the readiness of the passenger to choose the correct fare given the particular fare structure of the transit system to be used. Certainly passenger processing time at ticket machines increases with complex zone fare systems, which require some deciphering by the passenger at the machine prior to installing the correct fare.

Exhibit 4-16
Ticket Machine Examples

BART (Berkeley, CA) RTD (Denver)

Evaluation Procedures

To identify the required number of ticket machines at a station, pre-testing of the particular machine to be purchased could prove beneficial, to approximate an average passenger processing time. In many cases, the number of machines, or booths, to be required will be restricted by space, personnel, or cost constraints.

DOORWAYS AND FARE GATES

Design Factors

Different types of fare gates—manual vs. automatic—have different capacity characteristics.

Doorways and fare gates limit the capacity of a walkway by imposing restricted lateral spacing and by requiring pedestrians to perform a time-consuming activity. Because of these restrictions on capacity, doorways and fare gates will impact the overall capacity of a pedestrian walkway system within a transit terminal, and therefore will require additional design considerations. Fare gates are typically applied at heavy rail stations to control payment and passenger flow to and from a platform area. They are applied to a lesser extent at commuter rail and light rail stations, due to the proof of payment system associated with most of these systems.

Exhibit 4-17 illustrates the placement and operation of fare gate configurations in a transit terminal. There are three different types of fare gates applied in stations:

1. free admission (pre-pay prior to accessing fare gates);
2. coin- or token-operated; and
3. automatic ticket reader.

Free admission fare gates are typically applied after a pay booth at a transit station to monitor and control passenger flow into the platform area. Coin-operated fare gates may have single or double slots to accept change. Automatic ticket reader machines, using magnetic stripe farecards, have been used on newer heavy rail systems with distance-based fares, such as BART in the San Francisco Bay Area and Metro in Washington, D.C. A few stations still use station personnel to check and collect tickets before allowing transit passenger access through a fare gate to the platform area. This form of fare gate is most commonly used at sport stadiums and museums, rather than for transit applications.

Exhibit 4-17
Fare Gate Examples

Token (Toronto) Magnetic Stripe Farecard (BART-Berkeley)

The effect of doorways and fare gates on pedestrian flow will depend on the headway between pedestrians. When a pedestrian reaches a doorway or fare gate, there must be sufficient time-headway separation to allow that pedestrian to pass through the doorway or fare gate before the next pedestrian arrives. If time-headways between successive pedestrians are too close, a growing pedestrian queue will develop.

The capacity of a doorway or fare gate is therefore determined by the minimum time required by each pedestrian to pass through the entrance. Exhibit 4-18 summarizes observed average headways for different types of doorways and fare gates. Although it is recommended that observed headways be collected at fare gates for a transit terminal similar to the one under investigation, the values in Exhibit 4-18 may be used if field data is not available, with the lower value representing closer to a minimum headway.

Exhibit 4-18
Observed Average Doorway and Fare Gate Headways[R3]

Type of Entrance	Observed Average Headway (s)	Equivalent Pedestrian Volume (ped/min)
Doors		
Free-Swinging	1.0-1.5	40-60
Revolving-one direction	1.7-2.4	25-35
Fare Gates		
Free Admission	1.0-1.5	40-60
Ticket Collector	1.7-2.4	25-35
Single-Slot Coin-Operated	1.2-2.4	25-50
Double Slot Coin-Operated	2.5-4.0	15-25

Level of Service Standards

The level of service criteria used for evaluating doorway and fare gate operations are the same as those used for evaluating walkways (see Exhibit 4-15). The objective is to maintain a desirable average pedestrian flow rate (or walking speed) throughout the pedway system. The capacity of a doorway or fare gate will be based on the minimum headway required by a pedestrian to pass through the entrance.

Evaluation Procedures

Determining the Number of Doorways and Fare Gates

Similar to the evaluation procedures for walkways, the procedures to determine the required number of doorways and fare gates are based on maintaining a desirable pedestrian level of service. Following is a list of steps recommended for determining the required number of doorways and fare gates:

1. Based on the desired level of service, choose the maximum pedestrian flow rate from Exhibit4-15.
2. Estimate the peak 15-minute pedestrian demand.
3. Compute the design pedestrian flow (pedestrians per minute) by dividing the 15-minute demand by 15.
4. Compute the required width of the doorway or fare gate (in meters or feet) by dividing the design pedestrian flow by the maximum pedestrian flow rate.
5. Compute the number of doorways or fare gates required by dividing the required entrance width by the width of one doorway or fare gate (always round up).
6. Determine whether the design pedestrian flow exceeds the entrance capacity by following the procedures below.

Determining Entrance Capacity

As discussed above, the capacity of a doorway or fare gate is based on the minimum headway required by a pedestrian to pass through the entrance. The following steps may be used to compute the capacity for a given number of entrances:

1. Determine the minimum headway required (seconds) by pedestrians for a particular type of doorway or fare gate either through field observations or by using the lower headway value from Exhibit 4-18.
2. Compute an equivalent pedestrian volume (pedestrians per minute) by dividing 60 by the minimum headway required.
3. Compute total entrance capacity (pedestrians per minute) by multiplying the equivalent pedestrian volume by the number of doorways or fare gates.
4. Compute hourly pedestrian capacity by multiplying the total doorway or fare gate capacity by 60.

STAIRWAYS

Design Factors

In stations where the platform area at transit stations is grade separated from the rest of the station and the adjacent outside area, stairways have traditionally been applied as the primary vertical pedestrian movement system. Exhibit 4-19 shows typical treatments.

Exhibit 4-19
Stairway Examples

Miami Portland, OR

Critical passenger flows on stairways occur in the ascending direction.

An alternative figure using U.S. customary units appears in Appendix A.

The capacity of a stairway is largely affected by the stairway width. The width of stairway affects the pedestrians ability to pass slower-moving pedestrians and to choose a desirable speed. Unlike walkways, a minor pedestrian flow in the opposing direction on a stairway can cut capacity in half; therefore, stairway design should consider directionality of flow.

Because pedestrians are required to exert a higher amount of energy to ascend stairs when compared to descending stairs, lower flow rates typically result for the ascending direction. For this reason, all references to stairway capacity in this section will be confined to the ascending direction.

Ascending speeds on stairs have been shown to range from 12.2 m/min (40 ft/min) to 50.2 m/min (165 ft/min). This range represents a comfortable and safe rate of ascent for most pedestrians. pass slower-moving pedestrians.

Exhibit 4-20 illustrates the relationship between ascending speeds and pedestrian space. This exhibit reveals that normal ascending speeds on stairs are attained at an average pedestrian space of approximately 0.9 m^2/person (10 ft^2/person). Above approximately 1.9 m^2/person (20 ft^2/ person), pedestrians are allowed to select their own stair speed and to bypass slower-moving pedestrians.

Exhibit 4-20
Pedestrian Ascent Speed on Stairs(R3)

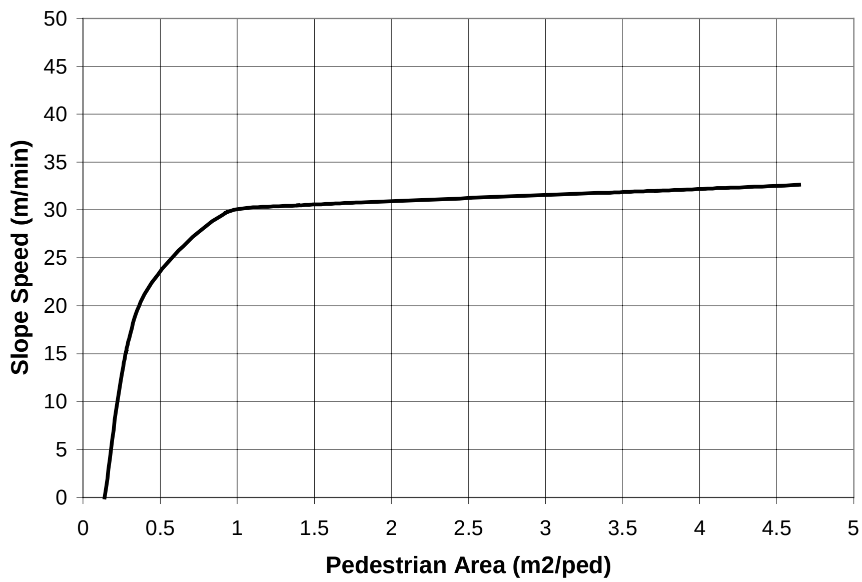
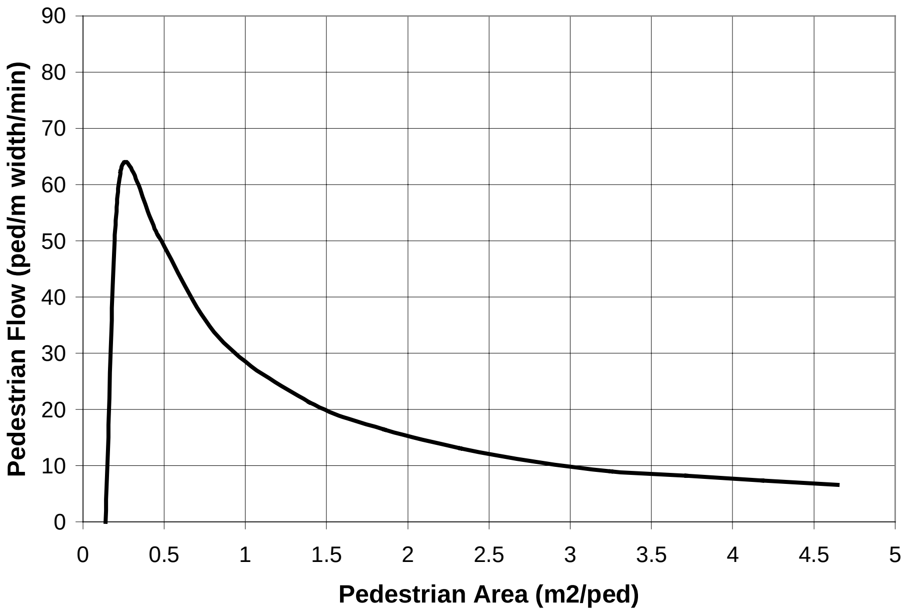


Exhibit 4-21 illustrates the relationship between flow rate on stairs in the ascending direction and pedestrians' space. As observed in this exhibit, the maximum ascending flow rate occurs at a pedestrian space of approximately 0.3 m^2/person (3 ft^2/ person). For this lower pedestrian space, ascending speeds are at the lower limit of the normal range (see Exhibit 4-20). In this situation, forward progress is determined by the slowest moving pedestrian. Although the maximum flow rate represents the capacity of the stairway, it should not be used for a design value (except for emergency situations). At capacity, ascending speeds are restricted and there is a high probability for intermittent stoppages and queuing.

Passenger queuing can also occur at the "destination" end of stairways, if people are forced to converge on too constricted a space. This can be a serious design deficiency in certain terminal facilities, with potential liability exposure. This is at least as important as insuring that adequate space is provided at entry points.

An alternative figure using U.S. customary units appears in Appendix A.

Exhibit 4-21
Pedestrian Flow Volumes on Stairs(R3)



Level of Service Standards

The required width of a stairway is based on maintaining a desirable pedestrian level of service. The level of service standards for stairways are based on average pedestrian space and average flow rate. Exhibit 4-22 summarizes the level of service criteria for stairways. Level of service E (55.8 passengers per meter width per minute or 17 passengers per foot width per minute) represents the capacity of a stairway.

Exhibit 4-22
Level of Service Criteria for Stairways(R3)

Level of Service	Average Pedestrian Space in m^2/ped (ft^2/ped)	Unit Width Flow in ped/m/min (ped/ft/min)	Description
A	≥ 1.9 (> 20)	≤ 16.4 (≤ 5)	Sufficient area to freely select speed and to pass slower-moving pedestrians. Reverse flow cause limited conflicts.
B	1.4-1.9 (15-20)	16,4-23.0 (5-7)	Sufficient area to freely select speed with some difficulty in passing slower-moving pedestrians. Reverse flows cause minor conflicts.
C	0.9–1.4 (10–15)	23.0-32.8 (7-10)	Speeds slightly restricted due to inability to pass slower-moving pedestrians. Reverse flows cause some conflicts.
D	0.7-0.9 (7–10)	32.8-42.6 (10-13)	Speeds restricted due to inability to pass slower-moving pedestrians. Reverse flows cause significant conflicts.
E	0.4-0.7 (4-7)	42.6-55.8 (13-17)	Speeds of all pedestrians reduced. Intermittent stoppages likely to occur. Reverse flows cause serious conflicts.
F	≤ 0.4 (< 4)	Variable to 55.8 (17)	Complete breakdown in traffic flow with many stoppages. Forward progress dependent on slowest moving pedestrians.

Evaluation Procedures

When designing stairways, the following factors should be taken into consideration:(R3)

- Clear areas large enough to allow for queuing pedestrians should be provided at the approaches to all stairways.
- Riser heights should be kept below 0.18 meters (7 inches) to reduce energy expenditure and to increase traffic efficiency.
- When a stairway is placed directly within a corridor, the lower capacity of the stairway is the controlling factor in the design of the pedway section.

When minor, reverse-flow traffic volumes frequently occur on a stair, the effective width of the stair for the major-direction design flow should be reduced by a minimum of one traffic lane, or 0.8 meters (30 inches).

Following are the steps necessary to calculate the width of stairway, stairway capacity, and queuing area required for a given peak pedestrian volume.

Stairway Width

The procedures to determine the required stairway width are based on maintaining a desirable pedestrian level of service. For normal use, it is desirable for pedestrian flows to operate at or above level of service C or D. However, in most modern terminals, escalators would be provided to accommodate pedestrians. Stairs, therefore, are typically provided as a supplement to the escalators to be used when the escalators are over capacity or during a power failure. Under these circumstances, maximum stair capacity, or level of service E (51.8 pedestrians per meter width per minute or 17 pedestrians per foot width per minute), may be assumed. Following is a list of steps recommended for determining the required stairway width:

1. Based on the desired level of service, choose the maximum pedestrian flow rate from Exhibit 4-24.
2. Estimate the directional peak 15-minute pedestrian demand for the stairway.
3. Compute the design pedestrian flow (pedestrians/minute) by dividing the 15-minute demand by 15.
4. Compute the required width of stairway (in meters or feet) by dividing the design pedestrian flow by the maximum pedestrian flow rate.
5. When minor, reverse-flow traffic volumes frequently occur on a stairway, the required width of the stairway should be increased by a minimum of one traffic lane (0.8 meters, or 30 inches).

Stairway Capacity

As discussed above, the capacity of a stairway is taken to be 51.8 pedestrians per meter width per minute (17 pedestrians per foot width per minute) (level of service E). Therefore, for a given stairway width, the following steps may be used to compute the capacity:

1. Compute the design pedestrian flow (pedestrians per minute) by multiplying the width of stairway by 51.8 pedestrians/meter width/minute (17 pedestrians/foot width/minute).
2. Compute the pedestrian capacity (pedestrians per hour) by multiplying the design pedestrian flow by 60.

Size of Queuing Area

1. Compute the capacity of the stairway using the above procedures.
2. Compute the maximum demand by determining the maximum number of pedestrians arriving at the approach of the stairway at one time.
3. Determine the number of arriving pedestrians exceeding capacity by subtracting the capacity from the demand.
4. Compute the required queue area by multiplying the number of pedestrians exceeding capacity by 0.5 m^2 (5 ft^2) per pedestrian.

ESCALATORS

Design Factors

Escalators have been installed in most new train stations where there is grade separation between the platform area and the rest of the station and the outside adjacent area. Typically escalators supplement the provision of stairways, in many cases located adjacent to one another. Exhibit 4-23 shows a typical escalator configuration at a transit station.

Exhibit 4-23
Typical Escalator Configuration at a Transit Station (Denver)

The capacity of an escalator is dependent upon the angle of incline, stair width, and operating speed. In the United States, the normal angle of incline of escalators is 30 degrees, and the stair width is either 0.6 or 1.1 meters (24 or 40 inches) (at the tread). Operating speeds are typically either 27.4 or 36.6 meters/min (90 or 120 ft/min). These operating speeds are within the average range of stair-climbing speeds.

Studies have shown that increasing the speed of an escalator from 27.4 to 36.6 meters per min (90 to 120 feet per min) can increase the capacity by as much as 12 percent. An interesting finding is that the practice of walking on a moving escalator does not significantly increase escalator capacity. A moving pedestrian must occupy two steps at a time, thereby reducing the standing capacity of the escalator.

As for stairways, both ends of an escalator will require some queuing area if passenger demand exceeds the capacity of the facility. This is especially important for escalators, as passengers are unable to queue on a moving escalator, as they (undesirably) might be able to on a stairway.

The size of the queuing area provided at the exiting end of an escalator is an important consideration.

Capacity Standards

Escalator manufacturers rate the maximum theoretical capacity of their units based on a 100 percent step utilization. Studies have shown, however, that 100 percent utilization is never obtained. Escalator steps not being utilized under a heavy demand may be due to any of the following factors:

- intermittent pedestrian arrival process;
- pedestrians' inability to board quickly;
- pedestrians carrying baggage or packages; and
- pedestrians' desire for a more comfortable space.

Because 100 percent utilization is typically not attainable, nominal design capacity values have been developed (see Exhibit 4-24). These values represent a step utilization of 1 person every other step on a 24-inch-wide escalator and one person per step on a 40-inch-wide escalator.

Exhibit 4-24
Nominal Escalator Capacity Values(R3)

Width at Tread m (in)	Incline Speed m/min (ft/min)	Nominal Capacity (persons/h)	Nominal Capacity (persons/min)
0.6 (24)	27.4 (90)	2040	34
	36.6 (120)	2700	45
1.0 (40)	27.4 (90)	4080	68
	36.6 (120)	5400	90

Evaluation Procedures

Number of Escalators

The procedures to determine the required number of escalators are based on the width and speed of the escalator being considered. Following is a list of steps recommended for determining the required number of escalators:

1. Estimate the directional peak 15-minute pedestrian demand for the escalator.
2. Compute the design pedestrian flow (pedestrians per minute) by dividing the 15-minute demand by 15.
3. Based on the width and speed of the escalator, choose the nominal capacity (pedestrians per minute) from Exhibit 4-24.
4. Compute the required number of escalators by dividing the design pedestrian flow by the nominal capacity of one escalator.

Size of Queuing Area

The possibility that escalators can generate large queues, even at pedestrian demands below nominal capacity, should be considered. Queues may generate when demand exceeds capacity or when pedestrian arrival is intermittent or persons are carrying baggage or luggage. For these situations, an adequate queuing area should be placed at the approach of an escalator based on an average pedestrian space of 1.65 m^2 (5 ft^2) per person. (Note: Where alternative stationary stairs are conveniently available, the maximum wait time for an escalator may be assumed to be one minute.) Sufficient space should also be provided at the discharge end of an escalator to avoid conflicts with other traffic streams. Following are steps to computing the required size of queuing area for the approach to an escalator:

1. Determine the capacity of the escalator from Exhibit 4-24.
2. Compute the maximum demand by determining the maximum number of pedestrians arriving at the approach of the escalator at one time. (Assume pedestrians having to wait more than one minute at the escalator will take the stairs, if available.)
3. Determine the number of arriving pedestrians exceeding capacity by subtracting the capacity from the demand.
4. Compute the required queue area by multiplying the number of pedestrians exceeding capacity by 1.65 m^2 (5 ft^2) per pedestrian.

ELEVATORS

Design Factors

Elevators in new or modified bus or rail stations are required in grade-separated facilities to meet ADA requirements.

Elevators are required in all new transit or modified transit stations in the U.S. to meet the Americans with Disabilities Act (ADA) requirements. Elevators are typically provided at one end of the platform. However, certain transit systems (e.g., BART and WMATA) provide elevators in the center of the platform at some stations. Separate elevators may be needed between the street and the concourse and between that level and the platforms. Side platforms require two elevators.

On-going elevator maintenance is important for keeping stations consistently ADA accessible.

Good, on-going elevator maintenance is important for maintaining accessibility for mobility-impaired passengers at transit stations. As a cost-saving measure, most transit stations provide only one elevator per platform, or from the concourse level to the street. However, when any of these elevators are out of service, the station is effectively inaccessible to mobility-impaired passengers. Although these passengers can be served during these times by directing them to alternate stations and providing them with paratransit bus service to their destination, it is much less convenient for these passengers and serves to reduce the accessibility and convenience of the transit system as a whole to ADA passengers.

Exhibit 4-25 shows a typical elevator location in a transit station. Traffic flow on elevators differs from other vertical pedestrian movers. As opposed to escalators and stairs which provide constant service, elevators provide on-demand service. Because of its characteristics, determining the capacity of an elevator is similar to determining the capacity of a transit vehicle.

Exhibit 4-25
Example Elevator Application at a Transit Station (Portland, OR)

Level of Service Standards

The level of service of an elevator system is typically based on average wait time. The tolerance level for an acceptable waiting time for elevator service at a transit terminal is around 30 seconds. Average pedestrian space, personal comfort, and degrees of internal mobility in the elevator cab are not considered as important because of the short time period associated with the elevator ride.

Elevator Capacity

The capacity of an elevator system depends on the following three factors:

- boarding and alighting characteristics of users;
- elevator travel time; and
- practical standing capacity of the cab.

Boarding and alighting times will depend on door width and whether passengers are carrying baggage or luggage. The number of passengers boarding may also have an affect on boarding rates. Studies that have investigated boarding rates for transit vehicles have found that boarding rates increase as the number of passengers increase due to "peer pressure." To determine average boarding and alighting times for a particular elevator system, it is recommended that field data be collected.

Elevator travel time will be based on the operating characteristics of the elevator, including the following:

- distance traveled (height of shaft);
- elevator shaft speed;
- shaft acceleration and deceleration rates; and
- elevator door opening and closing speeds.

The above factors will remain constant for a particular elevator system. The practical standing capacity of an elevator will be based on the following:

- presence of heavy winter clothing;
- presence of baggage or luggage; and
- users' familiarity with one another.

The presence of heavy clothing and baggage or luggage increases the required area per person, and therefore, reduces standing capacity. In addition, studies have shown that if traffic is composed of groups of persons known to each other, lower pedestrian space per person will be tolerated.

Although most persons require 1 m^2 (3 ft^2) or more to feel comfortable in an elevator, the standing capacity may be assumed to be 0.7 m^2 (2 ft^2) per person. As mentioned above, riders of elevators are more willing to accept lower personal space because of the short time period associated with the elevator ride.

PLATFORMS

Design Factors

Transit platforms function as queuing areas for passengers waiting for a transit vehicle to arrive and as circulation areas for both departing and arriving passengers. The effective platform area required is based on maintaining a minimum level of service for queuing and circulation. It is important to note that transit platforms have critical passenger holding capacities, that if exceeded, could result in passengers being pushed onto tracks or roadways. Exhibit 4-26 illustrates typical side and center, and high and low platform configurations at stations.

Exhibit 4-26
Typical Transit Station Platform Configurations

Center, High Platform (Miami) Side, Low Platform (Portland, OR)

Level of Service Standards

Queuing level of service standards for transit platforms and the same for bus stop waiting areas, and are illustrated in Exhibit 4-1. These criteria are based on average pedestrian space, personal comfort, and degrees of internal mobility. Passenger space in the level of service E category are experienced only on the most crowded elevators or transit vehicles. Level of service D represents crowding with some internal circulation possible; however, this level of service is not recommended for long-term waiting periods.

Evaluation Procedures

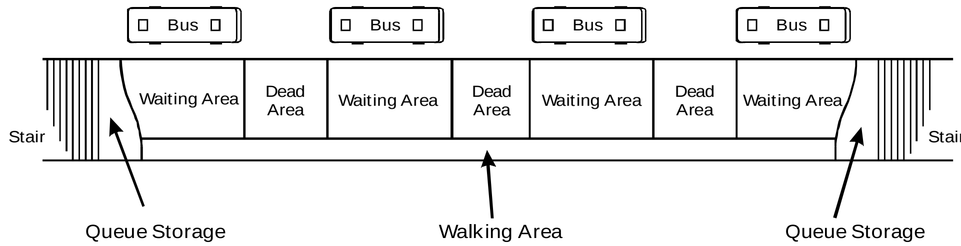
The shape and configuration of a platform is dictated by many system-wide factors. Platform length is typically based on transit vehicle length and the number of transit vehicles using the platform at any one time. Platform width is dependent upon structural considerations, pedestrian queuing space, circulation requirements, and entry/exit locations.

Transit platforms can be divided into the following four areas:[R11]

- walking areas;
- waiting areas;
- dead areas; and
- queue storage.

Exhibit 4-27 illustrates the use of these areas for a transit platform serving buses.

Exhibit 4-27
Four Areas of a Transit Platform(R11)



There are several different components of a platform which impact capacity and size requirements.

Walking and waiting do not occur evenly over the platform area. Some areas are used primarily for walking (e.g., near entry/exit locations and along the back edge of the platform) while other areas are used primarily for waiting (e.g., loading areas).

Areas that are generally not used by passengers are termed "dead areas." These areas are typically present between buses at a bus terminal or in front of or behind a train at a rail terminal. Dead areas should be taken into consideration when choosing the size and configuration of a platform.

Platform Sizing

The procedures to determine the size of a transit platform are based on maintaining a desirable pedestrian level of service. For transit platforms, the design level of service should be C to D or better. Following is a list of steps recommended for determining the desired platform size:

1. Based on the desired level of service, choose the average pedestrian space from Exhibit 4-1.
2. Estimate the maximum pedestrian demand for the platform at a given time.
3. Calculate the required waiting space by multiplying the average pedestrian space by the maximum pedestrian demand.
4. Calculate the additional walkway width needed by using the appropriate procedures for walkways described previously.
5. Calculate the queue storage space required for exit points (at stairs, escalators, and elevators) by using the appropriate procedures described previously.
6. Consider the additional platform space that will used as dead areas.
7. Add a 1-meter (3-ft) buffer zone (0.5 meters, or 18 inches on each side) to the width of the platform.
8. Calculate the total platform area by summing required waiting space, walkway width, queue storage at exit points, dead areas, and buffer zone width.

COMPREHENSIVE PASSENGER PROCESSING ANALYSIS

The various components of a transit station in many cases interact with one another in impacting station capacity, by their proximity to one another and with the number of transit passengers which have to be processed. To allow a comprehensive assessment of the interaction of different station components on capacity, a broader passenger processing system evaluation should be conducted for larger, more heavily-utilized stations. Simulation models are now available to model alternate transit station designs as to their ability to effectively process transit passengers within certain level of service parameters.

Transit station egress capacity is a key capacity consideration.

A key capacity analysis for larger transit stations is the egress capacity needed to accommodate passenger demands during the peak 15-minute period to ensure that the station platform is clear before the next train arrives. In this case, the general solution is as follows:

$$\frac{\text{Passengers/train}}{\text{Capacity (passengers/minute)}} \leq \text{Train headway (minutes)}$$

Equation 4-4

or

$$\text{Capacity (passengers/minute)} \geq \frac{\text{Passengers/train}}{\text{Train headway (minutes)}}$$

Equation 4-5

Because people may not use all available exits, some safety factor is needed. This could be as much as 20-30%.

Manual Method/Input to Simulation Models

In the absence of a transit station simulation model, a basic assessment of the interactions of different station components on capacity can be assessed by the establishment and evaluation of a link-node network.[R4] This network data also serves as a typical input into computer station simulation models. The methodology includes the following steps:

Step 1: Define the System as a Link-Node Network

Paths passengers take through a terminal (origin-destination pairs) are transformed into a network of links and nodes. Each link, being a passageway , can be described by four elements: (1) type—whether it is a level walkway, ramp, stairway, escalator, or elevator; (2) movements allowed—whether it is one-way or two-way (shared or not shared); (3) length (in meters or feet); and (4) minimum width (meters or feet or inches). Nodes are queuing points and/or decision points. They are typically fare collection devices, doors, platform entrances or exits, and junctions of paths.

Step 2: Determine Pedestrian Volumes for the Identified Analysis Period

For each pedestrian origin-destination pair within a station, a pedestrian volume would be assigned for the identified analysis period (typically the peak hour or the peak 5-15 minutes within the peak hour). Origin-destination pairs would distinguish between inbound and outbound passengers.

Step 3: Determine Path Choice

The particular path or alternate paths which a passenger must or can traverse between a particular origin-destination pair (for both inbound and outbound passengers) is identified.

Step 4: Load Inbound Passengers Onto the Network

Inbound passenger volumes for the analysis period are assigned to applicable links and nodes.

Step 5: Load Outbound Passengers Onto the Network

Outbound passenger volumes for the analysis period are assigned to applicable links and nodes.

Step 6: Determine Walk Times and Crowding on Links

In order to calculate the walk times and crowding measures on a link, the flow on that link should be adjusted to reflect peak within the peak hour conditions (typically 5-15 minutes).

Effective widths of links and nodes are the actual minimum widths or doorway widths. When a wall is located on one side of a corridor, 0.5 meters (1.5 ft) is typically subtracted. A buffer of 0.6 meters (2 ft) is typically subtracted for obstructions placed in corridors, such as trash cans and lockers. A buffer of 0.3 meters (1 ft) is typically subtracted for walls in stairwells because transit users on the outside often use handrails. Finally, 0.9 meters (3 ft) is typically subtracted to compensate for two-way movements on stairs.

The adjusted flow is then divided by the effective width to determine the number of pedestrians per meter or foot width per minute. For a given level of service, the average space mean speed can be identified from Exhibit 4-14 for walkways, Exhibit 4-22 for stairways, and Exhibit 4-26 for escalators.

Step 7: Determine Queuing Times and Crowding at Nodes

Passenger queues at nodes can be estimated using the following equations, which are considered to be appropriate for calculating the expected time in the queuing system, W, and the expected number in the queue, L_q:

$$W = \frac{S_R (A_R / S_R)^k P_0}{(k-1)!(kS_R - A_R)^2} + \frac{1}{S_R}$$

Equation 4-6

where:

W	=	expected time in the queuing system (minutes);
A_R	=	arrival rate (persons/minute);
S_R	=	service rate of single channel (persons/minute);
k	=	number of service channels; and
P_0	=	probability of no passenger queue at a particular node, from Equation 4-8.

$$L_q = \frac{A_R S_R (A_R / S_R)^k P_0}{(k-1)!(kS_R - A_R)^2}$$

Equation 4-7

where:

L_q	=	expected number in the queue (persons).

$$P_0 = \frac{1}{\left(\sum_{n=0}^{k-1} \frac{1}{n!}(A_R / S_R)n\right) + \frac{1}{k!}(A_R / S_R)^k \frac{kS_R}{kS_R - A_R}}$$

Equation 4-8

These equations are dependent on the assumption that arrival and service rates are randomly distributed according to the Poisson distribution. This assumption may be questionable for exiting passengers at certain rail stations and bus terminals, due to the high peaking nature of this movement, and should be modified through field investigation as appropriate.

Step 8: Determine Wait Times for Transit Vehicles

Wait times for transit vehicles are a key input to determining required queuing areas on platforms. A typical assumption used is that wait time is half the bus or train headway.

Step 9: Add Travel Time Components and Assess Overall Level of Service

Overall travel times for different origin-destination pairs can be totaled and averaged to identify an average passenger processing time through a particular transit station. This can then be translated into an overall passenger processing level of service.

Computer Simulation Models

Computer simulation models are increasingly being applied to identify passenger flows and queuing in major transit terminals. These models facilitate the evaluation of overall station layout alternatives, as well as sizing specific processing elements, such as walkways, stairways, escalators, and platforms.

Simulation models simplify transit station passenger processing analysis.

Real-Time Passenger Information Systems

In recent years, new electronic technology has been developed to provide improved traveler information systems. For transit stations, “real-time” passenger communications can assist in managing passenger flows and queues. This can include providing information on bus and train departure times, bus and train berth locations, and out-of-service elevators and other facilities.

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4. REFERENCES

1. Benz, Gregory P., "Application of the Time-Space Concept to a Transportation Terminal Waiting and Circulation Area," *Transportation Research Record 1054*, Transportation Research Board, Washington, DC (1986).
2. Demetsky, Michael J., Lester A. Hoel, and Mark A. Virkler, *Methodology for the Design of Urban Transportation Interface Facilities*, U.S. Department of Transportation, Program of University Research, Washington, DC (1976).
3. Fruin, John J., *Pedestrian Planning and Design*, Revised Edition, Elevator World, Inc., Mobile, Alabama (1987).
4. Griffths, John R., Lester A. Hoel, and M.J. Demetsky, *Transit Station Renovation: A Case Study of Planning and Design Procedures*, U.S. Department of Transportation, Research and Special Programs Administration, Washington, DC (1979).
5. "Highway Capacity Manual," *TRB Special Report 209,* Transportation Research Board, Washington, DC (1997).
6. Levinson, H.S., "Analyzing Transit Travel Time Performance," *Transportation Research Record 915,* Transportation Research Board, Washington, DC (1983).
7. Levinson, H.S., C.L. Adams, C.L., and W.F. Hoey, "Bus Use of Highways—Planning and Design Guidelines," *NCHRP Report 155,* Transportation Research Board, Washington, DC (1975).
8. Levinson, Herbert S. and Kevin R. St. Jacques, "Bus Lane Capacity Revisited," *Preprint 100,* presented at the Transportation Research Board 1998 Annual Meeting.
9. National Transportation Safety Board, "Highway Accident Summary Report: Bus Collision with Pedestrians, Normandy, Missouri, June 11, 1997," *Report PB98-916201,* NTSB, Washington, DC (1998).
10. St. Jacques, Kevin and Herbert S. Levinson, "Operational Analysis of Bus Lanes on Arterials," *TCRP Report 26*, Transportation Research Board, Washington, DC (1997).
11. *Transportation Planning Handbook,* Institute of Transportation Engineers, Prentice Hall (1992).
12. Texas Transportation Institute, "Guidelines for the Location and Design of Bus Stops," *TCRP Report 19,* Transportation Research Board, Washington, DC (1996).

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5. EXAMPLE PROBLEMS

1. Transit Center Design
2. Terminal Concourse Design
3. Escalator Addition
4. Required Queue Storage Area

Transit center design.

Example Problem 1[R5]

The Situation A transit agency plans to construct a suburban transit center.

The Question What are the “base year” 2000 and “design year” 2015 berth requirements?

The Facts

- ✓ The bus lines serving the proposed transit center are identified below. Year 2000 data are based on actual schedules, while year 2015 data are based on a growth forecast of 60% for local bus service and 100% for freeway bus service.
- ✓ Bus berths will be assigned according to principal geographical destinations.
- ✓ Bus dwell times will be approximately 5 minutes per bus passing through the center and 8 minutes for buses that begin and end trips there.

Route #	Route Name	Peak Direction Buses		Off-Peak Dir. Buses		Service Type
		2000	2015	2000	2015	
LOCAL SERVICE						
42	Holman Crosstown	8	13	0	0	Terminating
68	Brays Bayou Crosstown	4	6	0	0	Terminating
76	Lockwood Crosstown	4	6	4	6	Through
77	MLK Limited	6	10	6	10	Through
	Subtotal Local	22	35	10	16	
EXPRESSWAY SERVICE						
242	Clear Lake Park-and-Ride	3	6	1	2	Through
245	Edgewood Park-and-Ride	3	6	1	2	Through
250	Hobby Park-and-Ride	2	4	1	2	Through
255	Fuqua Park-and-Ride	4	8	1	2	Through
41	Garden Villas Limited	2	4	1	2	Through
147	Sagemont Express	2	4	1	2	Through
	Subtotal Express	16	32	6	12	
	TOTAL	38	67	16	28	

Comments

- ✓ In 2000, 22 local buses and 16 express buses will use the transit center in the peak direction, while some 10 local buses and 6 express buses will use it in the off-peak direction.
- ✓ Bus dwell times are longer than the 3-minute passenger service time needed to fill an empty bus to seated capacity, assuming that exact fares are paid on the bus, to allow for schedule irregularities and (for the terminating routes) driver layover time.

Steps

The table below provides estimated berth requirements for 2000 and 2015. The berths were estimated as follows:

1. The bus routes were grouped by geographic destination in 3 categories.

2. The "capacity" of each type of service was obtained by the equation $c = 60 / t_d$, where t_d was the specified dwell time (clearance time was neglected, as it is short in comparison to the dwell times at the transit center). Thus a 5-minute dwell time could accommodate 12 buses/berth/hour; an 8-minute dwell time, 7.5 buses/berth/hour.

3. The number of *inbound* berths for the a.m. peak hour were computed by dividing the number of buses by the berth capacity. Thus, for lines 42 and 68, in 1985, 12 buses would need 12 / 7.5 or 1.6 berths, rounded up to 2 berths.

4. The bus routes that *start* at the center would need only *inbound* berths. The other bus routes would need an equal number of *outbound* berths to accommodate p.m. peak hour bus flows and to ensure that each major geographic destination would have its own specified area.

The Results

For the year 2000, the following calculations result:

Route	Service Type	Dwell Time/Bus (min)	Buses/ Berth/ Hour	A.M. Inbound Buses	Inbound Berths	Max. Outbound Berths for P.M.	Total Berths
LOCAL SERVICE							
42-68	Start	8	7.5	12	2	0	2
76	Through	5	12	4	1	1	2
77	Through	5	12	6	1	1	2
	Subtotal			22	4	2	6
EXPRESSWAY SERVICE							
All	Through	5	12	16	2	2	4
	TOTAL			38	6	4	10

For the year 2015, the following calculations result:

Route	Service Type	Dwell Time/Bus (min)	Buses/ Berth/ Hour	A.M. Inbound Buses	Inbound Berths	Max. Outbound Berths for P.M.	Total Berths
LOCAL SERVICE							
42-68	Start	8	7.5	19	3	0	3
76	Through	5	12	6	1	1	2
77	Through	5	12	10	1	1	2
	Subtotal			35	5	2	7
EXPRESSWAY SERVICE							
All	Through	5	12	32	3	3	6
	TOTAL			67	8	5	13

The total berth requirements represent the sum of the inbound and outbound berths. As a result, 10 loading positions are needed for year 2000 conditions, and 13 loading positions are needed for year 2015 conditions. Ideally, 15 loading positions should be provided to account for growth and traffic fluctuations within the peak hour.

Note that 38 inbound buses with a berth capacity of 10 buses/berth/hour would require only 4 inbound loading positions in 2000 if routes were not separated geographically. However, this is *not* advisable when one considers clarity to the riding public, so that 6 berths are anticipated based on the grouping shown above.

Terminal concourse design: doors, corridor width, and stairs.

Example Problem 2[R3]

The Situation A two-level commuter transportation terminal will be constructed to serve a downtown area.

The Question Based on the estimated demand, how many entrance doors will be needed, how wide should the main access corridor be, and how many stairways will be needed and how wide should they be? In the event of a service stoppage, how will pedestrian level of service be affected?

The Facts
- ✓ The 15-minute design peak passenger demand is 5,000 passengers.
- ✓ During the peak 15 minutes, a short 5-minute micro-peak is expected to occur, with demand volumes estimated to be 50% higher than the average for the design period.

Comments
Commuter transportation terminals are subject to recurrent peaks of severe, but rather short, duration. Generally they are designed for the recurring 15-minute peak period, but the consequences of surges within the peak should be considered. Because the micro-peaks are of high volumes, space is usually restricted; however, their short duration and the fact that the users have knowledge of the facility may justify the assumption of lower levels-of-service.

Level of Service D (LOS D) would be representative of reasonable design for a facility of this type. Traffic flows for this design level are as follows:
- Entrances and corridors: 30.5-45.7 ped/min/m (from Exhibit 4-16)
- Stairs: 32.8-42.6 ped/min/m (from Exhibit 4-24)

Because the users are commuters, the higher value of the ranges will be applied.

Steps
(a) Entrance Doors
Assuming a 1-meter-wide door, the pedestrian flow rate at LOS D would be:

1 m x 45.7 ped/min/m = 45.7 ped/min

This flow rate is equivalent to a headway of:

$$\frac{60\,\text{sec/min}}{45.7\,\text{ped/min}} = 1.31 \text{ sec/ped}$$

and a distance between pedestrians of:

1.31 sec/ped x 1.3 m/sec (walking speed) = 1.7 m/ped

This is rather close, but compares with observed use of free-swinging doors. Also, during heavy traffic, pedestrians may be observed holding the door for the following pedestrian, reducing clearance times slightly.

The required number of doors is:

$$\frac{5000\,\text{peds}}{15\,\text{min} \times 45.7\,\text{ped/min}} = 7.3 \text{ or 8 doors, major flow only}$$

Two additional doors should be provided to serve the minor direction flow, so a total of 10 doors should be provided. At 1 meter width per door, the minimum width needed for these doors is 10 meters.

(b) Corridor Width
Based on building code requirements, minimum corridor width must be equal to the entrance width. However, the effective corridor width, with deductions for obstructions, should be used in calculations:

$$\text{Effective corridor width} = \frac{5000 \text{ peds}}{15 \text{ min} \times 45.7 \text{ ped/min/m}} = 7.3 \text{ m}$$

Add 0.6 m to each side of corridor for door openings; also add 1.2 m for column obstructions.

7.3 + 2 (0.6) + 1.2 = 9.7 m total corridor width.

(c) Stairway Width
For LOS D:

$$\text{Stairway Width} = \frac{5000 \text{ peds}}{15 \text{ min} \times 42.6 \text{ ped/min/m}} = 7.8 \text{ m}$$

In most modern terminals, escalators would be provided to supplement stairs. On the assumption that cost limitations allowed the installation of the only three escalators operating up, required stair width could be significantly reduced. Based on the observed capacities of Exhibit 4-26, virtually all pedestrians could be accommodated by the escalators. However, because this is a transit terminal, the designer should consider that a power failure might put all the escalators out of service. Some agencies do not permit pedestrians to walk on stopped escalators.

On the assumption that stationary stairs will supplement the escalators, and would be used totally only during a power failure, maximum stair capacity, or LOS E (55.8 ped/min/m from Exhibit 4-24), can be assumed. The width of the supplementary stairs is:

$$\text{Stair Width} = \frac{5000 \text{ peds}}{15 \text{ min} \times 55.8 \text{ ped/min/m}} = 6.0 \text{ m}$$

(d) Evaluation of the Micro Peak
The five-minute surge in traffic (50 percent greater than the 15-minute average) will cause temporary reductions in service levels and result in queuing at some service facilities. At the entrances, the micro peak is the equivalent of a surge flow of:

$$\frac{5000 \text{ peds} \times 1.5 \text{ (surge factor)}}{15 \text{ min}} = 500 \text{ ped/min}$$

For eight 1-meter-wide doors, this equates to a unit width flow of:

$$\frac{500 \text{ ped/min}}{8 \times 1 \text{ m}} = 62.5 \text{ ped/min/m}$$

This flow is in the LOS E range (see Exhibit 4-16). The doors have been designed for LOS D, which equates to a pedestrian flow rate of:

8 x 45.7 ped/min = 366 ped/min

The headway equivalent of the surge flow on the 8 doors is:

$$\frac{60 \text{ sec/min}}{(500 \text{ ped/min}) / (8 \text{ doors})} = 0.96 \text{ sec/ped/door}$$

and a distance between pedestrians of:

0.96 sec/ped x 1.3 m/sec (walking speed) = 1.2 m/ped

The door opening and clearance time is at the maximum. A close examination of the minor flow traffic characteristics might allow for partial use of the other two doors, otherwise more doors, or alternative entrance locations, are required. The use of an air curtain entrance, the width of the corridor, would satisfy all design assumptions.

The surge flow in the corridor is equal to the pedestrian volume divided by the effective corridor width:

$$\frac{500\ \text{ped/min}}{7.3\ \text{m}} = 68.5\ \text{ped/min/m}$$

This flow is the equivalent of LOS E (see Exhibit 4-17), which is below critical density flow, and could be tolerated for short periods without generating serious backups.

If a complete service stoppage should occur during the 15-minute design peak, pedestrian holding space for 5,000 persons would be required. Because the waiting period is of longer duration, a minimum pedestrian area of 0.7 m^2 per person (LOS C to D in Exhibit 4-1) is recommended for evaluation of concourse adequacy.

Concourse area for service stoppage:

$$5000 \text{ peds} \times 0.7\ \text{m}^2/\text{ped} = 3500\ \text{m}^2$$

Sufficient area should be provided for this contingency in all the public open space in the terminal. If this is not possible, alternative operating procedures should be developed to prevent a dangerous overcrowding.

The Results

For the identified peak passenger demand, a systematic approach was applied to size the number of doors and the corridor and stairway widths required. Level of service D was applied for normal peak 15-minute conditions, and LOS E for peak surge (5-minute) conditions.

Example Problem 3[R3]

Escalator addition.

The Situation A subway platform on an urban heavy rail line will be modified to install an up direction escalator at the center of a subway platform.

The Question What is the pedestrian queuing and delay for the proposed installation?

The Facts

- ✓ Field counts of passengers discharged by the subway trains show that maximum traffic occurs during a short micro-peak, when two trains arrive within two minutes of each other, carrying 225 and 275 passengers, respectively.
- ✓ The remaining trains in the peak period are on a 4-minute headway.
- ✓ The platform is 275 meters long, and 4.6 meters wide.
- ✓ Field observations of other subway stations in this city with similar passenger volumes reveal a maximum escalator capacity of 100 passengers per minute (for the assumed 36.6 m/min, one-meter-wide escalators in this example), as opposed to the nominal capacity of 90 pedestrians per minute in Exhibit 4-26.

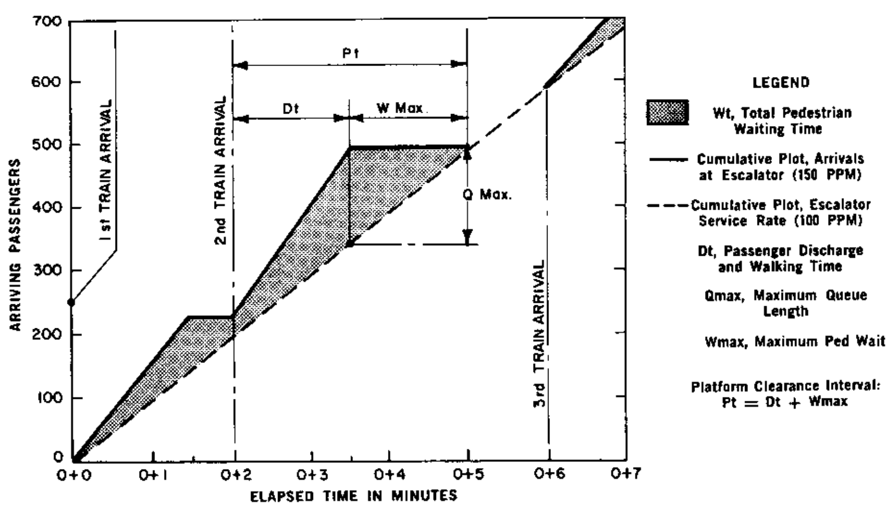
Steps

Construction of Time Clearance Diagram:

1. A graph is constructed (see the figure on the next page), with time, in minutes, as the horizontal axis, and pedestrians as the vertical axis.
2. The escalator capacity of 100 pedestrians per minute is then drawn (dashed sloped line).
3. The arrival rate at the escalator is a function of the train discharge time and walking time required to reach the escalator. If it is assumed that pedestrians are discharged uniformly along the length of the platform, and the escalator is located in the center of the platform, arrival time can be approximately represented on the clearance diagram by determining the time required to walk half the platform length. A commuter walking speed of 91.4 m/min (300 ft/min) is used in this example.

$$\text{Total arrival time} = \frac{\text{1/2 platform length}}{\text{average walking speed}} = \frac{137.5\text{ m}}{91.4\text{ m/min}} = 1.5\text{ min}$$

The two train arrivals, of 225 and 275 pedestrians, are plotted as solid lines on the time clearance diagram shown below.



Maximum Queue Size and Maximum Wait
Assuming all the passengers will use the escalator and not the stairs, the clearance diagram illustrates a number of significant facts. The stippled area between the pedestrian arrival rate(solid line), and the escalator service rate (dashed line), represents *total waiting time*.

Division of the waiting time area by the number of arriving pedestrians gives *average pedestrian waiting time*. The maximum vertical intercept between these two lines represents *maximum pedestrian queue length*. The maximum horizontal intercept represents the *clearance interval* of the platform.

The clearance diagram shows that a maximum queue size of 75 persons would be generated by the first train arrival, if all persons seek escalator service. It also shows that 25 persons will still be waiting for the escalator service when the next train arrives. The Maximum waiting time for escalator service after the first train arrival is one minute. The average pedestrian waiting time is 15 seconds. After the second train arrival, the maximum waiting and maximum queue size builds up to 1.5 minutes and 150 pedestrians, respectively. If it is assumed that pedestrians will divert to the stairs if the maximum escalator wait exceeds one minute, a one-minute-wide horizontal intercept on the graph shows that maximum queue size will not likely get larger than 50 pedestrians. This is about the limit observed for low-rise escalators of this type, where alternative stationary stairs are conveniently available.

Waiting Area and Platform Level of Service
At a jam area occupancy of about 0.5 m^2 per pedestrian, 100 pedestrians in a queue require 46.5 m^2 of waiting area. For the 4.6 meter-wide platform of this example, this queue would occupy about 9.1 to 12.2 lineal meters on the platform. If the platform is the one-sided-loading type, the escalator should be offset to minimize this queue interference.

The time clearance diagram indicates that with one train unloading, there will be a maximum of about 315 pedestrians walking along the platform and waiting for the escalator. This pedestrian volume results in an average pedestrian area of:

$$\frac{275\text{ m (length)} \times 4.6\text{ m (width)}}{315\text{ pedestrians}} = 4\text{ m}^2\text{ / pedestrian}$$

This pedestrian area equates to a LOS A (see Exhibit 4-1). Levels of pedestrian queuing capacity on the platform based on various levels of service are as follows:

$$\text{LOS E (Danger Level)} : \text{Capacity} = \frac{275\text{ m} \times 4.6\text{ m}}{0.3\text{ m}^2\text{ / ped}} = 4215\text{ ped}$$

$$\text{LOS D (Jam Capacity)} : \text{Capacity} = \frac{275\text{ m} \times 4.6\text{ m}}{0.5\text{ m}^2\text{ / ped}} = 2530\text{ ped}$$

$$\text{LOS B (Desirable Maximum)} : \text{Capacity} = \frac{275\text{ m} \times 4.6\text{ m}}{0.9\text{ m}^2\text{ / ped}} = 1405\text{ ped}$$

The Results

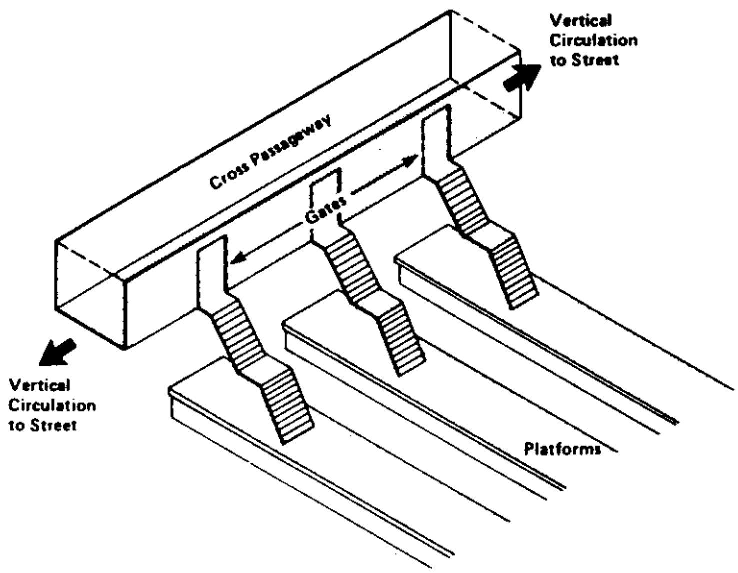
Based on the approximate headways and passenger loads used in this problem, it appears likely that a full hour delay would be required before dangerous crowding conditions would occur on this platform. However, the preferred maximum could be reached within approximately a 15-minute delay, which would not be an unusual occurrence.

Example Problem 4 (R1)

Required queue storage area.

The Situation

A new passenger facility, referred to as a cross passageway (depicted below) will provide access to and from the ends of platforms of a busy commuter rail terminal that currently has access at one end only. The cross passageway is essentially a wide corridor that will run perpendicular to and above the platforms, with stairs connecting the cross passageway to each platform. The cross passageway is connected to the surface at several points.



The Question

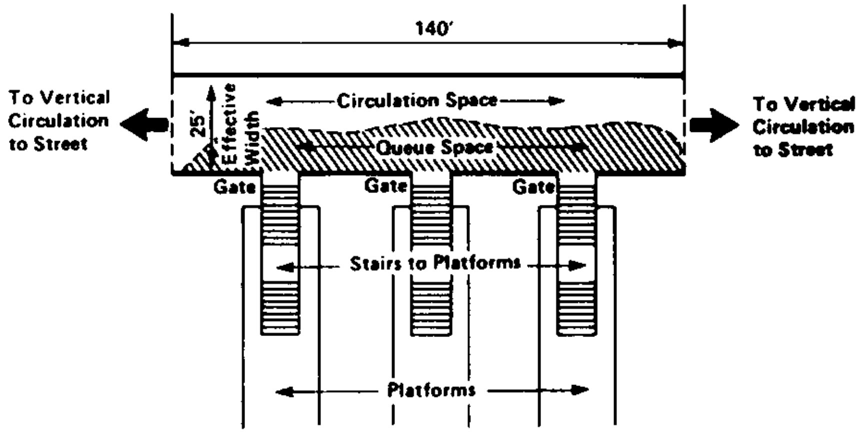
Can the corridor meet the space requirements of both queuing passengers and circulating passengers within a portion of the cross passageway adjacent to a departure gate?

The Facts

- ✓ Surveys showed that passengers departing on trains typically start to gather in front of a gate about 23 min before the train's scheduled departure time and assemble at the following rates:

Time Before Departure (min):	20	15	10	5	1
Departing Passengers (% gathered):	9	26	53	86	100

- ✓ The maximum accumulation of passengers outside the gate to the train platform occurs just before the opening of the gate--typically 10 min before train departure when 53 percent of the passengers leaving on the train are present. The accumulation of waiting passengers, if large enough, can easily affect the cross passageway width available to handle longitudinal flow.
- ✓ As shown in the figure on the next page, the cross passage way is 42.7 meters long with an effective width of 7.6 meters (i.e., the width actually available for passenger activities: the wall-to-wall dimension minus the width occupied by obstructions and columns and the boundary or "cushion" maintained by pedestrians along walls). During the 1 min before the opening of the departure gate, 194 people will be waiting in the cross passageway. The flow rate of people walking along the corridor during this time will be 167 people per minute.



Comments

- ✓ The problem is to examine whether the corridor can meet the space requirements of both queuing passengers and circulating passengers within a portion of the cross passageway adjacent to a departure gate.
- ✓ The analysis period is the 1 min before the opening of the gate when the maximum accumulation of waiting passengers will occur.

Steps

With a design criterion of LOS C, the average pedestrian queuing area is 0.9 m^2/ped (see Exhibit 4-1). This classification reflects the unordered (random) nature of the queue in this space, the need for some circulation and movement within the queue, and the comfort level expected by commuter rail passengers. The 194 people waiting will require:

$$194 \text{ ped} \times 0.9 \text{ m}^2/\text{ped} = 175 \text{ m}^2$$

The shape of the queue has to be estimated in order to determine the portion of the 4.6 meter-wide cross passageway that the queue will occupy. For this example, the waiting passengers, occupying 175 m^2 are assumed to be evenly distributed along the 42.7-meter linear dimension of the space. Therefore, the queue is expected to require the following width at the widest point:

$$\frac{175 \text{ m}^2}{42.7 \text{ m}} = 4.1 \text{ m}$$

This leaves 3.5 meters available for the flow of the 167 circulating passengers who would walk through the cross passageway during the 1-minute peak queue period. The unit width flow rate available is:

$$\frac{167 \text{ ped/min}}{3.5 \text{ m}} = 47.7 \text{ ped/min/m}$$

The Results

From Exhibit 4-17, this identified pedestrian flow rate equates to LOS D to E . In this level of service range, walking speeds and passing abilities are highly restricted. In addition, there will be a high probability of conflict for opposing pedestrian traffic streams.

APPENDIX A. EXHIBITS IN U.S. CUSTOMARY UNITS

Exhibit 4-12a
Pedestrian Speed on Walkways(R3)

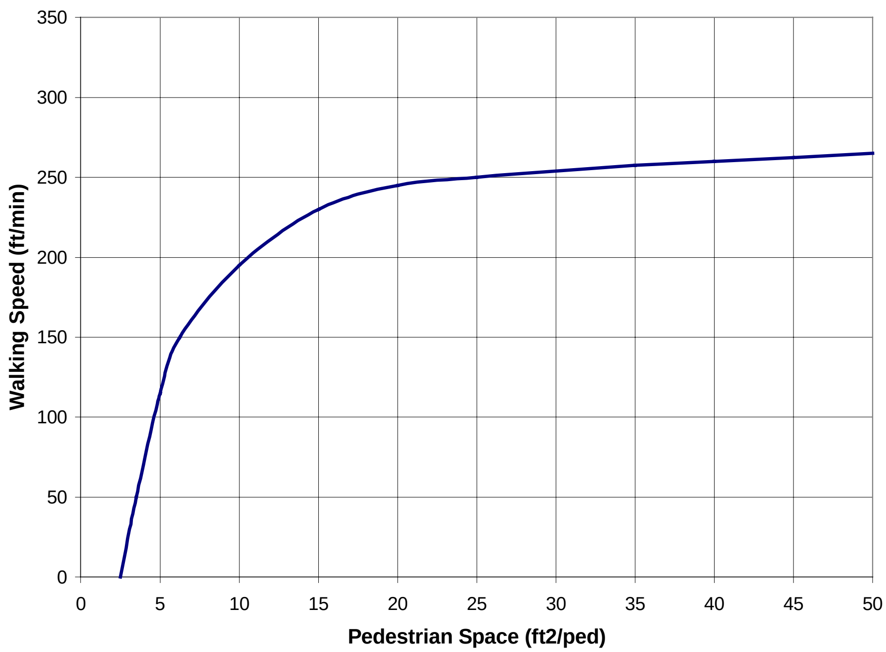


Exhibit 4-13a
Pedestrian Unit Width Flow on Walkways(R3)

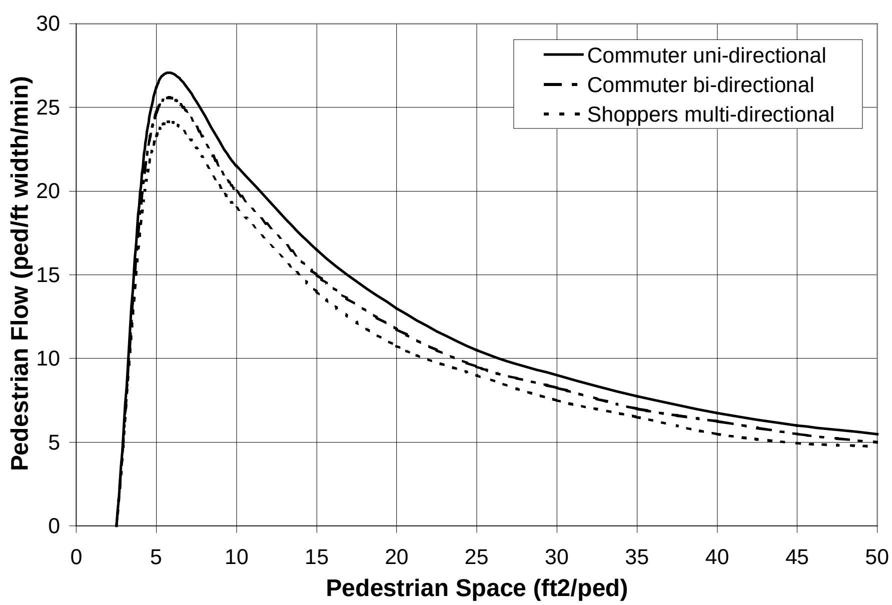


Exhibit 4-20a
Pedestrian Ascent Speed on Stairs(R3)

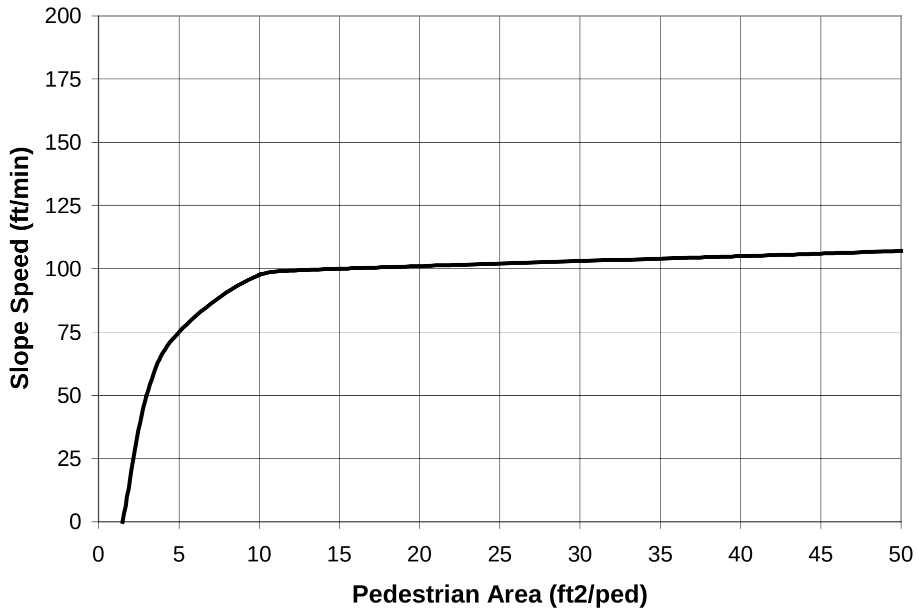


Exhibit 4-21a
Pedestrian Flow Volumes on Stairs(R3)