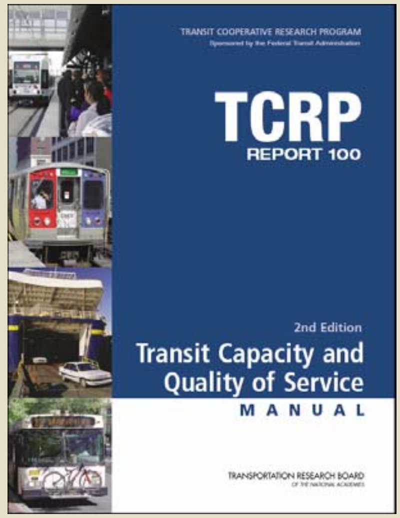
Stop, Station, and Terminal Capacity

Mark Walker
Parsons Brinckerhoff



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Stop, Station, and Terminal Capacity

Presentation Overview

- Brief introduction to the project
- Station types & configurations
- Passenger circulation and level of service
- Station elements and their capacities
- Example problems
- Questions to think about

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Project Overview

- Obtain user feedback on the TCQSM 2nd Edition (2003)
- Recommend additions, revisions, format
- Conduct gap-filling research
- Prepare TCQSM 3rd Edition
- Prepare information program

TCQSM Webinar Series Objectives

- Provide background on TCQSM material for focus group and online survey participants
- Expand industry's awareness of the manual and its potential uses
- Lay groundwork for updated training material when the new manual is published (2013)

Webinar Series Topics

- Overview of the TCQSM 2nd Edition
- Fixed Route Quality of Service
- Bus Transit Capacity
- Rail Transit Capacity
- Ferry Transit Capacity
- Stop, Station, and Terminal Capacity
- Demand-Responsive Transportation

www.tcqsm.org

Station Types and Configurations

Types of Stops, Stations, and Terminals

- Bus stops
  - On-street
  - Few or no amenities
- Transit centers
  - Usually off-street
  - Few to many amenities
- Transit stations
  - Off-street
  - Many amenities
- Busway stations
- Light rail stations
- Heavy rail stations
- Commuter rail stations
- Ferry docks and terminals
- Intermodal terminals

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Types of Stops, Stations, and Terminals

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Passenger Circulation and Level of Service

Principles of Pedestrian Flow

- Ped speed is related to density
  - The more pedestrians, the slower the average ped speed
- Flow (how many pedestrians can pass by a given point) is the product of speed and density:
  - V = S * D
  - Units: pedestrians per foot width per minute
- Average space per pedestrian is related to speed and flow
  - M = S / V,   units: ft^2/ped

Principles of Pedestrian Flow

- Most design problems relate to solving for either:
  - Station element width (e.g., stairway width)
  - Station element area (e.g., platform area)
- Result is a station element sized to accommodate a given number of persons per hour, at a design level of service

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Design Questions

- How many bus bays (loading areas) are needed?
- Is there enough room for passengers to wait and circulate?
- Is there enough space & passenger demand for particular amenities?

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Design Questions

- Additional considerations for stations and terminals:
  - Are passenger processing elements (e.g., stairs and fare gates) adequately sized?
  - Which station element constrains capacity?
  - Requirements for emergency evacuation?

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Design Issues

- Americans with Disabilities Act (ADA)
  - ADA requirements affect design
  - Addressed in TCQSM to the extent it impacts the sizing of station elements
  - TCQSM provides input into the design process, but isn't a design manual

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Emergency Evacuation

Emergency Evacuation Design

- Must address evacuation requirements (person flow determined from the maximum person accumulation and the maximum time to evacuate station)
- Ability to remove passengers from platform area before next vehicle or train arrives
- Overall passenger flow through station is an important consideration (bottlenecks!)

Emergency Evacuation Design

- NFPA1 130 general considerations:
  - Sufficient exit capacity to evacuate station occupants (including those on trains) from platforms in 4.0 minutes or less
  - Sufficient exit capacity to get from most remote point on platform to point of safety in 6.0 minutes or less
  - Second egess route remote from major egress route from each platform

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Emergency Evacuation Design

- Number of people to design for:
  - Loads of one train on each track during peak 15 minutes
    - Assume each train one headway late (i.e., is carrying twice its normal load, but no more than a maximum schedule load)
  - Passengers on platform during peak 15 minutes, assuming trains are one headway late

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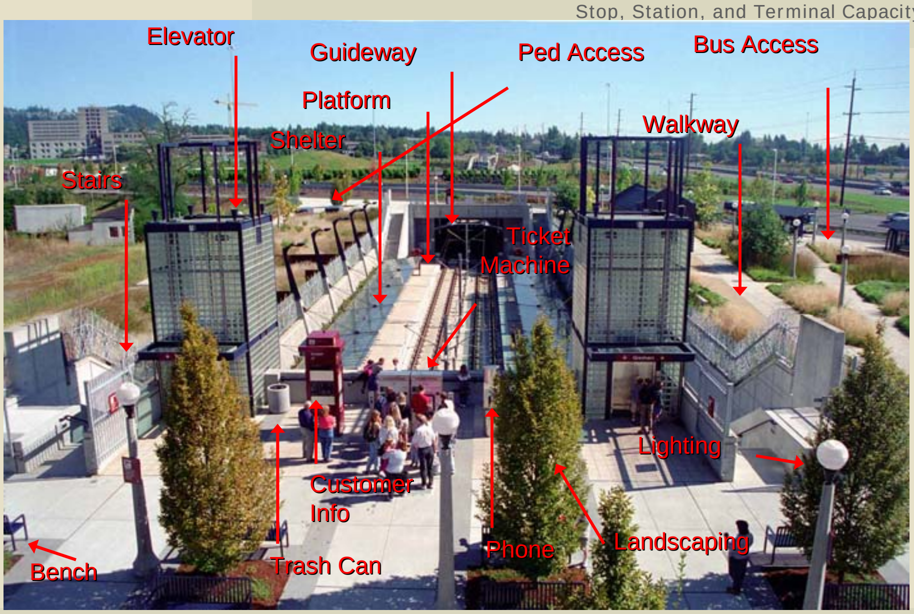
Design for Emergency Evacuation

- Maximum capacity required for normal operations or emergency evacuation will govern
- Because emergency evacuation routes may be different than routes taken by passengers during normal operations, you can't assume that evacuation needs will govern in all cases

Station Elements and Their Capacities



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Not Pictured…

- Faregates
- Park-and-ride
- Bike storage
- Artwork
- Electronic displays
- Station agents
- Doorways
- Moving walkways
- Restrooms
- Driver break areas
- Vending machines
- Escalators
- Kiss-and-ride

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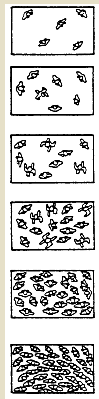
Passenger Waiting Areas

Passenger Waiting Areas

- Process for sizing passenger waiting areas is based on designing for a desirable level of service
- Concepts presented in Fruin's *Pedestrian Planning & Design*
- HCM has similar concepts, but intended for sidewalks—TCQSM's levels of service are intended for transit facilities
- Level of service measure: average space per person

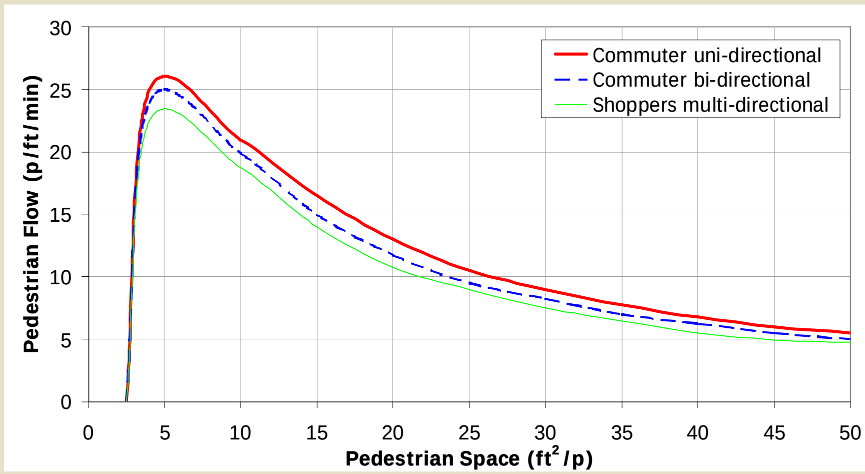
Waiting Area LOS



LOS A	>= 13 ft^2 per person
LOS B	10-13 ft^2 per person
LOS C	7-10 ft^2 per person
LOS D	3-7 ft^2 per person
LOS E	2-3 ft^2 per person
LOS F	< 2 ft^2 per person

Walkways

Pedestrian Flow on Walkways



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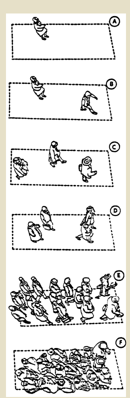
Walkway LOS



LOS A	>= 35 ft^2/p, avg. speed 260 ft/min
LOS B	25-35 ft^2/p, avg. speed 250 ft/min
LOS C	15-25 ft^2/p, avg. speed 240 ft/min
LOS D	10-15 ft^2/p, avg. speed 225 ft/min
LOS E	5-10 ft^2/p, avg. speed 150 ft/min
LOS F	< 5 ft^2/p, avg. speed <150 ft./min

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Walkway LOS

LOS	Pedestrian Space (ft²/p)	Expected Flows and Speeds: Avg. Speed, *S* (ft/min)	Flow per Unit Width, *v* (p/ft/min)	*v/c*
A	≥ 35	260	0-7	0.0-0.3
B	25-35	250	7-10	0.3-0.4
C	15-25	240	10-15	0.4-0.6
D	10-15	225	15-20	0.6-0.8
E	5-10	150	20-25	0.8-1.0
F	< 5	< 150	*Variable*	*Variable*

Walkways

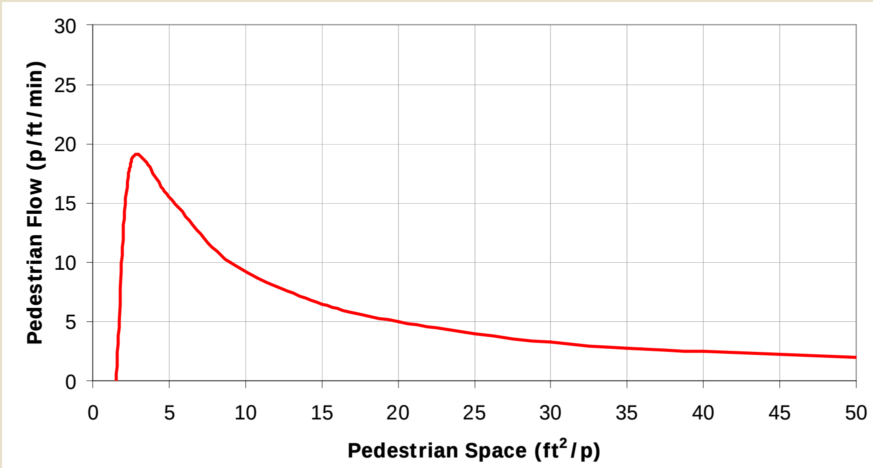
- Typical free flow ped speed for design: 250 ft/min
- Capacity occurs at LOS E/F threshold
  - Peds move at a shuffle

Walkway Design Process

1. Based on desired LOS, identify maximum flow rate per unit width
2. Estimate peak 15-minute demand
3. Allow for wheelchairs, users with large items
4. Compute design ped flow: (Step 2) / 15
5. Effective width = (Step 4 / Step 1)
6. Add buffer width: 1.5 feet on each side

Stairs and Escalators

Pedestrian Flow on Stairs



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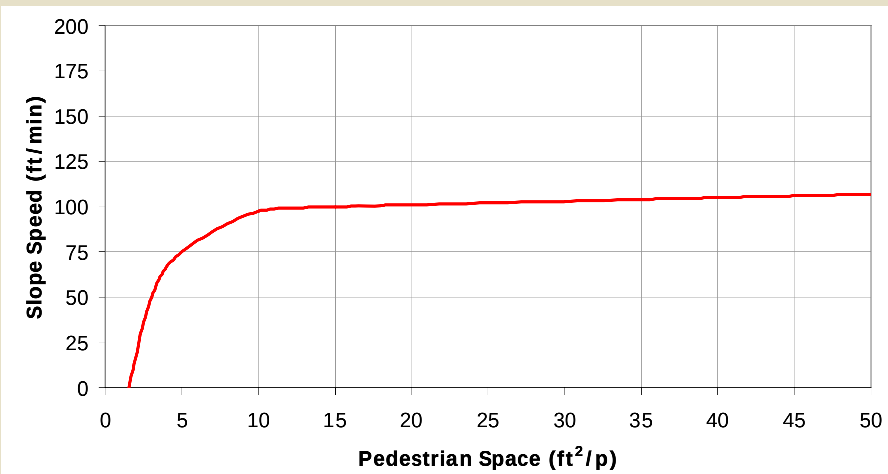
Pedestrian Ascent Speed on Stairs



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Stairway LOS

LOS	Avg. Ped. Space (ft²/p)	(m²/p)	Flow per Unit Width (p/ft/min)	(p/m/min)	Description
A	≥ 20	≥ 1.9	≤ 5	≤ 16	Sufficient area to freely select speed and to pass slower-moving pedestrians. Reverse flows cause limited conflicts.
B	15-20	1.4-1.9	5-7	16-23	Sufficient area to freely select speed with some difficulty in passing slower-moving pedestrians. Reverse flows cause minor conflicts.
C	10-15	0.9-1.4	7-10	23-33	Speeds slightly restricted due to inability to pass slower-moving pedestrians. Reverse flows cause some conflicts.
D	7-10	0.7-0.9	10-13	33-43	Speeds restricted due to inability to pass slower-moving pedestrians. Reverse flows cause significant conflicts.
E	4-7	0.4-0.7	13-17	43-56	Speeds of all pedestrians reduced. Intermittent stoppages likely to occur. Reverse flows cause serious conflicts.
F	≤ 4	≤ 0.4	*Variable*	*Variable*	Complete breakdown in pedestrian flow with many stoppages. Forward progress dependent on slowest moving pedestrians.

Stairway Capacity Factors

- Even minor reverse flows may reduce stairway capacity by as much as one-half
- Although sizing procedures may suggest a continuum of stairway widths, capacity is really added in one-person-width increments (roughly 30 inches)

Stairway Design Factors

- Much new construction will use escalators as the primary vertical circulation element
  - Can design to LOS E in this case
- Where stairs will be the primary vertical circulation element, design to LOS C to D
- Emergency evacuation needs may require better LOS during normal conditions

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Stairway Design Process

1. Based on desired LOS, identify maximum flow rate per unit width
2. Estimate peak 15-minute demand
3. Compute design ped flow: (Step 2) / 15
4. Required width = (Step 3 / Step 1)
5. If minor, reverse-flow use occurs, add width of one lane (30 inches)

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Escalator Capacity Factors

- Escalator width
- Operating speed

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Escalator Capacity Factors

- Manufacturers often state capacity based on a theoretical capacity—two people on every step—which is never obtained
- Capacity reduction factors
  - Intermittent ped arrivals
  - Ped inability to board quickly
  - Peds carrying baggage or packages
  - Ped desire for a more comfortable space

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Escalator Capacity

Type	Width at Tread (in.)	Width at Tread (m)	Incline Speed (ft/min)	Incline Speed (m/min)	Nominal Capacity (p/h)	Nominal Capacity (p/min)
Single-width	24	0.6	90	27.4	2,040	34
			120	36.6	2,700	45
Double-width	40	1.0	90	27.4	4,080	68
			120	36.6	5,400	90

- Nominal capacity values based on one person every other step (single-width), or one person every step (double-width)

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Elevators

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Elevator Usage

- Vertical circulation within station
- Deep station access
  - New York: 168th, 181st, and 191st Streets
  - Washington, DC: Forest Glen
  - Portland, OR: Washington Park
- When not working, impacts station access for mobility impaired, particularly where a single elevator is provided

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Elevator Capacity

- Calculated similarly to transit vehicle capacity:
  - Car capacity is combination of loading standard (area per passenger) and elevator floor area
  - Time to make round-trip, including time to load and unload passengers, and open and close doors
- Station access elevators sometimes have doors on two sides for simultaneous loading/unloading

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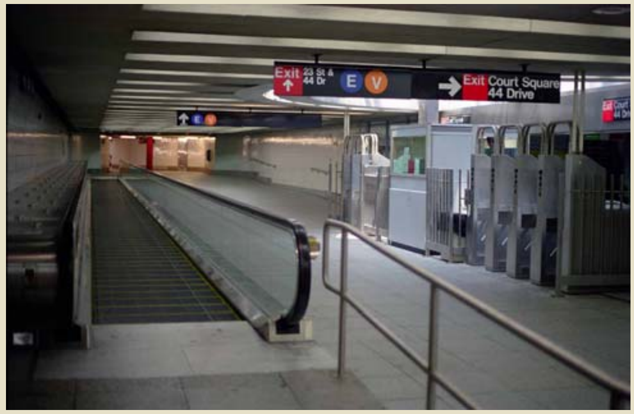
Moving Walkways



Moving Walkways

- Typical speed 100 ft/min, some up to 160 ft/min
  - Less than typical walking speed
- Capacity limited at entrance
  - Speed not a factor for capacity unless it causes persons to hesitate when entering
- Similar capacity as escalators
  - Double-width: about 90 p/min

Doorways

Doorway Capacity

Type of Entrance	Observed Average Headway (s)	Equivalent Pedestrian Volume (p/min)
Free-Swinging	1.0-1.5	40-60
Revolving, per direction	1.7-2.4	25-35

Fare Control

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Fare Control Capacity

- Each combination of equipment, fare media, and fare structure has distinct processing time

Type of Entrance	Observed Average Headway (s)	Equivalent Pedestrian Volume (p/min)
Free admission (barrier only)	1.0-1.5	40-60
Ticket collection by staff	1.7-2.4	25-35
Single-slot coin- or token-operated	1.2-2.4	25-50
Double-slot coin-operated	2.5-4.0	15-25
Card reader (various types)	1.5-4.0	25-40
High entrance/exit turnstile	3.0	20
High exit turnstile	2.1	28
Exit gate, 3.0 ft (0.9 m) wide	0.8	75
Exit gate, 4.0 ft (1.2 m) wide	0.6	100
Exit gate, 5.0 ft (1.5 m) wide	0.5	125

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Ticket Machines

Ticket Machine Capacity

- Time per passenger varies widely depending on machine design and complexity of fare system
  - Least standardized element of transit design
- Infrequent passengers require more time
- Consider impacts of out-of-service machines

Example Problems

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Example Problems

- 1. Transit center berth requirements
- 2. Stairway widths
- 3. Platform width for normal and delay conditions
- 4. Pedestrian queuing and delay
- 5. Corridor space requirements
- 6. Complex station sizing and analysis of alternatives

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Questions to Think About

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Questions to Think About

- What is missing from the section?
- What has changed in station design or analytical techniques since the 2nd Edition?
- How should pedestrian simulation software be covered?
- How should design for the disabled and emergency evacuation be addressed in the 3rd Edition?
- What new research should be conducted to obtain new data?

We Want Your Input on the TCQSM!

- Take our online survey to help shape the 3rd Edition's content
- Stay involved with the project
  - Give us your e-mail address after completing the survey and we'll keep you informed of future opportunities to provide input
- Do you go to the Transportation Research Board's Annual Meeting?
  - Attend the meeting of the Transit Capacity and Quality of Service Committee (AP015)

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