





Evacuation of Tall Buildings

History of Elevator Emergency Operations



•1973 Las Vegas MGM Grand Fire

- •188 Fatalities
- "Smoke" activated push buttons

-> DO NOT USE ELEVATORS IN CASE OF FIRE

- Passenger elevators during emergency (EN81-73, FEO)
 - •Phase 1 Elevators returned to refuge level
 - Manual, key switch return
 - Automatic return by alarm
 - Not in operation after return
 - Phase 2 Elevators can be used by firemen
 Key switch
- Protected firefighter's elevators (EN81-72, Pubel)



Planning Exit Routes for a Building

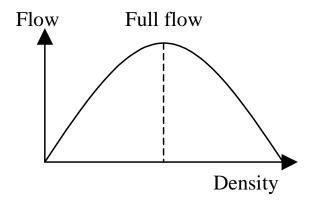


- Residential buildings
 - Two escape routes (one staircase + balconies or window openings)
- Commercial buildings
 - Two staircases minimum
- Planning of staircases
 - 3-10 m² per person assumed
 - Combined width 1200 mm for less than 120 persons + 400 mm for every additional 60 persons per floor
 - Walking distance to the stairs 30-45m

Egress Times by Staircases



- 2 staircases
 - 1200 mm wide
 - Full flow 2 persons/m²
 - Egress speed 0.6 m/s
- Stairways are impractical for evacuation of tall buildings
 - Too slow one minute per floor
 - Too crowded



Evacuation Times by Elevators vs. Staircases

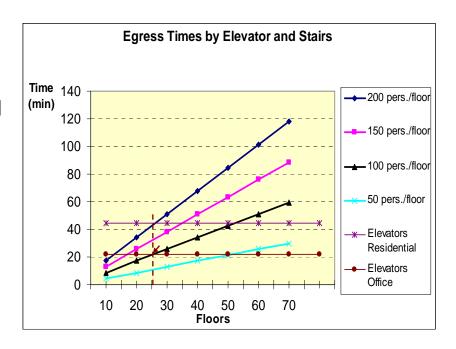


Two staircases

- Egress time increases by the number of floors
- In planning stairways only one floor population and distances are considered
- 20-25 floors down is practical limit

Elevators

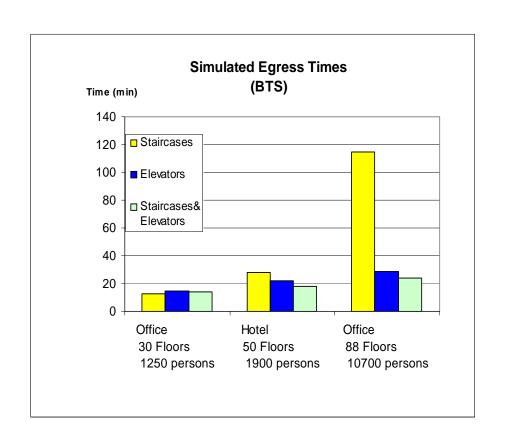
- Egress time independent of the number of floors
 - 20-30 minutes in offices
 - 40-50 minutes in apartment buildings
- In panning elevators total number of floors and population is considered



Egress Times in Tall Buildings



- Two stairways
 - Egress time increases by the number of floors
 - 20-25 floors down is practical limit
- Elevators
 - Egress time independent of the number of floors
 - 15-30 minutes in offices and hotels
 - 40-50 minutes in apartment buildings





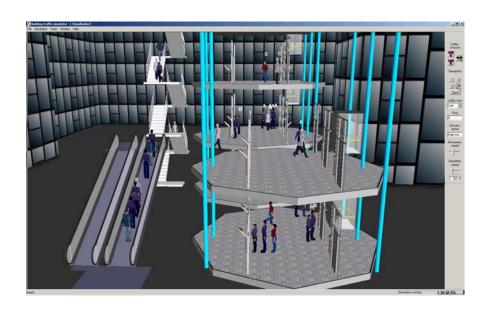


Building Traffic Simulator (BTS™)

Building Traffic Simulator (BTS™)



- Windows based
- Multiple elevator groups
- Escalators, staircases, autowalks
- 3D-view
- Used for
 - Testing group control systems
 - Elevator planning
 - Evacuation studies

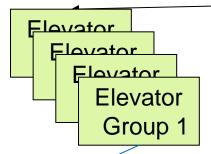


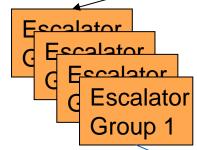
Building Traffic Simulator Processes



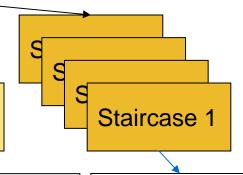
Building Setup

- floor layouts
- building shape and heigth
- tenants and population





Autowalk
C Autowalk
C Autowalk
C Autowalk
Group 1



Passenger

Traffic

- Serial simulation or
- Typical traffic patterns
- Passenger movement and queuing

Elevator Models

- Elevator status
- Destination calls
- Car Loading
- Door control
- Elevator position and movement

Group Control (GA,DCS,DDD, or IFC)

- Call allocation
- Elevator dispatching

Passenger Traffic

- Passenger position, movement and queuing

Escalator Models

- Loading and status

Passenger Traffic

- Passenger position, movement and queuing

Autowalk Models

Loading and status

Passenger Traffic

 Passenger position and queuing at floor levels

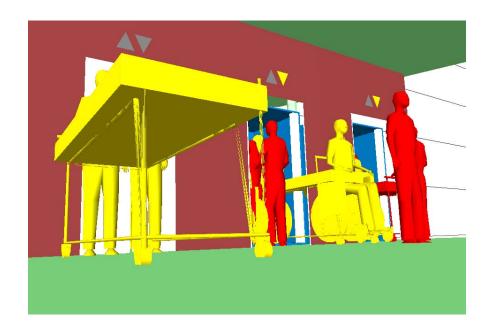
Staircase Models

- Handling capacity

Passenger Characteristcs in BTS



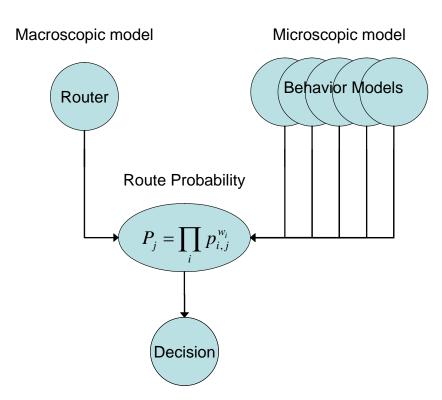
- Passenger groups with different characteristics (adults, children, elderly people, shopping trolleuys etcc.)
- Physical charateristics:
 - Walking speed
 - Space demand
 - Transfer time through doors
- Behavioural characteristics
 - Avoiding massive queues
 - Preferring elevators for long trips
 - Descending staircases more probable than ascending



Passenger Behavior Models in BTS



- Macroscopic Model
 - Shortest passenger route
- Microscopic Model
 - Reacts to prevailing conditions
- Behavior probabilities (p_{i,, j}) for each route a behaviour model
- Route probability (P_j) is a product of behavior probabilities
- Passenger selects the route randomly according to probability distribution
- Examples of behaviour model:
 - Route cost: the passenger selects more likely a fast route than a slow one
 - Queue length: the passenger avoids long queues
 - Walking distance: the passenger avoids long walks





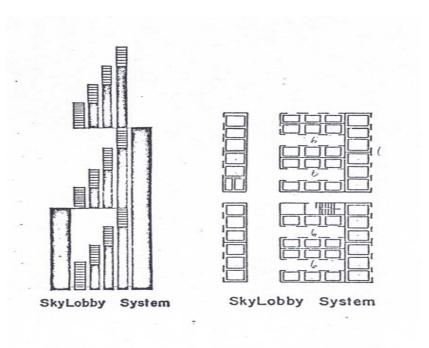


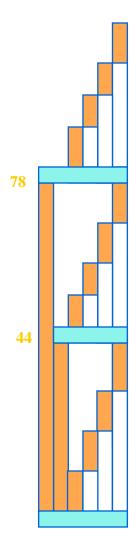
Evacuation Study for WTC

Single Deck Shuttles Single Deck Locals

- KONE
- Single Deck group
- Double Deck group

- WTC, New York
- Built in 1972
- 110 floors, 416 m
- 91 passenger elevators in tower





WTC Evacuation Scenarios

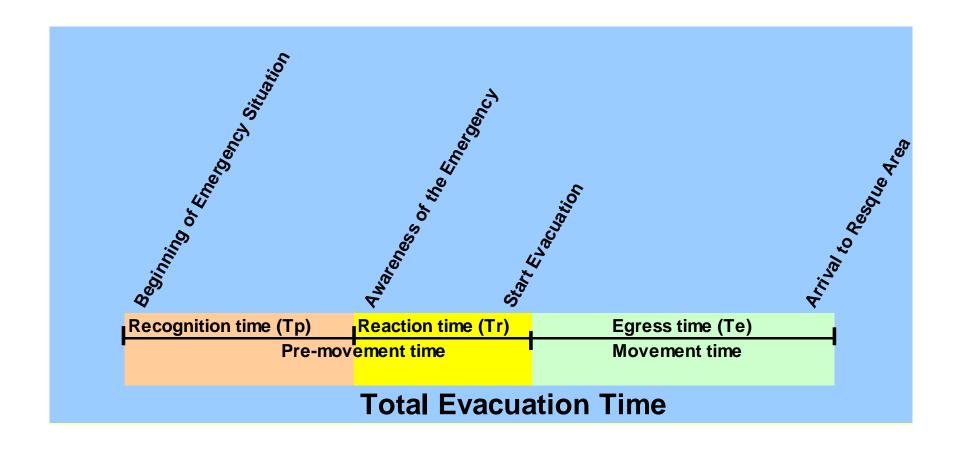


- 1. Phased evacuation of occupants from the emergency floor and floors above and below it travel three floors below the fire (600 persons)
- 2. Full capacity tower without visitors (19800 persons)
- 3. Full capacity tower with visitors (25500 persons)
- 4. September 11th capacity tower (8800 persons)



Evacuation Phases





Simulated Evacuation Times in WTC



Simulation results for staircses are about the same with different tools

Evacuation	Evacuation Delay (min):	Scenario 1 Time (min):	Scenario 2 Time (min):	Scenario 3 Time (min):	Scenario 4 Time (min):
EXODUS Stairs	0-10	11	112	142	55
EXODUS Stairs	No Delay	4	110	141	52
BTS Stairs	0-10	11	111	138	53
BTS Stairs	No Delay	4	109	137	51
BTS Elevators Only	No Delay	14	53	66	22
BTS Stairs+Shuttle E.	No Delay	14	53	67	29

Conclusion



- Currently every mega high-rise building evacuation is planned separately
- Regular evacuation rehearsals
- Current Plan for European Elevator Evacuation Code (EN81-74)
 - Protected elevators shall be provided only for disabled people with difficulties in moving (disabled, people with injuries)
- Current Activities in USA
 - All elevators to be used in evacuation
 - Protected elevator for fireman

