Lift and Escalators: Lift Traffic Analysis

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Contents

- Lift Traffic Analysis
- Lift Traffic Calculations
- Advanced Traffic Planning
Lift Traffic Analysis

- Assessment of demand
  - Traffic patterns (in an office building)
    - Morning UP peak
    - Evening DOWN peak
    - Two-way traffic (lunch periods)
    - Interfloor traffic
    - Other considerations, e.g. ‘Flexitime’ attendance
  - Estimation of population (occupant density)
  - Estimation of arrival rate
Traffic pattern in an office building

Up traffic
- Up peak
- Morning interfloor
- Lunch (in)

Down traffic
- Lunch (out)
- Afternoon interfloor
- Down peak

[Source: CIBSE Guide D]
Up peak traffic profile

[Source: CIBSE Guide D]
Down peak traffic profile

[Source: CIBSE Guide D]
## Estimation of population

<table>
<thead>
<tr>
<th>Building type</th>
<th>Estimated population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotel</td>
<td>1.5-1.9 persons/room</td>
</tr>
<tr>
<td>Flats</td>
<td>1.5-1.9 persons/bedroom</td>
</tr>
<tr>
<td>Hospital</td>
<td>3.0 persons/bedspace*</td>
</tr>
<tr>
<td>School</td>
<td>0.8-1.2 m² net area/pupil</td>
</tr>
<tr>
<td>Office (multiple tenancy):</td>
<td></td>
</tr>
<tr>
<td>- Regular</td>
<td>10-12 m² net area/person</td>
</tr>
<tr>
<td>- Prestige</td>
<td>15-18 m² net area/person</td>
</tr>
<tr>
<td>Office (single tenancy):</td>
<td></td>
</tr>
<tr>
<td>- Regular</td>
<td>8-10 m² net area/person</td>
</tr>
<tr>
<td>- Prestige</td>
<td>12-20 m² net area/person</td>
</tr>
</tbody>
</table>

* excluding patient

[Source: CIBSE Guide D]
## Percentage arrival rates and up-peak intervals

<table>
<thead>
<tr>
<th>Building type</th>
<th>Arrival rate (%)</th>
<th>Interval (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotel</td>
<td>10-15</td>
<td>30-50</td>
</tr>
<tr>
<td>Flats</td>
<td>5-7</td>
<td>40-90</td>
</tr>
<tr>
<td>Hospital</td>
<td>8-10</td>
<td>30-50</td>
</tr>
<tr>
<td>School</td>
<td>15-25</td>
<td>30-50</td>
</tr>
<tr>
<td>Office (multiple tenancy):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Regular</td>
<td>11-15</td>
<td>25-30</td>
</tr>
<tr>
<td>- Prestige</td>
<td>15-17</td>
<td>20-25</td>
</tr>
<tr>
<td>Office (single tenancy):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Regular</td>
<td>15</td>
<td>25-30</td>
</tr>
<tr>
<td>- Prestige</td>
<td>15-17</td>
<td>20-25</td>
</tr>
</tbody>
</table>

[Source: CIBSE Guide D]
Lift Traffic Analysis

• Estimation of quality of service
  • Actual average passenger waiting time (AWT)
    • Time between the instant of passenger arrival until the instant of the actual arrival of the lift
    • Shorter the waiting time, better the service
    • But cannot be measured easily
  • Interval of car arrivals at the main terminal
    • Often taken to estimate the probable quality of service
    • A part of the evaluation of handling capacity
    • $\text{AWT} \approx 85\%$ of the interval (assumed 80% car loading)
Probable quality of service in office buildings

<table>
<thead>
<tr>
<th>Interval (sec)</th>
<th>Quality of service</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤  20</td>
<td>Excellent</td>
</tr>
<tr>
<td>25</td>
<td>Very good</td>
</tr>
<tr>
<td>30</td>
<td>Good</td>
</tr>
<tr>
<td>40</td>
<td>Poor</td>
</tr>
<tr>
<td>≥  50</td>
<td>Unsatisfactory</td>
</tr>
</tbody>
</table>

[Source: CIBSE Guide D]
Lift Traffic Calculations

- Lift traffic calculations
  - (1) Based on classical formulae & results
    - For the worst 5-min period during morning up peak
  - (2) Based on a discrete digital simulation of the building, its lifts and the passenger dynamics
    - Such as for down peak, two-way & interfloor traffic
- Need to work at early design stage with architect or planner, and the client to establish the lift system & its design criteria
Lift Traffic Calculations

- Calculate up peak performance
  - Determine round trip time (RTT)
    - Time for a single lift to make a round trip
  - Select number of lifts ($L$)
  - Determine up peak interval (UPPINT)
    - Such as, $\leq 30$ sec (good)
  - Determine up peak handling capacity (UPPHC)
    - During the worst 5-min (300 sec) of up peak
Lift Traffic Calculations

\[ \text{RTT} = 2H t_v + (S + 1) t_s + 2P t_p \]

- \( H \) = average highest call reversal floor
- \( t_v \) = single floor transit time (s)
- \( S \) = average no. of stops
- \( t_s \) = time consumed when stopping (s)
- \( P \) = average no. of passengers carried
- \( t_p \) = passenger transfer time (s)

\[ \text{UPPINT} = \frac{\text{RTT}}{L} \]

\[ \text{UPPHC} = \frac{(300 \times L \times P)}{\text{RTT}} \]
Lift Traffic Calculations

- Parameters in RTT equation
  - Average no. of passengers ($P$)
    - $P = 0.8 \times$ rate capacity of lift car
  - Average highest call reversal floor ($H$)
    $$H = N - \sum_{i=1}^{N-1} \left( \frac{i}{N} \right)^P$$
  - Average no. of stops ($S$)
    $$S = N \times \left( 1 - \left( 1 - \frac{1}{N} \right)^P \right)$$
Lift Traffic Calculations

- Parameters in RTT equation (cont’d)
  - Single floor transit time, $t_v = \frac{d_f}{v}$
    - $d_f =$ average interfloor distance (m)
    - $v =$ contract (rated) speed (m/s)
  - For a lift serving an upper zone, an extra time to make the jump to/from the express zone to the main terminal must be added:
    \[
    RTT = 2 \, H \, t_v + (S + 1) \, t_s + 2 \, P \, t_p + [2 \, H_e \, t_v]
    \]
  - $H_e =$ number of average height floors passed through to reach the first served floor of the express zone
Lift Traffic Calculations

- Parameters in RTT equation (cont’d)
  - Time consumed when stopping
    \[ t_s = T - t_v = t_f(1) + t_c + t_o - t_v \]
    - \( T \) = floor-to-floor cycle time (s)
    - \( t_f(1) \) = single floor flight time (s)
    - \( t_c \) = door closing time (s)
    - \( t_o \) = door opening time (s)
  - Floor cycle time (\( T \)) has the most effect on RTT
    - Can be used to judge the quality of service
    - For a good system, \( T = 9 \) to 10 sec
Lift Traffic Analysis

- Parameters in RTT equation (cont’d)
  - Passenger transfer time \( t_p \), vague to define. It depends on:
    - Shape of lift car
    - Size and type of car entrance
    - Environment (commercial, institutional, residential)
    - Type of passenger (age, gender, purpose, etc)
Lift Traffic Calculations

- **Basic assumptions** of RTT equation
  - Average no. of passengers
  - Passengers arrive uniformly in time
  - All floors equally populated
  - All cars load to 80%
  - Rated speed reached in a single floor jump and interfloor height are equal
  - Other operating time (like dwell time) ignored
  - Traffic controller is ‘ideal’
Lift Traffic Calculations

- Average passenger waiting time (AWT)
  - Average time an individual passenger waits at a floor before being able to board a lift
    - Not dependent solely on UPPINT
    - Also affected by the average car load and the arrival probability distribution function
  - Some design criteria for different traffic patterns have been derived empirically based on the simulation method (see CIBSE Guide D)
Lift Traffic Calculations

- Computer software: SIMPLE (suite of iterative balance method and other programs for lift and elevator design)
Advanced Traffic Planning

Key considerations

• Lifts and escalators should provide
  • Sufficient handling capacity for the building's traffic
  • Short waiting and journey times throughout the day
  • Optimum use of core building space

• The main parameters are
  • **Handling Capacity (HC)** – the number of people the elevators can carry to upper floors within five minutes during the morning "up-peak"
  • **Interval (I)** – the average departure time for elevators from the main entrance during morning up peak
Advanced Traffic Planning

• Building categorization
  • The need for traffic planning varies according to the type and usage of the building
  • Typical categories:
    • Residential
    • Public service (e.g. subways, shopping centers, airports)
    • Hospital and multi-purpose buildings
    • Commercial mid-, high- and mega high rise buildings (e.g. offices, hotels, cruise liners)
Advanced Traffic Planning

- **Residential buildings**
  - Traffic intensity is rather low
  - Waiting times even twice as long as those in commercial buildings may be acceptable
  - Can normally be selected by using local, international or comparable standards

- **Public service** (airports/subways, shopping centres)
  - Travelling height is typically no more than a few floors
  - Escalators can handle many times the traffic of lifts
  - Autowalks speed the people flow across long walking distances
  - Lifts are usually provided for handicapped access and the transport of goods or equipment
Performance Criteria for Passenger Elevators

[Source: Kone]
Residential buildings – passenger traffic flow

[Source: Kone]
Advanced Traffic Planning

• **Hospitals**
  - Need detailed planning to cover emergency, service, bed, patient, visitor and staff transportation
  - Architecture and special needs e.g. the location of the operating theatre affect transportation arrangements

• **Multi-purpose buildings**
  - Separate elevators for different purposes
  - If the same lifts are to serve office and residential areas, they should be selected according to the highest estimated peak traffic demands
Advanced Traffic Planning

- **Mid-rise commercial buildings**
  - **Hotels**: the selection largely depends on the number of rooms and beds. Additional lifts are required for service purposes
  - **Office buildings**: three peak traffic hours generally occur: morning up peak, lunchtime mixed traffic and evening down peak
    - Up peak is normally used in lift planning
    - Lunch hour traffic is often heavier than the morning up peak
Advanced Traffic Planning

- **High-rise commercial buildings**
  - One lift group alone cannot meet all needs. They are often divided into zones, served by separate lifts groups.
  - In mega-high-rise buildings (> 50-60 floors), either double-deck lifts are used or lift groups are stacked on top of one another in sky lobby arrangements:
    - Shuttle groups serve traffic between the main entrance floor and the sky lobby.
    - Local elevator groups start from both the main floor and from the sky lobby.
    - Shuttle group criteria: HC > 16% / 5 min.; Interval < 32 sec.
Typical lift arrangements in Mega high rise buildings

[Source: Kone]
Typical double-deck lifts

[Source: http://www.elevator-world.com]