Introduction

- Of the many decisions that must be made by the designer of a multi-story building, probably none is more important than the selection of the vertical transportation equipment - that is the passenger, service, and freight elevators and the escalators.
- These items represent a major building expense; for a 25-story office building as much as 10% of the construction cost.
- The quality of elevator service is also an important factor in a tenant's choice of space in competing buildings.
Electric Traction Passenger Lift

- The car, cables, elevator machine, control equipment, counterweights, hoistway, rails, penthouse, and pit are the principle parts of a traction elevator installation.

- The car is a cage of some fire-resistant material supported on a structural frame, to the top member of which the lifting cables are fastened. By means of guide shoes on the side members, car is guided in its vertical travel in the shaft.

- The car is provided with safety doors, operating-control equipment, floor-level indicators, illumination, emergency exits, and ventilation.
Four to eight cables, depending on the car speed and capacity, are placed in parallel; in general, each rope is capable of supporting the entire load. The minimum factor of safety varies from 7.6 to 12.0 for passenger lifts and from 6.6 to 11.0 for freight lift.

The counter weight is made up of cut steel plates stacked in a frame attached to the opposite ends of the cables to which the car is fastened. Its weight equals that of the empty car plus 40% of the rated live load.

It serves several purposes: to provide adequate traction at the sheave for car lifting, to reduce the size of the traction machine, and to reduce power demand and energy cost.

Higher initial cost due to strengthen the overhead machine room floor, which must carry the additional structural load of the counter weight.

The shaft or hoist-way, is the vertical passageway for the car and counterweights. On the side walls are the car guide rails and certain mechanical and electrical auxiliaries of the control apparatus.

A gearless traction machine consists of a DC or AC motor, the shaft of which is directly connected to a brake wheel and driving sheave. The elevator hoist ropes are placed around this sheave.

The absence of gear means that the motor must run at the same relatively slow speed as the driving sheave, and these are generally used for high-speed lifts, i.e. speeds from 2.5 m/s to 10 m/s.

A gearless traction machine is superior to geared machines because it is more efficient and quieter in operation, requires less maintenance, and has longer life.
Geared Traction Machines

- A geared traction machine has a worm and gear interposed between the driving motor and the hoisting sheave. The driving motor can therefore be smaller, cheaper, high-speed unit rather the large, low-speed unit required by a gearless installation.
- These are used for car speeds up to 2.3 m/s and maximum rise of about 90 m.
- With an appropriate drive and control system, a geared traction machine can give almost the same high-quality, accurate, smooth ride as is available from a gearless installation.

Arrangement of Elevator Machines, Sheaves and Ropes

(a) Basic single-wrap rope arrangement. In (b) and (c), the rope passes over the traction sheave T and sheave S, doubles back over T, and then extends past S to the counterweight CW. This double-wrap arrangement provides additional traction at the drive sheave. (d) Roping arrangement for a basement machine room.
Safety Devices

- Main brake of an elevator is mounted directly on the shaft. The lift is first slowed by dynamic braking of the motor and the brake then operates to clamp the brake drum, thus holding the car still at floor.

- A dual safety device is used to stop the car automatically in case of over-speed:
  1. A centrifugal governor or an electronic speed control sensor cuts the power of the traction motor and set the brake in case of limited over-speed.
  2. If over-speeding continues, governor actuates two safety rail clamps, which are mounted at the bottom of the car and one either side.

- Oil or spring buffers are usually placed in the pit, not the stop a falling car but to bring it to a somewhat cushioned stop if it over-travels the lower terminal.
Elevator Hardware | Electric Traction Passenger Lift

Power Requirements for Traction Lifts

<table>
<thead>
<tr>
<th>Elevator Speed, 1pm</th>
<th>Group demand factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.55</td>
</tr>
<tr>
<td>200</td>
<td>0.55</td>
</tr>
<tr>
<td>300</td>
<td>0.55</td>
</tr>
<tr>
<td>400</td>
<td>0.55</td>
</tr>
<tr>
<td>500</td>
<td>0.55</td>
</tr>
<tr>
<td>600</td>
<td>0.55</td>
</tr>
<tr>
<td>700</td>
<td>0.55</td>
</tr>
<tr>
<td>800</td>
<td>0.55</td>
</tr>
<tr>
<td>900</td>
<td>0.55</td>
</tr>
<tr>
<td>1000</td>
<td>0.55</td>
</tr>
</tbody>
</table>

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Hydraulic Lift

The major advantage of hydraulic unit is the absence of an overhead machine room, a penthouse, and traction equipment.

- Elevator load is carried by the ground not by the structure.
- Hoist-way is smaller due to the absence of a counterweight and its guide rail.
- Cars can be lowered manually by the operation of oil valves.
- Essentially there is no lifting limit.

Operating expensive is higher due to absence of counterweight. These are limited to low-rise, low-speed applications. Ride quality is also inferior.

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Hydraulic Lift

Hydraulic Jack Arrangements
Lift Doors

Ideal Performance of Passenger Elevators

Ideal performance of an elevator installation will provide:

- minimum waiting time for a car at any floor level
- comfortable acceleration and rapid transportation
- smooth and rapid braking
- accurate automatic levelling at landings
- quick, quiet operation of doors
- good floor status and travel direction indication
- easily operated car and landing call buttons
- smooth, quiet, and safe operation of all equipment
- comfortable lighting
- reliable emergency and security equipment
Elevator Selection

Definitions/Terminology

- **Interval (I) or Lobby Dispatch Time**: the average time between departures of cars from the lobby.
- **Average Waiting Time**: the time spent by a person between arriving in the lobby and leaving the lobby in a car.

\[
\text{Average Lobby Waiting Time} = 0.6 \times \text{Interval}
\]

- **Registration Time**: waiting time at an upper floor after a call is registered.
- **Handling Capacity (HC)**: the maximum number of passengers that can be handled in 5 minutes of time. A system’s handling capacity is determined by two factors - car size and interval - and is independent of the number of cars.
- **Percent Handling Capacity (PHC)**: the minimum percentage of the building population that the system must handle in 5 minutes.

A good system for a diversified office building will handle no less than 12% of the building population.

Due to more urgent traffic demands, particularly at school and work exodus, PHC = 6-8 is recommended.
Elevator Selection

- **Travel Time or Average Trip Time (AVTRP)**: average time spent by the passengers from the moment they arrive in the lobby to the moment they leave the car at an upper floor. It is the sum of the lobby waiting time plus travel time to a median floor stop.
  - § In a commercial building context, a trip of less than 1 minute is highly desirable, a 75-second trip is acceptable, a 90-second trip is annoying, and a 120-second trip is the limit of tolerance.

- **Round Trip (RT) Time**: average time required for a car to make a round trip - starting from the lower terminal and returning to it. The RT time during up-peak traffic conditions, used for calculating elevator requirements is the sum of 4 factors:
  1. time to accelerate and decelerate
  2. time to open and close doors at all stops
  3. time to load and unload
  4. running time.
  - § Acceleration and deceleration times are calculated with a maximum of 1.2 m/s² because anything beyond that results in physical discomfort. *Running time at rated speed* takes place after the car has accelerated and before it begins to decelerate.

---

**T3: Car Passenger Capacity (p)**

<table>
<thead>
<tr>
<th>Elevator Capacity (lb)</th>
<th>Maximum Passenger Capacity</th>
<th>Normal Load per Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 (907)</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>2500 (1134)</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>3000 (1361)</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>4500 (2048)</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>4000 (1814)</td>
<td>28</td>
<td>22</td>
</tr>
</tbody>
</table>

\[
HC = \frac{300p}{I}
\]

- \(HC\) = handling capacity
- \(p\) = car capacity
- \(I\) = interval

\[
I = \frac{RT}{N}
\]

- \(RT\) = round trip time
- \(N\) = number of cars

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### Elevator Selection

#### C2: Round Trip (RT) Time

#### T4: Population of Typical Buildings

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Net Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFFICE BUILDINGS</td>
<td>172 PER PERSON/M2/PERSON</td>
</tr>
<tr>
<td>Diversified (multiple tenancy)</td>
<td>110-130 (10-12)</td>
</tr>
<tr>
<td>Normal</td>
<td>150-250 (14-23)</td>
</tr>
<tr>
<td>Single tenancy</td>
<td>90-110 (8-10)</td>
</tr>
<tr>
<td>Prestige</td>
<td>130-200 (12-19)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HOSPITALS</th>
<th>VISITORS AND STAFF PER BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>General private</td>
<td>3</td>
</tr>
<tr>
<td>General public</td>
<td>3-4</td>
</tr>
<tr>
<td>(large wards)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>APARTMENT HOUSES</th>
<th>PERSONS PER BEDROOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-rental housing</td>
<td>1.5</td>
</tr>
<tr>
<td>Moderate-rental</td>
<td>2.0</td>
</tr>
<tr>
<td>Low-rental housing</td>
<td>2.5-3.0</td>
</tr>
</tbody>
</table>

#### T5: Office Building Occupancy

<table>
<thead>
<tr>
<th>Building Height</th>
<th>Net Usable Area as Percentage of Gross Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 floors</td>
<td>Approximately 80%</td>
</tr>
<tr>
<td>0-20 floors</td>
<td>Floors 1-10 approximately 75%</td>
</tr>
<tr>
<td>0-30 floors</td>
<td>Floors 1-10 approximately 70%</td>
</tr>
<tr>
<td>0-40 floors</td>
<td>Floors 1-10 approximately 70%</td>
</tr>
<tr>
<td>21-30</td>
<td>Approximately 80%</td>
</tr>
<tr>
<td>31-40</td>
<td>Approximately 85%</td>
</tr>
</tbody>
</table>
Elevator Selection

**Example: Office Building with Diversified Use**

- Office building, downtown, diversified use, 14 rentable floors above the lobby, each 1115 m² net. Floor-to-floor height = 3.7 m. Determine a workable elevator system arrangement.

- **T2: Minimum PHC:**
  - Office Building: PHC = 13%

- **T1: Elevator Intervals:**
  - Good service: I = 25

- **T4: Population of Buildings:**
  - Diversified use, normal:
    - 11 m²/person.
    - \( \text{No. of persons} = 14 \times \frac{1115}{11} = 1400 \text{ persons.} \)
    - \( HC = 0.13 \times 1400 = 182 \text{ persons} \)
    - \( \text{Rise} = 14 \times 3.7 = 51 \text{ m.} \)
Option I: 3000 lb/2.5 m/s lift

Option I-A: 3000 lb: \( p = 16 \)

\[ \text{C1: AVRTTP:} \]
14 floors & 2.5 m/s: AVTRP = 76 s

\[ \text{C2: RT Time:} \]
14 floors & 2.5 m/s: RT = 143 s

\[ \Rightarrow HC = \frac{300p}{I} \quad I = \frac{RT}{N} \quad \Rightarrow N = 5.4 \]

Option I-A: \( N = 5 \)

\[ \Rightarrow \text{Actual PHC} = 5 \times 13/5.4 = 12\% \]

\[ \Rightarrow I = 143/5 = 28.4 \text{ s.} \]

Option I-B: \( N = 6 \)

\[ \Rightarrow \text{Actual PHC} = 6 \times 13/5.4 = 14.4\% \]

\[ \Rightarrow I = 143/6 = 23.8 \text{ s.} \]

Option I-A: is a good choice; using smaller car than II-A it is more economical, gives better results except for HC.

Option I-B: gives excellent interval and HC, but expensive option.

Option II-B: is also expensive due to higher speed.
Escalators & Moving Ramps

Introduction

The moving stairway, also referred to as an escalator or an electric stairway, was first operated at the Paris Exposition in 1900. Its modern successors deliver passengers comfortably, rapidly, safely, and continuously at constant speed and usually with no delay at the boarding level. The annoyance of waiting for elevators is eliminated. Also, no time is lost by acceleration, retardation, levelling, and door operation, or by passenger interference in getting in or out of the cars. Instead of formal lobbies and hallways leading to a bank of elevators on each floor and a ride in a small, enclosed box, the electric stairway is always in motion. inviting passengers to ride on an open, airy, observation type conveyance that can never trap them due to equipment or power failure.

Principle Parts of a Standard Escalator
Escalators & Moving Ramps

The Crisscross Arrangement of Escalator

Parallel Escalator
Moving Walks

Inclined Ramps