2

Passenger Transportation Systems

Helping persons move around the building is the primary function of the transportation infrastructure. There are several difficult requirements that have to be satisfied by any passenger transportation system, but the first one is *safety*. Potential dangers to passengers in buildings involve falling, crushing, getting trapped, and many other possibilities. People must be protected not only from equipment malfunctions and other accidents with external causes, but also from the unintended consequences of their own actions, whether due to carelessness, or deliberate misuse.

The invention of the *elevator safety device* by Elisha G. Otis, which he dramatically demonstrated in 1854 by cutting the suspending rope over his head [1], is seen as one of the crucial technical advances that made possible the birth of the *high-rise building*, and thus the modern metropolis (see Fig. 2.1).

However, this was only the beginning; today, modern elevators and other transportation systems have far surpassed that stage, and now employ a wide variety of other devices and design features for exceptional safety.

The modern transportation equipment has evolved mostly on the principle of making in-building travels ever safer, and pursuing efficiency and economy only when safety is assured. One piece of evidence for this is the gradual disappearance of such equipment that was once popular and widely used, but now their safety is no longer considered sufficient. An example is the *paternoster* elevator.

The paternoster works on the principle of the *ferris wheel*: its open cabins move continuously, up on the left side and down on the right. Periodically, one of the cabins will appear behind an opening for a short time, allowing a passenger to step in, assuming a certain nimbleness. The passenger then rides the cabin until arriving at the destination floor, where he will step out briskly. There is some amount of mechanical provision to prevent crushing, by an arrangement of moving flaps on both sides of the gap between cabins and floors; but generally it is a better idea not to get caught between the cabin and landing in the first place.

Fig. 2.1. An elevator group at the "Kolon Tower", Kwa Chon, Korea

At first glance, the idea of continuously moving cabins is appealing by its simplicity and the potential for high transportation capacity with no waiting time; however, experience has shown that this system can be dangerous, and new installations have been prohibited in most countries [1].

In the following section we will describe the most prominent member of the passenger transportation family, the elevator, in some detail. Other equipment will be reviewed only cursorily, to give an idea of the options that transportation engineers have.

For more detailed information about all aspects of vertical transportation, we recommend the works of Strakosch [2, 3] and Barney [4, 5].

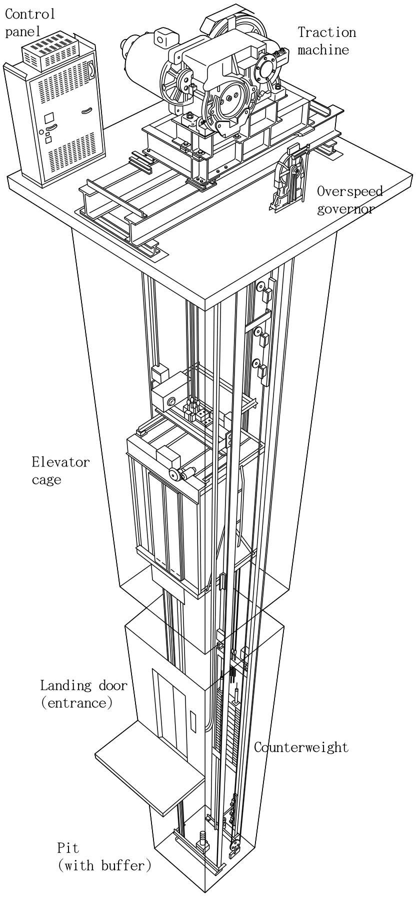

Fig. 2.2. A modern passenger elevator with structural parts shown in the machine room, hoistway, and landings

2.1 Elevators

Elevators are by far the most important transportation systems for handling both passenger and freight traffic in buildings. They provide safe, fast, and economical movement for people and goods, and they are able to cater to all kinds of traffic patterns.

The overall structure of an elevator is shown in Fig. 2.2. Starting from the top, we can see the main parts:

- the *traction machine*, driving the *traction sheave* with an electric motor,
- on the left, the *control panel* that houses the power and control electronics,
- the *elevator cab*, guided between *guiderails*,
- a *landing* with the *landing doors* closed,
- opposite to that, the *counterweight* that balances the weight of the cab.

2.1.1 Construction and Operation

The modern passenger elevator is predominantly of the so-called *traction type*, that uses steel wire ropes wound around rotating sheaves to lift the elevator cabin. Traction is achieved by the friction between the wire ropes and the grooves of the sheave.

In normal usage, the elevator operates automatically, according to the calls registered by users. Its sequence program controls the speed-control electronics, that in turn drives the main motor, to accurately execute the preprogrammed speed profiles, and to position the elevator at the landings with millimeter-order precision. The sequence program also controls the doors, the indicator lights, chimes, and other interface equipment.

2.1.2 Safety

Although wire ropes are designed with a very high safety factor and the occurrence of breakage is extremely rare, the elevator is further protected against falling by multiple safety devices, among them purely mechanical *safety catches* that grab the *guiderails*, when tripped by *overspeed sensors*.

It is generally acknowledged that the traction elevator is the safest and most reliable transportation device, especially when we consider the traffic volumes handled every day. Elevators are used by people of all ages, who in most cases do not even realize that "transportation" is taking place. To the typical user, the elevator appears just as a virtual doorway that happens to open to other floors. This trust by the public is earned by the exceptional safety record of the elevators.

2.1.3 Modern Technology

Technical developments of elevators have continued during the past century, resulting in speeds up to 1000 m min^{-1} (16.6 m s^{-1}) and capacities up to 120 persons. Modern elevators use sophisticated computerized control systems, high-performance materials, and a constant stream of innovation is driven by a fierce competition among the leading manufacturers.

The interested reader is referred to the trade journals, the most prominent among them *Elevator World magazine*, for fascinating accounts of not only the technical achievements, but also of the many social and cultural aspects connected with elevators. Modern aspects of vertical transportation equipment in the context of intelligent building systems is treated *e.g* by So [6].

2.1.4 Control

Elevators are controlled by *calls*: signals from push-buttons operated by the users. We talk of *hall calls*, the signals calling an elevator to a waiting person, and *car calls*, the signal from a person riding the elevator, telling it where to go.

Recently a third kind of call, the *destination call* is getting more and more popular. With destination calls, the waiting person signals the elevator not only their presence and intended direction, but also their destination. This allows more efficient control by grouping passengers by their destinations, thus reducing the stops made by the elevators.

Elevators acknowledge calls by lighting up the *tell-tale lamp* which is usually built into the hall call button, and eventually serve the call. This is however just a rough approximation; details of the interaction between users and elevators depend on the brand, the geographic area, and the profile of the building. Also, with the proliferation of graphical display devices, elevator systems are starting to provide more and more detailed information to users.

For the purposes of this book, the most important feature of elevators is their ability to operate in cooperating groups. By dividing the traffic dynamically among several elevators, it is possible to achieve an increase in total traffic-handling capacity that can significantly surpass the sum of the traffic capacity of isolated individual elevators.

In the rest of this book, we will be concerned with control methods that make possible such "something-for-nothing" effects.

2.2 Other Passenger Transportation Equipment

2.2.1 Escalators

Besides elevators, escalators are the mainstay of vertical traffic-handling equipment.

The escalator, as a mass transportation device, was developed and commercialized at the turn of the 20th century. Escalators provide a continuous, one-way connection between two levels, usually between consecutive floors. They operate on the principle of driving a connected chain of individual *steps*, running on rollers along two inclined loops of guiderails. They are equipped with a pair of handrails, driven synchronously with the steps, for the safety and convenience of the passengers. The structure of a conventional escalator is shown in Fig. 2.4.

Escalators are usually designed for one or two passengers/step (step width of 600–1000 mm), and operate at a speed between 30–45 $\mathrm{m \quad min^{-1}}$. Typical performance figures for escalators are given in [2]; the general range of carrying capacity achieved in practice is reported as about 2000–5400 persons/h.

There are some situations where escalators show clear advantages over elevators, as they can cope with very high, continuous traffic volumes, and there is no perceived waiting time when using them. These properties make them ideal for moving large crowds up or down for one or a few floor levels,

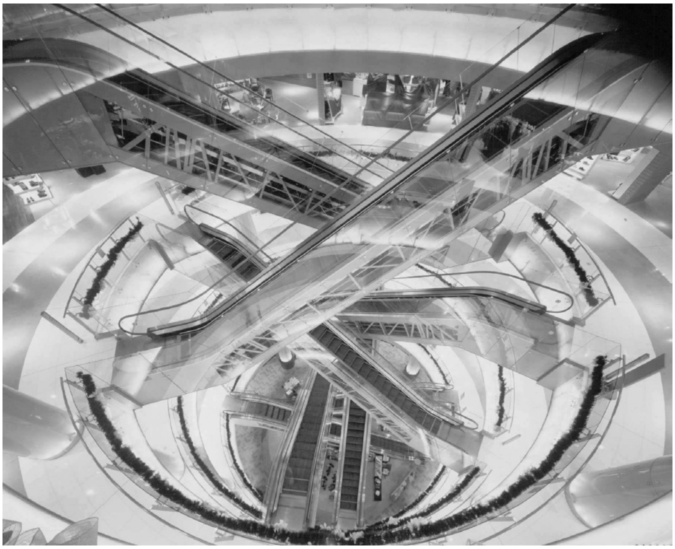

Fig. 2.3. Escalators at the "Miramar Entertainment Park", Taipei, Taiwan

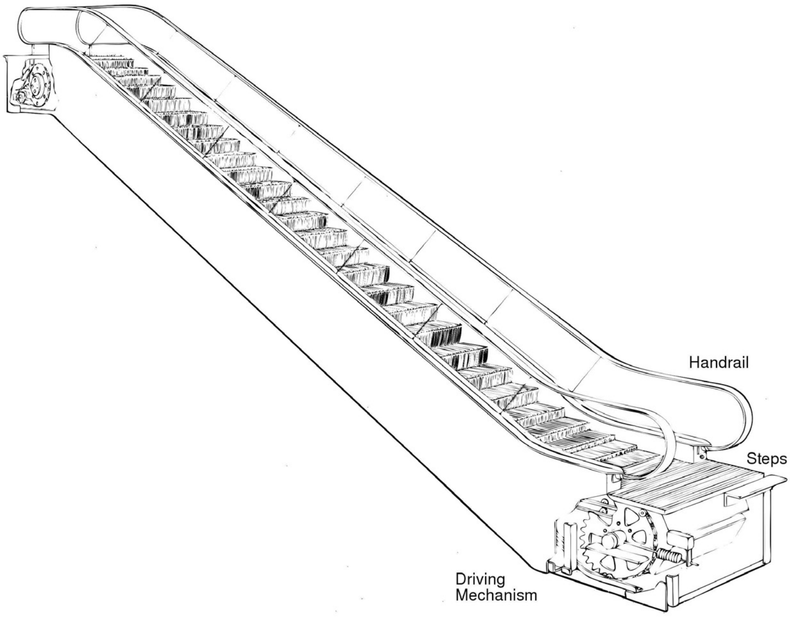

Fig. 2.4. Structure of the escalator. The driving mechanism, shown in breakout view, is embedded in the floor structure

which is the typical requirement in subway stations, airports, and other transit facilities.

They are also often used in department stores and other shopping centers, where they have the additional advantage of allowing passengers a continuous view of the surroundings (see Fig. 2.3). This feature is attractive for the shops, as it can increase the exposure of the sales areas.

Escalators do have, however, some shortcomings that limit their use. They are too slow for long distances (over about 10 to 15 floors), and they cannot be used by everyone, such as persons with physical disabilities, people with baby carriages and other bulky loads, or in any situation where there is a danger of the rider stumbling.

In the study of transportation systems in buildings, escalators can be treated as a first approximation as passive pathways that people traverse with a constant speed.

2.2.2 Moving Walkways

A variant of the escalator is the moving walkway, or horizontal escalator (see Fig. 2.5), which is often constructed similarly to the inclined escalator: as a continuous chain of steps, which are in this case not stair-shaped but flat.

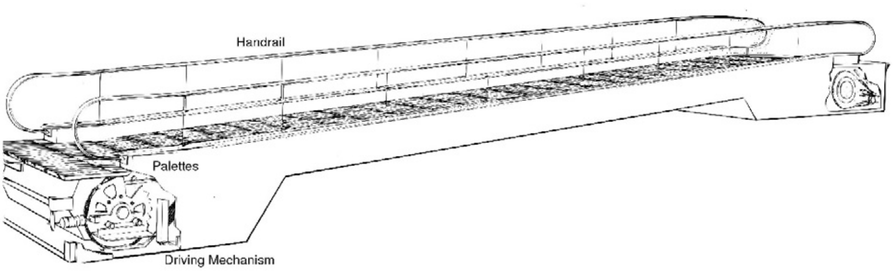

Fig. 2.5. Moving walkway. The driving mechanism, shown in a breakout view, is embedded in the floor structure

There are many variants; for instance, the load-carrying surface can be a rubber belt, running over horizontal rollers. Moving walkways can be inclined by a few degrees, which allows them to connect different concourse levels at airports, allowing people to ride them with baggage carts.

From the point of view of transportation, moving walkways can be treated in the same category as escalators.

2.2.3 Horizontal Elevators

Although in most buildings vertical movements dominate the transportation task, airports present a special case. In airports, the large horizontal distances between gates warranted the development of the horizontal elevator. These *people movers* appear to the public as small-sized short-haul trains, but in fact their technology is mostly borrowed from elevators. They move automatically from station to station in an enclosed driveway, with automatic doors, and their driving method is often the wire rope, just like the usual elevators.

In the future, we can expect horizontal elevators appearing in the urban scene, as ultra large-scale building complexes begin to require a horizontal transportation capability on medium distances.

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Control of Traffic Systems in Buildings
Markon, S.A.; Kita, H.; Kise, H.; Bartz-Beielstein, Th.
2006, XXII, 280 p. With online files/update., Hardcover
ISBN: 978-1-84628-448-9