Elevator Doors for Comfortable and Efficient Elevators

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Abstract

Comfortable elevators are quiet and smooth running elevators with short waiting times. The car should be spacious. The doors must run fast and quietly, and must be sufficiently wide.

Comfortable elevators must be efficient. They must be able to manage all the occurring traffic in a building. And the user should not get the feeling that waiting or travel time is long.

Efficient elevators need a sophisticated control unit, a specific speed, a good drive control system and, last but not least, fast moving doors.

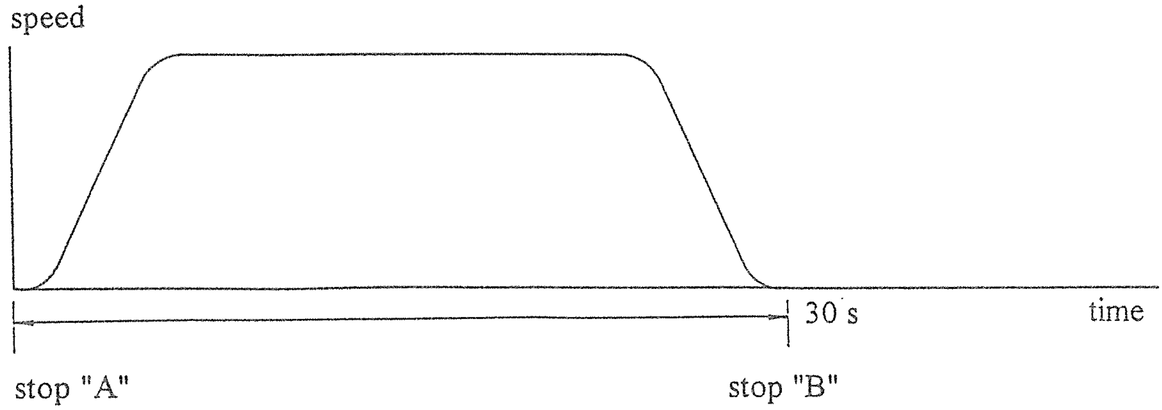
In the following, I intend to describe the importance of high tech doors for the efficiency of elevators.

Stop Lost Time

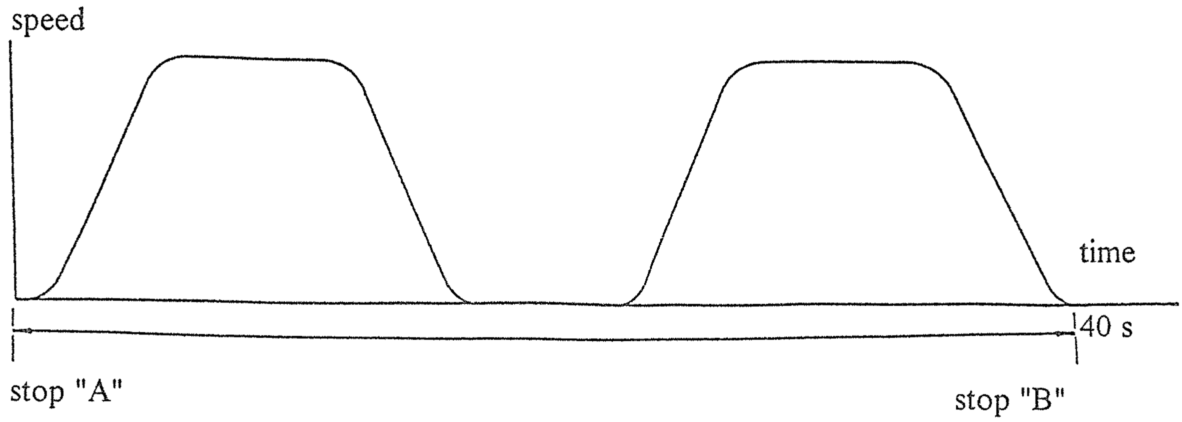
To specify efficient elevators in our office we use the word "Halteverlustzeit". We think, the English term can be "stop lost time".

Stop lost time is the time the elevator needs for one stop. For every elevator we can easily find the stop lost time by doing 3 measurements with a stop-watch.

1. Measurement of running time from level "A" to level "B" without intermediate stop



2. Measurement of running time from level "A" to level "B" with one intermediate stop



3. Measurement of door holding time during one intermediate stop
The door holding time in this example is measured with 4 s.

The difference between the first and the second measurement is the time we lose by one intermediate stop. In this time the door holding time is included.

To compare different stop lost times we have defined the door holding time in our stop lost time with 2 s. If the measured door holding time is different to 2 s, the difference has be taken into account.

If you take the figures used in our example, the stop lost time will be: **40-30-(4-2) = 8 s**

A stop lost time of 8 s is excellent and can only be reached with modern elevator techniques.

The achievable stop lost time depends on the door width, the door speed, the elevator speed, acceleration and deceleration.

Acceleration and deceleration should not be felt "sporty", but comfortable. Acceleration and deceleration are not to exceed 1.2 m/s^2. Jerk is not to exceed 1.5 m/s^3.

In all measurements, to find the stop lost time, the contract speed should be reached. If it is not reached, there are small deviations concerning the stop lost time. But this is not important to our considerations.

For traction elevators with 1.10 m wide two panel centre opening doors, the achievable stop lost time with high quality techniques is:

speed: 1.0 m/s	stop lost time: 7.0 s
speed: 1.6 m/s	stop lost time: 7.5 s
speed: 2.5 m/s	stop lost time: 8.0 s
speed: 4.0 m/s	stop lost time: 8.5 s
speed: 5.0 m/s	stop lost time: 9.0 s
speed: 6.0 m/s	stop lost time: 9.5 s

The stop lost time of new elevators with standard techniques usually is two to four seconds longer than shown. The stop lost time of old elevators is much longer. In a test procedure for an expert's report I measured the longest stop lost time I have ever seen with 30 seconds.

In our elevator specifications, we always use the term stop lost time. The fixed value of the stop lost time is made part of the contract.

Additionally, we use the term stop lost time for traffic analysis to demonstrate the effect of different stop lost times on the efficiency of elevators.

Elevator Traffic Calculation by Using the "Stop Lost Time"

The elevator traffic calculation is usually based on the up-peak traffic conditions. Even more important than the up-peak traffic is random interfloor traffic. But to design elevators for a new office building we only know the office floor area and the number of people in the building. We also know the quality of the building and the desired quality of the elevators.

A parameter for the quality of the elevators is the 5 minute peak rate (5MR). In our traffic calculation the 5 minute peak rate is used as an input value. For this we calculate the average interval time and the required average number of passengers in the car.

Input: for the building:

- U = total building population above the main terminal
- 5MR = desired up-peak rate in 5 minutes (percentage of building population above the main terminal, the elevators should transport in five minutes)
- N = number of floors above the main terminal
- H = travel height to the highest floor (m) and/or
- hi = floor height for every floor "i" (m)

for the elevators:

- L = number of elevators in a group
- v = contract speed (m per second)
- SLT = stop lost time (seconds)
- Tp = time per passenger to enter and to leave the car (seconds)

Output: per capacity diagram:

- P = average number of passengers in the car
- INT = average interval time (seconds)

Formulas for calculation:

HCr = U * 5MR/5

- HCr = required handling capacity = total number of passengers the elevator system must transport in one minute
- U = total building population above the main terminal
- 5MR = desired up-peak rate in 5 minutes (percentage of building population above the main terminal, the elevators should transport in five minutes)

The calculated handling capacity of the elevator system must be equal or higher than the required handling capacity. For the following diagrams we have to calculate the round trip time, the handling capacity and the average interval time for every possible number of passengers in a car.

HCp = **(p * L * 60)/RTTp**
INTp = **RTTp/L**

- HCp = capacity = number of passengers the elevators can transport in 1 minute with p passengers in a car
- INTp = interval time with p passengers in a car (seconds)
- p = every possible number of passengers in a car
- RTTp = round trip time with p passengers in a car (seconds)
- L = number of elevators in a group

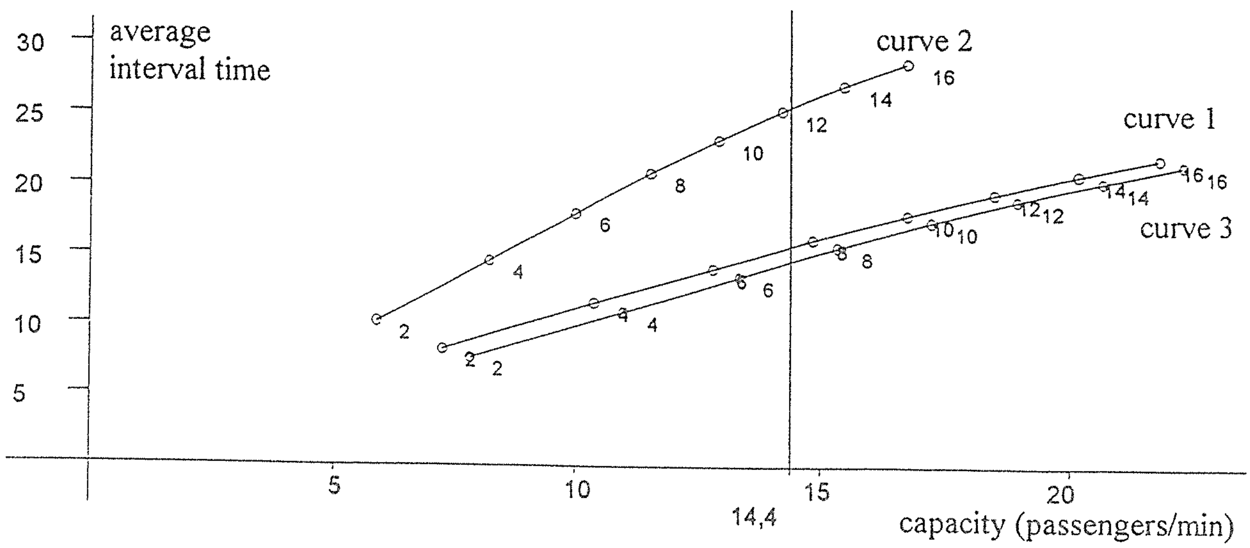
RTTp = (2 * W)/v + **SLT * (Sp + 1)** + **Tp * p**

- W = way to the average reversal point with p passengers in a car (m)
- v = contract speed (m per second)
- SLT = stop lost time (seconds)
- Sp = number of stops above the main terminal, with p passengers in a car, for N floors above the main terminal

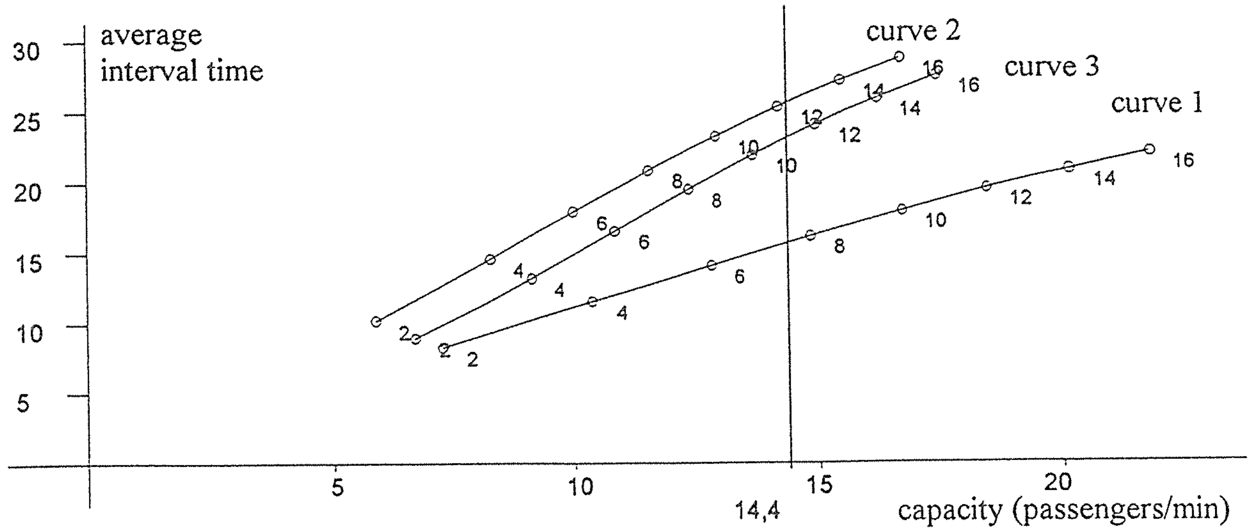
The calculation of the expected number of stops and the way to the average reversal point are done by known methods, but for every possible number of passengers in a car.

The figures beside the curves in the capacity diagrams represent the numbers of passengers in a car. The vertical line marks the required handling capacity. The point of intersection shows the average interval time and the average number of passengers in a car.

Capacity Diagram I



Capacity Diagram II



All curves in both diagrams show elevators in a building with 12 floors above the main terminal, a floor height of 3.50 m, and a population of 40 people on each floor. If the desired 5 minute peak rate should be 15 %, the required handling capacity for this building is 14.4 passengers per minute. A 15 % 5 minute peak rate is good for a comfortable office building with one or two tenants.

Curve 1 in both diagrams shows an elevator group with a contract speed of 2.5 m/s and a stop lost time of 8.0 s. You can see that for the required handling capacity a car must be filled with 7 to 8 passengers. The average interval time is nearly 30 s. These elevators are quite efficient for the described building.

Curve 2 in both diagrams shows the same elevator group with a stop lost time of 12.0 s. This is the usual stop lost time for most elevators with centre opening doors and a contract speed of 2.5 m/s. You can see that for the required peak rate a car must be filled with 12 to 13 passengers. The average interval time is nearly 50 s. With the higher number of passengers, these elevators would need bigger cars or, having the same cars in both cases, the elevators of curve 2 have a very low comfort level.

The average interval time of 50 s is too long and cannot be accepted. Without changing the stop lost time, an improvement is possible by increasing the number of elevators or by increasing the speed.

Curve 3 in diagram I shows an elevator group of 4 elevators with a stop lost time of 12 s. Curve 3 is nearly identical with curve 1. This example demonstrates that 3 elevators with a short stop lost time are nearly as efficient as 4 elevators with a long stop lost time. I repeat that a stop lost time of 12 s and more is common for existing elevators with a speed of 2.5 m/s.

Curve 3 in diagram II shows the same elevator group as in curve 2 with the same stop lost time of 12 s, but the speed increased to 4 m/s. Here curve 3 lies near curve 2. You can see that the higher speed is not able to compensate the worsening of the stop lost time. The higher speed can only compensate 1.5 s of the difference between the different stop lost times.

Naturally, this statement is only valid for this sample. But the trend is the same for all elevators. The more stops an elevator has the higher the influence of the stop lost time.

I have shown that short stop lost times are very important for the efficiency of elevators. And it must be said that short stop lost times can only be reached with good elevator doors. It means also that a long stop lost time in existing elevators can be reduced by modernising of the speed control system and by modernising of the elevator doors. In this way we can make old elevators much more efficient.

Shaft Width

To get a short stop lost time the shaft width must be designed to allow the arrangement of centre opening doors. One-side opening doors of best quality need a stop lost time which is in any case 2 s longer than with centre opening doors, because the door edge has to go twice as far by the opening and closing of the doors.

Elevator doors for efficient and comfortable elevators can only be two panel centre opening doors.

Door Panels

Quality doors must have solid door panels to close the shaft wall holes with reliability and to fulfil all demands of the authorities and all requirements of fire protection.

The door panels must have the possibility to be coated with stainless steel of all possible variations, with glass planes, brass, bronze, etc.

In any case the door panels must be stable enough. As a result, the weight of the door panels may be very high, depending on the door height, the door width, the door panel thickness and the covering.

Shaft Door Locking Device

Naturally, the door locking device must fulfil all safety requirements.

In addition, the door locking device has to lock the door without any time delay as soon as the door panels have reached their closing position. For this, it is necessary to use lock latches. Comfortable doors need lock latches with low noise.

Door Guides

Heavy door panels need stable and precise running guide rollers which are sufficiently dimensioned. They also need to run on stable and precisely fabricated door tracks.

High quality antifriction bearings and covers for vibration reduction on the rolling surface let the door panels run with low noise.

Door Operator

The door operator should be dimensioned sufficiently to be able to move the door panels with high speed. For high quality doors the door operator must be controlled. And in all positions of the running area the door speed must follow the optimal door running curve. The automatic speed control is required to reach the same running result on all landings with different friction relationships on each shaft door.

The different friction on each shaft door may be a result of different contamination of the door sills or, having elevators with high shafts, of different pressure relationships between the elevator lobby and the shaft on the different floors, especially during winter time with cold outside temperatures and bad wind conditions.

When the door closing is interrupted, it is very important, that the door stops with the shortest possible breaking distance. It has to be avoided that the door edge touches people or objects. The breaking distance has to be shorter than the controlled area in front of the door edge.

In any case, high quality door control systems calculate an optimal running curve to move the door panels from a random stop point to the door closing position or the open door position.

The maximal door speed can be adjusted separately for door opening and door closing.

There are doors, for which the elevator control system selects different door speeds depending on the intensity of the traffic. The doors may run slower when the traffic is low and the doors can run faster in order to increase the handling capacity when the traffic is high. My experience is, that this does not work without problems, because the passengers in the car cannot understand the different door speeds at different times. People tend to think, there are problems with the elevator system; and therefore they don't trust the elevators.

Connections from Door Operator to Door Panels

For high quality doors both car door panels are geared directly. Every car door panel is directly coupled with one shaft door panel.

The power impact should be in the centre of gravity of the car door panels. The coupling with the shaft door panels should also be in the centre of gravity of the shaft door panels.

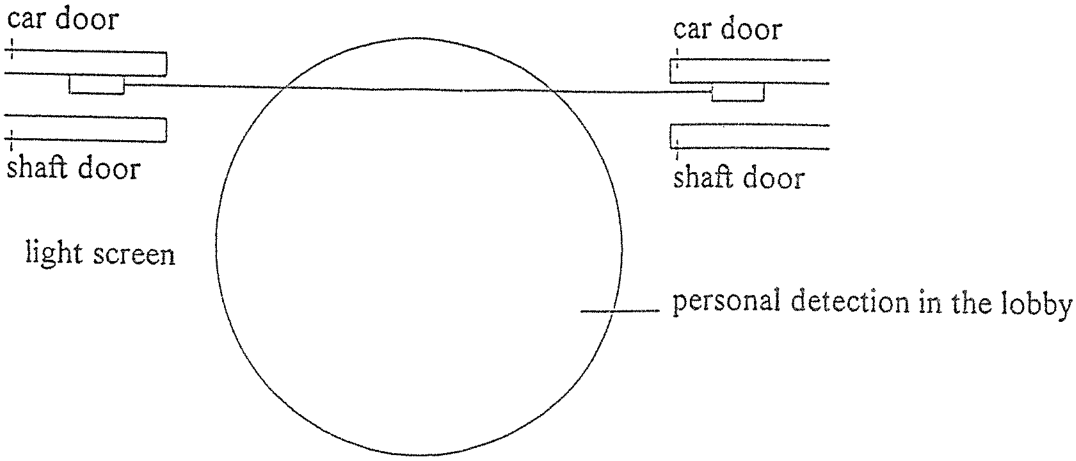
Door Edge Monitoring System

Door edge monitoring systems are necessary to avoid, that passengers are hit by the closing door panels.

High quality door edge monitoring systems must function independently from differing temperature and weather conditions. I think it is very important that they must also function independently from the differing quality of the maintenance and service personal.

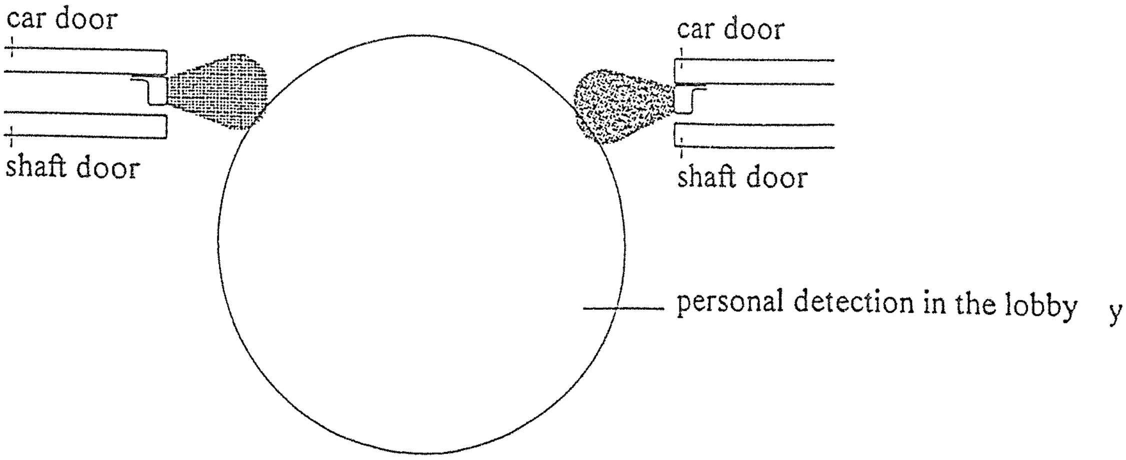
Modern door edge monitoring systems are able to do this. The newest systems are light screens which are able to recognise any object in one area between the edges. But they cannot recognise objects between the moving door edge surfaces, if they are out of the light screen area.

door with light screen and personal detection in the lobby



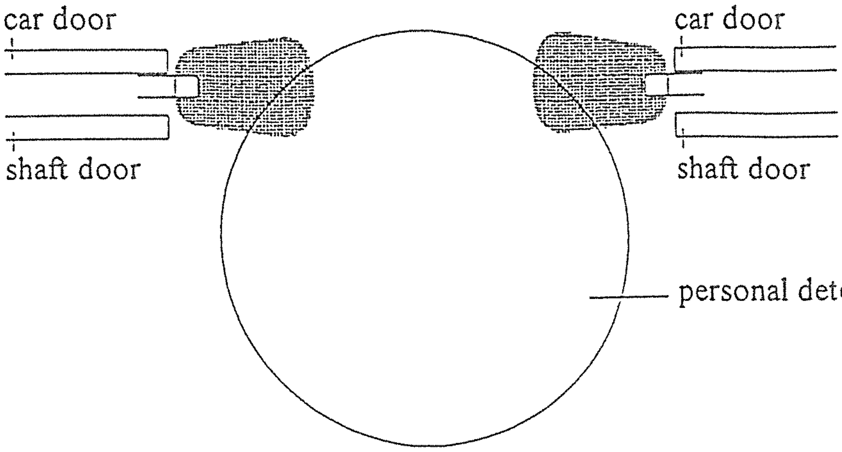
Sensitive edges have an electrical field and react to objects which interrupt the field lines. They detect the complete space in front of the door edges. But they do not function independently from differing weather conditions and their function is very dependent on the quality of the maintenance and service personal.

elevator doors with sensitive edge and personal detection in the lobby



A little better are sensitive edges in front of a moving mechanical edge, because the reacting zone is wider; and they have electrical switches to stop the door, if the mechanical edge is moved.

elevator doors with sensitive and mechanical edge and personal detection in the lobby



At the moment I think the light screens to be the better solution. There are also light screens which do not react to objects in the complete area between the door edges but only to objects which are in a reaction zone of nearly 200 mm in front of the door edge. For every system, the braking distance of the door has to be smaller than the reaction zone of the door edge monitoring system.

Personal Detection in the Lobby

All elevators I design, have a personal detection system to delay the start of the door closing as long as people or objects are still in the detected door area.

The detection is done by a sensor in the car door header. Detected is the space between the open doors as well as the lobby in front of the open shaft door.

As soon as a command is given to the control system of the elevator and the personal detection gives a "free" sign, the door should close. During closing time the detection is out of function.

Usually detectors react to heat changes or to light value changes. High quality detectors are able to differentiate movement directions and to select movements in direction to the door. By this way doors remain open only when there are movements in direction of the door. These detectors are very helpful, if elevators are placed directly on very busy floors, and if there is no special waiting area in front of the doors.

Door Holding Time

In the beginning, I explained that the term stop lost time includes the door holding time of 2 s. The door holding time is adjusted and varies more or less. Very often the maintenance people adjust the door holding time by their own feeling.

In reality, the adjusted door holding time must be in accordance with the arrangement of the elevators in the building. The door holding time must be long, if the distance is long between the waiting point in front of the elevator group and the stopping elevator. The door holding time must also be long if the elevators are often used by handicapped people. In some cases the adjusted door holding time may be 10 s and more.

The door holding time of 2 s in my traffic calculation is thought as an average lost time when nobody is using the door. The actual door holding time will be higher with each passenger entering or leaving the car.

If all passengers have entered or left the car during a time smaller than the adjusted door holding time, the door can be closed immediately by pushing the door close button on the car operation board.

The door close button is the simplest and the cheapest method of improving the handling capacity of elevators. I think the door close button should be present in every car, but especially in Europe very often this button is omitted.

Door Speed

The door opening speed is in principle not limited. The optimal door opening speed is given if the door opens in the approaching zone and is open at the same time the car is level with the floor.

The door closing speed can also be high if it is assured that people or objects cannot be touched by the closing door. This is the case with a good door edge monitoring system and with an effective personal detector system for the lobby.

After all, the limits to the impact energy, given by the authorities, must be met.

People who come to the elevator when the door is closing often try to reopen the door. This is not the way to get a good handling capacity and a short waiting time. Instead of interfering with the starting elevator it is better, that the late arriving passenger uses the next elevator.

The reopening process of elevator doors can be minimised by two methods:

The elevator does not accept any hall calls as soon as the door starts to close. The main reason for this procedure is, that the car is also able to start, when there is a permanent hall call activated by fire;

or the door closing speed must be so high, that people avoid touching the door edge. If the door monitoring system assures, that nobody is in the door space at the moment the door begins to close, people who are approaching the closing door must fear to get hit by a "guillotine". The intensity of the "guillotine effect" is higher the shorter the door closing time is. The door closing time depends on the door speed and the door width.

Door Width

In Germany, the minimum elevator door width in office buildings is 900 mm, for the transport of handicapped people in wheelchairs. This door width will replace the 800 mm in the existent ISO Norm .

The next door width in accordance with the ISO is 1100 mm. A 1100 mm wide two panel centre opening door needs a 2.40 m wide shaft. In Germany this shaft width can only be realised in special cases. I often design elevators with 1,00 m door width. The minimum shaft width in this case is 2.20 m.

Of course, elevator doors with 1.10 m width and more are more comfortable than doors with only 1.00 m width. In case of large door heights it is important to have wide doors to reach good door running characteristics. Large door widths decrease the time passengers need to enter and leave the car.

The advantage of 1.00 m wide doors is, that they need less time to open and close than wider doors need. In Germany, this advantage can compensate the disadvantage of the longer entering and leaving time.

I say in Germany, because office buildings in Germany are different to office buildings in the United States, for example. Office buildings in the United States have often a distance between the building core and the facade of 16 m and more. German office buildings have a distance between the building core and the facade of about 8 m. It is stated by German regulation, that each working place needs natural light and therefore must be situated near a window. The consequence of this regulation is, that the office space on each floor in Germany is much smaller than in the United States; and the number of people on each floor is also much smaller.

Due to different kinds of buildings, in order to reach the same handling capacity the elevators in Germany must stop more often. And less passengers enter and leave the car at each stop. This especially applies to the interfloor traffic. Often only one passenger enters or leaves the car during one stop.

Cost Benefit Analysis

High quality elevator doors improve the handling capacity and reduce travel and waiting time.

Higher handling capacity and shorter travel and waiting times can also be reached by higher speed or with additional elevators. Higher speed usually increases investment costs much more than high quality doors do. The advantage of higher speed is becoming smaller, the more often an elevator stops. With more stops the number of short distance runs increases and the higher speed will often not be reached. Additional elevators mean additional investment costs and additional maintenance costs. Naturally, with additional elevators the handling capacity, the travel and waiting time and the comfort can be improved.

When renovating elevators, two alternatives cannot be used: higher speed and additional elevators. Handling capacity and waiting time can only be improved by reducing the stop lost time and by reduction of stops.

Designing new elevators, investment and maintenance costs have to be calculated as well as the handling capacity. It is important to find the minimum of the relation of cost to handling capacity for each possible solution. In most cases it shows that the relation costs to handling capacity will be better with high quality doors.

Summary

An elevator door for comfortable and efficient elevators has to be a two panel centre opening door. It must run quietly for many years.

The door must have a high opening speed. It has to remain open only as long as passengers leave or enter the car. After this, if the door area is "free", it has to close immediately . The door closing speed should be high. In case the door edge monitoring system detects something, the door panels must stop without touching.

Bibliography

Jappsen H.	Glas-Aufzüge, in: Der Architekt 10/1988
Jappsen H.	Die moderne Steuerung -Förderleistungsgewinn durch Elektronik-, Heilbronner Aufzugstage 89
Jappsen H.	Aufzüge im Gästehaus Petersberg, in: Lift-Report, Heft 6 1990
Jappsen H.	Planung von Aufzugsanlagen, in: Der Architekt 9/1990
Jappsen H.	Aufwärts - Aufzugsanlagen im Hochhaus der DG-Bank, Frankfurt/Main, in: AIT - Architektur Innenarchitektur Technischer Ausbau, 10/1993

Biography

Hans M. Jappsen has been a mechanical engineer since 1961. For several years he worked in an elevator company in the area construction, project engineering, sales, calculation, and controlling. Since 1972 he is a consulting engineer for elevators. Together with Günter Stangier he has founded Jappsen + Stangier, Elevator Consulting Company, Germany in 1974. Hans M. Jappsen has designed the elevators for the most important buildings in Frankfurt/Main. Since 1993 his company has new offices in Augsburg and Berlin.

Hans M. Jappsen is member of the Arbeitsausschuß Aufzüge, Fachbereich Fördertechnik, Normenausschuß Maschinenbau im DIN Deutsches Institut für Normung e.V.

Hans M. Jappsen also works as a sworn expert at court.