# Planning groups of elevators for optimal performance and efficiency

## Group configurations define group efficiency and performance

All groups with large cars are inefficient. During periods of heavy traffic, large cars make many time consuming stops to distribute and/or collect high numbers of passengers. This implies long Round Trip Times (RTTs). Their performance and efficiency is worst during periods with heaviest traffic. During average traffic conditions RTTs are short and few passengers enjoy abundant car space.

This article’s aim is to prove that the configuration of groups (and particularly the relationship between the number of cars and the number of floors served) defines the performance potential of groups. Until now the theoretical performance potential of groups was not known. This has been a major handicap for the planning of groups that deliver optimal performance and efficiency under all traffic conditions. The discovery of the inherent relativity of group characteristics has solved this problem, because it makes the performance potential of groups transparent. Subsequently, it has enabled the design of intelligent destination group controls. These developments enable elevator contractors, consultants and architects to control all aspects of groups, including service qualities, and space and energy requirements.

## The inherent relativity of group characteristics

To appreciate the logic of relativity please consider a building that is served by one large elevator and compare its performance with a group of two elevators. The cars of the 2-car group can be much smaller - particularly so if we also consider that they will make fewer stops (i.e. have shorter RTTs). Consequently their contract loads can be less than 50% of the large single large car they replace. Passengers in the smaller cars will benefit from shorter waiting- and travel times.

Each increase of the number of cars of a group allows the use of smaller cars and improves time-dependent service qualities. This logic is true for any group and any type of group control. It is an inherent characteristic of groups. A six-car 800 KG traditional group (with UP/DOWN buttons in the lobbies and floor buttons in the cars) will outperform and deliver far better time-dependent service qualities than a four-car 1600 KG traditional group. Their space requirements are identical, the energy consumption of the six-car group is approximately 25 % less.

Increasing the contract load of a traditional six-car group with small cars does not affect its time-dependent service qualities. Larger cars will only enhance passenger comfort. If we increase the contract load to increase transport capacities for the purpose of serving additional floors, it is obvious that RTTs and all time-dependent service qualities will be worse. Existing traditional groups with six large cars usually serve three or four more floors than a four-car group. These six-car groups deliver worse performance than four-car groups, although their capital and maintenance costs are much higher.

## Traffic simulation

The facts of the relativity of group characteristics can, of course, be confirmed with traffic simulation. Although traffic simulation could have been used for the systematic comparison of groups with different configurations it seems this possibility was overlooked. Presently traffic simulations are primarily used to analyze the time-dependent service qualities of specific groups. For more information on traffic simulation and/or comparisons of groups with different configurations refer to chapters 10: “Traffic Simulation” and 8: “Planning intelligent destination elevators”, of your author’s book at website: elevatorgroupcontrols.com.

## Elevator group controls

Traditional group controls with UP DOWN buttons on landings are still well known as a relic of the past. They have been succeeded by destination group controls. Destination group controls require passengers to register their destinations; the group control reacts by assigning each passenger to a specific car. This concept was invented during the 1960’s by Mr. Leo Weiser Port. During the 1980’s these controls were re-introduced by Schindler on the basis of modern technology. Afterward, all major elevator companies have introduced proprietary destination group control systems.

Unfortunately the present generation of proprietary destination group controls is not intelligent, because they are not based on the inherent relativity of group characteristics.

## Intelligent destination group controls

The preceding paragraphs should not leave any doubt that the **values** of group performance parameters depend on group configuration. The **quality** of these parameters depends on the artificial intelligence of group controls. This requirement enables defining the essential function of intelligent destination group controls:

**To minimize and equalize the round trip times of all cars at all times**.

The quality of time-dependent performance parameters is defined by their **consistency**. For example: waiting times that vary from zero to 100 seconds do not signify high quality. This **bandwidth** is too wide. When RTTs are equalized and minimized, all time-dependent performance parameters will reflect this quality (i.e. bandwidths will be as narrow as possible and average parameters as short as possible). Minimized Round trip times maximize transport capacities and, consequently, minimize average car loads and their bandwidth.

The discovery of the inherent relativity of group characteristics and the development of intelligent destination group controls has disclosed that the **values and quality** of group performance parameters can be controlled by a single criterion: the **permitted number of stops** relative to UP and DOWN traffic densities.

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## The essence of intelligent destination group controls

We can envisage the cars of a group of elevators as a string of cars that rotate in a building or building zone. Although the cars move independently in their own hoist ways they do form a virtual string of cars. An intelligent group control is the flexible virtual string that connects the cars, controls their positions and minimizes and equalizes round trip times, relative to momentary traffic densities.

Minimizing and equalizing of round trip times is achieved by control of the number of permitted stops relative to momentary UP and DOWN traffic densities. The total number of permitted stops for each round trip is defined by the total of momentary UP and DOWN traffic densities. This total number of permitted stops is divided *pro rata* to the momentary traffic densities and assigned to the UP and DOWN segments of the next round trip to control the travel times of UP and DOWN trips as required to satisfy momentary traffic densities.

During periods of heavy traffic intelligent controls must prioritize shortest possible average times to destination *and* balance UP and DOWN transport capacities. Although waiting times increase when permitted numbers for UP and/or DOWN stops must be reduced to increase transportation capacities, the string of cars will rotate faster, reducing travel times in the cars. Even for the most extreme UP and DOWN traffic densities intelligent groups will ensure shortest possible and equitable time-dependent service qualities for all passengers. Fortunately most of the time traffic is not heavy enabling intelligent groups to concentrate on shortest possible consistent waiting times in combination with shortest possible average times to destination.

## Direct communication between passengers and intelligent controls

Intelligent group controls will greatly benefit from direct communication between individual passengers and group controls. This will enable the control to welcome each passenger and to indentify the assigned car and the time period till it departs to the usual destination of a specific passenger. The passenger (i.e. an authorized building user) can change the destination and will immediately get a revised car assignment. Occasionally a passenger may have to be informed of a change of the assigned car. Visitors must go to the reception/security desk for building entry.

Early in the 20th century, this type of communication was the task of elevator attendants and supervisors. Presently mobile phones enable a much better solution. Direct communication with individual passengers implies that intelligent group controls have complete data, in respect of the momentary requirements of all passengers (i.e., traffic conditions) at all times. It is obvious that building security systems can be greatly enhanced by intelligent group controls.

## The efficiencies of UP and DOWN transportation are interdependent

Efficient car operations imply that cars that complete their UP trips earlier also ensure earlier service to DOWN passengers. It is obvious that service qualities for

UP and DOWN passengers are interdependent. The method to balance service qualities with the numbers of permitted stops for UP and DOWN trips also explains why intelligent destination groups can guarantee best possible and equitable service qualities for UP and DOWN passengers under all traffic conditions.

It also explains why intelligent groups can increase UP and/or DOWN transportation capacities at any time by reducing the number of permitted UP and/or DOWN stops. These control decisions increase the average waiting time; however, the travel time in the cars will be shorter and the average time to destinations will be reduced, except for very low numbers of permitted stops.

## Configurations of groups with intelligent destination controls

Groups with intelligent destination controls are likely to have more and smaller cars. In line car configurations will be attractive because they save space and make it easier to plan groups with, for example, five or seven cars. All passengers will be aware of their assigned car and its time of departure. Consequently, their behavior will be relaxed. Short departure intervals and waiting times imply low numbers of waiting passengers, who distribute themselves throughout the lobby in accordance with car assignments.

Car size does not affect time-dependent service qualities. If, for example, one or more cars of a six-car group must have a contract load of 1000 KG or more for requirements other than passenger transportation, this is completely unproblematic for an intelligent group control.

More and smaller cars may cause extra costs; however, efficient groups and exact planning of a new building will usually allow a building project to increase its rentable floor area and/or its number of floors. Consequently exact group planning is likely to make a building project more attractive and more profitable.

## The remarkable efficiency of intelligent six-car groups

Simultaneous UP and DOWN traffic is the most demanding situation for any group. The following example will demonstrate the performance of an intelligent six-car group for UP and DOWN traffic densities of 7 % of the population per 5 minutes. This group serves a Low Rise zone with 14 upper floors, travel 56 m, contract load 800 KG, contract speed 2.5 mps and population of 1050 persons (75 per floor).

For the assumed extreme traffic conditions intelligent destination controls will permit only 4 additional stops during UP trips to the top floor and only 4 additional stops during DOWN trips to floor zero. This implies during UP trips the cars serve 5 destinations including the top floor. During DOWN trips from the top floor the cars also serve 4 intermediate floors before arriving at floor zero. For the top floor you may also read reversal floor. Under these conditions the average car load UP and DOWN will be approximately 6 persons.

The Door to Door Flight Time for a direct non stop trip to the 14th floor and vice versa is 30.4 seconds. The additional stops during the UP and DOWN trips increase the RTT by 8 s. each, for a total of 64 seconds (see box). The time cost for boarding and leaving the car is assumed to be 2 s. per passenger, for a total of 24 seconds. The average Round Trip Time will be consistently be approximately 150 seconds and the average interval between car departures will be approximately 25 seconds.

| DDFT's | | | RTT typical round trip | | | |
|---|---|---|---|---|---|---|
| | 14 | | UP trip | | 62.4 | s. |
| | 13 | | Nr of pas. | 6.1 | 12.2 | s. |
| 12.8 | 12 | | | | | |
| | 11 | | DOWN trip | | 62.4 | s. |
| | 10 | | Nr of pas. | 6.1 | 12.2 | s. |
| | 9 | | | | | |
| 14.4 | 8 | | **Round Trip Time** | | 149.2 | s. |
| | 7 | | | | | |
| | 6 | | Interval between | | | |
| 12.8 | 5 | | car departures | | 25.0 | s. |
| | 4 | | (150/6) | | | |
| | 3 | | | | | |
| 12.8 | 2 | | | | | |
| | 1 | | | | | |
| 9.6 | 0 | | | | | |
| 62.4 | | | | | | |

During the consistent intervals of 25 seconds an average of 6.1 persons enters the building (7% of 1050 = 73.5 persons per 300 s, i.e. 6.1 per 25 s). On the basis of the mathematical formula for probable stops these passengers have 5.1 probable destinations. This means that almost 100 % of the incoming passengers can be assigned to the first departing car. Their average waiting time will be approximately 13 seconds. In the unlikely event of passengers having 6 destinations it could be that one unlucky passenger may have to be assigned to the second departing car that leaves approximately 25 seconds later. Under the described circumstances the UP going cars will soon have an average car load of 6.1 passengers. DOWN going passengers have floor zero as their primary destination. We may assume they will experience average waiting- and travel times that are not worse than those of UP going passengers. During the extreme traffic conditions of our example the waiting time bandwidth for all passengers will be less than 30 seconds and the average waiting time less than 15 seconds.

The above data are conservative because they assume the cars always reverse on the top floor. Also the number of probable destinations for incoming passengers is conservative because the mathematical formula for probable stops assumes all floor populations and their working hours are identical. Consequently, the number of probable destinations is most likely less than 5.1. Consequently the time-dependent service qualities will probably be even shorter than the calculated averages of this example. They will also be highly consistent.

## Conclusions

This article proves that the configuration of a group defines its performance potential. Controls on the basis of permitted stops enable minimizing and equalizing of Round Trip Times during all traffic conditions. Consequently all service qualities can be optimized at all times.

When a group provides outstanding service qualities to incoming and outgoing passengers during heaviest UP and DOWN traffic, as demonstrated by the example, its service qualities during less-severe traffic conditions will not be worse.

It should be noted that the inherent relativity of group characteristics makes the evaluation of the efficiency of group configurations and group performance much easier.

The author would greatly appreciate comments and questions from readers.

**Author's bio**

The author of this article, Pieter J. de Groot, has many years of elevator contracting experience in Hong Kong and other cities in the Far East and Australia. In 1972 he was appointed Schindler Area Manager for Asia-Pacific. In this capacity he initiated and managed the formation of Jardine Schindler (Far East) Holdings SA (1974) and Schindler Lifts (Australia) Pty Ltd (1980). His involvement in the planning of many tall buildings caused a profound interest in the theoretical performance potential of groups. In 1975 de Groot met Mr. Leo Weiser Port the person who invented destination group controls and realized the first such group in Sydney, Australia during the late 1960's. De Groot noticed that this type of control should enable optimal group performance. After this meeting he promoted the re-incarnation of destination group controls. Several years later the Schindler group successfully re-introduced destination controls on the basis of modern technology. After retirement from Schindler de Groot decided to do his own research concerning the theoretical performance potential of groups and discovered the inherent relativity of group characteristics. This discovery enabled him to design intelligent destination group controls. He is the author of the book ''The planning and performance of groups of elevators'' that is published on his website: elevatorgroupcontrols.com.

**Edits 4th of January 2014:**

This paper was published in the January 2014 issue of Elevator World as an article under the heading Performance Analysis (Pages 86 to 89). The author inadvertently made a mistake on page 89 of this article that has been corrected in this edited version of this paper.
The percentage of passengers that can be assigned to the first departing car of 82 % was not correct. The probable number of destinations of the 6.1 incoming passengers that may go to anyone of 5 destinations is 5.1. This implies that almost 100 % of the incoming passengers can be assigned to the first departing car. Consequently their Average Waiting Time (AWT) will be approximately 13 seconds instead of 20 seconds. The author apologizes.
The author hopes that readers have noticed this error and concluded that the performance of the 6-car group is even more remarkable. The box with the RTT data was added to show the simplicity of performance evaluations for groups with intelligent destination controls that operate on the basis of permitted numbers of stops.