Title: **New Trends in Elevatoring Solutions for Medium to Medium-High Buildings to Improve Flexibility**

Authors: Johannes de Jong, KONE
Marja-Liisa Siikonen, KONE

Subject: Vertical Transportation

Keyword: Verticality

Publication Date: 2001

Original Publication: CTBUH London Conference 2001

Paper Type:
1. **Book chapter/Part chapter**
2. Journal paper
3. Conference proceeding
4. Unpublished conference paper
5. Magazine article
6. Unpublished

The heart of your building™

PUBLICATION

NEW TRENDS IN ELEVATORING SOLUTIONS FOR MEDIUM TO MEDIUM-HIGH BUILDINGS TO IMPROVE FLEXIBILITY

Johannes de Jong
E-mail: johannes.de.jong@kone.com
Marja-Liisa Siikonen
E-mail: marja-liisa.siikonen@kone.com

This paper was presented at CTBUH (Council on Tall Buildings and Urban Habitat) Conference, London, December 2001.

ABSTRACT

Medium to medium-high buildings with heights between 20 – 40 floors have traditionally been built using a minimum of 2 elevator zones: a low-rise zone and a high-rise zone. Passenger transfer between the two zones reduces flexibility in the use of these buildings because of the interfloor traffic. In Western Europe there is a clear demand to develop elevatoring systems which will enable the use of a single elevator zone in buildings higher than 20 floors. New elevator control technologies nowadays enable such elevator configurations. This article explains in detail alternative elevator arrangements available at the moment. Their consequences on the traffic handling in the building and the space required are considered. This article will also explain the different selection criteria required for each different elevator system.

1 INTRODUCTION

By splitting a building into more than one zone served by elevators, the number of stops is reduced, resulting in faster round trip times for each car. Elevators therefore make more trips and transport more people. This is the basis for the zoning method used in high rise buildings all over the world. Conventionally one elevator group typically serves a zone of up to 20 floors in office buildings. Too short zones become expensive while too long zones suffer from reduced handling capacities and long journey times.

With modern computer control systems, the number of stops elevators make can be reduced, and thus Handling Capacity increased. As a result of the fewer stops it is now possible to extend the number of floors served by a single zone. According to the present study, the number of served floors can theoretically be extended up to 40-50% higher than earlier.

This will allow the use of single zones in buildings up to about 35 served floors depending on the case, increasing rental flexibility and reducing the core space requirements even further. This has been noticed by architects who now try to apply these space-reducing elevator systems in buildings in many major cities in Europe.

Simulation of elevator traffic in buildings, using each manufacturer's propriety software, has been the only way to verify the outcome of different elevator arrangements. It has been extremely difficult for architects and their consultants to accurately define the number of required elevators. With this paper, the intention is to give easy to apply dimensioning instructions with different elevator configurations for general use.

2 DIMENSIONING CRITERIA

2.1 Daily elevator traffic

Figure 1 shows three different traffic components, and the total daily traffic for the stacked three components, measured in a typical multi-tenant office. Incoming traffic consists of passengers entering the building; outgoing traffic includes people leaving the building, and there is also interfloor traffic between the floors.

One can clearly see an up-peak in the morning and another at the end of the lunch hour from the figure of incoming traffic. There are also two down-peaks, one at the beginning of the lunch hour, and another at the end of the day when people leave the office. Interfloor traffic does not show a clear peak. It is rather low in multi-tenant office buildings, but clearly higher in single-tenant office buildings.

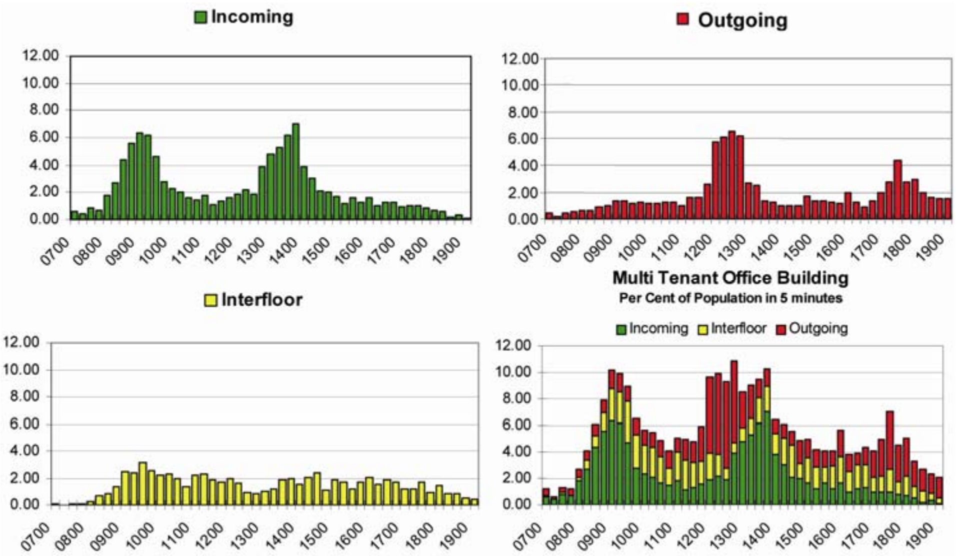


Figure 1. Daily passenger traffic in a multi-tenant office building scaled to the total population in the building

From the combined daily traffic curve it can be seen that the lunch hour traffic is often longer in duration, and often even heavier, than the morning up-peak. For the elevator control system, lunch hour traffic is the most difficult situation.

2.2 Elevator dimensioning

The number of elevators, their speeds and sizes for a new building are defined using theoretical up-peak traffic. Cars are assumed to fill up to 80% when they leave the lobby to the upper floors. For conventional single deck elevators and control systems using up and down buttons this gives a good basis for elevator dimensioning. Through experience it has been found that if these elevators can handle up-peak, they can also handle other traffic situations, such as lunch hour traffic and down-peak. According to elevator traffic simulations, in mixed traffic elevators can handle 20-40%, and in down-peak even 80% more traffic than in up-peak.

In conventional elevator dimensioning, criteria for the up-peak Handling Capacity and Interval for different types of buildings are used. The selection criteria are fairly well standardized all over the world. Handling Capacity criteria adjusts the car sizes and the shaft area. Interval justifies the number of elevators in the group. Both Handling Capacity and Interval are calculated from up-peak round trip time (RTT)

$$RTT = 2Ht_v + (S+1)t_s + 2Mt_m$$

H is the highest reversal floor, S is the number of probable elevator stops during up trip, and M is the average number of passengers carried inside a car, tv refers to the time it takes for an elevator to travel one floor distance with nominal speed v, ts is the elevator stop time including door times and the additional time caused by acceleration and deceleration, and tm is the total passenger transfer time in or out of the car. Handling Capacity (HC) shows how many passengers elevators can transport from the main entrance to upper floors in five minutes

$$HC=0.8\, c\, L\, 300/\, RTT$$

where c is the rated capacity of the car in persons, and L is the number of cars in group. Interval shows the frequency how often elevators leave the main entrance at up-peak

$$I = RTT\, /\, L$$

Average passenger waiting times can be roughly estimated (Barney, 98) from Interval

$$WT = [0.4+(1.8\, M\, /AC-0.77)^2]*I$$

where AC is the actual capacity of the car in persons. Passenger journey times, the total time passenger spends in an elevator system first waiting and then riding inside the car, can roughly be estimated from the equation (Siikonen, 97)

$$JT = WT + RTT/2$$

Speed of the elevators is defined by the travel time from the lowest to the highest served floor. Conventionally in cases where there are more than 20 floors in the building, it is not recommended that one group will serve the whole building. Even with a group of seven-eight cars Handling Capacity and Interval can be good. With rough rules of thumb, zoning of elevator groups are recommended if the number of served floors exceed 20. The reason is that with more than 20 floors, passengers have to travel an enormously long time inside a car, and passenger journey time becomes long.

3 ALTERNATIVE ELEVATOR ARRANGEMENTS

3.1 Destination control system

In a destination control system, passengers already give their destination calls at the landing floor. Passengers are immediately assigned to an elevator, and they have to wait for the particular elevator assigned to them. When the car arrives, no car calls inside the car have to be registered. The control system already has more information of the passenger journey at the stage when the elevator is allocated to the call. With more accurate information available, the control system can book people going to the same destination floors in the same cars. In this manner, the number of stops due to the destination (car) calls is reduced. Average passenger waiting and journey times are obtained by simulating the traffic with destination control system.

3.2 Double deck elevators

Double deck elevators have two cars attached to each other. At the entrance floor, passengers are guided to upper or lower deck according to the even or odd destination floor. During up trip elevator will stop to every other floor only, and unload and load both decks simultaneously. Ideally, the number of stops is only half of the real number of stops. This theoretically doubles the Handling Capacity per shaft during up peak compared to a single deck elevator (Kavounas, 1985; Siikonen, 2000)

$$RTT_d = 2H_d t_v + (S_d+1)t_s + 2Mt_{md}$$

If a landing call is give from the upper floor, elevator will accept car call to any floor for both decks. Then the number of probable stops increases and the handing capacity decreases to about 1.5 times greater than handling capacity of a single deck elevator. Waiting and journey times in up-peak traffic can be estimated from equations (4) and (5), and using equation (6).

3.3 Traffic handling of different arrangements

Both destination control system and double deck control system boost Handling Capacity by decreasing the number of car call stops during the up-peak. For instance, instead of eight conventional elevators even five double deck elevators can handle the traffic in the building with an even bigger Handling Capacity (see Figure 2). A group of eight single deck cars has a Handling Capacity of about 12%, and five double deck elevators can transport about 18% of the population in five minutes. Waiting times with fewer cars will be longer, but journey times in up-peak can be even less than with more conventional elevators. This is due to the decreased number of destination call stops.

Johannes de Jong & Marja-Liisa Siikonen

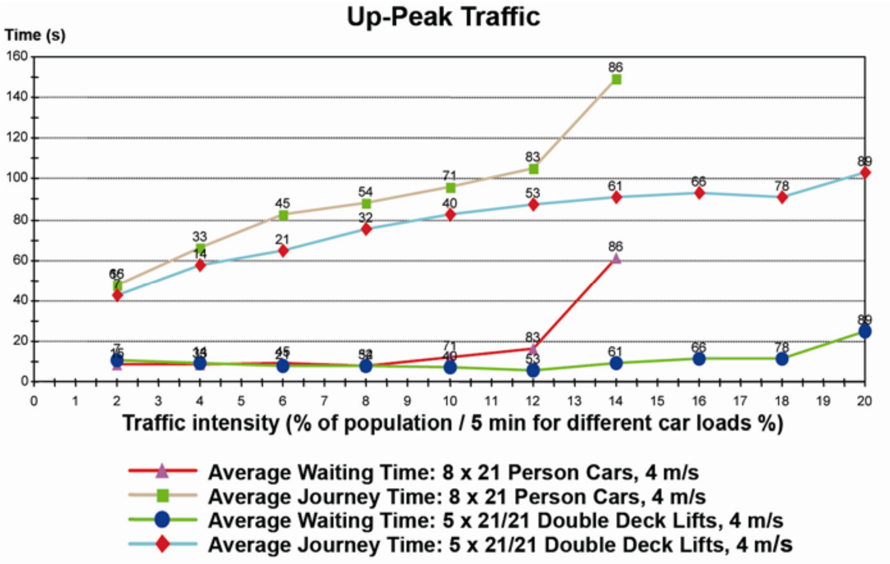


Figure 2. Up-Peak: Passenger waiting and journey times for eight conventional single deck elevators, and five double deck elevators with the same deck size

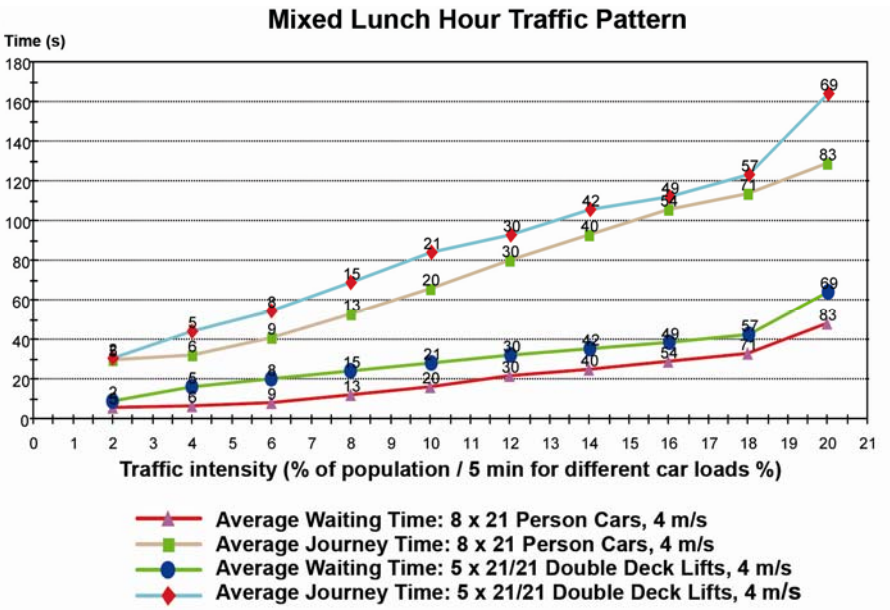


Figure 3. Lunch Hour: Passenger waiting and journey times for eight conventional single deck elevators, and five double deck elevators with the same deck size

With mixed lunch hour traffic patterns, the number of served floors with destination control and double deck elevators increases compared to the up-peak situation. Double deck elevators can stop both decks at any floor, and theoretically the number of stops is doubled. With a destination control system, passengers arriving at an upper floor can each be destined to different floors.

If they will be allocated to different elevators, several elevators have to stop at the "landing call" to pick up the passengers instead of one elevator picking them all up with a conventional system. A conventional system has the same number of served floors in all traffic situations. As can be seen from Figure 3, in this traffic situation Handling Capacities are about the same with eight single deck elevators as with five double decks. To guarantee the same service with all three systems during all times of day, higher up-peak Handling Capacity criteria for the destination control and double deck elevators should be used than for conventional control systems. Or, the same effect can be obtained if a smaller car load factor (e.g. 60%), is used when planning elevators for double deck elevators or for a destination control system.

4 GRAPHS FOR ELEVATOR PLANNING

4.1 Assumptions for selection graphs

Nine selection graphs for choosing a suitable elevator group in an office building are shown. In calculating the graphs it is assumed that there is one entrance floor in the building (or two for double decks). Floor height in the building is assumed to be 3.6 meters.

Selection graphs are made for pure up-peak traffic. Passengers arrive at the entrance floor and travel to upper floors. In selecting the elevator speed, Travel Time with nominal speed from the lowest to the highest served floor is assumed to last 20 seconds. As an example, for the travel height of 100 meters, a speed of 5.0 m/s (= 100m / 20s) is selected.

For a conventional single deck elevator group using up and down call buttons, Handling Capacity criteria of 13% of the population in five minutes is used. For double deck elevator groups and single deck elevator groups with a destination control system, Handling Capacity criteria of 17% in five minutes is used to guarantee equal service with conventional single deck elevators during mixed traffic.

In a destination control system, there is no Interval with the same meaning as for conventional control systems and double deck systems. With all three systems, Handling Capacity, passenger waiting times and journey times have the same definition and meaning. Since with up-peak boosters, passenger waiting times become longer than accepted with conventional control systems, journey time is selected as the criteria to define an acceptable passenger service level. Three journey time classes - excellent, good and fair - are chosen with limits 90, 100 and 110 seconds respectively. If journey time exceeds 110 seconds, service of the elevator group becomes unacceptable.

4.2 Interpretation of the elevator selection graphs

Elevator selection graphs for the three alternative elevator systems are shown on pages 11-13, introduced with three different loads: 17, 21 and 24 person car sizes. The maximum population an elevator group can handle is shown as a function of the number of floors. Curves for the groups from four to eight elevators are shown.

The maximum number of floors and population a group of eight elevators can handle with good journey times are shown in Table 1. A conventional single deck group with eight elevators and a 17 person car load can handle about 25 floors with less than 1500 persons in the building. With a destination control system about 32 floors can be served with about 1700 people in the building. Eight double deck elevators for two times 17 person load can comfortably handle about 30 floors with 2000 people.

Table 1. Maximum population and number of floors in a multi-tenant office building a group of eight elevators can serve with a good service level

Good Journey Times	**17 Person Load**		**21 Person Load**		**24 Person Load**	
	Floors	**Population**	**Floors**	**Population**	**Floors**	**Population**
Conventional Group	25	1500	20	1800	17	2000
Destination Control	32	1700	30	2100	27	2300
Double Deck System	30	2000	28	2500	26	2700

According to the table, double deck elevators can handle the traffic in buildings with largest population. With a destination control system, the maximum number of floors can be handled with good service times.

5 CONCLUSION

As a conclusion, with modern elevator technology about 30-50% more floors can be served with higher population in the building than with conventional elevator arrangements. The comparison was made for a multi-tenant office building. For a conventional elevator group, Handling Capacity of 13% of population in five minutes was used in defining the graphs. For destination control and double deck system, 17% of population in five minutes was used. In normal European office buildings, conventionally only about 20 floors can be served with acceptable passenger service times. According to the results, with a destination control system a building with about 30 floors can be served with the same passenger service level and with double deck system about 28 floors with the same service level.

With conventional elevator groups, passenger waiting times are the shortest since passengers can choose any of the cars of the elevator group. With double deck groups, waiting and journey times are often longer since the number of elevators is smaller compared to conventional groups with equal Handling Capacity. With destination group, passenger waiting times are longer since the passenger has to enter a specific car, not any cars that arrive at the floor. Journey times, however, can be even shorter that with conventional systems.

REFERENCES

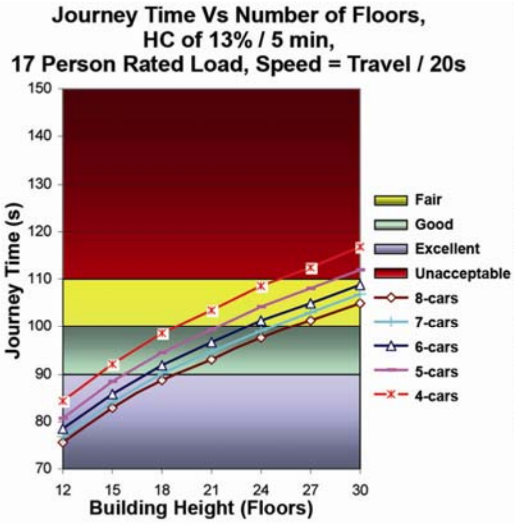
Barney, G. C., 1998. UPPEAK, DOWN PEAK & INTERFLOOR PERFORMANCE REVISITED, Elevator Technology 9, Proceedings of ELEVCON '98, October 5-7,1998, Zürich, Switzerland, IAEE, pp. 31-40. ISBN 0 9525696 5 5

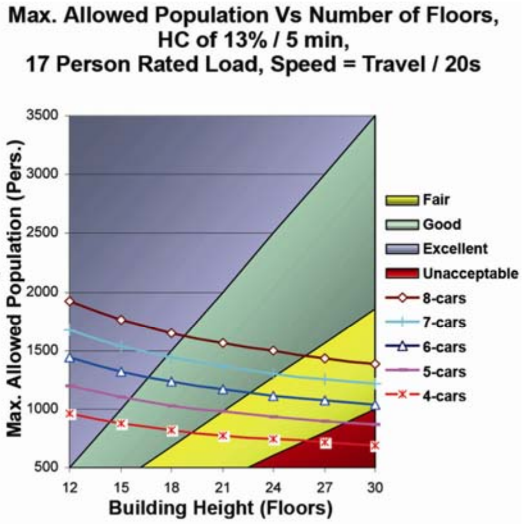
Kavounas, G. T., 1989. Elevatoring analysis with double deck elevators, Elevator World, Vo1.11 , pp.65-72.

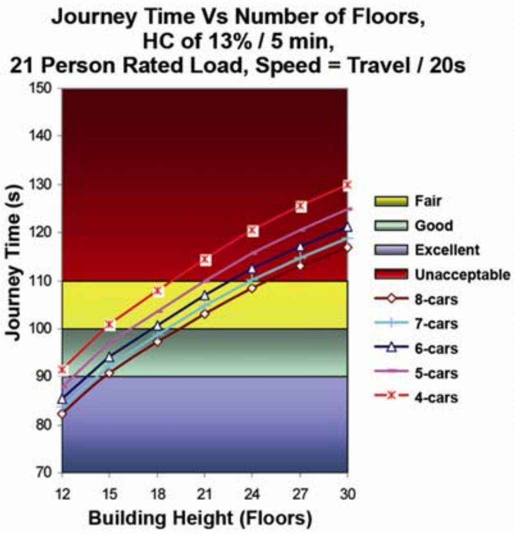
Siikonen, M-L., 1997. PLANNING AND CONTROL MODELS FOR ELEVATORS IN HIGH-RISE BUILDINGS, Ph.D Thesis, Helsinki University of Technology, Research Reports A68, 246 p. ISBN 951-22-3753-9

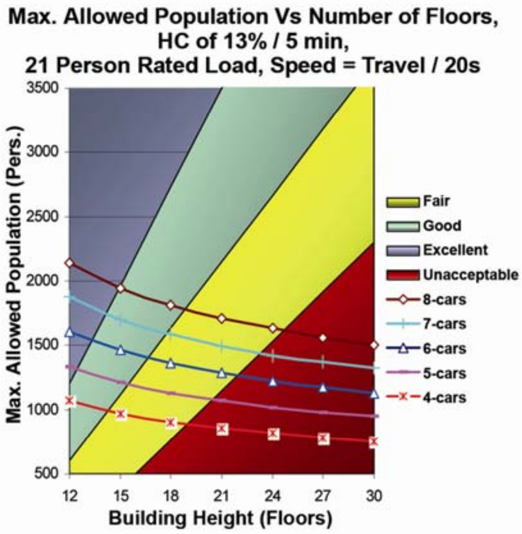
Siikonen, M-L., 2000. ON TRAFFIC PLANNING METHODOLOGY, Elevator Technology 10, Proceedings of ELEVCON 2000. Berlin, Germany, May 9-11, IAEE, pp. 267-274. ISBN 965-555-006-0.

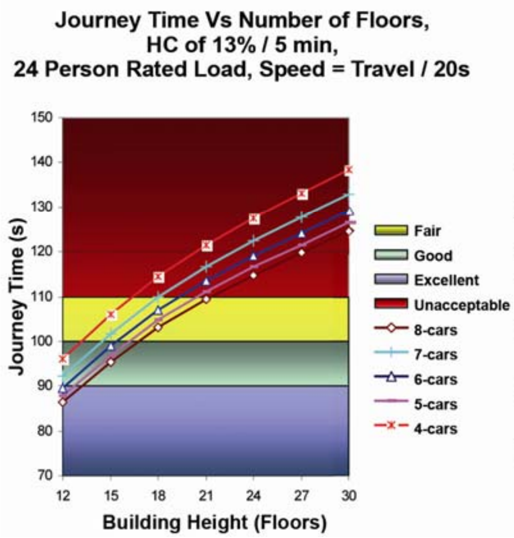
Conventional Single Deck Group with Full Collective Control System

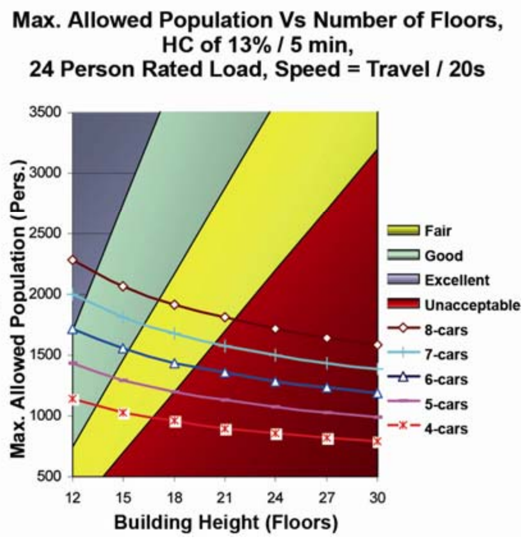




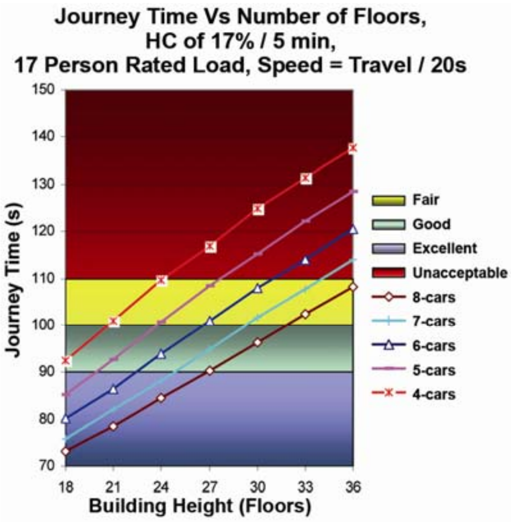


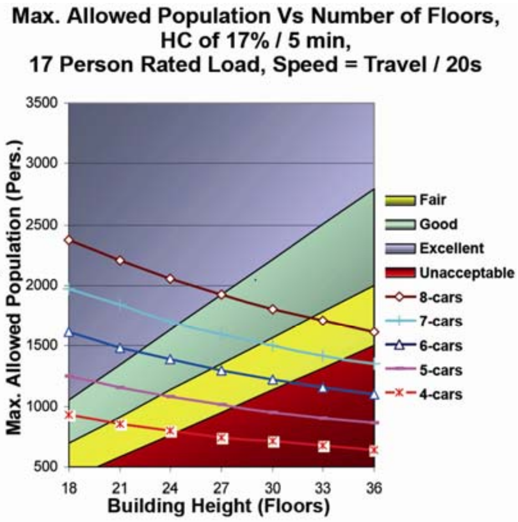


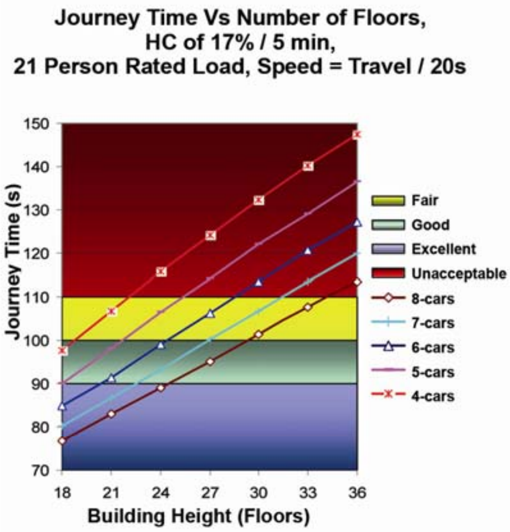


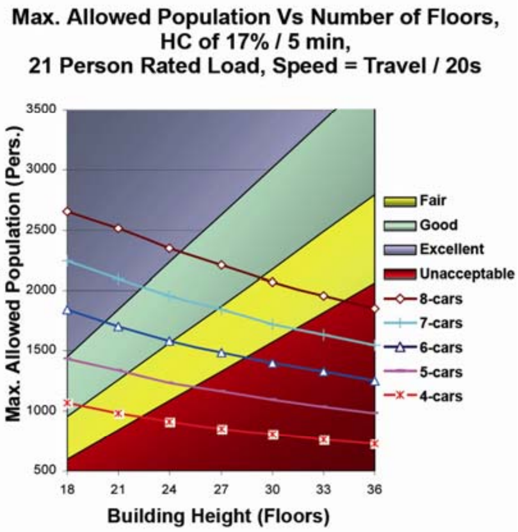


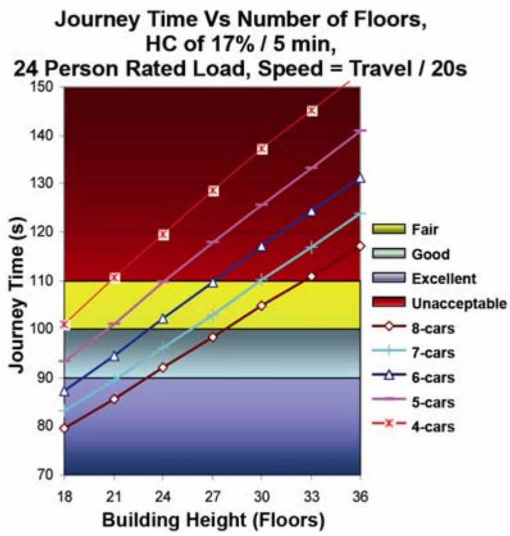
Single Deck Group with Destination Control System

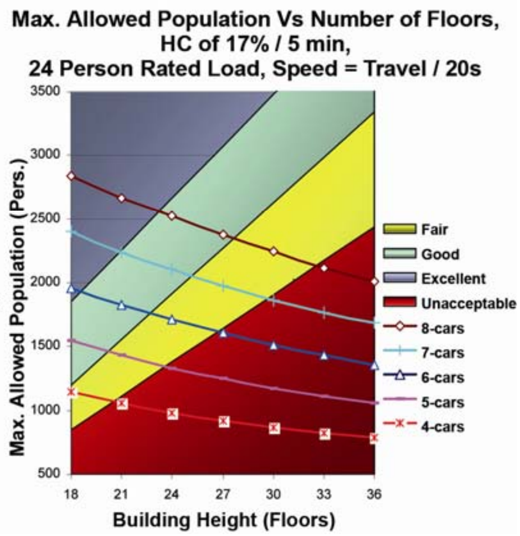




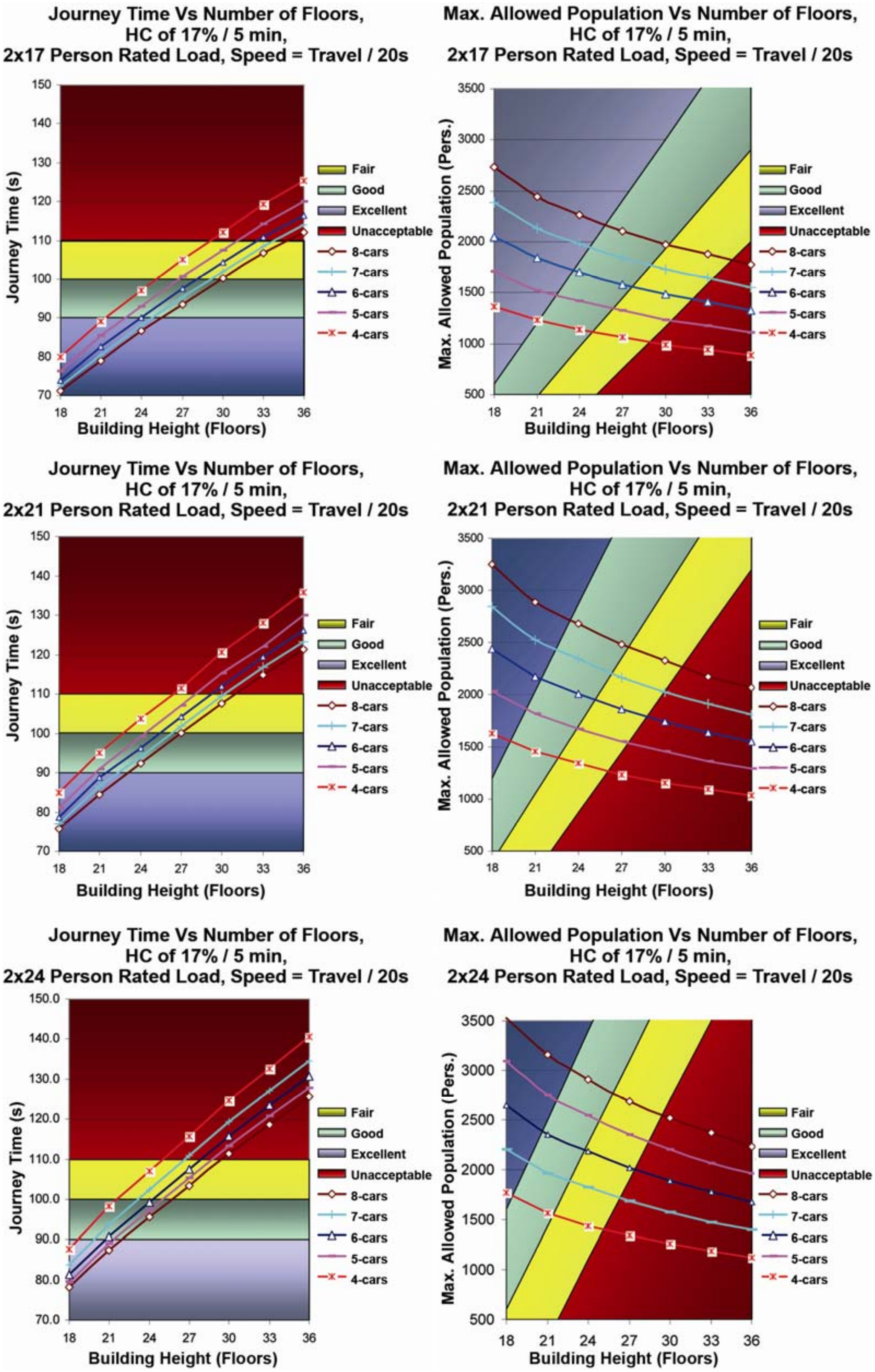








Double Deck Group with Full Collective Control System



Johannes de Jong & Marja-Liisa Siikonen