Layered Zoning for tall and slender buildings

Introduction

Virtually all tall buildings are sub-divided in zones that are served by groups of 4 or 6 elevators. These groups with large single-deck cars reflect the planning concepts of the attendant operated elevators of the early 20th century. When long ago attendants were abolished these groups lost their human intelligence. Traditional controls with up /down buttons in the lobbies and floor buttons in the cars continued to be the standard group operating system. Without attendants the performance of groups became erratic and inefficient. This was the reason why in the past the use of large cars became a must.

The planning of groups with large cars became habitual. Planners were not aware that large cars are inherently inefficient and a great waste of space and energy. This paper proves, that a new zoning concept on the basis of double- or triple deck cars and intelligent destination controls, can reduce the space requirements for groups by up to 50 % in comparison with those in existing buildings.

Intelligent destination group controls are based on the inherent relativity of group characteristics. For detailed information please refer to the paper: Planning groups of elevators for optimal performance and efficiency. This paper was published in the January 2014 issue of Elevator World. It can be downloaded from website: elevatorgroupcontrols.com

Layered Zoning

Envisage a 30-story building zoned in layers of A and B floors. The two lowest floors are entrance floors that are connected by escalators and herein identified as AØ and BØ. The 28 upper floors consist of 14 pairs of A and B floors. The lowest pair is identified as floors A1 and B1, the next higher pair as A2 and B2 and so on. All A floors form building zone A, and all B floors form building zone B.

The two zones are served by one group of six double-deck cars. The lower deck of each car is identified with the character A, and the upper deck with B. The A deck of each car serves only A floors and the B deck only B floors. This implies the maximum number of destinations of the double-deck group is 14.

Floor distances

The distances between A and B floors are 4 m and match the distance between the A and B decks of the cars. The distance between a B floor and an A floor above may vary. This article will not consider alternatives for double-deck cars that can adjust the distance between their A to the B decks.

Performance during heaviest simultaneous UP and DOWN traffic

This article evaluates the performance of the 6-car double-deck group previously outlined for simultaneous up and down traffic of 7% of the population per 5 min. These traffic conditions are extreme and unlikely to occur in a real building. We assume the following characteristics:

Travel distance AØ to A14 and BØ to B14 is 112 meters (14 X 8 m)
Contract speed 6 m/s
Contract Load 800 KG per deck
Population 1960 persons (28 X 70).

During the assumed traffic conditions intelligent destination controls will permit service to only five destinations for up trips, including the top or reversal destination. During down trips from the top/reversal destination, cars serve four more destinations before arrival at destination zero.

On the basis of the *permitted numbers of stops / destinations* average round trip times (RTTs) will be 177 s., with an average interval between departures of 30 s. (See box). The average car-deck load will be approximately 6.8 passengers.

Total	Number of	**30 Floor building served by 6 double-deck cars**							
DDFTs	destinations	Total travel distance 112 m.				Door to door			
74.7	14	UP trip		74.7	s.	Flight Times (DDFTs)			
	13	Nr of incoming passengers during interval	13.7						
15.3	12	Average Nr of passengers per deck	6.8	13.7	s.	Distance		DDFT	
	11					8	m	11.2	s.
	10	DOWN trip		74.7	s.	16	m	13.6	s.
13.6	9	Nr of outgoing passengers during interval	13.7			24	m	15.3	s.
	8	Average Nr of passengers per deck	6.8	13.7	s.	32	m	16.9	s.
15.3	7					40	m	18.2	s.
	6					48	m	19.5	s.
	5	**Round Trip Time**		176.8	s.	56	m	20.8	s.
	4								
16.9	3	Average interval between car departures		29.5	s.	This table is valid for			
	2					contract speed 6 m/s			
	1								
13.6	0								

The time required for a typical up trip is the sum of five door to door flight times (DDFTs), plus the assumed time costs for boarding and disembarkation of the average number of 6.8 passengers on each car deck.

Down trips will be just as long. The departure times from floor zero; the top floor; and, in fact, all floors, are controlled and coordinated by the intelligent destination control. These controls operate on the basis of time tables for each car and each round trip. Consequently all time-dependent service qualities are predictable and highly consistent.

Number of UP Passengers and Probable Number of Destinations

During a period of 5 min. with an up traffic density of 7 %, the number of passengers entering the building will be 137 (7*19.6). During an interval of 30 s. the number of incoming passengers is only 13.7 (137/300*30). The mathematical formula for the probable number of destinations of a group of 13.7 passengers that may go to 14 destinations returns the number 8.8. The first departing car serves five destinations and this implies that 57% of the incoming group, (i.e. 7.8 passengers on two floors) can be assigned to the decks of the first departing car on the basis of "first come first served" until the number of permitted stops is exhausted. The average waiting time (AWT) for these passengers will be approximately 15 s. The remaining 43% of the passengers, (i.e. 5.9 passengers on two floors) may have a maximum of 9 destinations. Their probable number of destinations is 4.4, which implies all can be assigned to the second next departing car. These passengers will have to await the departure of the first car plus 30 seconds more until the departure of the second car. For these passengers the AWT is approximately 38 s. (interval*1.25). The AWT for all passengers will be approximately 25 seconds. The longest waiting time (i.e. the waiting time bandwidth) will be approximately 45 seconds (interval*1.5).

During the next interval another group of 13.7 incoming passengers will again produce a sub-group of 43% that will be assigned to the second next departing car. It is obvious that the average car deck load will soon be approximately 6.8 persons.

Service qualities for DOWN passengers

The assignment of down going passengers to specific cars is also based on "first come first served" until the number of permitted stops is exhausted. Down calls that cannot be assigned to the first available car will be assigned to the second available car. Assigning of down or up going passengers to a car going in the wrong direction but scheduled to reverse direction at the next stop can be used to enhance group efficiency. We may confidently assume that down going passengers will not experience waiting- and travel times worse than those of incoming passengers.

Conservative calculation method

The calculation method of this evaluation is conservative, because it assumes that all trips reverse at the top destination. The mathematical formula for probable destinations assumes that all floor populations and their working hours are identical. In a real building this will not be true; consequently the real numbers for probable destinations are likely to be lower than the theoretical numbers. The assumed time for door opening and closing is 4.5 s. and 2 s. for the entry and exit of one passenger. For smaller cars and doors, these times will be shorter.

Performance if Permitted Destinations are increased to SIX

If the number of permitted destinations is increased to six, all performance data will be worse. The average RTT increases to 200 s., and the average car deck loads to 7.6 passengers. The AWT increases by more than 1 s. and the bandwidth by 5 s. The most significant change is the 10 s. increase of the longest passenger travel times in the cars to reversal floors. This negatively affects the average time to destination for all passengers with an increase of 5 s.

Performance during Moderate Traffic Conditions

“Moderate traffic conditions” are defined as simultaneous up and down traffic densities of 3% of the population per 5 minutes. In a real building, traffic densities are likely to be less during the majority of operating hours.

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During the assumed traffic conditions, intelligent destination controls may permit service to four destinations during up and down trips. On the basis of this number of permitted stops average RTTs will be 136 s. and the average interval between departures 23 s. The average number of incoming passengers per interval is about 4.5 passengers and their probable number of destinations is four. Consequently all passengers can be assigned to the decks of the first departing car. Car deck loads will be approximately 2.3 passengers. AWTs for all passengers will be approximately 11 s. Incoming passengers may not distribute equally over both entrance floors, but these variations will not affect group efficiency.

Performance for moderate traffic conditions if Permitted Number of Destinations is reduced to THREE

Group service qualities improve if the number of permitted destinations is reduced from 4 to 3 because the average RTT is reduced to 112 seconds, and departure intervals to 19 s. Average car deck loads are reduced to 1.8 passengers. The AWT for all passengers is reduced to approximately 10 s. The percentage of incoming passengers that can be assigned to the first departing car is reduced to slightly less than 100 %. The most significant change is the reduction of the longest passenger travel times in the cars to reversal destinations by 12 s. This implies that, on average, passengers arrive approximately 6 seconds earlier at their destinations. These data are an indication of the flexibility and performance reserves of groups with intelligent destination controls. They also explain why and how building managers can influence the service qualities of intelligent groups.

Interfloor traffic

Direct trips between destinations are possible if target destinations are already scheduled as permitted stops or are still available as permitted stops. If a direct trip is not possible an interfloor passenger will be informed of the assigned car, as usual. In this case, the trip to the target floor will usually be a trip in the assigned car via floor zero for a down car, or via the reversal floor for an up car. Please note that in multitenant buildings, interfloor traffic is very small. During periods with extreme traffic densities, it may assumed to be negligible. During moderate traffic conditions flexibility of the number of permitted destinations and direct communication with all passengers via mobile phones will ensure efficient interfloor traffic.

Performance during UP or DOWN PEAK traffic

The 6-car double-deck group can service up-peak traffic densities of 12 % by permitting service to only four destinations during UP trips. Down trips will be non-stop (30 s). This results in average RTT's of 110 s., average car deck loads of 7 passengers and AWT's of 20 seconds. The waiting-time bandwidth will be approximately 42 s., because, theoretically about 2 passengers (one per deck) of the passengers arriving during a specific interval may have to be assigned to the third departing car. The few down going passengers (typical for up-peak conditions) will be assigned to upward cars. For down-peak traffic the same methods will produce the same results.

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Building volume savings / Footprint reductions

Hoist ways usually occupy the full height of a tall building. For this reason comparisons, of the footprints of alternative configurations are good indicators of their space requirements.

Existing 30-floor buildings are usually served by a Low- and a High Rise group of four cars, each with a contract load of 1600 KG. Their net internal hoist way area is approximately 28 m^2 per group. Their lobbies and hoist way enclosures may double their floor space requirements to 56 m^2 per floor and per group. For two groups their maximum total floor space requirement may be 2 X 56 X 30 = 3360 m^2. On floors without entrances lobby space may be reduced to corridor space, a saving of possibly 14m^2 per floor (i.e. on 28 floors a total of 392 M^2). In this case their total floor space requirement is reduced to 2968 m^2.

The net internal hoist way area of the 6-car double deck group is also 28 m^2. Including lobbies and enclosures and its total floor space requirement may be as high as 56 m^2. The total floor space requirement of this group would be 30 X 56 = 1680 m^2. Thus, the additional floor space that results from the application of intelligent destination controls and Layered Zoning for the 30 floor building of this study is 2968 - 1680 = 1288 m^2. These floor space savings increase exponentially with the height of a building, because hoistways for additional upper floors reduce the rentable areas of lower floors. Additional footprint savings for groups with intelligent destination controls may be possible on account of smaller lobbies in view of few waiting passengers and in-line configurations.

Traffic Simulation and contractual performance guarantees

Until now, traffic simulation was used to disclose performance parameters of specific groups with *proprietary group controls* for assumed traffic conditions. In the future, the role of traffic simulation will be very different, because the time-dependent service qualities and the up and down transportation capacities of groups with intelligent destination controls are predictable for any combination of up /down traffic densities. This implies group service qualities can be contractually guaranteed.

Consequently intelligent groups do not require traffic simulation to disclose performance data. However, traffic simulation can be used for independent confirmation of calculated service qualities during the building planning phase. Guarantees of service qualities for a range of defined traffic densities are likely to become a standard element of future elevator contracts.

These methods also imply that traffic simulation can be used to check the functionality of intelligent group controls. If traffic simulation does not deliver the calculated / predicted performance data something is wrong in the control system.

Groups with multi-deck cars

Future buildings may well be served by groups with eight or more multi-deck cars that serve many floors with a paternoster-like mode of car operation. These groups

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may be seen as a chain of cars that are connected by a software string instead of roller chains. During heavy traffic the string of cars rotates faster because they make fewer stops. These groups will feature very short intervals, and waiting- and travel times. The cars can be small because the number of passengers per deck will be very low. The vertical traffic experience will be very different in comparison with existing buildings. These configurations could be a topic for another article.
Please do note that multi-deck cars also permit tall buildings on small building sites. Apartment buildings served by two or three double- or triple-deck cars will be practical and economical.

Conclusions

The discovery of the inherent relativity of group characteristics has been a shock for the author and this may well apply for many others in the elevator industry. Particularly for those of us who tried to solve this problem with complicated algorithms, traffic calculations, traffic analysis, and traffic simulation, the question that remains is: “Why was relativity such an elusive problem?” The short answer: The performance of groups of elevators is a four dimensional problem in which time is the 4th dimension.

Time “costs” control all aspects of group performance, because each stop causes a great loss of time. Cars must slow down and stop, doors have to open, passengers go in and/or out, doors close, and the car must start and accelerate again. These time costs explain why control of the permitted number of stops controls all group characteristics. This simple fact is the basis of intelligent destination group controls.

Intelligent destination group controls can enhance the role of elevator contractors in the building industry. They are likely to be the providers of intelligent building management systems. Insecurity in respect of group planning and performance is eliminated. Group configurations will define the maximum height and the efficiency of future buildings.

To ignore the innovation potential of intelligent destination controls, (i.e., the continued use of group controls that do not control numbers of permitted stops and, consequently, do not facilitate optimal car operations and contractual performance guarantees) is not advisable.

Elevators are already the pumping hearts of tall buildings; the author suggests that intelligent groups will also become the brains of future intelligent buildings.

The author will greatly appreciate reactions and questions from readers.

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Author's biography

The author of this paper, 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. Subsequently destination group controls became the industry standard. 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. De Groot's book *The planning and performance of groups of elevators*, and articles on this topic can be read or downloaded from his website: elevatorgroupcontrols.com.

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