Traffic Performance of Elevators with Destination Control

by Jörg Lauener

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This article highlights the attributes of destination control with regard to the resulting traffic performance and, in the absence of a traffic-simulation program, offers a shortcut method that allows assessment of the up-peak traffic performance using conventional traffic-analysis software to obtain results. It is a rudimentary but useful tool, especially during building-core design, where it quickly displays a suitable layout of the vertical-transportation system, along with options and comparisons. Generally, stage one of a building's design is to determine the core layout before going any further by positioning and fixing the number of required elevator shafts, the zoning of elevators, the location of machine rooms, and sky lobbies and escalators (if applicable).

However, there are so many different design options available on the market that for larger projects, it would be prudent to get an equipment update from the major elevator suppliers and select the most suitable of all possible layout options before settling on the final tender specification. At the early design stage, the main criterion would be to arrive at a vertical-transportation arrangement that can achieve the required traffic performance with minimal hardware and space requirements. Other information such as the track record of an elevator contractor, the installation contract price, the running cost considering the cost of maintenance, loss in revenue for space taken up by the system and cost of electric power, etc. will have to be taken into consideration at the tender evaluation stage.

The application of different options also changes with the type of building (residential, office, hotel, mixed purpose, special purpose), and different elevator suppliers can offer different solutions. Any one of them could entail:

◆ Elevators, escalators or moving walks
◆ Passenger, service, goods or other purpose elevators
◆ Single zoning or sub-zoning
◆ Direct elevatoring from the main entrance (including sky lobbies) fed by express elevators from the main entrance
◆ Up/down elevatoring of local elevator groups from sky lobbies
◆ Single-deck, double-deck or triple-deck elevators
◆ Elevators with or without machine rooms
◆ Destination control or conventional control
◆ Elevators of the same group serving different floors
◆ Handicapped requirements
◆ Special access and security requirements, etc.

However, this article will focus on describing a simple method that can determine the up-peak traffic performance of elevators with destination group control (DGC), which usually shows that the same performance can be achieved with a reduced number of elevators compared to the number of units of a conventional group control (CGC). (Since not all elevator suppliers offer destination control, tender specifications often allow for both types of control.)

DGC Vs. CGC

During the design stage of a building, a speedy answer to the traffic

performance of different vertical-transportation arrangements is desirable. Most building designers may be familiar with using conventional software for elevator-traffic analyses of CGC systems, but not necessarily so for those of DGC. This simplified method allows for the determination of the traffic performance of elevators with DGC by using the same conventional software as for CGC with the aim to efficiently arrive at a useful and prudent result. Once a layout has been fixed and an arrangement with DGC looks acceptable, a computer simulation should then be carried out to verify the preliminary traffic-performance results and cover the down-peak and two-way traffic modes.

For the elevator user, the fundamental difference between the CGC and DCG systems lies in the registration of the hall and car calls, and signage. In the case of CGC, an elevator is called to a landing by registering a hall call in the landing-button board. When the elevator arrives, the elevator user will enter the car and register a call in the car panel to travel to the selected floor.

In the case of DGC, there are no call panels inside the cars because elevator users key in their destinations at the lobby before entering a car. When registering a call, an indicator built into the landing-button pad will then immediately show which of the elevators in the group has been assigned to service that particular call. For identification purposes, the elevators in a group are usually designated with letters A, B, C . . . The signage is further enhanced by indicators placed in the entrance columns of each car confirming which destination floors a car will be serving during its immediate upcoming trip. It should be noted that with DGC, the assignments of registered destination floors are dynamic, i.e., for every new roundtrip, the respective elevators will be assigned to serve different registered destination floors to meet ever-changing traffic demands.

Traffic Performance Comparison Between DGC and CGC

Roundtrip time (RTT) is a direct measurement of the transportation efficiency of elevators. Looking at an up-peak traffic condition, the average RTT under DGC will be considerably shorter, because DGC organizes the traffic in such a manner that the elevators only stop at a reduced number of floors during each roundtrip. The reason for such an improvement is that when elevator users key in their destinations at the lobby, same-floor passengers will be directed to enter the same car, i.e., a car will then be filled with passengers whose destinations are limited to typically only two, three or four floors, depending on the total number of floors to be served by the group of elevators and the number of elevators in the group.

In the case of CGC, since the control system remains oblivious as to which floors passengers intend to travel to until their destinations have been registered inside the car via the car panel, the cars are randomly filled with passengers having many different floor destinations, which then forces the elevators to stop at that many floors, thus slowing down the elevator service. For example, with CGC, a 1600-kg capacity car serving 15 upper floors will on average stop at 10-11 different floors during each roundtrip to let passengers disembark, whereby each stop will add around 10 seconds to the RTT. On the other hand, with DGC, an elevator will only stop at, say, two, three or four different destinations. In addition, with less stops per roundtrip, the elevators will on average attain higher speed between stops than with CGC, further contributing to a shortening of RTT.

Traffic Analyses – Up-Peak Condition

Basic Data Required

A traffic analysis is pretty straightforward unless some special factors have to be considered such as floors for restaurants, banking, conventions, clubs, carparks, basements, etc. The basic data required to carry out a traffic analysis can be limited to the following four items:

◆ Number of tenants on upper floors (assuming same average numbers per floor)
◆ Number of floors to be served
◆ Travel distance from main entrance to top floor and main entrance to first upper floor
◆ Required handling capacity

The following parameters are then determined in accordance with usual industry standards:

◆ Car capacity
◆ Car fill factor
◆ Door type (center opening or telescopic) and door width
◆ Elevator speed

Other parameters of the program are:

◆ Average weight per passenger (usually 68-75 kilograms, but dependent upon the prevailing code of practice [COP])
◆ Passenger transfer time (average time per passenger to enter and egress a car)
◆ Door opening/closing time
◆ Door block time (time delay before door closing after last person has passed through)
◆ Premature door open time (initiation of door opening before car has reached floor level). Premature door opening may not be allowed under some COPs.
◆ Brake-release time
◆ Drive startup delay time
◆ Rate of acceleration/deceleration
◆ Jerk (rate of change of acceleration/deceleration)

Example

For DCG, take a simple office building with the following specifications:

◆ Number of floors to be served: 16 (G, 1-15)
◆ Travel distance: G/F-15/F: 64 meters; G/F-1/F: 8 meters
◆ Number of tenants on upper floors: 1,200 (an average of 80 persons per floor)
◆ Required five-minute handling capacity: 15%

The computer input data for DGC shall be the same as for CGC, except for the average number of upper floors to be served per elevator per roundtrip and the average car fill factor. The two parameters differ for the following reasons:

◆ *Average number of floors served per elevator per roundtrip:* The control system under DGC constantly endeavors to equalize the workload among the elevators in the same group. This means that, for instance, with 15 office floors to be served by a group of eight elevators, the control system should on average ideally assign 15 floors/8 elevators = 1.875 stops per elevator per roundtrip (exclusively the mandatory stop at the ground floor). With a group of six elevators, the ideal load sharing would require the control system to assign *on average* 15 floors/6 elevators = 2.5 stops per elevator per roundtrip (Table 1). However, since this method is to determine a prudent result, we add 0.5 stops to Table 1's results and round up to the next integer. Therefore, for a group of eight elevators, one would arrive at three stops per roundtrip (1.875 + 0.5 and rounded up to the next integer), and for a group of six elevators, at four stops (2.5 + 0.5 and rounded up to next integer), always excluding the mandatory stop at the ground floor.
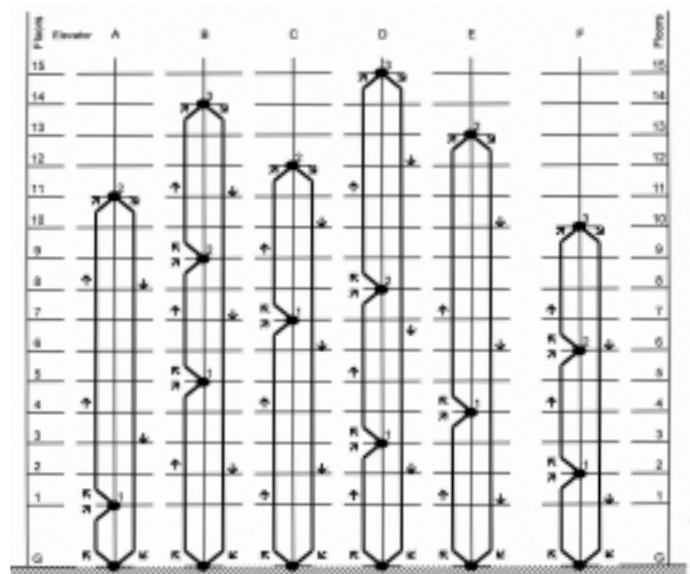
Figure 1: The typical duty assignment of destination control with ideal load sharing during an up-peak traffic condition. Each of the six elevators serves an average of 2.5 upper floors per roundtrip.

◆ *Average Car Fill Factor:* Experience has shown that DGC cars are less crowded than those with CGC control. In our example for CGC, we assume an average car fill factor of 70%; for DGC, we assume a reduced car fill factor of 60%. The car fill factor differs between different societies. In Asia, one would use a higher car fill factor than in the U.S. or Europe because of the difference in the average size of people and the difference in culture. We first start by analyzing the traffic performance of a group of elevators with CGC:

Input Data for CGC	
Total population (persons)	1,200
Car capacity (kg)	1600
Car fill factor (%)	70
Average weight per passenger (kg)	75
Door type	center opening
Door width (mm)	1,100
Number of upper floors	15
Total travel distance (m)	64
Travel (main entrance to first upper floor [m])	8
Speed (nominal [mps])	3.5
Min. required handling capacity (%)	15
Result	
RTT (seconds)	196.8
Interval time (seconds)	24.6
Five-minute handling capacity (%)	15.2
Number of elevators required	8

Input Data for DGC

For DGC, we use the same input data as above for CGC, except for the number of floors to be served per elevator (per roundtrip) and the average car fill factor. We first start by determining the average number of stops an elevator will have to make per roundtrip. The number of stops per roundtrip changes with the number of elevators involved and, since the number of elevators with DGC can usually be reduced, we determine here that the number of stops (exclusive of the ground floor) is also based on some smaller car groups to check their traffic performance, i.e.:

◆ For 8 elevators: 3 stops per roundtrip (15 Floors/8 elevators + 0.5, rounded up to next integer)
◆ For 7 elevators: 3 stops per roundtrip
◆ For 6 elevators: 4 stops per roundtrip
◆ For 5 elevators: 4 stops per roundtrip

One cannot be sure of the number of stops (upper floors) to use in the analysis, because the number of elevators required is still unknown. In this example, we start with three upper floors and check the result with regard to the handling capacity achieved and the number of elevators required. If it shows that a group of seven or eight elevators will be required to meet the handling capacity of 15%, then the applied number of three upper floors is correct. On the other hand, if the handling capacity is far above the required 15% target, fewer elevators are required, and the analysis has to be repeated (in this case,

with four or more upper floors). Table 2 shows the traffic performance for different group sizes of 8, 7, 6 and 5 elevators, with associated numbers of 3, 3, 4 and 4 floors, respectively.

Input Data for DGC				
Total population (persons)		1,200		
Car capacity (kg)		1600		
Car fill factor (%)		60		
Average weight per passenger (kg)		75		
Door type		center opening		
Door width (mm)		1,100		
Number of upper floors served per roundtrip for group sizes of 8, 7, 6 & 5 elevators		3, 3, 4 & 4		
Total travel distance (m)		64		
Travel (main entrance to first upper floor [m])		8		
Speed (nominal [mps]):		3.5		
Minimum required handling capacity (%)		15		
Results for Different Group Sizes				
	8-E	**7-E**	**6-E**	**5-E**
RTT (seconds)	112	112	124.4	124.4
Interval time (seconds)	14.0	16.0	20.7	24.9
Five-minute Handling capacity (%)	22.8	20	15.4	12.9
Number of elevators required	8	7	6	5

The above table's RTTs for car groups of eight and seven, and six and five elevators are the same because the numbers of floors applied are the same. In this example, the result shows that DGC would require a group of six elevators to reach the required handling capacity of 15%, while CGC, as calculated earlier, would require eight elevators.

Further Points of Interest

Running a comparison of the traffic performance between DGC and CGC with the same software will produce useful results precisely because the only variable will be the number of stops per roundtrip and the car fill factor. The described shortcut method of traffic analysis for DGC is meant to produce conservative results, and it further served the purpose here to demonstrate the difference in traffic performance between DGC and CGC. Below some applied factors of prudence:

◆ The ideal average number of stops assigned per roundtrip is added by 0.5 stops and rounded up to the next integer.
◆ In this method, we use the full travel height to calculate the RTT, although the elevators will, on average, not have to travel the full height. While the elevators will, of course, service all floors including the top floor, some cars will return to the main landing from lower levels, all as dictated by the algorithm of the control system, thus resulting in a reduced average travel distance.
◆ Because of the reduced number of stops per roundtrip, a higher number of passengers will egress cars at the same time, with the effect that the passenger transfer

becomes more efficient and therefore the passenger transfer time could be somewhat reduced.

◆ Reduced car fill factor (as compared with CGC).

Since the duty cycle of the elevators during up-peak is much more demanding than during down-peak with CGC, the determination of the required numbers of elevators has to be based on up-peak criteria. As a consequence, there is an inherent over-capacity of elevators during down-peak, achieving a higher than required handling capacity. The reason is that during up-peak with CGC, cars are randomly filled with passengers of many different floor destinations. This is not the case during down-peak mode, because odds are that all down-peak passengers will travel to the same destination (the main entrance). During down-peak, cars will usually be already filled to capacity within two or three stops before heading down to the main entrance, which basically has the same shortening effect on RTT as with DGC control during up-peak, where cars will stop only at two, three or four upper floors during a roundtrip.

DGC has also been called an up-peak booster, which is certainly correct since with the reduced number of stops during roundtrips, DGC does improve the up-peak performance significantly. One can say that DGC has brought the up-peak performance of the elevators into line with the otherwise much better down-peak performance, resulting in a well-balanced utilization of the elevators. As shown, the persistent discrepancy in performance between up-peak and down-peak with CGC can be avoided with DGC control, where the RTT for up-peak is reduced to approximately that of down-peak, thus improving the elevator performance and, in most cases, permitting a reduction in the actual number of required elevators.

There is, of course, still the two-way traffic to be considered, which can be most demanding to an elevator system. In an office building, two-way traffic will normally occur during working hours and lunchtime, when it will usually stay within moderate levels and is of little concern. Heavy two-way traffic can occur if, for instance, special-function floors like restaurant floors or convention floors, etc. are commonly served by elevators that are also providing normal elevator service to other floors in the building. Such a mixed demand can be severely disruptive to the elevator service. The best way to alleviate the problem is to provide special-function floors with separate elevator service or, if possible, to place such floors in the podium of the building where they can be serviced by escalators. In cases where separate elevator service is not possible, the elevator performance needs to be evaluated to find out whether the anticipated level of two-way traffic can be handled sufficiently by a proposed vertical-transportation system. But here also, due to the fact that the control system knows in advance where elevator users wish to go before entering a car, DGC will be able to organize such muddled traffic in a much more efficient manner than CGC.

By virtue of its characteristics, DGC allows more floors to be packed into the same zone than would be economically feasible with CGC. This can be demonstrated by the results obtained from the example, where the office building under scrutiny requires eight elevators with CGC but only six with DGC to reach the required 15% handling capacity. Would one choose to retain the original eight elevators but controlled by DGC one could add an extra five floors to the original 15 office floors, thus serving a total of 20 office floors with a total tenancy of 1,600 persons (80 persons per floor X 20 floors) and still comfortably meet the 15% handling capacity. Having more floors directly linked and served by the same group of elevators can add to the efficiency of a building. ⊕