Chapter 5: Traditional elevator planning

Summary: The planning of "collective selective" (traditional) elevators is ruled by the following maxim: When a group of elevators can satisfy the maximum arrival rate of passengers during UP PEAK traffic their transport capacities under all traffic conditions will be alright. This maxim implies that building planning, i.e. the configuration of traditional groups is based on their UP PEAK transport capacities. Consequently the planning of traditional groups is very simple and inflexible. Calculated data on the basis of so-called “traffic calculations” define the maximum UP PEAK transport capacity of groups.

Traditional elevators

The term “traditional groups” refers to "collective selective" elevators which derive from the signal controls of early last century. These elevators lost their "brain power" when technology replaced their attendants and supervisor. The supervisor and attendants of the past improved the efficiency of groups during periods of heavy traffic by guiding passengers going to the same floor(s) to a specific car to reduce Round Trip Times (RTT’s) and increase transport capacities. They knew their passengers and used their intelligence and experience to optimize elevator services.

Passengers of "collective selective" groups without attendants can enter any car and go to any floor by pressing a floor button in the car. Consequently the number of stops during any round trip of traditional elevators is decided by chance. This implies the UP and DOWN transport capacities of traditional groups, its efficiency, cannot be controlled by "brain power".

The UP PEAK transportation capacity of a traditional group is usually called Distribution Capacity and abbreviated as DC5, meaning the percentage of the population that a group can distribute into a building in a period of 5 minutes. For calculating the DC5 of a group “traffic calculations” usually assume that DOWN traffic is NIL, i.e. cars do not make stops during DOWN trips.

The planning / configuration of groups was - and still is - ruled by the single criterion:

A group must satisfy the assumed maximum arrival rate of passengers.

<u>This criterion makes the planning of traditional groups very simple and inflexible</u>.

In tall buildings with several groups of elevators each group should have approximately the same DC5 to assure that the elevator service qualities are similar for the whole building.

Planning a 4-car Low Rise group for a building with a population of 75 persons/floor

The Comparative Performance Table (CPT) below shows the RTT, DC5 and other performance parameters for 8 alternatives of a building that is served by a 4-car group of "collective selective" elevators with a contract load of 1600 KG. The maximum car load is assumed to be 16 passengers (load factor 80 %).

The top line is valid for a building with only 9 upper floors. For this building the elevators have a RTT of 129.5 seconds and a high DC5 of 22.0 %. The second line is valid for a building with 10 upper floors and so on. Each additional floor increases the RTT and reduces the efficiency of the group because the time to distribute 16 persons into the building increases. The zone population increases with each additional floor and consequently the DC5 declines rapidly as the number of floors increases.

Number of upper floors served	Floor designation highest floor	Total zone population	Total travel in meters	Contract speed in m/sec.	Average car load in persons	Number of "selected floors"	Number of "probable stops"	Average RTT Low & High trips in seconds	Average Travel Time in the car in seconds	Average time for group to serve all floors once	% of population distributed into building by 4 elevators in 5 min.	Average Time To Destination in seconds (= AWT + ATTC)	Average departure INTERVAL from floor zero	Cycle INTERVAL: INTERVAL for AWT calculation	Theoretical minimum Average Waiting Time (AWT) in seconds
Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: 1600 KG								See NB		See NB					
9	9	675	36	2.5	16	9	7.6	129.5	50.5	129.5	22.0	66.7	32.4	32.4	16.2
10	10	750	40	2.5	16	10	8.1	136.7	53.3	136.7	18.7	70.4	34.2	34.2	17.1
11	11	825	44	2.5	16	11	8.6	143.4	55.9	143.4	16.2	73.8	35.9	35.8	17.9
12	12	900	48	2.5	16	12	9.0	149.7	58.3	149.7	14.2	77.0	37.4	37.4	18.7
13	13	975	52	2.5	16	13	9.4	155.7	60.6	155.7	12.6	80.1	38.9	38.9	19.5
14	14	1050	56	2.5	16	14	9.7	161.5	62.7	161.5	11.3	82.9	40.4	40.4	20.2
15	15	1125	60	2.5	16	15	10.0	166.9	64.7	166.9	10.2	85.6	41.7	41.7	20.9
16	16	1200	64	2.5	16	16	10.3	172.2	66.5	172.2	9.3	88.0	43.1	43.0	21.5
Characteristics of elevators and building								NB: For "collective selective" groups: RTT = RTT L&H = Cycle RTT.							
Speed							>	see table		Distance 0 to 1			4	meters	
Acceleration and deceleration rates							1	m/s^2		Typical floor distance			4	meters	
Jerk rate							1	m/s^3		Population			75	pers./floor	
Door closing time							2.5	seconds		Car load in persons			>	see table	
Door opening time							2	seconds		Traffic			UP		
Time gain advanced door opening							0	seconds							
Time allowance car IN/OUT each passenger							2	seconds						Chap5dia1	

The calculated data above are identical with the data from traditional traffic calculations. The Comparative Performance Table (CPT) is a “tool” introduced by this book to show the interdependencies between the characteristics of a building, its population and the performance of its elevators. CPT’s facilitate the evaluation of the traditional planning process.

The calculation methods of Comparative Performance Tables are described in Chapter 13: “Transparent performance calculations”. These methods will enable readers to double-check all data. The RTT calculation methods of this book also introduce two new parameters:

Average Travel Time in the Car (ATTC) and Average Time To Destination (ATTD). The theoretical minimum ATTD equals the ATTC plus the theoretical minimum Average Waiting Time (AWT). Please note that the AWT is a misleading performance parameter for reasons explained in the next chapter. The ATTC is a reliable parameter because it is based on the exact calculation for the average RTT. The ATTD is meaningful because it consists for approximately 75 % of the reliable ATTC.

The terms "selected floors", “RTT Low and High trips”, “Cycle RTT and Cycle INTERVAL are required for evaluation of the performance of groups with "intelligent destination" controls and will be defined later.

For "collective selective" groups the average RTT L & H and the Cycle RTT are identical and equal to the RTT of traditional groups. Consequently the Departure INTERVAL and Cycle INTERVAL are identical as well.

Traditional performance standards for "collective selective" elevators

The traditional “rules of thumb” for planning "collective selective" elevators are:

- DC5 = 14 to 15 %: Elevator service will be good
- DC5 = 12.5 %: Elevator service will be satisfactory
- DC5 = 10% Elevator service will be poor

Selection of the number of upper floors served

In case the group of the above CPT is expected to satisfy an arrival rate of 14 % of the population per 5 minutes this 4-car group should serve a maximum of 12 upper floors. If this design criterion is reduced to 12.5 % the group can serve 13 upper floors and so on. It is obvious that the estimates of the future population and the expected maximum arrival rate of passengers are decisive for planning of groups of "collective selective" elevators.

It is difficult to obtain up-to-date data of traffic densities in existing buildings. To explain the logic and methods for planning "collective selective" elevators this lack of data is no problem because this can be done with assumed arrival rates, however, for planning a new building this information is obviously of great interest.

Building owners usually want the elevators to serve the maximum possible number of upper floors that is compatible with the estimated population and the expected maximum arrival rate of passengers. This is a logical requirement because the owners want to optimize the return on investment. The desire to maximize the number of floors served often leads to groups serving one or even two floors more than the optimal number of floors on the basis of realistic population- and arrival rate estimates. Such buildings we call under-elevatored. Many tall buildings are probably marginally elevatored, i.e. they only just satisfy the maximum arrival rate.

The 6-car group alternative with small cars

It seems that 6-car groups with small cars do not exist. The reason for their non-existence might be that small elevators are more expensive per KG of contract load and six small elevators will cost more than four large ones. In the CPT below we study a building with 12 upper floors and a population of 900 persons served by a 6-car group. We vary the number of persons in the car to find the number that delivers a DC5 of 14 %.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 6-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: variable														Chap5dia2	
12	12	900	48	2.5	12	12	7.8	131.2	51.2	131.2	18.3	62.1	21.9	21.9	10.9
12	12	900	48	2.5	11	12	7.4	125.8	49.1	125.8	17.5	59.6	21.0	21.0	10.5
12	12	900	48	2.5	10	12	7.0	120.2	46.8	120.2	16.6	56.8	20.0	20.0	10.0
12	12	900	48	2.5	9	12	6.5	114.2	44.4	114.2	15.8	53.9	19.0	19.0	9.5
12	12	900	48	2.5	8	12	6.0	107.8	41.8	107.8	14.8	50.8	18.0	18.0	9.0
12	12	900	48	2.5	7.3	12	5.6	103.0	39.9	103.0	14.2	48.5	17.2	17.2	8.6
12	12	900	48	2.5	7	12	5.5	100.9	39.0	100.9	13.9	47.4	16.8	16.8	8.4
12	12	900	48	2.5	6	12	4.9	93.5	36.0	93.5	12.8	43.8	15.6	15.6	7.8

The CPT shows that a 6-car group with an average car load of 7.3 passengers, i.e. a contract load of 800 KG, delivers the same DC5 of 14.2 % as the 4-car group with a car load of 16 persons. In the table below we compare the parameters of both groups.

Number of cars in the group	4	6	
Contract load (maximum in KG)	1600	800	
Contract load (maximum in persons)	20	10	
Contract speed in m/sec	2.5	2.5	
"Footprint" of each elevator in m^2	8.0	5.3	
"Footprint" of group, excl. lobbies	32	32	
Av. number of passengers in the car	16.0	7.3	
"Probable stops"	9.0	5.6	
RTT	149.7	103.0	
DC5	14.2	14.2	
Theoretical minimum Dep. Interval	37.4	17.2	
Theoretical minimum AWT	18.7	8.6	
Average Travel Time in the Car (ATTC)	58.3	39.9	
Average Time To Destination (ATTD)	77.0	48.5	Chap5dia3

The maximum transport capacity of each small car equals about 70 % of each large car. The small elevators are far more efficient than the large ones. Their theoretical minimum Departure INTERVAL is 50 % less. Shorter departure intervals reduce waiting times and carloads. Reduced numbers of passengers reduce "probable stops" and average Round Trip Times. The service frequency of the small car group is twice the frequency of the 4-car group and their theoretical minimum Average Waiting Time (AWT) is more than 50 % shorter.

It is remarkable that 6-car groups with small contract loads do not exist because their performance improvement is automatic. This implies that groups of "collective selective" elevators with large cars are inherently inefficient. The “footprints” of both groups are identical, i.e. the 6-car group does not reduce the rentable areas of the building. As a matter of fact lobbies could be smaller because doubling of the service frequency reduces the average number of waiting passengers.

The guesstimated capital cost of the 6-small-car group is about 30 % more than the 4-large-car group. This is not a logical explanation for their non-existence because many 6-car groups with large contract loads do exist. These groups use the additional transport capacity provided by two more cars to serve 3 or 4 additional floors. The next chapter: “Average Waiting Time (AWT) the misleading parameter” proves that 6- and 8-car groups with large cars are particularly inefficient, cost much more and their service qualities are worse in comparison with 4-car groups. In addition they require more space reducing rentable areas.

The only logical reason for the non-existence of 6-car groups with small cars seems to be the incorrect assumption that large cars are efficient. A contributing factor is the misleading AWT produced by “traffic” calculations. This is unfortunate because 6-car groups with small cars offer superior performance. They are a more economical solution too, particularly if we take into account their space- and energy savings and increased rentable areas.

The formula for "probable stops" obscured the relativity of transport capacities and time-dependent service qualities. The apparently correct data of traffic calculations and the preoccupation of sales engineers and consultants with the performance parameter Average Waiting Time (AWT) is probably the reason why the theoretical performance potential of groups has not been a subject of research.

Although the new insights disclosed in this chapter can be used to substantially improve the performance of future "collective selective" groups, it does not enable best-possible performance. The service qualities of traditional groups cannot be predicted or guaranteed because the random destinations of passengers control virtually all car movements. Particularly during periods of heavy traffic – when efficiency is most important – their performance is defined by chance and their drive- and door systems, i.e. "muscle power".

In the next chapter we will review another inherent and negative characteristic of traditional groups: The “bunching” of cars.

In the remainder of this chapter we will not consider small cars but review traditional elevator planning for mid- and high rise elevators and the influence of large floor populations.

Planning a 4-car Low Rise group for a building with a population of 100 persons/floor

We have seen that the 4-car group of the example on page 2 can serve 12 upper floors if the population is 75 persons/floor and the expected maximum arrival rate 14 %. If the population per floor is assumed to be 100 the contract load of the elevators must be increased or the number of floors served reduced, or both, to maintain a DC5 of 14 %.

The CPT below assumes the group serves 12 upper floors and varies the car load in persons to find which car load yields a DC5 of 14 % that will match the expected maximum arrival rate.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 **4-cars**	ATTD	Dep. INT	Cycle INT	AWT
Contract load: variable														Chap5dia4	
12	12	1200	48	2.5	16	12	9.0	149.7	58.3	149.7	10.7	77.0	37.4	37.4	18.7
12	12	1200	48	2.5	20	12	9.9	165.1	63.9	165.1	12.1	84.5	41.3	41.3	20.6
12	12	1200	48	2.5	24	12	10.5	178.3	68.5	178.3	13.5	90.8	44.6	44.6	22.3
12	12	1200	48	2.5	26	12	10.8	184.3	70.5	184.3	14.1	93.5	46.1	46.1	23.0

The top line shows that a car load of 16 persons yields a DC5 of 10.7 % only. With 12 upper floors the car load has to be increased 26 persons to achieve a DC5 of 14.1 %.

The nominal contract load would have to be 2600 KG. A contract load of 2600 KG is unusual, will cause high costs and take up much building space.

Please note that increasing the car load from 16 to 26 persons (+62.5 %) increases the DC5 from 10.7 to 14.1 % (+32 %). These data confirm that the efficiency of "collective selective" elevators decreases when the average car load in persons increases. The interdependence between contract load and group efficiency is easily overlooked when elevator planning is done with individual traffic calculations instead of CPT 's.

The next CPT's show the performance parameters of groups serving 11 and alternatively 10 upper floors. The car load varies to find the number of floors that can be served by a 4-car group with an acceptable contract load and a DC5 of 14 %.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: variable														Chap5dia5	
11	11	1100	44	2.5	14	11	8.1	135.1	52.8	135.1	11.3	69.7	33.8	33.8	16.9
11	11	1100	44	2.5	16	11	8.6	143.4	55.9	143.4	12.2	73.8	35.9	35.8	17.9
11	11	1100	44	2.5	18	11	9.0	150.9	58.6	150.9	13.0	77.5	37.7	37.7	18.9
11	11	1100	44	2.5	20	11	9.4	157.8	61.0	157.8	13.8	80.7	39.5	39.4	19.7
10	10	1000	40	2.5	14	10	7.7	129.0	50.5	129.0	13.0	66.6	32.3	32.2	16.1
10	10	1000	40	2.5	16	10	8.1	136.7	53.3	136.7	14.0	70.4	34.2	34.2	17.1
10	10	1000	40	2.5	18	10	8.5	143.7	55.8	143.7	15.0	73.8	35.9	35.9	18.0
10	10	1000	40	2.5	20	10	8.8	150.1	58.0	150.1	16.0	76.8	37.5	37.5	18.8

For 11 upper floors and a maximum car load of 20 persons the DC5 is 13.8 %. This alternative requires a contract load of 2000 KG. On the basis of traditional traffic calculations the combination 10 upper floors and contract load of 1600 KG is usually the preferred configuration for the assumed 14 % arrival rate. These comparisons give us an insight why a contract load of 1600 KG is virtually a world-standard for existing "collective selective" groups.

Planning Mid Rise and High Rise groups (75 persons/floor)

Planning 4-car groups of "collective selective" elevators for much taller buildings is just as easy. The CPT's below review Mid Rise groups for a building with a population of 75 persons per floor and an expected maximum arrival rate of 14 %.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: 1600 KG														Chap5dia6	
9	21	675	84	3.15	16	9	7.6	158.0	66.0	158.0	18.0	85.7	39.5	39.5	19.7
10	22	750	88	3.15	16	10	8.1	164.7	68.8	164.7	15.5	89.4	41.2	41.2	20.6
11	23	825	92	3.15	16	11	8.6	170.9	71.3	170.9	13.6	92.7	42.7	42.7	21.4
12	24	900	96	3.15	16	12	9.0	176.7	73.6	176.7	12.1	95.7	44.2	44.2	22.1
9	21	675	84	4	16	9	7.6	150.6	63.4	150.6	18.9	82.2	37.7	37.6	18.8
10	22	750	88	4	16	10	8.1	157.0	66.1	157.0	16.3	85.7	39.3	39.3	19.6
11	23	825	92	4	16	11	8.6	163.0	68.6	163.0	14.3	89.0	40.8	40.7	20.4
12	24	900	96	4	16	12	9.0	168.5	70.9	168.5	12.7	92.0	42.1	42.1	21.1
9	21	675	84	5	16	9	7.6	145.8	61.8	145.8	19.5	80.0	36.5	36.5	18.2
10	22	750	88	5	16	10	8.1	152.1	64.6	152.1	16.8	83.6	38.0	38.0	19.0
11	23	825	92	5	16	11	8.6	157.9	67.0	157.9	14.7	86.7	39.5	39.5	19.7
12	24	900	96	5	16	12	9.0	163.2	69.3	163.2	13.1	89.7	40.8	40.8	20.4

Above CPT's enable comparison of groups serving 9 to 12 upper floors and speeds of 3.15 to 5 m/sec. The group with 11 upper floors and speed 3.15 m/sec. Yields a DC5 of 13.6 %. A bit too low for the expected maximum arrival rate. When we increase the speed to 4m/sec the DC5 improves to 14.3 % and matches the expected arrival rate. Any PC with the software to make CPT's can produce these tables in seconds. It is clear that the terms simple and inflexible are applicable to qualify the planning of groups of "collective selective" elevators.

The Appendix to this chapter shows the analysis for the High Rise group.

In case this building is planned on the basis of a maximum arrival rate of 12.5 % instead of 14 % each group could serve one more floor and the total number of upper floors could be increased from 33 to 36. The CPT's for this alternative showing all 3 groups is also included in the Appendix.

DOWN PEAK Transport Capacity (TC5)

This book uses the abbreviation TC5 for the DOWN Transport Capacity in % of the population per 5 minutes to distinguish this characteristic from the DC5. The maximum TC5 of "collective selective" elevators can be up to 50 % higher than their maximum DC5 if we assume cars may reach full load after few stops and then travel non-stop to floor zero.

In Chapter 16: "Module for heavy simultaneous UP and DOWN traffic" the service qualities for DOWN passengers of groups with "collective selective" and "intelligent destination" controls are reviewed in detail.

Conclusions

- The examples of this chapter show that traditional planning methods for groups of "collective selective" elevators are simple and inflexible because the estimated population and the expected maximum arrival rate of passengers dictate the configuration of groups.

- Elevator "brain power" cannot influence the UP PEAK performance of "collective selective" elevators.

- The remarkable congruence of existing 4-car groups with "collective selective" controls in existing buildings is completely logical. It simply is the best compromise for 4-car groups with controls that are not intelligent. All existing traditional groups with SIX or more <u>large</u> cars are inefficient**.**

- It is probably true that the majority of traditional groups in existing buildings deliver service qualities that must be rated as marginal or worse during periods of heavy traffic.

Appendix: Comparative Performance Tables for High Rise Group and all three groups in case the maximum arrival rate is 12.5 % instead of 14 %.

Appendix to chapter 5: “Traditional elevator planning”

Low, Mid and High Rise groups if the population is 75 persons per floor and expected maximum arrival rate 14%

	DC5	Speed
Low Rise serves 12 upper floors: 0-1-2-3...........11-12	14.2 %	2.5 m/sec.
Mid Rise serves 11 upper floors: 0-13-14...........22-23	14.2 %	4.0 m/sec.
High Rise serves 10 upper floors: 0-24-25..........32-33	14.3 %	4.0 m/sec.

The CPT below shows that a High Rise group with a contract speed of 4 m/sec can serve 10 upper floors if the expected maximum arrival rate is 14 %.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: 1600 KG														Chap5dia7	
9	32	675	128	4	16	9	7.6	172.6	74.4	172.6	16.5	96.0	43.2	43.1	21.6
10	33	750	132	4	16	10	8.1	179.0	77.1	179.0	14.3	99.5	44.8	44.8	22.4
11	34	825	136	4	16	11	8.6	185.0	79.6	185.0	12.6	102.7	46.3	46.2	23.1
12	35	900	140	4	16	12	9.0	190.5	81.9	190.5	11.2	105.7	47.6	47.6	23.8

Low, Mid and High Rise groups if the population is 75 persons per floor and expected maximum arrival rate 12.5 %.

	DC5	Speed
Low Rise serves 13 upper floors: 0-1-2-3...........12-13	12.6 %	2.5 m/sec.
Mid Rise serves 12 upper floors: 0-14-14...........24-25	12.5 %	4.0 m/sec.
High Rise serves 11 upper floors: 0-26-27..........35-36	13.0 %	5.0 m/sec.

The CPT’s below show the selection criteria for each group.

Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: 1600 KG														Chap5dia8	
12	12	900	48	2.5	16	12	9.0	149.7	58.3	149.7	14.2	77.0	37.4	37.4	18.7
13	13	975	52	2.5	16	13	9.4	155.7	60.6	155.7	12.6	80.1	38.9	38.9	19.5
14	14	1050	56	2.5	16	14	9.7	161.5	62.7	161.5	11.3	82.9	40.4	40.4	20.2
11	24	825	96	4	16	11	8.6	165.0	69.6	165.0	14.1	90.2	41.3	41.2	20.6
12	25	900	100	4	16	12	9.0	170.5	71.9	170.5	12.5	93.2	42.6	42.6	21.3
13	26	975	104	4	16	13	9.4	175.5	73.9	175.5	11.2	95.8	43.9	43.9	21.9
10	35	750	140	5	16	10	8.1	172.9	75.0	172.9	14.8	96.6	43.2	43.2	21.6
11	36	825	144	5	16	11	8.6	178.7	77.4	178.7	13.0	99.7	44.7	44.7	22.3
12	37	900	148	5	16	12	9.0	184.0	79.7	184.0	11.6	102.7	46.0	46.0	23.0

Planning "collective selective" elevators is really as simple as shown on this page.

NB: The CPT's in this book are computer generated and small differences with “manually” calculated data may occur. These are caused by the use of rounded data in manual calculations.