Chapter 8: Planning "intelligent destination elevators"

Summary: Elevator planning is a search for the best-possible compromise between several interdependent and conflicting considerations. Its objective is defining the best-possible building plan / group configuration for a specific project that delivers transport capacities and time-dependent service qualities for a defined range of traffic conditions that can be contractually guaranteed. The required building volume shall be as small as possible to maximize rentable areas. Capital-, maintenance- and energy costs shall be as low as possible. "Intelligent destination elevators" enable the best-possible compromise for any building because "Intelligent destination" group controls can simultaneously control the efficiency and the service qualities of any group under all traffic conditions.

An introduction to elevator planning

A group of elevators is always a compromise between several interdependent and conflicting considerations because the elevators must deliver under all traffic conditions the required transport capacities and best-possible time-dependent service qualities but occupy the least possible building space. Capital-, maintenance- and energy costs should be as low as possible.

Planning problems increase exponentially with the building height. When a building requires two or more groups of elevators the hoistways of the groups to the Higher Zones pass through the Lower Zones increasing the building volume required for elevators. Rentable floor areas are reduced. High Rise elevators cost far more but have a smaller transport capacity on account of longer travel distances.

Buildings with several zones usually employ one or even two groups of **express elevators to sky lobbies** to economize the building volume required for elevators. Express elevators are the ultimate "destination" elevators. With double- or multi-deck cars they can transport large numbers of passengers through one set of hoistways.

With today's elevator technology the **maximum height of a building is determined by its "footprint"**, i.e. the dimensions of the building site. A building with a small footprint faces the problem of finding enough space for groups of elevators sooner than a building with a large footprint. This implies: **The relationship between the "footprint" of a building and the "footprints" of the groups of elevators serving this building is decisive for the maximum possible building height.**

Building sites on which the construction of tall buildings is possible and permitted are rare and expensive. The total costs for a site and its development usually demand that a new building must deliver the maximum rentable area. This implies **best-possible elevator planning is essential for the best-possible return on investment.**

Building planning criteria

This chapter assumes that groups of "intelligent destination elevators" must be able to satisfy UP PEAK traffic densities of 12.5 % of the population per 5 minutes. Chapter 16: "Module for heavy simultaneous UP and DOWN traffic", proves that these groups can provide UP and DOWN passengers with equivalent time-dependent service qualities under all traffic conditions. Groups with a DC5 of 12.5 % can deliver much higher DOWN PEAK transport capacities (TC5's).

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The DC5 of 12.5 % assumed as the prime planning criterion for this chapter may be considered conservative because the introduction of flexible working hours and new working habits enabled by modern communication technologies have probably reduced traffic peaks in comparison with the peaks of 10 or 20 years ago.

The planning examples of this chapter compare the service qualities of groups with "Intelligent destination" controls with the service qualities of "collective selective" (traditional) groups. These comparisons are based on identical traffic densities.

The study of comparisons is demanding, however, when several conflicting considerations are involved it is essential to make these comparisons.

"Intelligent destination groups" with smaller cars improve service qualities, reduce costs and occupy less space.

The following will prove that a 4-car 1200 KG group of "intelligent destination elevators" serving a 13 storey building with a population of 975 persons can outperform a 4-car group of "collective selective" elevators with a contract load of 1600 KG.

The 4-car group of "collective selective" elevators with a **contract load of 1600 KG** has a **maximum DC5 of 12.6 %**. The data line below shows the UP PEAK performance parameters of this specific group.

Nr flrs	Top	Pop.	Trav.	Contr.	Car	Sel.	Prob.	Av. RTT	ATTC	Cycle	DC5	ATTD	Dep.	Cycle	AWT
served	floor			speed	load	floors	stops	L & H		RTT	**4-cars**		INT	INT	
Contract load: 1600 KG (20 persons)														Chap8dia1	
13	13	975	52	2.5	16.0	13	9.4	155.7	60.6	155.7	12.6	80.1	38.9	38.9	19.5

The Comparative Performance Table (CPT) below shows that an identical group of "intelligent destination elevators" except for the **contract load of 1200 KG** has THREE options for delivering a DC5 of 12.6 %. Option "selected floors" = 6.5 is probably the preferred solution. The "selected floors" pattern 6.5 can be seen in Chapter 14 page 3.

Nr flrs	Top	Pop.	Trav.	Contr.	Car	Sel.	Prob.	Av. RTT	ATTC	Cycle	DC5	ATTD	Dep.	Cycle	AWT
served	floor			speed	load	floors	stops	L & H		RTT	**4-cars**		INT	INT	
Contract load: 1200 KG (15 persons)														Chap8dia2	
13	13	975	52	2.5	12.0	13	8.0	136.1	52.9	136.1	10.8	69.9	34.0	34.0	17.0
13	13	975	52	2.5	12.0	12	7.8	134.0	52.0	145.2	11.0	70.1	33.5	36.3	18.1
13	13	975	52	2.5	12.0	11	7.5	131.4	50.9	155.2	11.2	70.3	32.9	38.8	19.4
13	13	975	52	2.5	12.0	10	7.2	128.2	49.6	166.7	11.5	70.4	32.1	41.7	20.8
13	13	975	52	2.5	12.0	9	6.8	124.5	48.2	179.8	11.9	70.7	31.1	45.0	22.5
13	13	975	52	2.5	12.0	8	6.4	120.1	46.6	195.2	12.3	71.0	30.0	48.8	24.4
13	13	975	52	2.5	10.5	6.5	5.4	102.6	41.9	205.2	12.6	67.6	25.7	51.3	25.7
13	13	975	52	2.5	8.5	4.33	3.9	83.3	34.9	249.8	12.6	66.1	20.8	62.5	31.2
13	13	975	52	2.5	7.5	3.25	3.0	73.1	31.1	292.2	12.6	67.6	18.3	73.1	36.5
13	13	975	52	2.5	6.4	2.17	2.1	62.1	26.9	372.4	12.7	73.4	15.5	93.1	46.5
13	13	975	52	2.5	5.0	1	1.0	48.4	21.7	629.3	12.7	100.4	12.1	157.3	78.7

To deliver a DC5 of 12.6 % the number of "selected floors" must be reduced to 6.5. For this option the realistic ATTC is 41.9 seconds and the ATTD 67.6 seconds. These times are much shorter than the comparable values of the traditional group. The theoretical minimum AWT of the traditional group appears to be shorter, however, its real AWT will be much longer for reasons explained in Chapter 6: “Average Waiting Time (AWT) the misleading parameter”.

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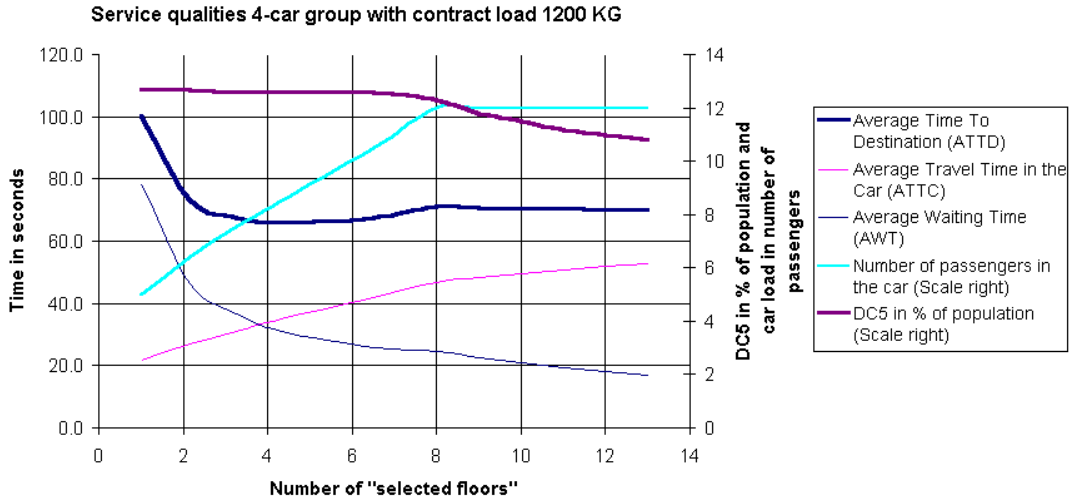
The theoretical minimum AWT's for "intelligent destination" elevators as stated in CPT's are calculated on the basis of **rigid adherence to patterns.** Their realistic minimum AWT's will be shorter on account of the "First come first served" mode of car operation.

The calculated service qualities of above CPT are shown below as graphs.



The travel comfort for passengers of the "intelligent destination elevators" is better because the mode of car operation "selected floors" = 6.5 reduces the average **number of "probable stops" from 9.4 to 5.4**. This means the group will operate with low numbers for permitted stops. The load factor is 70 % instead of 80 %, i.e. cars are less full. Control of the number of stops implies consistent Round Trip Times (RTT's) and INTERVALS. This means the bandwidths of all time-dependent service qualities are optimized. The traditional group operates with full cars and is in fact **out of control**.

The **advantages** of 1200 KG group of "intelligent destination elevators" are:

- Passengers arrive at their destinations earlier
- Travel times in the cars are substantially reduced
- Average car loads are reduced
- Average Waiting Times will be much more consistent
- The group can substantially increase its DC5.
- The "footprint" of the 1200 KG group including the lobby area will be approximately 5 square meters smaller
- Capital, maintenance and energy costs will be substantially reduced.

SIX-car groups with small cars

The outstanding characteristics of "intelligent destination elevators" will encourage the use of 6-car groups with even smaller cars because a **taxi-type service** instead of bus-service will be attractive if the "footprint" of the group is reasonably small. The following example demonstrates that a **6-car group** of "intelligent destination elevators" with a contract load that equals **half of the contract load** of a 4-car group of "collective selective" elevators can serve at least one more floor than the 4-car "collective selective" group **and deliver substantially improved service qualities**.

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The basis for our comparison will again be the 4-car group of **1600 KG** "collective selective" elevators **serving 13 upper floors.** Its UP PEAK performance parameters are stated below.

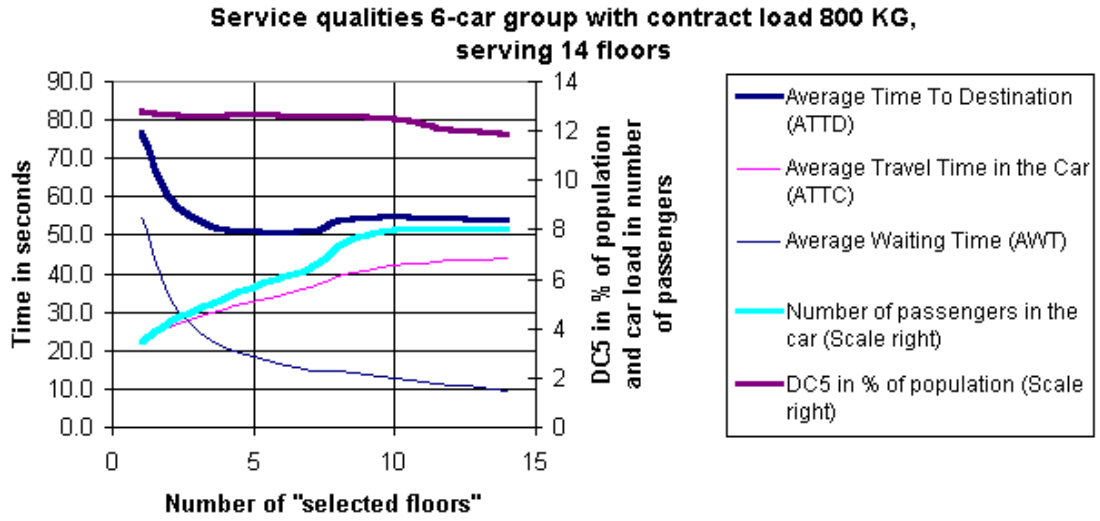
Nr flrs served	Top floor	Pop.	Trav.	Contr. speed	Car load	Sel. floors	Prob. stops	Av. RTT L & H	ATTC	Cycle RTT	DC5 4-cars	ATTD	Dep. INT	Cycle INT	AWT
Contract load: 1600 KG (20 persons)														Chap8dia1	
13	13	975	52	2.5	16.0	13	9.4	155.7	60.6	155.7	12.6	80.1	38.9	38.9	19.5

The above parameters will be compared with those of a **6-car group of 800 KG** "intelligent destination elevators" **serving 14 floors and a population of 1050 persons**. Please note that **the "footprint" of a 6-car group of 800 KG elevators equals the "footprint" of a 4-car group of 1600 KG elevators**.

The CPT and graphs below shows the options of the 6-car group for delivering DC5's of 12.6 %, i.e. the absolute maximum DC5 of the 4-car group.

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: 800 KG (10 persons)														Chap8 dia4	
14	14	1050	56	2.5	8	14	6.3	115.5	44.2	115.5	11.9	53.8	19.3	19.2	9.6
14	14	1050	56	2.5	8	13	6.1	114.5	43.8	123.3	12.0	54.1	19.1	20.5	10.3
14	14	1050	56	2.5	8	12	6.0	113.3	43.4	132.2	12.1	54.4	18.9	22.0	11.0
14	14	1050	56	2.5	8	11	5.9	111.4	42.8	141.8	12.3	54.6	18.6	23.6	11.8
14	14	1050	56	2.5	8	10	5.7	109.5	42.3	153.4	12.5	55.1	18.3	25.6	12.8
14	14	1050	56	2.5	7.8	9	5.4	105.7	40.9	164.5	12.6	54.6	17.6	27.4	13.7
14	14	1050	56	2.5	7.4	8	5.0	100.7	39.4	176.2	12.6	54.1	16.8	29.4	14.7
14	14	1050	56	2.5	6.5	7	4.4	88.5	36.6	176.9	12.6	51.3	14.8	29.5	14.7
14	14	1050	56	2.5	5.6	4.67	3.4	75.7	32.4	227.1	12.7	51.3	12.6	37.9	18.9
14	14	1050	56	2.5	5	3.5	2.8	68.0	29.7	272.2	12.6	52.4	11.3	45.4	22.7
14	14	1050	56	2.5	4.3	2	1.9	58.1	26.2	406.7	12.7	60.1	9.7	67.8	33.9
14	14	1050	56	2.5	3.5	1	1.0	47.0	21.8	658.4	12.8	76.7	7.8	109.7	54.9

The calculated service qualities of above CPT are shown below as graphs.



The group delivers DC5's of 12.6 % from "selected floors" = 9 and below. Please note that the use of the direct trip pattern "selected floors" = 7 will not be required because

the use of a permitted number of stops of 6 or 7 will deliver even better time-dependent service qualities.

The table below shows a direct comparison between the data of the 1600 KG 4-car "collective selective" group and the 800 KG 6-car group of "intelligent destination elevators" assuming this group uses "selected floors" = 7 to satisfy the prevailing UP PEAK traffic density of 12.6 %.

Group control	Col. sel.	Intelligent	
Number of cars	4	6	
Contract load (maximum in KG)	1600	800	
Contract load (maximum in persons)	20	10	
Number of floors served	**13**	**14**	
Travel	52	56	
Population served	975	1050	
"Footprint" of group in M^2 excluding lobby	32	32	
Number of "selected floors"	13	7	
Av. number of passengers in the car	16.0	6.5	
Load factor	80%	65%	
"probable stops"	9.4	4.4	
DC5	12.6	12.6	
ATTC	60.6	36.6	
Theoretical minimum AWT	19.5	14.7	
ATTD	80.0	51.3	Chap8dia5

The capital cost of the 6-car group will be higher but the additional floor served reduces the capital cost per floor. **The value of the additional floor served, the service quality improvements and energy savings will be the decisive factors of this comparison**.

Although the comparison shows that **all service quality data of the 6-car group are much better** it is not a fair comparison for the "intelligent destination elevators". The real AWT of the "collective selective" group is likely to be much longer than the theoretical minimum of 19.5 seconds. The AWT of the "intelligent destination elevators" is much more realistic because the "First come first served" mode of car operation improves all time-dependent service qualities. The **Waiting Time bandwidths of the 6-car group will be much narrower and at a level well below the bandwidths of the "collective selective" group**.

The column “carload” of the CPT on the previous page provides data for the probable number of passengers in case the **permitted number of destinations for a specific UP trip is set in relation to data in the column "probable stops"**. This reversal of interpretation of CPT’s enables control of the RTT by setting the permitted number of stops/destinations that will be accepted for the NEXT departing car. Passengers are served on a "First come first served" basis and service denial is delayed till the last possible moment.

This mode of car operation may slightly increase the average RTT, however, the operational data structure mentioned in the previous chapter will disclose and confirm that all time-dependent service qualities are substantially improved by these control methods.

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Reconsideration of the 36 storey building configured in Chapter 5

Chapter 5: “Traditional elevator planning” showed that three 4-car groups of 1600 KG "collective selective" elevators can serve a 36 storey building if the maximum arrival rate is assumed to be 12.5 %. The performance parameters of all three groups serving the **36 storey building** are stated in the table below.

Nr flrs	Top	Pop.	Trav.	Contr.	Car	Sel.	Prob.	Av. RTT	ATTC	Cycle	DC5	ATTD	Dep.	Cycle	AWT
served	floor			speed	load	floors	stops	L & H		RTT	**4-cars**		INT	INT	
Contract load: 1600 KG (20 persons, "collective selective" control)														Chap8dia7	
Low Rise group															
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
Mid Rise group															
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
High Rise group															
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
					Averages for:			ATTC	70.0		ATTD	91.0		AWT	21.0

The first example of this chapter shows that the LOW RISE group of the 36 storey building can be replaced by a 4-car group of 1200 KG "intelligent destination elevators". The MID and HIGH RISE groups can be replaced by 1200 KG "intelligent destination elevators" as well. The CPT below shows all performance parameters in case the 36 storey building is served by groups of 1200 KG "intelligent destination elevators".

Nr flrs	Top	Pop.	Trav.	Contr.	Car	Sel.	Prob.	Av. RTT	ATTC	Cycle	DC5	ATTD	Dep.	Cycle	AWT
served	floor			speed	load	floors	stops	L & H		RTT	**4-cars**		INT	INT	
Contract load: 1200 KG (15 persons, "intelligent destination" control)														Chap8dia8	
Low Rise group															
13	13	975	52	2.5	10.5	6.5	5.4	102.6	41.9	205.2	12.6	67.6	25.7	51.3	25.7
Mid Rise group															
12	25	900	100	5	11	6	5.2	116.5	50.8	233.0	12.6	79.9	29.1	58.2	29.1
High Rise group															
11	36	825	144	6	10.7	5.5	4.8	123.6	55.1	247.2	12.6	86.0	30.9	61.8	30.9
					Averages for:			ATTC	49.2		ATTD	77.8		AWT	28.6

The parameters of the "intelligent destination elevators" are based on direct trip patterns that serve all floors with TWO direct trips. The contract speeds of the MID- and HIGH RISE groups are increased to 5 and 6 m/second. This is necessary because the efficiency improvement of "Intelligent destination" controls does not affect the flight times of the cars for the UP trip to the lowest upper floor nor the return trip, i.e. the **efficiency improvement is smaller for Mid and HIGH rise groups**.

Comparison of the above data shows that passengers arrive at their destinations an average of 13.2 seconds earlier. The AWT’s appear to be longer, but as mentioned earlier this direct comparison does not do justice to the "intelligent destination elevators".

The average ATTC is 20.8 seconds shorter. The average load factor is 72 %. The cars make about 4 stops less! Passengers of the "intelligent destination elevators" enjoy significantly improved comfort, particularly if we take into consideration that the "collective selective" group is in fact out of control when the UP traffic density is 12.6 %.

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Relationship group footprint and total rentable area

The footprints of the 1200 KG intelligent groups are approximately 1 m^2 smaller than the footprints of the 1600 KG elevators. If we assume that the lobby area of each 4-car group can be reduced by a modest 1 m^2 as well, the total footprint saving will be 5 m^2 per group. For 3 groups the total footprint saving will be 15 m^2 per floor.

When the **core area** of the building is reduced by 15 m^2 the rentable area of each floor will increase accordingly. This implies the **total rentable area of the building increases by 37 X 15 = 555 m^2.** The total number of floors is 37, floor zero and 36 upper floors.

When the population per floor is 75 persons the rentable area per floor might be approximately 750 m^2, assuming a floor space of 10 m^2 per person. An increase of the rentable are with 15 m^2 per floor **increases the total rentable area of the building by two percent**.

The total cost of elevators for tall buildings usually is well below 10 % of the total building cost. The value of the increased rentable area will make "intelligent destination elevators" an outstanding investment.

Please note that in case the contract load of the 6-car group is increased from 800 KG to 1000 or 1200 KG the time-dependent service qualities will not improve. Passenger comfort will be improved because the cars will never be full.

If the contract load of a group is increased it can serve an additional floor(s), however, time-dependent service qualities will be less good. These remarks show that intelligent destination group controls **completely change the range of planning options for new buildings**.

Conversion of "collective selective" groups to "Intelligent destination" group control

When "Intelligent destination" group controls become available their first application will be conversion of existing installations. These installations will do a better job of confirming their performance than the examples of this book.

"Intelligent destination elevators" will be able to operate exactly like "collective selective" groups, i.e. the building management can demonstrate their advantages by alternating the mode of car operation on consecutive days. This type of test will probably be stopped soon by the protests of passengers.

Conversion of 4-car groups into 6-car groups

Existing 4-large-car groups can be converted into 6-small-car groups that will deliver major improvements of service qualities because service frequencies increase by up to 100 % during periods of heavy traffic. Three small cars can be installed in each hoist-way for two large cars. This means that conversion into a 5-car group (2 large and 3 small cars) is another option.

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Future elevator planning

The examples of this chapter are only a few of many new planning options that will become possible when "Intelligent destination" group controls are available. **Groups with more but relatively small cars will become particularly attractive** in view of their outstanding service qualities and their best-possible footprint in relation to the number of floors served.

Groups of Double Deck local elevators will probably receive renewed attention because "Intelligent destination" group controls will enable better use and coordination of DD cars. **Local groups with DD cars or Triple Deck cars offer great potential for minimizing the building volume required for elevators**.

One aspect of building planning will not change: **The quality of elevator services is decided during the building planning phase.** Estimates of the future populations of a building will remain a most important input for elevator planning. Problems that building populations may cause 10 or 20 years later should be addressed during the planning phase. On the basis of these estimates the elevator contractors will be expected **to contractually guarantee performance standards and service qualities.**

Building planning will be facilitated by the CPT “tool” introduced by this book. Traffic simulation will be another important “tool”. The probably high degree of correlation between CPT's and data obtained by simulation may well reduce the need for traffic simulation.

The concept: **several cars moving on linear motor tracks in few hoistways** is exiting, however, when a car decelerates and stops the cars behind must decelerate and stop as well to maintain a minimum safety distance between cars. This implies that after stopping a car should get out of the way, i.e. move horizontally towards the landing doors, for unloading and loading of passengers. In case a car does not get out of the way the cars behind cannot continue their journey. For express elevators linear motor drives may be feasible but for local groups their application appears to be unlikely.

Local elevators with two or more decks can save building space by other means. For example a 45 storey apartment building could be served by THREE triple deck elevators. Each one of the three lowest floors of such a building would be the main entrance and car parking floor for 15 levels of apartments. Each car deck serves one main floor and15 levels of apartments. For an apartment building this is a viable and simple solution. With "Intelligent destination" group controls a 3-car group will be able to satisfy all traffic conditions.

The combination of multi-deck local and multi-deck express elevators offers immediate solutions for very tall buildings. The odd and even floors of a building can form separate building zones and each zone is served by a specific deck of a DD group. With 6-car groups service qualities will be very good.

In office buildings THREE adjacent floor levels can be assigned to 3 zones. Floors 1, 4,7,10 etc would form ONE zone and floors 2, 5,8,11 etc a second zone. Floors 3, 6,9,12 etc would be the third building zone. In buildings that are planned this way groups of SIX relatively small **3-deck cars** can deliver outstanding service qualities. For 30 to 40 storey buildings this type of planning will enable major space savings.