Chapter E: The new World Trade Center towers, New York:
The consequences of bad planning.

Introduction.

Groups of elevators are infamous for long waiting times, particularly during periods of heavy traffic. Elevator companies apparently intend to perpetuate this feature. It is obvious that both waiting- and travel times should be as short as possible, and their total, i.e. the time to destination, should be the shortest possible optimum under all traffic conditions. Unfortunately, elevator companies promote large cars, i.e. they indirectly promote configurations with few large cars instead of groups with more and smaller cars. These configurations imply a direct conflict with the inherent relativity of group characteristics and make optimal time-dependent service qualities impossible.

Group E of tower 4 of the World Trade Center in New York is an example of such a group. This chapter explains and proves why outdated (empirical) group planning methods and group controls make optimal performance impossible. For this reason, this book claims: The design and installation of inefficient groups continues.

Incomplete information.

The September 2014 issue of ELEVATOR WORLD featured an article about the grand opening of Tower 4 of the World Trade Center in New York on 13 November 2013. This article provides detailed information of the configurations of the five groups of single-deck elevators, which serve five building zones. A copy of this article is available under downloads.

The article concentrates on the management and complexities of executing this major building within an aggressive time schedule. The planning and functionality of its vertical transportation systems is limited to the opaque statement: “Ownership was sold on the equipment’s features and benefits starting with Schindler’s PORT destination-dispatching technology.”

This article has induced the author to study the websites of all parties involved in the new WTC buildings. He searched for information about features and benefits, i.e. any information or explanation of the operations and performance of the groups of elevators, which serve this building. Which requirements defined the planning of WTC 4? The results were disappointing; none of the websites communicates pride, satisfaction, or expectations in respect of the efficiency or service qualities of the groups of elevators. The elevators of each tower are marked on the floor plans just like the seats and desks for the people working in these buildings.

Objectives of vertical transportation systems.

The purpose of buildings is to provide space for living and working. Building populations and their activities are the essence of tall buildings. Groups of elevators form a network that facilitates these activities. <u>The efficiency and functionality of groups are a main element of the factors, which define the quality of tall buildings</u>. Why the planners of the new WTC buildings have nothing to say about the vertical transportation systems is hard to understand. Does it mean the performance of groups of elevators is perfectly clear and further information or discussion is superfluous? It seems each party involved in the planning of groups has its own reasons for avoiding the topic of group performance.

Performance insecurity.

Architects and building owners are insecure in respect of group planning and performance. They are not yet aware that the planning of groups with intelligent destination controls is an exact task, which assures that each group will deliver its group specific optimal performance, and contractually guaranteed service qualities.

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The main cause of this insecurity are elevator companies, which ignore the inherent relativity of group characteristics, i.e. the knowledge that group performance is predictable and controllable. Apparently, they feel optimal group performance is not in their best interest. This feeling is understandable; optimal group performance implies the performance of groups, i.e. the software and logic of groups, is standardized. This disturbing innovation of group control systems will affect competition for new buildings and the maintenance of existing groups. These concerns are probably the reasons why the topic of group performance is taboo.

Most elevator consultants and industry associations are probably aware of the inherent relativity of group characteristics; however, it seems they also prefer the status quo.

This chapter will analyze group E of WTC 4 to prove and demonstrate why and how intelligent group controls define the configuration of groups, their time-dependent service qualities and efficiency.

Before doing so this chapter will review other planning aspects of group E, which reduce its efficiency. These aspects, which affect the performance of group E, apply for all groups of the new WTC buildings.

WTC 4 and WTC 1: The absence of Sky Lobbies.

The original WTC buildings featured double-deck express elevators to Sky Lobbies. This innovative concept is a sound basis for improving the efficiency of tall buildings. The new WTC buildings, including WTC 4, avoid the use of Sky Lobbies. Exception: Tower WTC 1, which features a Sky Lobby on level 64. A group of TEN single-deck express elevators connects this Sky Lobby with the Main Lobby on floor 1. A separate single-deck 5-car express group connects the Main lobby with the ONE WORLD OBSERVATORY on level 100. These two express groups, which do not and cannot support each other, are from a safety, efficiency, and operational point of view, a major planning fault. If a building requires two Sky Lobbies, one intelligent express group can and should serve both Sky Lobbies. An intelligent group assigns passengers to specific cars, i.e. can control traffic to and from two Sky Lobbies. This ability is important for emergencies. It is not known why the express elevators have single-deck cars. Double-deck cars have much higher transport capacities and reduce building space requirements. These planning faults of WTC 1 are incomprehensible.

WTC 4: Zone transfer floors.

Groups B, C, D and E have zone transfer floors on levels 42, 51 and 62. Passengers to and from floors 1 and 62 will always use group E to benefit from direct trips. This means stops of group D at floor 62 will be limited to zone D inter-floor traffic. Traffic between building zones is usually negligible, consequently stops at floor 62 for zone transfer purposes will be rare. Floor 62 of group E is likely to attract traffic from floor 61 (zone D), because the direct trips of group E will be an attractive reward for a short walk up or down. Conclusion: Zone transfer floors do not improve vertical transportation systems; they negatively affect the performance of two groups. The author recommends abolishing the stop (doors) on floor 62 for group E to reduce its number of floors served to 10 and enhance its performance. The same recommendation is valid for the stops at floor 51 of group D and at floor 42 of group C.

Intelligent groups provide exact data of traffic between zones, because passengers of intelligent groups register destinations via their mobile phone for car assignment. Intelligent groups inform passengers of their next car assignment shortly before arrival on the transfer floor.

WTC 4: The entrances at floor C1.

Each group of WTC 4 has <u>one car</u> with an entrance on level C1. The purpose of this door is probably to facilitate direct trips to and from a car-parking area on floor C1 for VIP's. For the VIP's this implies long waiting times. During periods of heavy traffic, the loss of one, of only six or eight cars, for direct trips will negatively affect service qualities for other users. The entrances on floor C1 are likely to get little use, because two escalators and the hydraulic elevator F1 connect floor C1 with the main lobby.

WTC 4: Service elevators.

The three service elevators of WTC 4 serve an extremely high number of floors (68, 69 and 49). The numbers of stops, which are marked on the diagram (see article) with an x, are even higher. It seems unlikely that these elevators are suitable for automatic operation.

WTC 4: Performance evaluation of High Rise group E.

Appendix 1 presents a performance evaluation model for the 6-car group E with contract load 3500 lbs. = 1600 KG and contract speed 1800 fpm = 9 mps. The DDFT table states the door-to-door flight times for all possible travel distances, which facilitate round trip time (RTT) calculations for any round trip. The figures 1 in the line "Stops" indicate a car stop. The permitted destinations, i.e. stops, during each round trip are defined by the time of call entry (first-come first-served). The author trusts this EXCEL calculation model is self-explanatory. This model enables readers to calculate the service qualities for any configuration of group E and assumed traffic densities. The assumed numbers of passengers, which demand service during a specific departure interval, is an indirect method to define traffic densities.

The calculation of Appendix 1 is valid for a simultaneous up and down traffic density of approximately 4 % of the population (1540 persons) per 5 minutes. For this traffic density, an intelligent 6-car group can guarantee an average RTT of 205.8 s, an average waiting time of 19.4 s and an average time to destination of 91.5 s for up and down going passengers. At which floors the cars stop has little effect on these data. If we increase the assumed number of incoming/outgoing passengers to 9 the average RTT with passengers increases by 8 seconds to 213.8 s, traffic densities to 4,92 %, the average waiting time to 25.3 s and the average time to destination to 99.4 s. The higher traffic density implies that an average of 1.9 persons, of the assumed number of nine passengers per interval, are assigned to the second available car, increasing the average waiting time from 19.4 to 25.3 s.

An intelligent group can contractually guarantee the calculated service qualities for the assumed traffic densities. The performance of an intelligent group will at least be slightly better than calculated because the calculation method is conservative.

Appendix 2 presents a performance calculation for an alternative 9-car group with a contract load of 800 KG and the same contract speed of 9 mps. The floor area defined by the "footprint" of the hoist ways of six 1600 KG cars of group E permits an alternative configuration with nine 800 KG elevators. This alternative configuration facilitates a substantial increase of service frequencies under all traffic conditions, i.e. the average interval between car arrivals and average waiting times are shorter. Short intervals imply less service demands per interval and per floor, i.e. less passengers waiting in lobbies. Elevator lobbies can be smaller. The calculation of appendix 2 proves that a 9-car intelligent group can accommodate heaviest simultaneous up and down traffic of 4.9 % of the population and guarantee average waiting times of 10.8 seconds and average times to destinations of 76.4 s. The comparable values for the 6-car intelligent group: 25.3 s. and 99.4 s, i.e. 130% and 30 % longer. The performance data of group E with a proprietary group control will be even worse, because large cars imply the group control does not minimize permitted stops.

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Simultaneous heavy up and down traffic is the most demanding traffic condition for any group, i.e. the 9-car group will deliver superior service qualities during all traffic conditions. The key to its better performance is more cars, which enable higher service frequencies and shorter intervals. Control of permitted stops facilitates optimizing of both transport capacities and time-dependent service qualities. During simultaneous up/down traffic of approximately 5 %, approximately 96 % of all passengers can board the first available car of the 9-car group.

An alternative 8-car group with a contract loads of 1000 KG would also outperform the existing 6-car group E, but with longer time-dependent service qualities in comparison with a 9-car group. The number of cars determine the time-dependent service qualities of groups, larger contract loads or car dimensions do not affect service qualities.

Mode of car operations.
Groups with cars moving in separate hoist ways have a great advantage: It is possible to control cars individually. Please envisage a group as a string of cars, which rotate in a building zone. Its speed of rotation should be as high as possible for maximizing transport capacities. The number of cars in the string defines the distances between cars, i.e. intervals and average waiting times. Cars can and do overtake each other. Control of the position of cars in their imaginary string is an important task of intelligent destination group controls. They permanently optimize the position of each car. A car, which reverses direction on a lower floor than the car ahead, assumes a revised position, which immediately affects the assignment of passengers. The intelligent control of permitted numbers of stops and assignment of individual passengers to specific cars controls the speed of rotation and all service qualities of intelligent groups.

Traffic simulation.
The author assumes that traffic simulation disclosed the performance of group E and its proprietary control during the planning phase, i.e. the performance data of group E are probably available. Apparently, these data were not suitable for publication. Comparisons of traffic simulation data (or recorded operational data) with the calculated data of appendix 1 are of interest. The author would gladly publish such comparisons in an additional appendix to this chapter. Please note that traffic simulation can confirm calculated performance data, however, they do not confirm that specific group configurations are the best possible solution for a new building. <u>Traffic simulation data provide misleading performance data, if group planning is not based on the inherent relativity of group characteristics</u>.

Traffic simulation facilitates performance comparisons of identical groups with different proprietary group control systems under identical traffic densities. Please refer to Chapter 10: Traffic simulation for more information.

Emergency evacuation.
The 9-car group requires 30.5 minutes for zone evacuation, the 6-car group 27.2. It is unlikely that the evacuation capacity was decisive for the 6-car configuration decision. An increase of the contract load to 900 KG and slightly larger cars, or deactivation or adjustment of maximum permitted carloads during emergencies, could have equalized evacuation capacities.

For evacuation of a building or a specific zone(s) all evacuation possibilities, including service elevators and stairways are decisive.

Building security.
To check the identity of all persons entering a building is probably the most important security

system for any building. Intelligent group controls are pre-destined to facilitate these systems, because they communicate direct with each building user via their mobile phone or similar device. Visitors must go to the reception (security) desk to identify themselves and declare the purpose of their visit etc. Intelligent group controls facilitate a permanent and comprehensive security system. These systems may have special identification abilities for an entire building or specific floors. The access of building users and visitors can be restricted to specific floors. Access can be time controlled. If a passenger leaves a car on a non-access-floor, or otherwise arrives on a non-access floor, the passenger and security are informed and can immediately communicate with each other. The possibilities are endless. Direct communication with all building users, via their mobile phones, implies that building managers can communicate instantaneously with the entire building population, or the population of an entire floor(s), or all personnel of a specific tenant and so on. In an emergency or other exceptional situation, these abilities will be most valuable.

Energy consumption.

In chapters 8 & 16, the author proved that the optimal contract load of intelligent 4-car groups is 1200 KG. Consequently, the substitution of a traditional 4-car group with a contract load of 1600 KG by a 4-car 1200 KG intelligent group will reduce energy consumption by approximately 25%. Substitution of an intelligent 4-car 1200 KG group by an intelligent 6-car 800 KG group will greatly improve time-dependent service qualities but will not greatly affect energy consumption. Alternative configurations for group E with nine (800 KG) or eight (1000 KG) cars would have entailed energy savings of up to 25 %, in comparison with the installed 6-car group.

Concluding remarks.

The flawed planning and bad performance of group E is typical for groups with low numbers of large cars. Unfortunately, this implies that virtually all existing groups are inefficient. During approximately 100 years, this inefficiency was excusable because the elevator industry was not aware of the inherent relativity of group characteristics. The optimal performance of groups of elevators appeared to be an insolvable problem. The author's discovery of the inherent relativity enabled the design of intelligent destination group controls, which has solved this problem. Although no elevator company or associated organization has refuted or denied the relativity of group characteristics, it seems elevator companies are confident they can ignore this knowledge and perpetuate the use of inefficient proprietary group controls to protect their maintenance business. This practice is inexcusable.

Approximately 10 years ago, the author began to inform leading elevator companies of the relativity of group characteristics and its potential for optimal group performance. The information included his control concepts for realizing intelligent destination group controls. After about two years of promotion, he realized elevator companies were adamant to the adoption of this innovation potential. Subsequently, he filed his own patent application in 2008. In 2012 and 2013, the U.S. Patent and Trademark Office granted patents for these concepts. After filing his patent application he continued to promote intelligent controls, wrote several articles for ELEVATOR WORLD on this topic, and in 2010 he published his book: "The planning and performance of groups of elevators" on his website elevatorgroupcontrols.com. During all these years, his objective was to induce an elevator company to adopt intelligent destination group controls. In 2016, he abandoned this objective, revised his website to start communicating the knowledge of the planning and performance of intelligent groups to building owners and architects.

It is most regrettable that elevator companies continue to obscure the real planning and performance potential of groups by pretending the control of groups continues to be an insolvable problem. This practice causes millions of passengers to waste time and increases the space- and energy requirements of groups. During the planning of tall buildings elevator companies and consultants should inform owners and architects about the relativity of group characteristics, i.e. the group configurations and intelligent control systems, which enable optimal group performance. By withholding this information, building planners receive incomplete, i.e. misleading information; a correct planning procedure is not possible. This practice implies that elevator companies intentionally degrade the performance of groups with flawed configurations and proprietary group controls, which cannot deliver optimal performance. Apparently, the only motivation to do so is the protection of maintenance activities. Clients may prefer groups with few large cars, worse service qualities and reduced efficiencies; however, elevator companies apparently do not expect customers to reject improved performance and efficiency. Publications of elevator companies and associated organizations of the elevator industry deliberately avoid topics, which concern the planning and performance of groups of elevators. Information about traffic flows and time-dependent service qualities in existing buildings appear to be confidential data.

To demonstrate the simplicity of group performance evaluation and planning the author designed the calculation model of appendices 1 and 2. These models prove that a DDFT table of a specific group defines all service qualities, for any combination of up and down traffic densities. Group planning is an exact task.

Another aspect of the new WTC buildings seems to confirm the author's concern about the efficiency of its groups: Otis supplied 47 escalators and 21 elevators for the WTC transportation hub, but none of the groups for the new office towers. This is a great surprise because Otis was the pre-eminent contractor for the original WTC buildings. The absence of Otis in the new office towers suggests a controversy, in respect of elevator planning, between the parties responsible for the re-development of the WTC complex and Otis. The innovative double-deck express elevators of the original WTC buildings contributed substantially to alleviate the inefficiency of single-deck local groups. This may be an element of a suspected planning controversy. However, OTIS is undoubtedly also aware of the inherent relativity of group characteristics and this may well have been another reason to avoid contracts for groups with configurations, which are unlikely to deliver best possible performance.

The concept of Layered Zoning and multi-deck local groups, proposed in chapter C, facilitates very tall buildings without Sky Lobbies and lifts the efficiency and performance of vertical transportation systems to a new level. Which multi-tenant building will be the first to apply this concept? Particularly for small building sites, Layered Zoning offers an attractive potential. This also applies for high-rise apartment buildings. Intelligent destination group controls will introduce a new era for building planning.

Comments and questions are invited.

Enclosures 1 & 2: Performance evaluations group E with 6 and 9 cars.

NB: <u>Edits 16 November 2016:</u> Revision of the name of this chapter and corrections of various text elements.

Appendix 1: Performance evaluation of group E with 6 large cars

Evaluation of			6	car group with contract load					1600	KG		5	permitted stops for UP trips +					4	additional stops during dn trips					
Flr nrs	1	62	63	64	65	66	67	68	69	70	71	72	71	70	69	68	67	66	65	64	63	62	1	
Flr levels	0.0	240.9	244.8	248.7	252.6	256.5	260.4	264.3	268.1	272.0	275.9	279.8	275.9	272.0	268.1	264.3	260.4	256.5	252.6	248.7	244.8	240.9	0.0	
										UP stops:		5	(Without counting stops at floor levels zero)								Total stops:		9	
Stops	1	1			1		1		1			1			1			1		1		1	1	
at level	0	240.9	0.0	0.0	252.6	0.0	260.4	0.0	268.1	0.0	0.0	279.8	0.0	0.0	268.1	0.0	0.0	256.5	0.0	248.7	0.0	240.9	0.0	
CLPS	0	0.0	240.9	240.9	240.9	252.6	252.6	260.4	260.4	268.1	268.1	268.1	279.8	279.8	279.8	268.1	268.1	268.1	256.5	256.5	248.7	248.7	240.9	Total
Tr D	0	240.9	0.0	0.0	11.7	0.0	7.8	0.0	7.8	0.0	0.0	11.7	0.0	0.0	11.7	0.0	0.0	11.7	0.0	7.8	0.0	7.8	240.9	559.6
DDFT	0	41.3	0.0	0.0	12.5	0.0	11.3	0.0	11.3	0.0	0.0	12.5	0.0	0.0	12.5	0.0	0.0	12.5	0.0	11.3	0.0	11.3	41.3	177.8
CLPS: Car level previous stop, Tr D: Travel distance from previous stop, DDFT: Door to door flight time.																					DDFT Table			
Number of upper floors served					11		**Contract speed 9 m/s**					88.9	14	102.9							Column 1 floor nrs			
RTT without passengers								177.8		5	**permitted destinations for up trip plus**						4	**for dn trips.**			Column 2 distances in m.			
Assumed nr of UP passengers					7		5.36	14	Time for entry and exit				5.36 is probable nr of destina-								column 3 DDFT's in sec.			
Assumed nr of DN passengers					7		5.36	14	Time for entry and exit				tions of inncoming passengers								1	0	0.0	
RTT with passengers								**205.8**		5.36 Number of floors over which downgoing											2	3.9	9.7	
										passengers are probably distributed											3	7.8	11.3	
Per 5 minutes each car can make								1.46	round trips												4	11.7	12.5	
UP Transport capacity of group per 5 minutes								61.22	persons		% of Pop.		3.98	%							5	15.5	13.5	
DN Transport capacity of group per 5 minutes								61.22	persons		% of Pop.		3.98	%							6	19.4	14.5	
Assumed zone population				140	per floor			1540													7	23.3	15.3	
																					8	27.2	16.0	
Departure Interval (RTT/Nr of cars)								34.3													9	31.1	16.8	
Av. nr of passengers assigned to 1st dep. car								6.5		Their total waiting time				112.1							10	35.0	17.4	
Av. nr of passengers assigned to next dep. car(s)								0.5		Their total waiting time				23.9							11	38.9	18.1	
Average waiting time UP passengers (AWT)								**19.4**					Total:	136.0	div by	7		19.4			62	240.9	41.3	
Average waiting time DN passengers								19.4		Equal to average waiting time UP passengers											63	244.8	41.7	
Longest travel time in the car for UP passengers								102.9		Total of DDFT's up trip + up carload *2, see blue marked data above.											64	248.7	42.2	
shortest travel time in the car for up passengers								41.3		DDFT to floor 62											65	252.6	42.6	
Average travel time in the car (ATTC)								**72.1**		seconds		Duiring simultaneous up/down traffic and identical									66	256.5	43.0	
Average time to destination (ATTD)								**91.5**		seconds		carloads ATTC's, ATTD's and AWT's are the same.									67	260.4	43.5	
Evacuation time								**27.15**		minutes		See calculation below									68	264.3	43.9	
Longest non-stop round trip without passengers								91.3		Average non-stop round trip without passengers								86.9			69	268.1	44.3	
Shortest non-stop round trip without passengers								82.6		**Av. non-stop round trip with**					**20**	**passengers**		**126.9**			70	272.0	44.8	
Nr of trips to evacuate population by						one	car	77.0													71	275.9	45.2	
Nr of trips to evacuate population by						6	cars	12.8		1629	seconds		27.2	minutes							72	279.8	45.6	

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Appendix 2: Performance evaluation group E with 9 small cars

Evaluation of			9	**car group with contract load**					800	**KG**		**4**	**permitted stops for UP trips +**					**3**	**additional stops during dn trips**					
Flr nrs	1	62	63	64	65	66	67	68	69	70	71	72	71	70	69	68	67	66	65	64	63	62	1	
Flr levels	0.0	240.9	244.8	248.7	252.6	256.5	260.4	264.3	268.1	272.0	275.9	279.8	275.9	272.0	268.1	264.3	260.4	256.5	252.6	248.7	244.8	240.9	0.0	
										UP stops:		4	(Without counting stops at floor levels zero)								Total stops:		7	
Stops	1	1			1				1			1			1			1				1	1	
at level	0	240.9	0.0	0.0	252.6	0.0	0.0	0.0	268.1	0.0	0.0	279.8	0.0	0.0	268.1	0.0	0.0	256.5	0.0	0.0	0.0	240.9	0.0	
CLPS	0	0.0	240.9	240.9	240.9	252.6	252.6	252.6	252.6	268.1	268.1	268.1	279.8	279.8	279.8	268.1	268.1	268.1	256.5	256.5	256.5	256.5	240.9	Total
Tr D	0	240.9	0.0	0.0	11.7	0.0	0.0	0.0	15.5	0.0	0.0	11.7	0.0	0.0	11.7	0.0	0.0	11.7	0.0	0.0	0.0	15.5	240.9	559.6
DDFT	0	41.3	0.0	0.0	12.5	0.0	0.0	0.0	13.5	0.0	0.0	12.5	0.0	0.0	12.5	0.0	0.0	12.5	0.0	0.0	0.0	13.5	41.3	159.7
CLPS: Car level previous stop, Tr D: Travel distance from previous stop, DDFT: Door to door flight time.																					DDFT Table			
Number of upper floors served					11		**Contract speed 9 m/s**					79.8	10	89.8							Column 1 floor nrs			
RTT without passengers								159.7		4	**permitted destinations for up trip plus**						**3**	**for dn trips.**			Column 2 distances in m.			
Assumed nr of UP passengers					5		4.17	10	Time for entry and exit				4.17 is probable nr of destina-								column 3 DDFT's in sec.			
Assumed nr of DN passengers					5		4.17	10	Time for entry and exit				tions of inncoming passengers								1	0	0.0	
RTT with passengers								**179.7**		4.17 Number of floors over which downgoing											2	3.9	9.7	
										passengers are probably distributed											3	7.8	11.3	
Per 5 minutes each car can make								1.67	round trips												4	11.7	12.5	
UP Transport capacity of group per 5 minutes								75.14	persons		% of Pop.		4.88	%							5	15.5	13.5	
DN Transport capacity of group per 5 minutes								75.14	persons		% of Pop.		4.88	%							6	19.4	14.5	
Assumed zone population				140	per floor			1540													7	23.3	15.3	
																					8	27.2	16.0	
Departure Interval (RTT/Nr of cars)								20.0													9	31.1	16.8	
Av. nr of passengers assigned to 1st dep. car								4.8		Their total waiting time				47.9							10	35.0	17.4	
Av. nr of passengers assigned to next dep. car(s)								0.2		Their total waiting time				6.1							11	38.9	18.1	
Average waiting time UP passengers (AWT)								**10.8**					Total:	54.0	div by	5		10.8			62	240.9	41.3	
Average waiting time DN passengers								10.8		Equal to average waiting time UP passengers											63	244.8	41.7	
Longest travel time in the car for UP passengers								89.8		Total of DDFT's up trip + up carload *2, see blue marked data above.											64	248.7	42.2	
shortest travel time in the car for up passengers								41.3		DDFT to floor 62											65	252.6	42.6	
Average travel time in the car (ATTC)								**65.6**		seconds		Duiring simultaneous up/down traffic and identical									66	256.5	43.0	
Average time to destination (ATTD)								**76.4**		seconds		carloads ATTC's, ATTD's and AWT's are the same.									67	260.4	43.5	
Evacuation time								**30.5**		minutes		See calculation below									68	264.3	43.9	
Longest non-stop round trip without passengers								91.3		Average non-stop round trip without passengers								86.9			69	268.1	44.3	
Shortest non-stop round trip without passengers								82.6		**Av. non-stop round trip with**					**10**	**passengers**		**106.9**			70	272.0	44.8	
Nr of trips to evacuate population by						one	car	154.0													71	275.9	45.2	
Nr of trips to evacuate population by						9	cars	17.1		1830	seconds		30.5	minutes							72	279.8	45.6	