Chapter B: Group Configuration and Evaluation

Introduction

The efficiency and performance of intelligent groups depends primarily on their configuration and secondly on the intelligent control of car operations. Intelligent groups monitor and record all movements of cars and doors, fluctuating carloads, and many other data, to facilitate analysis of their efficiency and performance. Chapter 9: “Artificial experience system” describes these systems and their objectives. Although written many years ago, this chapter is still relevant. Analysis of recorded data yield accurate values for the Door to Door Flight Times (DDFT’s) of cars for all possible travel distances. DDFT’s include door closing- and opening times and car travel times. DDFT’s are the basis of the calculated- and recorded data structures of intelligent groups.

Each Round Trip Time (RTT) of a car is the sum of the DDFT’s of all floor-to-floor trips during a specific round trip, plus the time costs of passengers entering and leaving cars. This chapter demonstrates that DDFT based data structures make the performance and efficiency of groups transparent, i.e. predictable and controllable.

Door to Door Flight Times (DDFT’s) and Round Trip Times (RTT’s)

Table 1		
Door to Door Flight Times		
(DDFT's) for direct trips to all floors.		
Floor numbers	Floor levels in meters	DDFT in seconds
0	0	0.0
1	4	9.6
2	8	11.2
3	12	12.5
4	16	13.8
5	20	15.2
6	24	16.5
7	28	17.8
8	32	19.2
9	36	20.5
10	40	21.8
11	44	23.2
12	48	24.5
13	52	25.8
14	56	27.2
15	60	28.5
16	64	29.8
17	68	31.2

Each group of elevators has a group specific DDFT table, which should be a standard element of any offer or contract for a group of elevators. Table 1 is an example of such a table for a 6-car group, serving 17 floors, contract speed 3 m/s, and contract load 800 KG. This group serves a population of 1275 persons (17 X 75). This chapter provides examples of performance evaluations for this group. The DDFT’s of Table 1 assume acceleration- and deceleration rates of 1 m/s^2.

Calculated data structures, which comprise all RTT’s for all possible round trips and numbers of passengers, are based on the DDFT’s of Table 1. Data structures enable intelligent groups to instantaneously asses the modes of car operation, i.e. the permitted numbers of stops for the up and down segments of round trips, for any combination of momentary up and down traffic densities. Intelligent groups select for each round trip the preferred number of permitted stops and control car operations and the assignment of passengers to specific cars accordingly.

During the planning phase, calculated data structures use an assumed time cost per passenger for car entry and exit for performance evaluations. After installation the recorded data structure, which uses data learned from the analysis of group operations, assumes control of car operations.

Traffic conditions / Traffic density patterns

Knowledge of traffic conditions in existing buildings is important for the planning of new buildings. Chapter 2: “Population- and traffic density patterns” provides an example of such patterns for an imaginary building. Flexible working hours and modern communication systems probably have moderated traffic peaks in office buildings. Unfortunately, it seems impossible to find information or graphs of traffic densities in existing buildings.

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Some elevator companies claim group controls manage traffic flows. This is typical disinformation; it suggests traffic conditions are the main problem of groups of elevators. This is not true; traffic is spontaneous and not manageable. Group controls must manage car operations to deliver the best possible response to momentary up and down traffic densities.

Intelligent groups communicate directly with each passenger and have at all times exact information of the transportation requirements of all passengers, i.e. data of momentary traffic densities. Intelligent groups will deliver traffic density graphs for each floor, the entire zone, and If required, for a specific tenant. Future graphs will include average waiting- and travel time data.

The lack of information in respect of traffic conditions in existing buildings and the service qualities of existing groups is an indication that elevator companies are not proud of their most prestigious product line. The author suggests readers to “google” questions about groups of elevators, for example: traffic densities, or configurations, or service qualities etc. Even a superficial survey of the huge numbers of results will disclose the lack of meaningful information in respect of the efficiency and performance of groups.

The probability of passengers having the same destinations

So-called “traffic” calculations for traditional groups use a mathematical formula to predict the number of probable stops of cars to calculate maximum up peak transport capacities (Chapter 13 Appendix 1). Intelligent group controls use this formula to assess the probable number of destinations of incoming passengers during specific departure intervals. It can also predict over how many floors, numbers of down going passengers during specific intervals, are probably distributed.

Building planners should be aware that this formula assumes all floor populations, and their working conditions, are identical. These assumptions are usually not correct; consequently, we may assume the coincidence of passengers having the same destination will be somewhat higher, i.e. calculated coincidence numbers are conservative. Analysis of data of real groups will disclose the relationship of numbers of passengers and their numbers of destinations, i.e. realistic coincidence information for a specific building.

Light to Medium up OR down traffic

Table 2 RTT calculation

Dest's served during U/D trips	Levels of destina- tions served	Distance between destina- tions	DDFT in seconds
0	0	0	0.0
2	8	8	11.2
7	28	20	15.2
10	40	12	12.5
11	44	4	9.6
13	52	8	11.2
17	68	16	13.8
Total DDFT's UP trip			73.6
Non-stop down trip			31.2
Total all DDFT's			104.8
Assumed car load 7 pas.			
Car entry & exit passengers			14.0
ROUND TRIP TIME			118.8
Av. Dep. interval (RTT / 6)			19.8
Av. waiting time (interval/2)			9.9
Av. travel time (9.6+73.6)/2			41.6
Av. time to destination			51.5

Table 2 calculates the RTT for round trips with six permitted stops during the up trip and a non-stop return trip to floor zero. The calculation assumes seven incoming passengers per interval of 19.8 seconds, who are assigned to the first departing car. The number of incoming passengers per 5 minutes is 300/19.8*7= 106.1 or 8.3 % of the population. The probable number of destinations of seven incoming passengers, who may have 17 destinations, is 5.9. For the assumed traffic density of 8.3%, carloads are likely to fluctuate from 5 to 8 persons. It may happen that it is not possible to assign a seventh incoming passenger to the first departing car; however, the assignment of eight passengers to a first departing car is likely too. The intelligent group of our example can certainly guarantee an average waiting time of approximately 10 seconds for short or long periods with an up traffic density of 8.3 %.

The calculated data for in-coming passengers are also valid for seven out-going passengers who register a call for floor zero during an interval of 19.8 seconds. Seven out-going passengers are likely to be distributed over 5.9 floors and will be assigned to the first available down going car, which is allowed six permitted stops. The service qualities for up or down passengers are identical.

Heavy up OR down traffic

Up OR down traffic densities up to approximately 8.3 % of the population per 5 minutes are unproblematic. For traffic densities, exceeding 8.3% it is contra-productive to increase the permitted number of stops from six to seven or eight. More permitted stops imply longer average round trip times and longer departure intervals, i.e. the number of incoming or outgoing passengers per interval increase significantly, because, both traffic density and the interval increase. However, group transport capacity is reduced if the number of stops is increased! For very high up or down traffic densities the permitted number of stops must be reduced. This implies incoming passengers are assigned to two or even more cars. Some incoming passengers may catch the first departing car because they are early or have destinations already pre-assigned to other waiting passengers, but others must be pre-assigned to the second departing car.

Larger cars improve passenger comfort, or may be a legal requirement, or important for moving furniture etc.; however, building planners should know that maximum transport capacities cannot be increased by larger cars. This implies virtually all existing groups are inefficient, i.e. cause a substantial waste of energy and loss of time for passengers, because their group controls are inefficient. This book proves these facts. Existing groups will independently confirm these facts after conversion to intelligent controls. Traffic simulation will also confirm these facts when intelligent controls have been realized. In spite of these facts, elevator companies continue to supply groups with six and even eight large cars**.**

Appendix 1 demonstrates why and how "selected floors" pattern = 9 can accommodate up or down traffic densities of maximum 10.5 %. With patterns "selected floors" = 8 or 7 or 6 the maximum up or down transport capacities can be increased even further.

"Selected floors" patterns

This book refers to "selected floors" patterns as a method to evaluate the performance of intelligent groups and to demonstrate their most important abilities, i.e. to substantially increase transport capacities and to distribute transport capacities evenly over all floors. "Selected floors" patterns are the basis for a calculation model to assess group performance as **IF** car operations and assignment of passengers strictly adhere to “selected floors" patterns. An intelligent group may use these modes of car operations for extreme traffic conditions. However, a well-planned intelligent group will assign incoming passengers to the first departing car on basis “first come first served” (FCFS) mode of car operations, i.e. to the first up-going car provided its number of permitted destinations is not yet exhausted and it has not yet reached full load. This means each car has a strictly limited number of permitted random destinations, or permitted stops in the case of down traffic. This mode of car operations implies the average reversal floor for eight passengers who may have 17 destinations is 15.6 (Chapter 13, Appendix 2). The average reversal floor of pattern "selected floors" = 9 of Appendix 1 is 14.7. This differential slightly increases the average RTT for the FCFS mode of car operations. The calculation methods of this book are conservative; moreover, the coincidence of passengers having the same destinations is likely to be higher. For these reasons, this book refers to "selected floors" patterns as its basic method to control group performance. These references imply that an intelligent group control will usually control efficiency with the FCFS mode of car operations or, exceptionally, strict adherence to "selected floors" patterns.

Carloads in numbers of passengers have little influence on RTT's. Higher contract loads of 900 or 1000 KG improve the flexibility for accommodating a late incoming passenger(s), *with a permitted destination*. The evaluation examples of this chapter are based on a contract load of 800 KG to stress the importance of controlling the number of permitted stops. The cars of intelligent groups can be as large and contract loads as high as the customer may wish, however, planners must be aware they are irrelevant for maximal transport capacities. For more information about "selected floors", please refer to Chapter 14: Patterns for "selected floors".

Simultaneous up and down traffic

Simultaneous up/down traffic is the most demanding traffic condition for any group. Table 3 calculates the round trip time for trips with four permitted stops for up trips, and three additional permitted stops during down trips. The calculation assumes that during each round trip the cars transport four passengers up and down, who are the assumed numbers of passengers entering and leaving the building during the average intervals of 21.6 seconds. The calculation method assumes the reversal floor is the top floor for all trips. All passengers are assigned to the first available car by the FCFS mode of car operations.

Table 3 RTT calculation			
Dest's served during U/D trips	Levels of destinations served	Distance between destinations	DDFT in seconds
0	0	0	0.0
3	12	12	12.5
11	44	32	19.2
15	60	16	13.8
17	68	8	11.2
Total DDFT's UP trip			56.7
DOWN trip			
17	68	0	0.0
12	48	20	15.2
10	40	8	11.2
5	20	20	15.2
0	0	20	15.2
Total DDFT's DOWN trip			56.7
Total all DDFT's			113.5
Assumed car load 4 + 4 pas.			
Car entry & exit passengers			16.0
ROUND TRIP TIME			129.5
Av. Dep. interval (RTT / 6)			21.6
Av. waiting time (interval/2)			10.8
Av. travel time (9.6+56.7)/2			33.2
Av. time to destination			44.0

Four in-coming and out-going passengers per interval of 21.6 seconds equals 55.6 passengers per 5 minutes = 4.4 % of the population. These passengers enjoy short average waiting times of approximately 10.8 seconds.

Question: Will a down-going car achieve a carload of four passengers? Collection of a down passenger on the reversal floor is not certain; however, for an intelligent group the chances to collect four passengers for down trips are good. A down passenger on floor 15 can be assigned to the up-going car, which is scheduled to reverse at its next stop. A reversing car may have an additional opportunity to collect a down passenger if the reversal floor is not the top floor. In this case, a down call on a higher floor is served first, and the stop for the up passenger is made after reversal. The intelligent control will of course politely inform the passenger, who is delayed by this process, why his or her stop was delayed until after reversal. The delayed exit of the last up passenger improves the chance of collecting a down passenger on the exit floor. NB: Efficiency is also a communication problem.

If we make the calculation of Table 3 for <u>five and four permitted stops</u> and average car loads of five passengers the RTT increases to 151 seconds and the average interval to 25.1 seconds. Five passengers per interval of 25.1 seconds (average waiting time 12.6 s) implies the number of up/down passengers per 5 minutes will be 59.8 = 4.7 % of the population per 5 minutes.

Appendix 2 of this chapter shows a **calculation model for any RTT**. This calculation model represents the basis of a traffic simulation program. The horizontal data lines state the vertical traffic data and their interdependence. The calculations for carloads of 6 and 7 passengers (color marked) disclose that control of the permitted number of stops facilitates simultaneous traffic densities, which exceed 6 % of the population per 5 minutes; however, average waiting times will increase substantially, because passengers must be assigned to two or even three cars. The calculations again prove that control of the permitted number of stops is the only way to control transport capacities during periods of heavy traffic.

Simultaneous up and down traffic densities of 6 % per 5 minutes are most unlikely to occur in any building because it would mean 12 % of its population are using the elevators during a 5-minute period.

Please note that the number of permitted stops can be varied for each round trip. For a series of several roundtrips during periods with heavy simultaneous up/down traffic, the number of permitted stops of a specific trip(s) can be varied by one stop to “fine-tune” transport capacities during a series of many trips. This means a gradual reduction or increase of permitted stops is possible in response to anticipated changes of traffic densities.

Moderate simultaneous UP and DOWN traffic

Most of the time traffic conditions are moderate. Passengers of intelligent groups will enjoy service qualities disclosed by the calculation of Table 3. Average waiting times will be very short. Cars make many direct trips, i.e. average travel times in the cars are short. An existing 6-car group, with large cars, will after conversion to intelligent controls, demonstrate its improved time-dependent service qualities and reduced average carloads more convincingly than any calculation of this book. Readers familiar with 6-car groups in existing buildings (usual contract load 1600 KG) will probably realize the described service qualities are far better than their experience in existing buildings.

Inter-floor traffic

The author suggests this type of traffic is unproblematic. During periods of heavy traffic, inter-floor traffic will be small, if any. It can be satisfied by up or down going cars, which stop at the required destination either before or after reversal. Exceptionally, i.e. only during very heavy traffic, a passenger may have to be advised to change to another car on a reversal floor.

During periods with moderate traffic densities, intelligent groups have ample transport capacities and flexibility to serve inter-floor traffic. In multi-tenant buildings, inter-floor traffic is probably small at all times. Future intelligent groups will inform about inter-floor demands. This information will be of help to decide whether inter-floor traffic requires special attention.

Modernization of existing groups

The conversion of an existing 6-car group serving 17 floors and contract loads of 1600 KG, with intelligent controls, will probably be a good demonstration of the performance improvements, which this book hopes to convey to its readers.

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The modernized group can of course perform in accordance with the calculations of Tables 2 & 3. Average carloads in numbers of passengers will be substantially reduced after conversion and demonstrate the improved group efficiency.

An under-elevatored building will most probably resolve its transport capacity problems during periods of heavy traffic. Although the optimal minimum contract load of a 6-car group is approximately 800 KG, a modernized group may demonstrate that a minimum of 900 KG is preferable.

Concluding remarks

Intelligent destination group controls will be both, the simplest and the most efficient group control system.

The specific service qualities and performance data, as required for a new building, are decisive for the configurations of intelligent groups. Shorter time-dependent service qualities imply more cars, which may be smaller. Intelligent controls facilitate the realization of the specified time-dependent service qualities. The inherent relativity of group characteristics and calculated data structures facilitate an exact group planning process. Performance data will be subject to contractual guarantees.

This process is entirely different to the empirical planning methods of the present.

The author will greatly appreciate comments and questions from readers.

Appendix 1: Pattern for “selected floors” = 9.

Appendix 2: Service to random upper floors (first come first served)

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Appendix 1: Pattern for "selected floors" = 9

The pattern "selected floors" = 9 below reduces the permitted numbers of destinations during 17 consecutive roundtrips to nine to reduce average RTT's and increase maximum up OR down transport capacities.

The contract load of 800 KG and the rigid assignment of passengers in accordance with this pattern are the basis of an RTT calculation method. The pattern and calculated data are useful to visualize how indirect control of permitted stops, i.e. by limiting the number of permitted destinations, influences group performance and efficiency. The permitted number of stops of 8 passengers which may have 17 destinations is: 5.49 (Chapter 13, Appendix 1). This number defines the RTT's of the pattern below. The calculated data prove that control of the permitted number of stops is an effective method for controlling the RTT's of car operations.

Trip nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Number of "selected floors" = 9							9									
Floor nrs																	
17		X		X		X		X		X		X		X		X	X
16		X		X		X		X		X		X		X	X		X
15		X		X		X		X		X		X	X		X		X
14		X		X		X		X		X	X		X		X		X
13		X		X		X		X	X		X		X		X		X
12		X		X		X	X		X		X		X		X		X
11		X		X	X		X		X		X		X		X		X
10		X	X		X		X		X		X		X		X		X
9	X		X		X		X		X		X		X		X		X
8	X		X		X		X		X		X		X		X	X	
7	X		X		X		X		X		X		X	X		X	
6	X		X		X		X		X		X	X		X		X	
5	X		X		X		X		X	X		X		X		X	
4	X		X		X		X	X		X		X		X		X	
3	X		X		X	X		X		X		X		X		X	
2	X		X	X		X		X		X		X		X		X	
1	X	X		X		X		X		X		X		X		X	
0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Av. RTT	92.7	114.3	95.7	114.3	98.3	114.3	100.9	114.3	103.6	114.3	106.3	114.3	108.9	114.3	111.6	102.0	114.3
	X	permitted destinations / floors served									floors not served (omitted floors)						

The average reversal floor level is	14.7
The total time to make 17 round trips is	1834.0 seconds
During this time period the group enables service to each floor	9 times
The maximum number of passengers which can be transported during all 17 round trips = 17 X 6 X 8 =	816.0 pas.
The maximum number of passengers transported per 5 minutes is (816 / 1834 =0.444 passengers per second X 300)	133.5
Expressed as a percentage of the population 133.5 / 12.75 =	10.5%
The average time period, which facilitates service to each floor once, is named Cycle Time. Its duration is: 1834 / 9 =	203.8 seconds
The average interval between the start of Cycles = 203.8 / 6 =	34.0 seconds
The average waiting time for passengers, cycle interval / 2 =	17.0 seconds
The average travel time in the cars is	42.6 seconds
The average time to destination is	59.6 seconds

Flr nrs	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Flr lvls	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	0	
Stops	0			3								11				15		17					12		10					5						
at level	0	0	0	12	0	0	0	0	0	0	0	44	0	0	0	60	0	68	0	0	0	0	48	0	40	0	0	0	0	20	0	0	0	0	0	
CLPS	0	0	0	12	12	12	12	12	12	12	12	44	44	44	44	60	60	68	68	68	68	68	48	48	40	40	40	40	40	20	20	20	20	20	0	
Tr D	0	0	0	12	0	0	0	0	0	0	0	32	0	0	0	16	0	8	0	0	0	0	20	0	8	0	0	0	0	20	0	0	0	0	20	136
DDFT	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	0.0	0.0	0.0	13.8	0.0	11.2	0.0	0.0	0.0	0.0	15.2	0.0	11.2	0.0	0.0	0.0	0.0	15.2	0.0	0.0	0.0	0.0	15.2	113.5
Stops	0			3				7				11				15		17					12		10					5			2			
at level	0	0	0	12	0	0	0	28	0	0	0	44	0	0	0	60	0	68	0	0	0	0	48	0	40	0	0	0	0	20	0	0	8	0	0	
CLPS	0	0	0	12	12	12	12	28	28	28	28	44	44	44	44	60	60	68	68	68	68	68	48	48	40	40	40	40	40	20	20	20	8	8	0	
Tr D	0	0	0	12	0	0	0	16	0	0	0	16	0	0	0	16	0	8	0	0	0	0	20	0	8	0	0	0	0	20	0	0	12	0	8	136
DDFT	0.0	0.0	0.0	12.5	0.0	0.0	0.0	13.8	0.0	0.0	0.0	13.8	0.0	0.0	0.0	13.8	0.0	11.2	0.0	0.0	0.0	0.0	15.2	0.0	11.2	0.0	0.0	0.0	0.0	15.2	0.0	0.0	12.5	0.0	11.2	130.6

Stops	Destinations assigned to passengers by "first come first served" mode of car operations
at level	Floor levels of assigned destinations
CLPS	Car level previous stop
Tr D	Travel distance from previous stop
DDFT	Door to door flight time for trip distance, from DDFT Table

Permitted stops			4 + 3			4 + 3			5 + 4			5 + 4	
ROUND TRIP TIME without passengers			113.5			113.5			130.6			130.6	
Assumed nr of up passengers		4	8		6	12		5	10		7	14	
Assumed nr of down passengers		4	8		6	12		5	10		7	14	
RTT with passengers		8	129.5		12	137.5		10	150.6		14	158.6	
Interval	RTT/6		21.6						25.1				
Average waiting time			10.8						12.5				
Zone poplation	1275												
Nr of round trips per 5 minutes			2.32			2.18			1.99			1.89	
Nr of cars			6			6			6			6	
Nr of passengers transported	Total		111.2			157.1			119.5			158.9	
Nr of passengers transported	up		55.60	4.36 %		78.55	6.16		59.77	4.69 %		79.46	6.23 %
Nr of passengers transported	down		55.60	4.36 %		78.55	6.16		59.77	4.69 %		79.46	6.23 %

Colour implies passengers are transported by 2 or more cars.

Door to Door Flight Times

DDFT's for direct trips to all floors.

Column 1	Floor numbers
Column 2	Floor levels
Column 3	DDFT's for direct trips

0	0	0.0
1	4	9.6
2	8	11.2
3	12	12.5
4	16	13.8
5	20	15.2
6	24	16.5
7	28	17.8
8	32	19.2
9	36	20.5
10	40	21.8
11	44	23.2
12	48	24.5
13	52	25.8
14	56	27.2
15	60	28.5
16	64	29.8
17	68	31.2