UNIQUE DESIGN FOR A HIGH RISE HQ OFFICE BUILDING

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ABSTRACT

"Elevatoring" high rise buildings calls for experience, knowledge of the latest technology and its potential, ability to model the traffic performance of proposed systems and sometimes ingenuity to respond to the special constraints of the architectural structure and building design. All these factors and others impinge upon the "elevatoring" solution. It is rare however for an "elevatoring" solution to set new precedents in elevator system design. This paper however describes just such a solution which was one of several theoretical ones developed during 1992 for a proposed headquarters building in Frankfurt, Germany for the architects Sir Norman Foster & Partners. The unique qualities of the design are highlighted by the need for new terminology to be developed and calculations to be carried out from first principles.

1. INTRODUCTION

Architects rightly look for "elevatoring" solutions sympathetic to their building design. Solutions should also match their aspirations for core design and space planning. Also high on the agenda are the user's requirements and the spatial efficiency of the solution. When the author arrived in the architect's office one Friday afternoon in April 1992 the scale and special nature of the building design first became apparent.

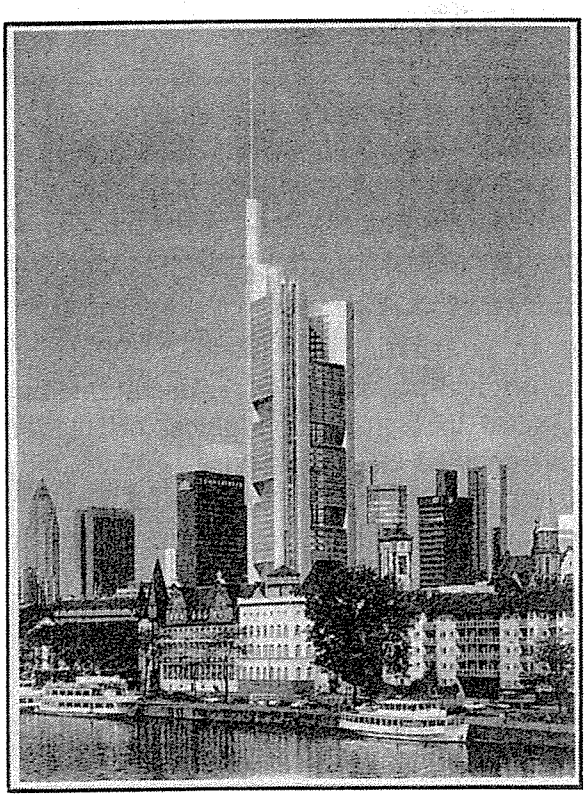

Figure 1 Computer Generated Image of the new HQ building

In Figure 1 above is a computer generated image of the proposed building in the foreground set into a collage of the Frankfurt skyline. What the architect was looking for was an "elevatoring" solution matching as closely as possible the unique structure and design of the building. The building design, at that stage, was of a triangular shape in plan with curved sides extending up to some 54 office levels with plant levels above. Levels 4 to 47 formed the major office content. These levels were arranged as a progression of three floor sectors or "villages" moving up the building. Each "village" has a garden on its lowest floor with an atrium extending up into the other two floors to give the two office "wings" on each floor a garden outlook. There was also a central atrium which linked three "villages" together to form a nine floor high central void repeating up the building.

A cross section through part of the building is illustrated below in Figure 2.

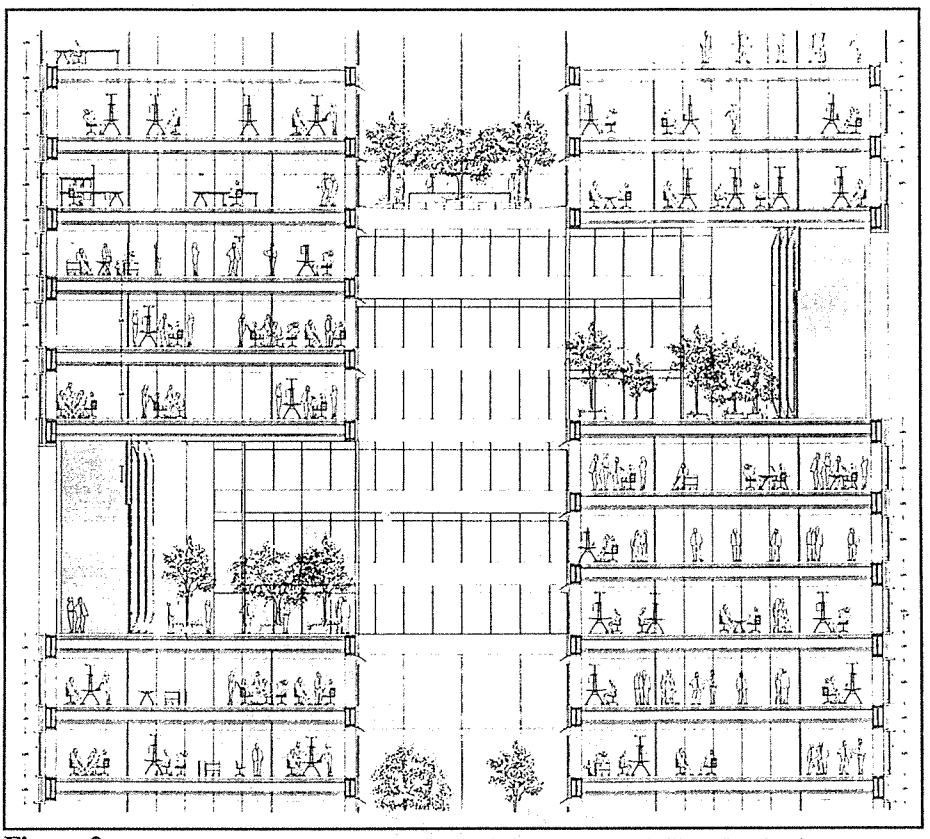

Figure 2 Cross section through the HQ building depicting three floor "villages" and atriums

As the "villages" progress up the building they rotate by 120 degrees, producing a cycle of three "villages" before the original orientation is regained. One possibility was to consider the five "villages", which had the same geographical orientation, as a "village" group possibly requiring a closely coupled elevator service. For the purposes of description we adopted a colour code for each of the "village" groups i.e. red, yellow and blue reflecting the three geographical orientations. Some of the elements of our brief were as follows:

1. The areas designated for elevator cores were in the three corners of the building.

2. We should attempt to minimise or eliminate the necessity for transfer levels between groups of elevators thereby simplifying users journeys made between different levels of the building especially as this was a single tenant HQ building.

3. Users arriving at any given level via the elevators should preferably always alight at the core furthest from the garden thereby minimising their potential walking distance into the offices as they would be at a central point between the two wings.

4. The design should, preferably, accommodate three goods/firefighting elevators.

5. Male and female toilet pods have to be accommodated at each level within two out of three of the elevator cores.

6. Levels 4 and 47 represent conference/bridge link and reception/executive dining areas to be easily accessible by all building occupants.

7. It is envisaged that on levels 48 to 54 there will be senior management and directors offices together with kitchen, executive/guest dining, secretarial and administrative support areas. Up to 300 persons could be resident at or above level 47 which will be a secure area with its own separate local elevator system with all persons being screened through a reception desk facility at level 47.

8. The nominal building population was given as 60 persons per floor.

9. The architect would like to have elevators visible from the exterior of the building to act as a feature especially prominent after dark by illumination of the outline of the cabs.

2. BASIS OF DESIGN

Utilising the above criteria the author experimented with the architect to look at how to accommodate a very compact elevator core containing sufficient elevators to allow users to always alight from an elevator at his or her destination opposite the "garden". To do this we would not utilise conventional elevator zones with contiguous floors but rather serve a "village" group by serving all three floors of a given three floor "village" then skipping past six floors to the next "village".

By working with the architect to get the "villages" to step around in the right sequence it was possible to produce a scenario where all three cores could be loaded with a roughly comparable population and a balanced number of stops to meet the minimum traffic design criteria of having an average interval of under 30 seconds and a handling capacity greater than 15%. Since neither our standard calculation or simulation facilities were geared to analysing situations where a given group of lifts does not serve a contiguous set of floors the calculations, given at the end of this paper, were carried out from first principles making adjustment to the "average jump" etc to allow for the special building design.

The basis of the "elevatoring" solution proposed can be described as follows. All elevators travel the entire height of the building. There are three cores (red, yellow and blue) consisting of six passenger elevators and one goods/firefighting elevator in each. On the "red" levels there is a primary "red" core, where all six elevators can stop, this is located in the corner of the building directly opposite the "garden". Similarly for the "blue" and "yellow" cores.

The building arrangement is depicted generally in the following diagrams.

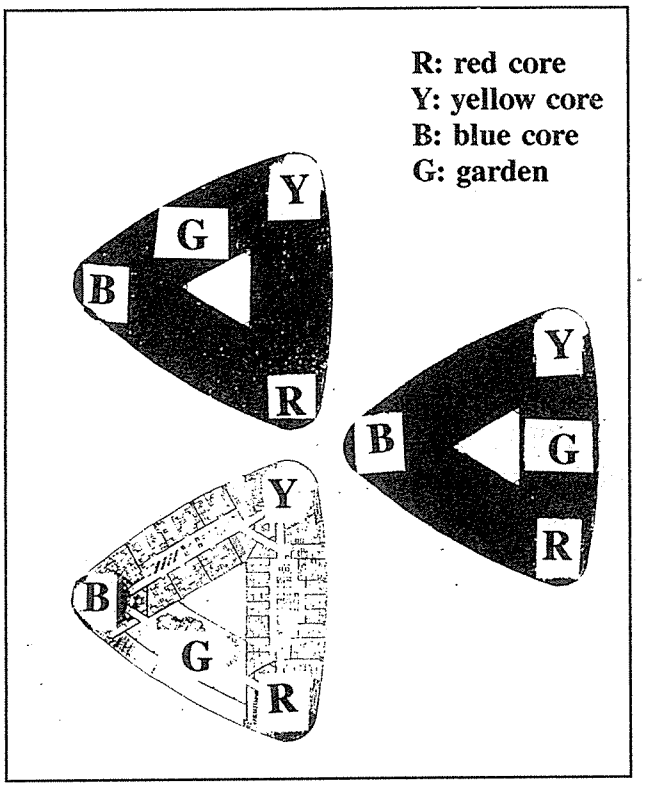

Figure 3 Orientation of Garden Atriums and Cores - Plan

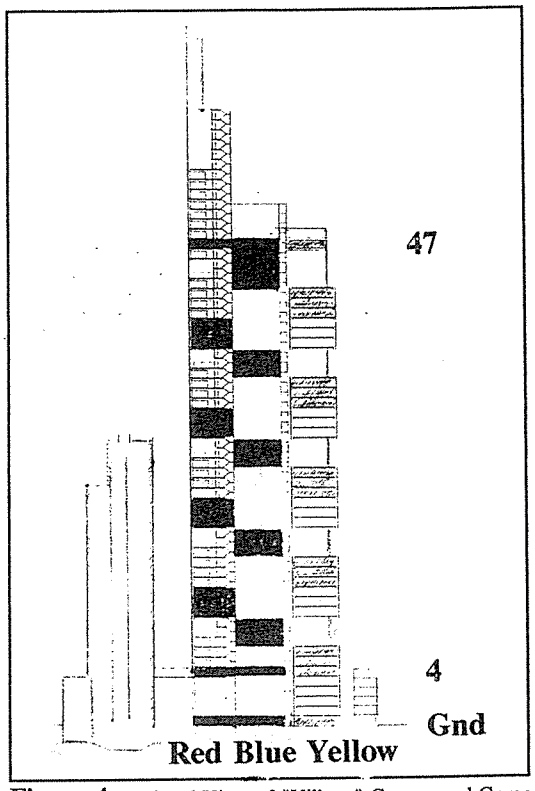

Figure 4 Sectional View of "Village" Groups and Cores

3. SPACE PLANNING OF CORES

The base "elevatoring" solution proposed can, in general terms, be said to fit the outline requirements for having all elevators placed within the three existing core locations already identified in the architects' plans. The design proposed also encompasses the space for the toilet pods at each level and a goods elevator in each of the three cores. Figure 5 below depicts an outline layout for the core.

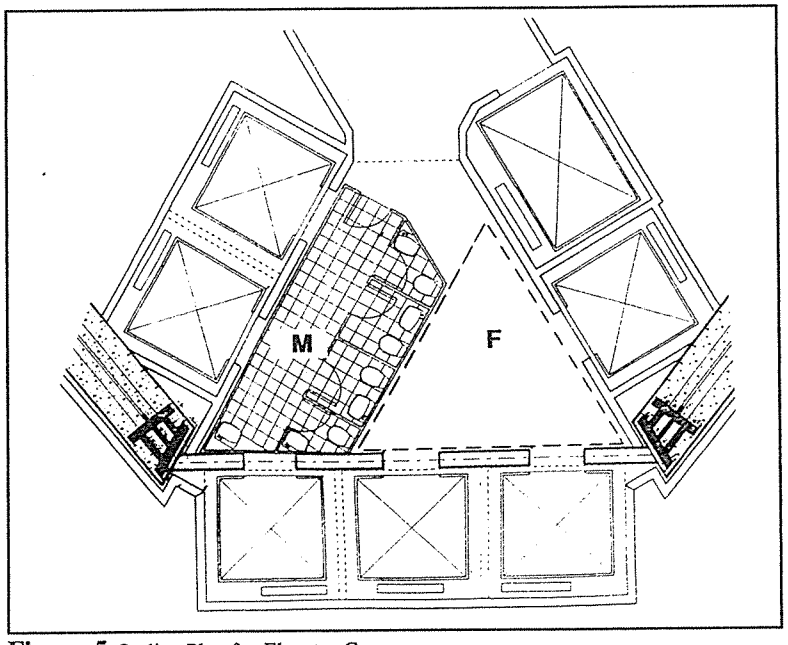

Figure 5 Outline Plan for Elevator Core

The six passenger elevators in the layout shown are 1,600kg/21 person nominal capacity. We utilised a standard 1100mm two panel centre opening arrangement of doors. The design also meets the architect's needs for having cars visible from outside the building. After sunset by appropriate illumination of the outline of each of the cars the three corners of the building would be dramatically enlivened at the sight of moving elements travelling up and down the full height of the tower.

By "handing" the design of the toilet pods i.e. designing left hand male and right hand female and distributing one in each of the non-primary (secondary) lobby cores throughout the building the requirements for accommodating the toilet pods at each level are met.

It was at this point that the thought occurred that it might be feasible to utilise the secondary cores at each level to permit travel between different coloured "villages". By designing the toilet pods as shown it was always possible to have access to three of the cars in each of the secondary cores at each level of the building. These secondary lobbies were designated "Hall Call Lobbies" because their purpose would be only to collect passengers travelling to alternative colour villages by responding to hall calls at these levels. It would not be possible, under normal circumstances, for passengers to register these secondary lobbies as destinations during normal operation. Figure 5 shows a typical secondary core lobby area with a male toilet pod fitted. The remaining space, which is used to accommodate a female toilet pod in the other secondary lobby at that level, can in this core be used as the "Hall Call Lobby".

Concerns on the width of the lobby entrance and the relative angular positions of the entrances were addressed by building a full scale mock up of the lobby at the architects offices. By fine tuning the angular arrangement of the lobby walls, placing a central call pedestal in the primary lobbies, "filling in" the corners of the lobbies it could be demonstrated that the arrangement was not only viable in circulation terms but also space efficient as well.

4. USER'S PERSPECTIVE

This unique approach would bring tremendous benefits to the user. Now it would be possible, within this 50 floor single tenant environment, to travel directly from any floor in the building to any other floor simply by walking to the correct core associated with one's destination floor. No need to transfer between groups of elevators with associated loss of time and additional walking distances involved.

The "elevatoring" solution is entirely logical and straightforward from the viewpoint of the user subject only to some initial orientation. Furthermore the design, whilst being unique to our knowledge, would be in perfect harmony with the unique design of the building itself.

It might well prove advantageous, from the user's viewpoint, to associate each level in the building with the "village" orientation for that level e.g East, West or North (or Red, Yellow or Blue). The orientation of the garden is the key to deciding which core to walk to in order to obtain an elevator capable of taking one directly to the required destination level. The only rule for the user to have to remember is whether the destination level is associated with a North, East or West (or Blue, Red or Yellow) core. One simply adds the orientation to the building level, e.g. 36 North (Blue), to obtain all the necessary information required to reach that floor. Thus to travel to level 36 from any other level in the building one would walk to the North elevator core and take the elevator to level 36.

At the special floors Ground, 4 and 47 all three groups of six passenger elevators are available to deal with the traffic arriving at or departing from those particular floors. Likewise travel to these floors can be facilitated from any of the three cores in the building.

Typically each elevator will have about 15 destination floors but will, in addition, be able to stop in response from hall calls to a further 15 levels.

In order to minimise the number of persons likely to require access to the secondary "hall call lobbies" it would be necessary to reinforce the linkage between "villages" with the same orientation via the elevator system thereby ensuring the majority of interfloor traffic occurred between primary lift lobbies as is the case in conventional "elevatoring" solutions without "hall call lobbies". This linkage could be developed by using the organisational design theories of the British authors Tutt & Adler. Essentially departments between which there is known to exist close links and interchange of personnel are stacked in common "village" cores, i.e. all red or blue or yellow, thereby ensuring that the bulk of interfloor traffic takes place between the primary elevator lobbies where all six elevators are present. This elevator scheme can thus be designed not only about the building design itself but the organisational needs of the end user.

A further attraction of the building and "elevatoring" solution is its simplicity of floorplate layout and its democratisation of workplaces other than their strictly vertical location. The elevator system would allow the closest possible linkage between all departments and building users reasonably possible. Such close linkage with its time-saving features is not normally on offer in conventional high rise buildings which usually consist of three or more zones of elevators often tending to isolate and discourage movement around the building and interaction between all levels and departments. Single user high rise buildings with conventional "elevatoring" solutions do not, by their very nature, encourage vertical movement within the building. This building with this particular "elevatoring" solution would offer that opportunity.

5. TRAFFIC PERFORMANCE

Up Peak Traffic

The calculations given at the end of the paper indicate that during "up peak", when the secondary "hall call lobbies" would not be activated, the elevators would be able to meet the normal traffic design criteria that would be applied to a building of this nature.

Down Peak Traffic

As a conventional elevator installation the solution will handle over 22.5% of the "village" group population during down peak traffic. It is likely that the building design, with three contiguous floors in each village, will assist in increasing the down peak traffic handling capacity as elevators will doubtless often call at three levels within one village, become fully loaded, and then return non-stop to the ground floor. Six elevators are also ideal as they will cycle round the five "down peak sectors" - emulating an up peak sectoring algorithm in reverse.

Interfloor Traffic

Handling capacity is available to handle more than 33% of the building population using the lifts every hour. Indeed there is sufficient capacity to tolerate one lift being out of service at any one time which should enable maintenance work to be carried out during normal working hours.

Figure 6 below indicates the provisional periods when the "hall call lobbies" would be activated thereby enabling users to make inter "village" transfers. The design and operation of the "hall call lobbies" in the secondary cores at each level perfectly suits those periods of the day when non-intensive levels of traffic are anticipated. The careful location of departments in the building would also assist in ensuring optimum performance from the proposed elevator system.

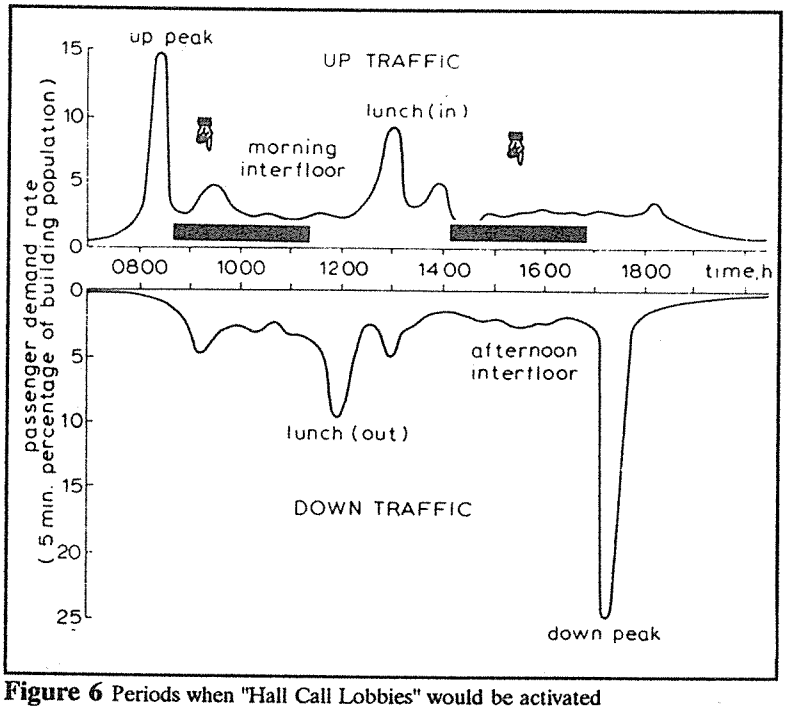

Figure 6 Periods when "Hall Call Lobbies" would be activated

6. TECHNICAL CONSIDERATIONS

Clearly some special hardware and software will need to be "tailored" to facilitate the "hall call lobby" system. The control system software for the three groups of elevators would need some specialised development in order to afford the following features over and above those found on modern microprocessor control systems generally available.

In each case in the tower every elevator in a given group serves a series of primary lobbies. In addition each group is split in half in order to serve "secondary" lobbies where three cars out of each group may respond to hall calls only. The number of destination call buttons in the car corresponds to the number of "primary" lobbies served by the group in that core. During normal operation a number of important parameters would pertain which would enable the building management and the elevator control system itself to regulate the average system response times both in the "primary" and secondary i.e. "hall call" lobbies. These parameters are as follows:

A. The relative prioritisation of hall calls in "secondary" lobbies relative to "primary " lobbies. Intrinsic with the arrangement of lifts is the premise that, on average, the system response times in the "secondary" lobbies will be twice as long as those in the "primary" lobbies. To redress this it is envisaged that hall calls registered in "secondary" lobbies will be given a higher priority than those registered in the "primary" lobbies.

The weighting of the priority which "secondary" lobby hall calls are given over "primary" lobby hall calls should be variable and under the control of the building management. It might range from zero (equal ranking with primary lobby hall call) to unity (where cars will bypass all other hall calls in order to service the "secondary" lobby hall calls before <u>any</u> "primary" lobby hall calls).

B. Average system response times will be monitored for "primary" lobbies only (ASRTP) "secondary" lobbies only (ASRTS) and all floors served by the group in a given core (ASRT). "Secondary" lobby "disabling" will occur according to pre-programmed levels of average system response time being exceeded. The control program will "disable" the secondary lobby hall pushes based upon the recorded moving average response times exceeding specified levels e.g. due to a car out of service, excessive interfloor traffic or excessive traffic in general. The "disabling" of secondary lobbies shall also cause the illumination of an electronic sign over the lobby entrance depicting the non-availability of the "secondary " lobby to users.

The building management would thus be able to set the conditions for "disabling" the "secondary" lobbies according to their desire from the keyboard of the elevator management system. The programming would therefore include logical statements such as:

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        IF ASRTP > 30 SECS THEN DISABLE
OR,     IF ASRTS > 60 SECS THEN DISABLE
OR,     IF ASRT  > 45 SECS THEN DISABLE
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Thus, once the parameters for the relative prioritisation of the "secondary" lobby hall calls had been programmed by the building management the elevator control system would, to a degree, actually "control" the system response times users would be subjected to by "enabling" and "disabling" the "secondary" lobbies accordingly.

C. In addition the "up peak" control algorithms that would be used would be fully flexible according to the demands placed upon a given group of elevators at any time. The control system would be able to operate normal "up peak", "up peak sub-zoning" and "up peak sectoring". Features and facilities would be incorporated on the elevators such that the selection of the type of "up peak" control in operation could be made automatically according to pre-programmed building management requirements or switched manually according to building management's requirements.

7. CONCLUSIONS

Never follow blindly conventional solutions to non-conventional buildings and situations. Frequently the building design drives the "elevatoring" solution, very rarely is the reverse true. This paper illustrates that there are solutions possible outside the conventional approach.

TRAFFIC CALCULATIONS

1. DATA

Floor assignments, populations, etc.

Gound	Main entrance.	n/a
1, 2, 3	Not served.	nil
4	Bridge to adjacent building.	assume nil for calculations
5, 6	Office floors; orientated to Floor 4.	60 persons/floor
7-46	Office floors arranged in threes, as below.	60 persons/floor
47	Upper reception.	transfer by South core only

Interfloor distance: 3.70 m

Village Group	Floors served						
RED	4	5-6	13-15	22-24	31-33	40-42	47
YELLOW	4	7-8	16-18	25-27	34-36	43-45	47
BLUE	4	10-12	19-21	28-30	37-39	46	47

Lift dynamics, etc.

Rated speed:	7.0 m/s
Rated acceleration:	1.2 m/s^2
Rated jerk:	2.0 m/s^3
Single floor flight time:	4.2 s
Door size:	1,100 mm
Door opening time:	1.6 s
Door advance opening:	(0.9 s)
Door closing time:	2.5 s

Passenger data:

Rated car capacity:	1,600 kg
Nominal capacity:	21.0 persons
Actual capacity:	16.8 persons
Design capacity:	14.0 persons
Passenger transfer time:	1.0 s

2. UPPEAK ANALYSIS

Design Requirements:

Uppeak arrival rate: 15%
Uppeak interval: <30 s
Uppeak car load: 80 % of actual capacity
Uppeak average passenger waiting time (AWT): <25 s
Uppeak average passenger time to destination (AJT): <90 s

Assumptions:

1. Consider worst cases: lifts always travel to Floor 47.
2. Consider lifts do not stop at Floor 4 during Uppeak.
3. Population per floor: 60 persons (except Floor 47 at 300 persons)

Calculations: RED village

[Calculations for YELLOW and BLUE villages follow the same procedure]

Population to be served:	12 x 60 + 1 x 300 = 1020
Handling capacity required:	1020 x 15 % = 153
Calculation data:	N = 13; P = 14; H = 47; S = 8.8
	tv = 3.7/7.0 = 0.53 s; tp = 1.0 s
	T = 4.8 + 1.6 - 0.9 + 2.5 = 8.0 s

Using: RTT = 2Htv + (S+1)(T-tv) + 2Ptp
RTT = 2 x 47 x 0.63 + (8.8+1)(8.0-0.53) + 2 x 14 x 1
= 49.8 + 73.2 + 28.0 = 151 s

Correction for average jump:
As S=8.8 average jump is 47/8.8 = 5.3 floors
tf(1) = 4.8; tf(5.3) = 8.5;
assumed tf(5.3) = 4.8 + 4.3 x 0.53 = 7.1 s;
error = 8.5 - 7.1 = 1.4 s

Total RTT error = 9.8 x 1.4 = 13.7 s
Corrected RTT: RTT = 151.0 + 13.7 = 164.7 s

For 6 cars:
INT = 164.7/6 = 27.5 s
HC = 300 x 14/27.5 = 153 persons/5-min
AWT = 0.85 x 27.5 = 23.4 s [using 0.85INT]
AJT = 0.5(47x0.53+8.8(8.0-0.53)+3x14x1) + 23.4 [using AJT = 0.5(Htv +S(T-tv)+3Ptp)+AWT]
= 89.7 s

3. INTERFLOOR ANALYSIS

Assumptions:
1. The six cars in each group serve its group of villages. At any given floor three of the cars in a each of the other two groups serve the other villages. Thus there is a potential of 30 (typically) hall call stops and 15 car call stops for any group.
2. Assume that floors are grouped, by activity, in villages and in village groups, of occupants who work together. For example: marketing and sales; training and personnel.
3. A busy lift system is one where the one third of the building occupants use a lift every hour. Assume 50 % of this third travel within their village group and the other 50 % are split equally between the other two village groups.

Requirements: [Consider the RED group as typical.]
Population using lifts every hour: = 16 x 60 x 0.33 = 317 persons
Population using the lifts every 5-min: = 317/12 ≈ 26 persons
In any 5-min period this is about 26 stops or about 1 hall calls per floor served.
Assume the worst case of each hall call causing a new car call. [ie: no coincident calls.]
Assume the worst case of calls to both terminal floors, during any cycle of activity.
Thus there will be about 60 stops per 5-min period shared by 6 cars.
Therefore each car will stop 10 times per 5-min period.

Calculation: typical case
Assume one person in a car, which travels up 47 floors and stops twice and one person travels down 47 floors in a car which stops twice.
The RTT is: = 2 x 47 x 0.53 + 4 x (8.0-0.53) + 4 x 1 x 1 = 83.7 s
Number of trips per car per 5-min: = 300/83.7 = 3.6
Number of stops in 5-min: = 4 x 3.6 ≈ 14
This is more than the required activity (10 stops).

REFERENCE
Barney, G.C. & Dos Santos, S.M.: "Elevator Traffic Analysis", IEE/Peter Peregrinus, 1985