TRAFFIC DESIGN TABLES

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ABSTRACT

Formulae for the calculation of passenger handling performance of lift systems are well known. Lift makers use tables applicable to their product range to estimate Round Trip Times, Interval, Handling Capacity, etc. Tables are sometimes included in codes of practice. BS5655: Part 6: 1985 provides performance data tables, but does not explain the basis on which they are derived. This paper derives the basis for the tables in BS5655 and shows their limitations. The ISO 4190/6 standard and the CIBSE Guide are also reviewed. The paper goes on to present a new set of design tables for general use.

1. REVIEW OF TRAFFIC DESIGN

The first attempts to size a lift system to meet passenger demands occured in the 1920's when Basset Jones (1923) derived a formula for the probable average number of stops that a lift would make under up peak traffic conditions. The derivation of a formula for the probable average highest floor for the same conditions was not made until the 1970's (Tregenza, 1972). Procedures for the calculation of the round trip time (RTT) of a lift and from it the interval (UPPINT), five minute handling capacity (UPPHC) and percentage of the building population served (%POP) under up peak traffic have been used for many decades. Strakosch (1967) divides the RTT into running time and standing time. The CIBSE Guide Part B15 (1972) considers the RTT to be the sum of running time, door operating time and passenger transfer time. Both methods, although effective, are untidy in their operation; leading to possible error. A formalisation of the RTT calculation was first given by Barney & Dos Santos (1974) as a simple three term formula. This formula and the associated ones for UPPINT, UPPHC and %POP are given in Figure 1. These formulae are now universally accepted as an appropriate method for sizing a lift installation to meet the demands of a building's users.

2. CRITIQUE OF STANDARDS AND GUIDES

2.1. British Standard BS5655: Part 6

The British Standards Institution issue documents giving recommendations to the Lift Industry. BS2655 was issued in parts during the 1950's together with a Code of Practice CP407 in 1972. These are being replaced by BS5655 again in parts (series not yet complete). This critique will be concerned with BS5655: Part 6: 1985, Section 4. This document continues to perpetuate misconceptions and myths from CP407:1972. Three errors (two minor and one major) have been selected for discussion.

2.1.1. Comparison of lift performance.

In section 4.1.3. the statement ".... calculations (of the traffic handling capabilities of lifts) can only be put to limited use of a comparative nature. For instance, they can with advantage be used to compare the capabilities of lifts in a group with different loads and speeds provided the same set of factors are used for all cases. On the other hand, they can not be used to compare the capabilities of different makes of lift used for a given group of lifts"

The traffic handling capability of a lift is dependent on the variables described in the RTT equation given in Figure 1. This equation does not include a term defining a lift maker, but of course the terms tv and ts are dependent on the equipment a manufacturer may offer for a particular installation. The statement should be changed to "... calculations can be used with advantage to compare the capabilities of lifts with different loads, speeds and operating times in order to select a lift suitable for the intended environment."

Round Trip Time (RTT) (s)

$$RTT = 2Htv + (s+1)ts + 2Ptp$$

Up Peak Interval (UPPINT) (s)

$$UPPINT = \frac{RTT}{L}$$

Up Peak Handling Capacity (UPPHC) (persons per 5 minutes)

$$UPPHC = \frac{300}{INT} \times P \quad \text{or} \quad \frac{300}{RTT} \times L \times 0.8\ CC$$

Percentage Population served (%POP)

$$\%POP = HC \times \frac{100}{U}$$

$$H = N - \sum_{i=1}^{N-1} \left[\frac{i}{N}\right]^P$$

$$S = N \times \left[1 - \left[\frac{N-1}{N}\right]^P\right]$$

P = O.8 x CC
L = number of cars
N = number of floors above the main floor
CC = contract capacity
tv = interfloor time (S) $= \frac{df}{v}$
df = interfloor distance (m)
v = contract speed (m/s)
ts = stopping time (S) = T−tv
T = tf(1) + to + tc
tf(1) = single floor flight time (s)
to = door opening time (s)
tc = door closing time(s)
U = total building population (persons

FIGURE 1: LIFT DESIGN FORMULAE

2.1.2. Quality and quantity of service.

Section 4.1.4.4 states "The interval ... provides a criterion for measuring the quality of service. The average waiting time may therefore be expressed theoretically as half this interval, but in practice it is probably nearer three quarters of the interval."

Interval is a criterion for Quantity of Service as reflected in an installation's Handling Capacity (see Figure 1). Passenger Average Waiting Time (AWT) is a criterion for Quality of Service, which Section 4.1.4.4 rightly states can not be easily measured. However a theoretical relationship is available based on statistical analysis (Barney & Dos Santos, 1977;) relates AWT to car load (%CC). The relationship shows the AWT increasing from 0.5 x UPPPINT for car loads below 50% of CC; to 0.85 x UPPINT at a car load of 80% of CC; to 3 or 4 times UPPINT at car

CC [P] / N (N+1) v	8 [6.4]	10 [8.0]	13 [10.4]	16 [12.8]	21 [16.8]
5 (6) 1.0	76 (76)				
1.6	62 (64)	71 (72)	78 (78)	84 (84)	94 (95)
6 (7) 1.6	68 (70)	78 (78)	86 (84)	98 (93)	103(105)
7 (8) 1.6	74 (74)	85 (84)	94 (93)	102(105)	113(114)
-					
8 (9) 1.6			100 (99)	109(108)	121(120)
2.5			92 (91)	99 (97)	
9 (10) 1.6			107(105)	116(114)	129(132)
2.5			97 (96)	105(103)	118(120)
10 (11) 1.6			113(111)	123(120)	
2.5			102(101)	110(108)	124(128)
11 (12) 2.5			107(105)	115(115)	130(132)
3.5				113(109)	129(129)
12 (13) 2.5			111(108)	120(120)	136(138)
3.5				118(115)	135(136)
13 (14) 2.5			115(113)	125(124)	142(144)
3.5				122(120)	139(140)
14 (15) 2.5			119(116)	129(128)	147(148)
3.5				125(125)	144(144)
15 (16) 2.5			123(120)	133(132)	152(156)
3.5				129(129)	148(151)
16 (17) 2.5			126(124)	137(136*)	156(160)
3.5				132(131)	152(156)
17 (18) -					
3.5				136(135)	157(160)
Other Conditions	v=1.0m/s I=9.5s				
	v=1.6m/s T=8.0s	v=1.6m/s T=8.75s	v=1.6m/s T=8.75s	v=1.6m/s T=8.75s	v=1.6m/s T=8.75s
			v=2.5m/s T=8.25s	v=2.5m/s T=8.25s	v=2.5m/s T=8.25s
				v=3.5m/s T=8.6s	v=3.5m/s T=8.6s

TABLE 1 Round Trip Time values (in seconds) given in BS5655: Part 6: Section 4 compared to values calculated from data specified in 'other conditions'. (* error in BS 5655)

loads over 95% of CC. Thus for the conventional assumption of 80% car occupancy, AWT = 0.85 UPPINT.

2.1.3. Performance data.

Section 4.1.4.5. Tables 3 and 4, described as "Passenger lifts performance data", give values of UPPINT and UPPHC for a number of suggested installations serving from 5 to 17 floors above the main floor. Neither the method of calculation nor the specific installation data used is given. An enquiry to the BSI secretariat produced the statement: "The guidance material given in the code of practice is the result of considerable experience within the lift industry over the past 20 years or more and is therefore emperical in nature, being a concensus collation of data provided by a number of manufacturers represented on our drafting committee". The basis on which the tables were produced has thus not been documented and the use of the tables could lead to inappropriate recommendations. The following analysis provides the missing information.

Tables 3 and 4 give values for the up peak interval and its associated up peak handling capacity for different groups of cars. This information can be reduced to a value for the RTT of each proposed lift system. This has been done and the values are shown in parentheses in Table 1.

To check these values requires the solution of the RTT equation given in Figure 1. Some of the variables used in the RTT equation are given in Part 6 i.e. df, v, CC and N, but others are not i.e. H,S, P, tf(1), to, tc, tp. These latter variables will need to be found.

As the Part 6 tables give values for UPPINT and UPPHC, it should be possible to determine the average number of passengers carried (P), using the UPPHC equation given in Figure 1. After checking a large number of the entries the value of P was found to approximate to 0.8 x CC.

The average number of stops (S) can be calculated using the formula given in Figure 1, but the average highest reversal floor (H) will be taken as N, as it is unlikely that the Part 6 draughting committee would be aware of a formula for H.

The average time for a passenger to enter or leave a car will be taken as 1.0s.

No information is given or can be easily deduced for T [T=tf(1)+to+tc] and values for these component times will have to be discovered by the trial and error application of the RTT equation (using a computer).

Table 1 gives the results of this analysis. A very close match has been found using the missing time (T) values given at the foot of the table. The likely component times to make up T are:

v=1.0 m/s; T=9.5 [tf(1)=6.5 s, tc=2.0 s, to=1.0 s]
v=1.6 m/s; T=8.0 [tf(1)=5.5 s, tc=2.0 s, to=0.5 s]
v=1.6 m/s; T=8.75 [tf(1)=5.5 s, tc=3.0 s, to=0.25 s]*
v=2.5 m/s; T=8.25 [tf(1)=5.2 s, tc=3.0 s, to=0.05 s]*
v=3.5 m/s; T=8.6 [tf(1)=5.0 s, tc=3.0 s, to=0.6 s]

Practical values for single floor flight times and door closing times are suggested and the door opening times have been adjusted (on the assumption advance door opening is employed) to make up the difference. Two cases (marked *) can be seen to be unlikely.

Table 1 should be used in substitution of Tables 3 and 4 of Part 6 as the user is now totally aware of the parameters on which they are based. However it is recommended that a designer elicit the relevant information from a supplier and use the RTT equation to obtain the exact information.

2.2. International Standard ISO 4190/6-1984 (E)

The International Standards Organisation issue documents, regulations and guidance on an international basis. It is up to each country to accept, reject or add national modifications to such standards (ISO 4190/6 is not adopted in Britain). ISO 4190/6 purports to "lay down rules relating to the planning and selection of lift installations for use in residential buildings, in order to ensure an adequate service". Three quality levels are specified as 60, 80 and 100 second intervals at the main floor.

2.2.1. General comments

(a) Quality levels (Section 1)
As stated in Section 3.1.2 interval does not indicate a quality level, but a quantity level, and the same remarks apply.
(b) Theoretical time of travel (Section 3.4)
This is not a useful definition as this time can not exist in practice. The intention is to cause the installation of faster cars, in order to meet the specified interval criterion. It would be more meaningful to define the actual time to run between the terminal floors of a building. This would then include acceleration, deceleration, levelling, etc. giving an idea of the likely performance of an installation.
(c) Number of lifts and their characteristics (Section 4.1)
It is difficult to understand the logic in this section. Item b) states "if one lift is planned, its rated load has to be at least 630 kg and its rated speed at least 0.63 m/s". There is no reason why a 400 kg (6 person) car can not be installed running at 0.40 m/s, if that is adequate for the purpose. Item c) adds to the confusion by demanding "in each group of lifts:

- the rated speed of all lifts has to be at least 1.00 m/s and
- the rated load of at least one lift has to be 1000 kg".

Twenty different installations are recommended ie:

From: 1 x 630 kg @ 0.63 m/s to: 3 x 1000 kg @ 2.5 m/s

In between these extremes there are such absurd configurations as:

2 x 630 kg + 1 x 1000 kg @ 1.0 m/s
1 x 400 kg + 1 x 1000 kg @ 1.6 m/s
1 x 630 kg + 2 x 1000 kg @ 2.5 m/s

Only five of the configurations are sensible, namely those with cars having identical characteristics. The effect of installing cars of mixed sizes is to make the interval between successive arrivals at the main floor very irregular and queueing will occur after the departure of the smaller cars from the main floor. In addition there will be engineering difficulties with different sizes of machines, drive controls, doors, etc.

2.2.2 Installation selection graphs

The main purpose of the Standard is to provide selection graphs called Programme 60, Programme 80 and Programme 100. (The number indicates the likely maximum interval the selected lift installation would produce). Figure 2 reproduces the graph for Programme 100). A great deal of data is provided from which the graphs have been computed, viz:

N (1-20); CC (400/630/1000 kg); P (5/7/11);
V (0.63/1.00/1.60/2.50 m/s); ts (9.5/10.0/9.5/9.5 s);
df (2.8 ±0.2 m); tp (3.5 s).

Examination of the graphs in Figure 2 indicates that the horizontal lines between configurations '1' and '3'; '3' and '8'; and '8' and '16' represent where a change of speed is necessary for the theoretical terminal floor to terminal floor time to be maintained (in this case at less than 40 s). The curved lines indicate where a change of configuration is necessary to provide the required handling capacities with the changes in the number of floors served. The graphs are plotted for populations per floor from 8 to 40 persons. The lines representing populations from 12 to 36 persons are meaningless and distracting.

The graph is used as follows: decide the total population to be served in a particular building and then to look for the intersection between this value and the number of floors to be served. At the intersection a particular configuration will be suggested. The assumption is that the chosen configuration will then meet the required interval of (in this case) 100s.

The graphs adhere (more or less) to the calculations shown in Figure 1, four "spot" check calculations illustrates this statement.

(a) Single car serving 4 floors.

N = 4, P = 7, v = 0.63 m/s (tv = 4.4 s), T =9.5 s, tp = 1.75 s,

from tables H = 3.9, S = 3.7, Using the RTT equation:

RTT = 2x3,9x4.4 + 4.7x5.1 + 2x7x1.75 = 82.8 s
HC = 25.4 (INT = 82.8 s)
POP = 339 (85/floor)

(b) Single car serving 8 floors.

N = 8, P = 7, v = 1.00 m/s (tv = 2.8 s), T = 10.0 s, tp = 1.75 s

from tables H = 7.4, S = 4.9, Using the RTT equation:

RTT = 2x7.4x2.8 + 5.9x7.2 + 2x7x1.75 = 108.4 s
HC = 19.3 (INT = 108.4 s)
POP = 256 (32/floor)

(c) Two cars serving 20 floors

N = 20, P = 11, v = 1.6m/s (tv = 1.75 s), T = 9.5 s, tp = 1.75 s

from tables H = 18.8, S = 8.6. Using RTT equation:

RTT = 2x18.8x1.75 + 9.6x7.75 + 2x111x1.75 = 178.7 s
HC = 37 (INT = 89.4 s)
POP = 493 (24.3/floor)

(d) Three cars serving 19 floors

N = 19, P = 11, v = 2.5 m/s (tv = 1.12 s), T = 9.5 s, tp = 1.75 s

from tables H = 17.9, S = 8.5, Using RTT equation:

RTT = 2x17.9x1.12 + 9.5x8.4 + 2x11x1.75 = 158.4 s
HC = 62.5 (INT = 52.8 s)
POP = 833 (43.8/floor)

Comparing the three sets of values:

	Interval	HC/floor	Comments
(a)	83	85	Interval low; HC twice required
(b)	108	32	Interval (approx) 100 s; HC high
(c)	89	24	Interval low; HC little high
(d)	53	44	Interval half required; HC little high

Thus the graphs can only be used for rough guidance as the interval varies from the suggested 100s, and the handling capacity is always higher than required. In actual systems the interval will always adjust to match the arrival rate of passengers, until the cars are loaded to 100%, when queueing will occur.

It is not sensible to use these graphs blindly without understanding their basis. For example reading the standard would lead to assumption that a selection from one of the graphs would give the interval specified. This is not true. Any design should always be calculated using the formulae in Figure 1.

2.3 CIBSE Guide: Section B15: Vertical Transportation.

[CIBSE is the Chartered Institution of Building Services Engineers, originally the IHVE, the Institution of Heating and Ventillating Engineers].

The CIBSE publish a Guide to the installation and design of many building services. Section B15 was drafted in 1972 and is now being revised. It comprises a general guide to lifts and escalators. A calculation method is given, which has all the right components, but which tries to use first principles to calculate single floor jump times and door operating times. The method also fails to recognise the use of the highest reversal floor H. Unlike the standards it does present a professional engineering approach to design. The traffic design method presented, however, has long been overtaken by modern proceedures, which it can be hoped will be included in the revised addition.

2.4 ASME A17.1. Handbook to the safety code for elevators and escalators.

[ASME is the American Society of Mechanical Engineers]

There is no reference in this document to traffic design, it is probable that American practice will follow the Strakosch method mentioned in the Introduction.

3. A TABULAR DESIGN METHOD

There is a need for the professional engineer to be able to produce a satisfactory traffic design for a lift installation without either blindly following methods set out in standards or being unnecessarily involved in the application of formulae. A method is presented below, which allows the designer to quickly size a lift installation, whilst still being in control of the design parameters.

3.1. Calculation of Round Trip Time (RTT)

Table 2 provides RTT values for a wide range of lift systems viz: N: 3 to 24 floors and CC: 6 to 26 persons (400 to 2000 kg)

The range of floors has been chosen for the most common range likely to be encountered ie 2 floor systems have not been considered and normally building zones do not exceed 24 floors served above the main floor.

The contract capacities (CC) have been chosen to fit the ISO 4190 Standard R10 dimension series (R stands for Renard) ie 1,00, 1.25, 1.60, 2.00, 2.50, 3.15, 4.00, 5.00, 6.30, 8.00, 10.00 (Crouy-Chanel, 1986). This leads to practical car sizes of:

6 person (400 kg)*
8 person (630 kg)
10 person (800 kg)
13 person (1000 kg)
16 person (1250 kg)
21 person (1600 kg)
26 person (2000 kg)

(* out of sequence car size to fill a gap at the lower end for a small flats lift)

If another load series such as 8, 10, 12, 16, 20, 24 is employed interpolate between two adjacent columns for values for 12, 20 and 24.

The contract speeds (v) have been chosen from the ISO 41190 Standard R5 dimension series ie 1.00, 1.60, 2.50, 4.00, 6.30, 10.00. This leads to practical car speeds of:

0.25 m/s, 0.40 m/s (not tabulated: goods lifts only)
0.63 m/s, 1.00 m/s, 1.60 m/s, 2.50 m/s, (3.15 m/s),
4.00 m/s, (5.00 m/s).

Table 2 gives two suggested speeds for each value of N (floors served above the main floor). The changeover to a faster pair of speed values occurs, when the lower of the two speeds causes a trip from the main floor to the highest floor to take longer than approximately 25 to 30 s. (This trip time is measured from the time the car doors start to close at the starting floor, until the car doors are 90% open at the destination floor.) The two speeds in parenthesis (3.15, 5.00) have been selected out of the R5 sequence in order to give a better speed choice for buildings with 12 floors or more.

The RTT has been calculated assuming:

T = 10 s; df = 3.3 m; tp = 1.0 s;

Variations in these parameter values are given in the table.

For changes in tp a figure is given for ±0.2 s changes as a constant at the top of each column. For example if tp is to be assumed as 1.2 s add the value at the head of the column to the RTT value.

For changes in T a figure is given in each row for ±1.0 s change in T, which must be added or subtracted from the main value of RTT in the first column of each row.

For changes in df or v a figure is given in each row for ±10.0% change in df and ∓9% change in v, which must be added or substracted from the main value of RTT in the first column of each row ie, for a smaller df of 3.0 m subtract the given figure or for a 9% lower speed (2.5 to 2.3 m/s say) add the given figure. A complete example of use is given at the foot of the table.

3.2. Determination of Handling Capacity

Having obtained a value for RTT for a given or proposed lift configuration, it is now necessary to determine the resulting Handling Capacity (UPPHC). Thus if the number of cars is known a value for the interval (UPPINT) can be determined. Or for a desired UPPINT the required number of cars can be found. Figure 2 enables the UPPHC to be determined for specific values of UPPINT and CC.

3.3. Examples of Use

3.3.1. Known lift configuration

Given the following data:

N = 15; L = 4; CC = 13; v = 2.5; df = 3.3 tp = 1.2;
to = 2.0; tc = 3.0; tf(1) = 6.0;

Thus T = 2 + 3 + 6 = 11 s

From Table 2: RTT = 133.4 s

As T is 11 s then 8.7 s must be added
As tp is 1.2 s 4.2 s then must be added
to give RTT = 146.3 s

As L = 4 then UPPINT = 38.8 s
From Figure 2: UPPINT = 80.4 persons/five miniutes

3.3.2. Known values of N, UPPHC and UPPINT

In this case it is required to determine the number and size of cars required to serve the building.

N = 10; UPPHC 150; UPPINT = 30;

From Figure 2: there are two possible choices.

either: CC = 16; when the UPPINT will be equal to 25.6 s,
or: CC = 21; when the UPPINT will be equal to 33.6 s

From Table 2: there are four possible choices.

CC	v	RTT	L	UPPINT	UPPHC	Notes
16	1.60	132.2	5	26.4	145.2	(A)
16	2.50	124.1	4	31.0	123.9	(B)
21	1.60	147.8	5	29.6	170.3	(C)
21	2.50	140.2	4	35.0	144.0	(D)

Notes:

(A) UPPINT much lower and UPPHC just lower than required, UPPCC could be increased to 150, if 4 s could taken off RTT, by making T = 9.5 s then UPPINT = 25.6 s.
(B) UPPINT ok, but UPPHC too low. Reject
(C) UPPINT ok, but UPPHC too high. Reject
(D) UPPINT much higher and UPPHC just lower than required. UPPHC could be increased to 150 by reducing T to 9.5 s, then UPPINT would be 33.6 s.

It would appear that 5 x 16 @ 1.6 or 4 x 21 @ 2.5 will meet the UPPHC criterion, the former at a lower UPPINT and the latter at a higher UPPINT. If UPPHC was not the important criterion than either 4 x 16 @ 2.5 or 5 x 21 @ 1.6 will meet the UPPINT criterion, the former with a lower UPPHC and the latter at a higher UPPHC.

4. CONCLUSION

The recommendations given in BS5655: Part 6 and ISO 4190/6 are confusing and do not give the basis on which they have been presented. The CIBSE Guide does not go far enough and misses out important information.

A method has been given here, which explains the foundations on which it is based and which allows the professional designer control over all the important parameters. The method is non proprietry and only requires the provision of CC, v and T from the lift contractor.

It is important that Standards and Recommendations employ the best advice, experience and knowledge available. Unfortunately in Britain the British Standards Institution does not accept advice from expert sources. An attempt to comment on a draft for the remote monitoring of lifts elicited the following comments from the Director, Standards:

> "We would have expected that any comments received would have come either from committee members or from the organisations which they represented, and it would have been appropriate for your comments to have been returned to us through your source.

And from the Secretary of the MHE/4 Committee:

> "... committee documents are private and confidential ..."

(It emerged in correspondance that the draft for the remote monitoring of lifts is being written by a working group of NALM, who are a trade organisation.)

Having now seen that errors appear in BS5655 in an area, where this author has expertise, it is possible that errors occur elsewhere. As BSI do not provide an open forum for the development of lift standards and rely on a trade organisation for their drafting, it would seem most appropriate that a professional institution take over the role of draughting committee. In Britain the relevant institution is the Chartered Institution of Building Services Engineers. Should this recommendation be implemented then the resulting committee members would all act as individual experts and not as representatives of their employers.

5. REFERENCES

Barney, G.C., and Dos Santos, S.M.: "A survey of conventional design for lift systems", Lift, July/August 1974

Barney, G.C. and Dos Santos, S.M.: "Elevator traffic analysis, design and control" Peter Peregrinus, 1977 (2nd, Ed: 1985)

Crouy-Chanel, F.: "International standardisation in the lift industry", Elevator Technology (Ed G.C. Barney), Ellis Horwood, 1986

IHVE (now CIBSE) Guide: Section B15 Vertical Transportation, 1972.

Jones, Bassett: "The probable number of stops made by an elevator", GE Rev., 26, (8), pp 583-587.

Strakosch, G.R.: "Vertical transportation: elevators and escalators", Wiley, 1967 (2nd Ed: 1983)

Tregenza, P.R.: "The prediction of passenger lift performance", Archit. Sci. Rev., 15, pp 498-54, 1972.

6. BIOGRAPHICAL NOTES

After some years in the electronics industry Dr. Barney read for his B.Sc. and M.Sc. degrees at Durham University. He obtained his Ph.D. in 1965 for the development of a four quadrant thyristor power supply for the Birmingham University proton synchrotron. In 1967 he joined UMIST as a lecturer and was promoted to senior lecturer in 1971. Dr. Barney has been working on lift systems for over 20 years and has authored over 50 papers and written or edited four books. He is Chairman of the International Association of Elevator Engineers Steering Committee. His current appointment is with the University of Manchester as Director of Networking.

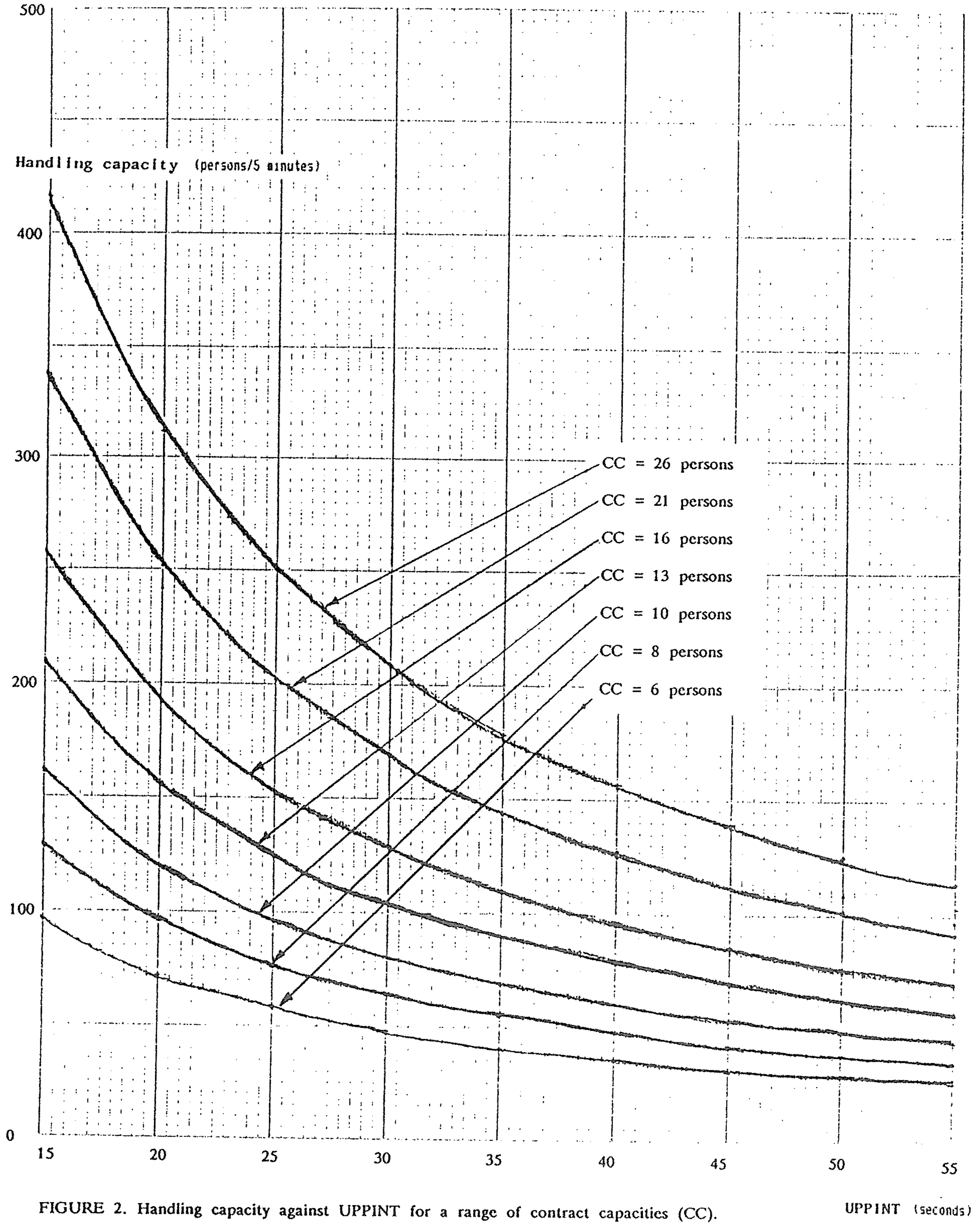

FIGURE 2. Handling capacity against UPPINT for a range of contract capacities (CC).

CC		6 Persons (400 kg)			8 Persons (630 kg)			10 Persons (800 kg)			13 Persons (1000 kg)			16 Persons (1250 kg)			21 Persons (1600 kg)			26 Persons (2000 kg)		
N	v	RTT	: Variations :tp±0.2s ±1.9s :T±1.0s:df±10% : : v∓9%		RTT	: Variations :tp±0.2s ±2.6s :T±1.0s:df±10% : : v∓9%		RTT	: Variations :tp±0.2s ±3.2s :T±1.0s:df±10% : v∓9%		RTT	:Variations :tp±0.2s ±4.2s :T±1.0s:df±10% : : v∓9%		RTT	: Variations :tp±0.2s ±5.1s :T±1.0s:df±10% : : v∓9%		RTT	: Variations :tp±0.2s ±6.7s :T±1.0s:df±10% : : v∓9%		RTT	: Variations :tp±0.2s ±8.3s :T±1.0s:df±10% : : v∓9%	
3	0.63	56.5	3.6	1.1	61.4	3.8	1.1	65.5	3.9	1.1	70.9	4.0	1.1	75.9	4.0	1.1	84.0	4.0	1.0	92.1	4.0	1.0
3	1.00	52.4	3.6	0.7	57.4	3.8	0.7	61.6	3.9	0.7	67.0	4.0	0.7	72.1	4.0	0.7	80.2	4.0	0.7	88.2	4.0	0.7
4	0.63	67.5	4.0	1.8	73.7	4.4	1.7	78.7	4.6	1.7	85.0	4.8	1.6	90.6	4.9	1.6	99.1	5.0	1.6	107.2	5.0	1.6
4	1.00	60.9	4.0	1.1	67.3	4.4	1.1	72.5	4.6	1.1	79.0	4.8	1.0	84.7	4.9	1.0	93.2	5.0	1.0	101.4	5.0	1.0
5	1.00	68.4	4.3	1.6	76.1	4.8	1.5	82.4	5.2	1.5	90.0	5.5	1.4	96.5	5.7	1.4	105.9	5.9	1.3	114.4	6.0	1.3
5	1.60	62.4	4.3	1.0	70.4	4.8	1.0	76.8	5.2	0.9	84.7	5.5	0.9	91.3	5.7	0.9	100.8	5.9	0.8	109.4	6.0	0.8
6	1.00	75.4	4.5	2.1	84.2	5.1	2.0	91.3	5.6	1.9	100.2	6.1	1.8	107.5	6.4	1.8	117.9	6.7	1.7	127.0	6.9	1.7
6	1.60	67.6	4.5	1.3	76.6	5.1	1.3	84.1	5.6	1.2	93.3	6.1	1.1	100.9	6.4	1.1	111.5	6.7	1.1	120.7	6.9	1.0
7	1.00	82.0	4.7	2.6	91.7	5.4	2.6	99.7	6.0	2.4	109.6	6.6	2.3	117.9	7.0	2.2	129.4	7.5	2.1	139.2	7.7	2.0
7	1.60	72.3	4.7	1.6	82.3	5.4	1.6	90.7	6.0	1.5	101.0	6.6	1.4	109.6	7.0	1.4	121.5	7.5	1.3	131.6	7.7	1.3
8	1.60	76.8	4.8	1.9	87.6	5.6	1.9	96.7	6.3	1.8	108.1	7.0	1.7	117.7	7.6	1.7	130.8	8.2	1.6	141.8	8.5	1.5
8	2.50	69.8	4.8	1.2	80.8	5.6	1.2	90.1	6.3	1.2	101.9	7.0	1.1	111.7	7.6	1.1	125.2	8.2	1.0	136.4	8.5	1.0
9	1.60	81.0	4.9	2.3	92.5	5.8	2.2	102.3	6.5	2.1	114.7	7.4	2.0	125.2	8.0	2.0	139.6	8.8	1.8	151.6	9.2	1.8
9	2.50	72.9	4.9	1.4	84.6	5.8	1.4	94.6	6.5	1.4	107.4	7.4	1.3	118.2	8.0	1.2	133.0	8.8	1.2	145.2	9.2	1.1
10	1.60	85.1	5.0	2.6	97.2	5.9	2.5	107.6	6.7	2.5	120.9	7.7	2.4	132.2	8.4	2.3	147.8	9.3	2.1	160.8	9.9	2.0
10	2.50	75.8	5.0	1.7	88.1	5.9	1.6	98.7	6.7	1.6	112.4	7.7	1.5	124.1	8.4	1.4	140.2	9.3	1.4	153.5	9.9	1.3
11	2.50	78.6	5.0	1.9	91.4	6.0	1.8	102.6	6.9	1.8	117.1	7.9	1.7	129.6	8.8	1.6	146.9	9.8	1.5	161.2	10.5	1.5
11	3.15	74.8	5.0	1.5	87.6	6.0	1.5	98.9	6.9	1.4	113.6	7.9	1.4	126.2	8.8	1.3	143.7	9.8	1.2	158.2	10.5	1.2
12	2.50	81.3	5.1	2.1	94.6	6.1	2.1	106.2	7.0	2.0	121.5	8.1	1.9	134.7	9.1	1.9	153.2	10.2	1.7	168.6	11.0	1.7
12	3.15	77.0	5.1	1.6	90.3	6.1	1.6	102.1	7.0	1.6	117.6	8.1	1.5	130.9	9.1	1.5	149.6	10.2	1.4	165.1	11.0	1.3
13	2.50	83.9	5.1	2.3	97.6	6.2	2.3	109.7	7.1	2.2	125.7	8.3	2.1	139.6	9.3	2.1	159.1	10.6	1.9	175.5	11.5	1.8
13	1.15	79.2	5.1	1.8	92.9	6.2	1.8	105.1	7.1	1.8	121.3	8.3	1.7	135.3	9.3	1.6	155.1	10.6	1.5	171.7	11.5	1.5
14	2.50	86.5	5.2	2.5	100.6	6.3	2.5	113.1	7.3	2.4	129.7	8.5	2.4	144.1	9.6	2.3	164.8	11.0	2.1	182.1	12.0	2.0
14	3.15	81.3	5.2	2.0	95.4	6.3	2.0	108.0	7.3	1.9	124.8	8.5	1.9	139.4	9.6	1.8	160.3	11.0	1.7	177.8	12.0	1.6
15	2.50	89.0	5.2	2.7	103.4	6.4	2.7	116.3	7.4	2.7	133.4	8.7	2.6	148.5	9.8	2.5	170.1	11.3	2.4	188.3	12.4	2.2
15	3.15	83.4	5.2	2.2	97.8	6.4	2.1	110.8	7.4	2.1	128.1	8.7	2.1	143.4	9.8	2.0	165.2	11.3	1.9	183.7	12.4	1.8
16	3.15	85.4	5.3	2.3	100.2	6.4	2.3	113.5	7.5	2.3	131.3	8.8	2.2	147.1	10.0	2.2	169.9	11.6	2.0	189.2	12.8	1.9
16	4.00	80.5	5.3	1.8	95.3	6.4	1.8	108.6	7.5	1.8	126.6	8.8	1.8	142.5	10.0	1.7	165.5	11.6	1.6	185.1	12.8	1.5
17	3.15	87.5	5.3	2.5	102.5	6.5	2.5	116.1	7.5	2.5	134.4	9.0	2.4	150.7	10.2	2.3	174.3	11.9	2.2	194.4	13.2	2.1
17	4.00	82.2	5.3	2.0	97.2	6.5	2.0	110.8	7.5	1.9	129.3	9.0	1.9	145.7	10.2	1.8	169.6	11.9	1.7	190.0	13.2	1.7
18	3.15	89.4	5.3	2.7	104.7	6.5	2.7	118.6	7.6	2.7	137.3	9.1	2.6	154.1	10.3	2.5	178.5	12.1	2.4	199.5	13.5	2.3
18	4.00	83.8	5.3	2.1	99.0	6.5	2.1	112.9	7.6	2.1	131.8	9.1	2.0	148.7	10.3	2.0	173.4	12.1	1.9	194.6	13.5	1.8
19	3.15	91.4	5.3	2.8	106.9	6.6	2.9	121.0	7.7	2.8	140.2	9.2	2.8	157.4	10.5	2.7	182.5	12.3	2.6	204.2	13.8	2.4
19	4.00	85.4	5.3	2.2	100.9	6.6	2.2	115.0	7.7	2.2	134.3	9.2	2.2	141.7	10.5	2.1	177.1	12.3	2.0	199.1	13.8	1.9
20	3.15	93.3	5.4	3.0	109.1	6.6	3.0	123.4	7.7	3.0	143.0	9.3	2.9	160.5	10.6	2.9	186.4	12.6	2.7	208.8	14.1	2.6
20	4.00	86.9	5.4	2.4	102.6	6.6	2.4	117.0	7.7	2.4	136.7	9.3	2.3	154.5	10.6	2.3	180.6	12.6	2.2	203.3	14.1	2.1
21	4.00	88.5	5.4	2.5	104.4	6.6	2.5	119.0	7.8	2.5	139.0	9.4	2.5	157.1	10.8	2.4	184.0	12.7	2.3	207.4	14.4	2.2
21	5.00	88.5	5.4	2.0	99.3	6.6	2.0	114.0	7.8	2.0	134.1	9.4	2.0	152.3	10.8	1.9	179.4	12.7	1.8	203.0	14.4	1.8
22	4.00	90.0	5.4	2.6	106.1	6.7	2.7	120.9	7.8	2.7	141.3	9.4	2.6	159.8	10.9	2.5	187.2	12.9	2.4	211.3	14.6	2.3
22	5.00	84.7	5.4	2.1	100.8	6.7	2.1	115.6	7.8	2.1	136.1	9.4	2.1	154.7	10.9	2.0	182.4	12.9	1.9	206.6	14.6	1.9
23	4.00	91.5	5.4	2.8	107.8	6.7	2.8	122.8	7.9	2.8	143.5	9.5	2.8	162.3	11.0	2.7	190.3	13.1	2.6	215.0	14.9	2.5
23	5.00	86.0	5.4	2.2	102.2	6.7	2.2	117.2	7.9	2.2	138.0	9.5	2.2	156.9	11.0	2.2	185.2	13.1	2.1	210.1	14.9	2.0
24	4.00	93.0	5.4	2.9	109.5	6.2	2.9	124.7	7.9	2.9	145.6	9.6	2.9	164.7	11.1	2.8	193.4	13.3	2.7	218.6	15.1	2.6
24	5.00	87.2	5.4	2.3	103.6	6.7	2.4	118.8	7.9	2.4	139.8	9.6	2.3	159.1	11.1	2.3	187.9	13.3	2.2	213.4	15.1	2.1

TABLE 2: Table to determine the Round Trip (RTT) in seconds for different Contract Capacities (CC) from 6 to 26 persons (400-2000 kg) for buildings of 3 to 24 floors (N) above the main floor at two contract speeds (v). The floor to floor cycle time (T) is taken as 10s; the interfloor distance as 3.3m and the one way passenger transfer time (tp) as 1.0s. Variations to be added to RTT are given for T±1s; df±10%; v∓9% (subtract values for increases in speed); and tp±0.2s.

METHOD OF USE: Assuming values for N, CC and v are known find the value for RTT from the table. Make any adjustments to the value for slower/faster cycle time, slower/faster contract speed, different interfloor distance and value for passenger transfer time. EG: N=10, CC=10, v=2.5m/s, T=9s, df=3.0m, tp=1.2s. RTT from the table is: 98.7s. Subtract 6.7s to account for T=9s, subtract 1.6s to account for df=3.0, add 3.2s to account for tp=1.2s giving: 93.6s.