Rated Load and Maximum Available Car Area
A Proposal to Revise EN81-20, Table 6

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Abstract. In the USA during the 1920s, concerns were expressed that large lifts were being overloaded owing to the lift attendants in the cars pushing passengers into their cars. On group systems this was aggravated by the human despatchers forcing passengers into the cars. The result was the density of the passenger load increased as the cars got bigger. Non-domestic buildings were designed in the USA for a uniformly distributed load of 60 pound per square foot (psf) on open areas of building floors and this was used for lift car floors. To ensure passenger safety the load bearing was increased to 100psf for lifts carrying 10,000lb (A17.1:1925), and in 1937 to 127.5psf (A17.1:1937) for lifts carrying 37,500lb. This resulted in a nonlinear relationship between passenger load and the available car area on which they stand. This can be seen in Table 6 of BS EN81-20:2020/BS ISO8100-1:2019.

NOTE 1: Whenever EN81-20 is referred to in this paper it means: BS EN81-20:2020/BS ISO8100-1:2019

Societal changes, where individuals do not tolerate the discomfort of other individuals intruding into their personal space; and technological advances in load weighing, demands a reconsideration of the space a passenger occupies and its corresponding rated load. A proposal to revise the relevant standards is presented.

The concept of a Body Area Index is introduced to allow for a wide range of body weights across the world.

NOTE 2: Imperial measures are referred to and these may be converted as one pound (lb) = 0.454 kg and one square foot (sf) = 0.093 m^2.

1 BASIC TRAFFIC DESIGN

When lift traffic designers size a lift installation to meet a specific passenger demand (say, 12% of the likely building population), at a defined performance level (say, providing an interval of 25 seconds), the lift traffic designer specifies the number of lifts, their rated speed, door times, etc. AND the average number of passengers (P) to be transported on each trip.

Passengers do not conveniently arrive in batches of P passengers, but randomly. The lift traffic designer accommodates this statistical variation by estimating the maximum number of passengers (P_{max}) to be transported to be:

$$P_{max} = \frac{P}{0.8} \qquad (1)$$

This is the maximum number of passengers to be accommodated. But what is the rated load?

NOTE 3: Equation (1) contains the denominator 0.8, that means that P is taken as 80% of $Pmax$. The 80% estimation is a common statistical adjustment.

Inside each lift car there is a rating plate, which states the rated load (Q) in kg. It often also states the maximum number of passengers that can be safely transported according to the formula in clause 5.4.2.3.1a), BS EN81-20:2020 [1] or BS ISO 8100-1:2019 [2]:

$$P_{max} = \frac{Q}{75} \tag{2}$$

and the result rounded down to the nearest whole number.

NOTE 4: In Equation (2) the denominator figure of 75 assumes that the average passenger weight is 75kg.

The rated load (kg) is $75P_{max}$. For example, P_{max} is 17 persons, then the rated load is 1275kg.

2 THE RATIONALE IN THE CHOICE OF THE 75kg PER PASSENGER

The rationale for the choice of 75kg is hidden in American standards as far back as 1925.

A graph was published (shown here as Figure 1) in the US ANSI A17.1: 1925 *Safety code for elevators*. [3]

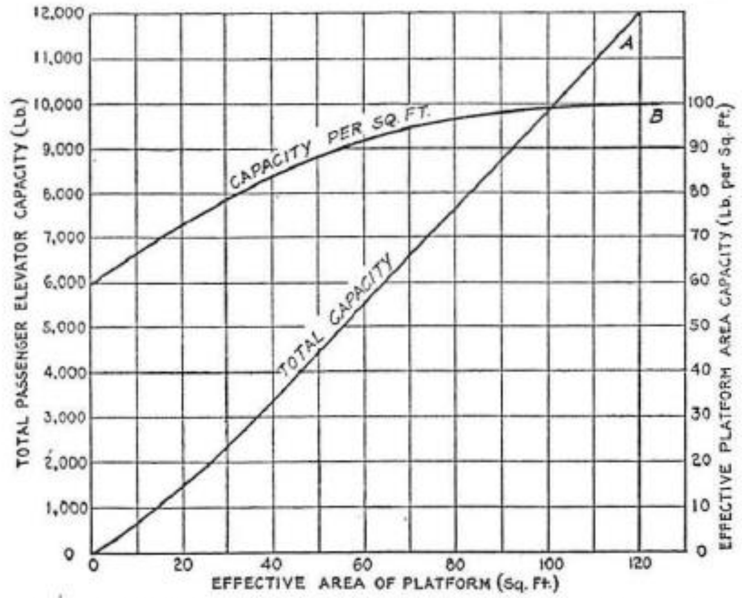

FIG. 4 PLOT SHOWING PASSENGER-ELEVATOR CARRYING CAPACITY CORRESPONDING TO EFFECTIVE PLATFORM AREA

NOTE: For passenger elevators having effective platform areas above 120 sq ft the contract load shall be not less than 100 lb per sq ft.

Figure 1: Figure 4 from A17.1:1925

Curve A on this graph shows the rated passenger capacity (load) in pounds (lb) [left y-axis] for a range of effective car platform areas in square feet (ft^2) [x-axis]. Curve B shows load (lb) per ft^2 (psf) [right y-axis]. Note this is nonlinear. The same graph is published in the A17.1:1931.

In July 1935, the UK Building Industries National Council published a *Code of Practice for Electric Passenger & Goods Lifts and Escalators* [4]. In it they stated:

> *c) A plate shall be affixed to each lift car in a conspicuous position and shall bear at least the following particulars: -*
>
> *(i) The contract load of (goods) lift in cwts. and/ or lbs.*
>
> *(ii) The maximum capacity of (passenger) lift in passengers, calculated at 150 lbs. per passenger.*

There was no supporting graph and no indication of the car platform area. But it implies the assumption an average passenger weighs 150lb. A17.1:1937 [5] provides the graph of 1925 and assumes a passenger weighs 150lb (Rule 217c) supporting the British view.

In May 1943, the UK Building Industries National Council revised their 1935 COP [6] to include a graph, shown here as Figure 2. This graph is clearly based on the US ANSI A17.1: 1925 (Figure 1) but rationalised to suggest a 50ft^2/5000lb pairing rather than the 50ft^2/4400lb. The ANSI A17.1:1945 [7] adopted this rationalisation.

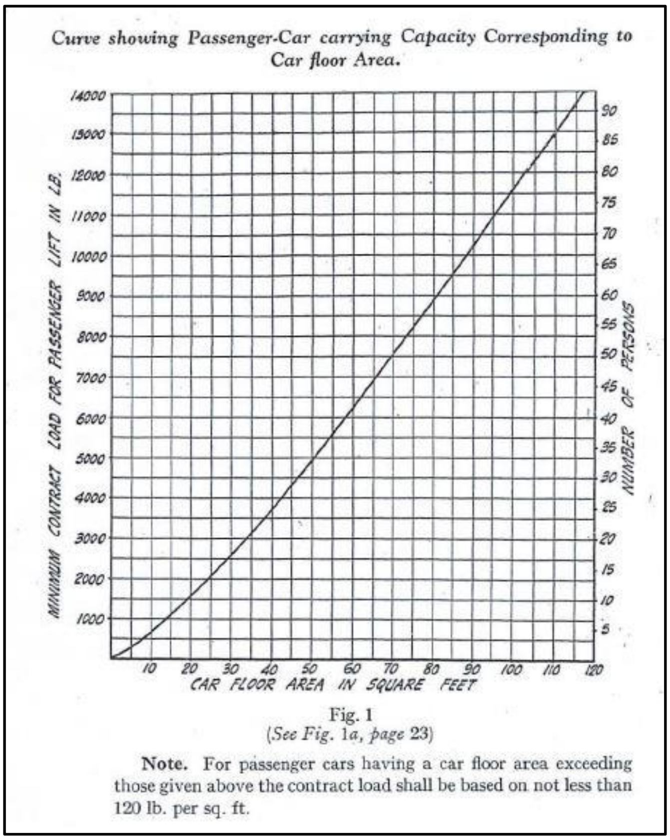

Figure 2 Extract for 1943 Code of Practice

Why is the curve not linear? This is due to Curve B of Figure 1, which shows the lift car floor loading increases from 60psf to 100psf. Why is this?

It was the custom in the 1920s/1930s for lifts to have an attendant to drive the lift. Where there was a lift group, often there was a (human) despatcher on the landing forcing passengers into the cars. These two persons had the function to squeeze as many people as possible in a lift before it was despatched. This led to the observation that the density of passengers increased as the cars got larger. Curve B was the solution. It shows the car floor loading increases from 60psf to 100psf (and later higher to 127.5psf). That is more passengers per square foot!

Another factor was there were no reliable load weighing devices to stop lifts starting up in an overload condition.

This imposed nonlinearity coped with possible overloading at that time as there is a limit to how many people can be squeezed into a small space.

Versions of this graph were included in BS2655, Part 1:1958 [8] and 1970 [9].

By 1955 A17.1 had equations to represent the curves in Figure 2, see PD ISO/TR11071-2:2006, Table 11 [10].

The curve had a discontinuity at available car areas (Ac) above 5m^2/50ft^2. This was a pragmatic point as very few passenger lifts had rated loads greater than 2500kg/5000lb. Lifts up to this point followed a quadratic equation (3).

Up to 5m^2 use Equation (3):

$$Q=35.05Ac^2 +325.7Ac \qquad (3)$$

After the discontinuity point, A17.1 continued with a different quadratic equation (4A), but CEN used a linear equation (4B).

A17.1 used

$$Q = 2.454Ac^2 +610.3Ac - 620.1 \qquad (4A)$$

CEN standards uses a linear equation.

$$Q = 625(Ac - 1) \qquad (4B)$$

NOTE 5: In Equations (3), (4A) and (4B) the variable Ac is in m^2.

Curves are difficult to read and the BS 5655-1:1986/EN81-1:1985 [11] standards used these equations and produced Table 1.1 for a number of rated load values. Table 6 in both EN81-20:2020 and ISO 8100-1:2019 are identical to Table 1.1. Table 1 below shows an extract of common rated loads from EN81-20:2020 plus the ISO recommended rated load of 1800kg, which is missing from Table 6.

Table 1: Extracts from Table 6, EN81-20:2020

Rated load (Q) (kg)	**Maximum available car area** (A_c) (m^2)
450	1.30
630	1.66
800	2.00
1000	2.40
1275	2.95
1600	3.56
1800	3.88
2000	4.20
2500	5.00 (c)
(c) Increases by 0.16m^2 for each extra 100kg	

3 CURRENT SPACE PER PASSENGER

Consider Table 2.

The third column has been added to Table 1 to show the rated number of passengers (rounded down), weighing 75kg each according to Equation (2). This is the number the in-car rating plate displays. The fourth column has been added to show the space that each passenger is allocated to occupy. Notice the diminishing space per passenger.

Table 2: Space per passenger according to EN81-20:2020, Table 6

Rated load(Q) (kg)	Maximum available car area (A_c) (m²)	Rated passengers (P_{max})	Space per passenger (m²)
450	1.30	6	0.22
630	1.66	8	0.21
800	2.00	10	0.20
1000	2.40	13	0.18
1275	2.95	17	0.17
1600	3.56	21	0.17
1800	3.88	24	0.16
2000	4.20	26	0.16
2500	5.00 (c)	33	0.15
NOTE 6: Passenger figures are rounded down.			

The passengers in a 450kg car have a personal space of 0.22m^2 (1.30/6), but the passengers in a 2500kg car have a personal space of 0.15m^2 (5.00/33). As passengers board a large lift car they eventually begin to intrude into other passengers' personal space (shown dashed in Figure 3). Eventually there is no space left and intimate body to body contact occurs (shown solid line in Figure 3). It reaches the crush situations that are seen on subway systems, such as the London Underground. Lift passengers do not tolerate this and are uncomfortable and refuse to board.

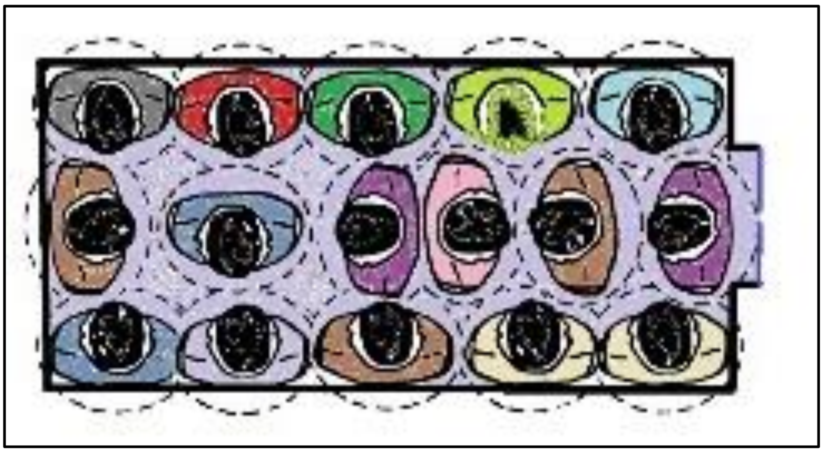

Figure 3 Room for one more?

NOTE 7: Illustrates a 1275kg car with 16 passengers – the in-car rating plate indicated 17 passengers. The average body ellipse is assumed to be 0.21m^2 at 75kg/passenger.

This confirms there is not enough room in the car for the average sized passengers.

Observations made by this author and others since 1990 noted that lift cars do not fill to the number of passengers indicated on the in-car rating plate and conclude it cannot be relied upon for traffic design. This is because passengers do not like the discomfort of their personal space being violated. There are exceptions where passengers have a strong motivation to sacrifice comfort: a group of passengers travelling together may "squash in"; passengers with an urgent need to travel; a student prank.

Leenders in his analysis of EN81-1:1985/BS5655-1:1986 [12] writing in 1986 says

> *"Laboratory experiences conducted in the States half a century ago indicated people could squeeze themselves into a car up to 32% overload and that 42% could even be reached but I suspect that it needed some exterior help as in the Japanese subway".*

An expert writing in PD ISO/TR11071-2:1996 [10] opines:

> *8.2.1 While the entire subject of capacity and loading has historically been treated in safety codes as one and the same, it might be more meaningful in the future writing of safety codes to cover* {1} *loading as a separate issue from* {2} *capacity. One* {2} *refers more appropriately to the traffic-handling capability, whereas the other* {1} *refers to the maximum carrying capacity, which has a direct bearing on safety.*

The conclusion is passengers need more space.

4 PROPOSED SPACE PER PASSENGER

Using work by Fruin [13] and others, this author suggested in CIBSE Guide D:1993 [14] that the "standing area" for a person weighing 75kg should be 0.21m^2. This is the area of Fruin's body ellipse of 600mm by 450mm and scales up from the original assumption of a person weighing 150lb standing on two square feet.

The average passenger area of 0.21m^2 is now quoted and used extensively, see ISO 8100-32:2020 [17].

Applying this space requirement, the car area for a 33-person car should be 6.93m^2. A range of necessary available car areas are shown in Table 3.

Table 3: Proposed revision of EN81-20, Table 6 for traction and hydraulic lifts

Rated load Mass (Q) (kg)	Maximum available car area (A_c) (m^2)	Maximum number of passengers (P_{max})	Average number of passengers (P)
450	1.26	6.0	4.8
630	1.76	8.4	6.7
800	2.24	10.7	8.6
1000	2.80	13.3	10.6
1275	3.57	17.0	13.6
1600	4.48	21.3	17.0
1800	5.04	24.0	19.2
2000	5.60	26.7	21.4
2500	7.00	33.3	26.6
3000	8.40	40.0	32.0
4000	11.20	53.3	42.6
5000	14.00	66.7	53.4
10000	28.00	133.3	106.6
15000	42.00	200.0	160.0
20000	56.00	266.7	213.4
Beyond 20000 kg, add 0.21 m^2 for each extra 75 kg/0.28 m^2 for each extra 100 kg. For intermediate areas, the rated load can be determined by 360 × A_c. All passengers have an average weight of 75kg Numbers of passengers are average values and are decimal			

NOTE 8: A wider range of values can be found in Table (5).

NOTE 9: The maximum number of passengers is shown as a decimal value and for practical purposes would be rounded down.

What is being suggested here is that the maximum area available for a specific rated load should be increased to accommodate the size of passengers, not what they weigh. The nonlinearity of available car area/rated load ratio is removed. The lift traffic designer has a realistic value for maximum car occupancy.

A similar concept was made available for hydraulic lifts, see Table 7 of EN81-20:2020. The argument supporting this concession can be found in PD ISO/TR11071-2:1996.

5 SAFETY

Passenger safety is paramount.

EN81-20:2020 Table 6 increases the live loading from 350kg/m^2 for small cars (eg: rated load 450kg) to 500kg/m^2 for large cars (eg: rated load 2500kg). This is illogical for lifts – it should be linear.

In **Table 3** the rated load is the prime parameter, and the lift components shall be designed for the stated rated load. With modern load weighing devices (not available in the 1920s/1930s) a lift will not start if it is overloaded, by for example, the presence of too many passengers or heavy goods. This safety provision is supported by the other (and less obvious) safety requirements in EN81-20 that the braking and traction components shall withstand excess loads of 125% rated load. In practice, a lift only ever carries the rated, and 125% rated loads, when under test.

Table 4: Proposal to revise Table 6, EN81-20 – a larger range of values

Rated load Mass (Q) (kg)	Maximum available car area (A_c) (m^2)	Maximum number of passengers (P_{max})	Average number of passengers (P)	Rated load Mass (Q) (kg)	Maximum available car area (A_c) (m^2)	Maximum number of passengers (P_{max})	Average number of passengers (P)
100 (a)	0.37	1.8	1.0	1350	3.78	18.0	14.4
180 (b)	0.58	2.8	2.0	1425	3.99	19.0	15.2
225	0.63	3.0	-	1500	4.20	20.0	16.0
300	0.84	4.0	-	1600	4.48	21.3	17.0
375	1.05	5.0	-	1800	5.04	24.0	19.2
400	1.12	5.3	-	2000	5.60	26.7	21.4
450	1.26	6.0	4.8	2500	7.00	33.3	26.6
525	1.47	7.0	5.6	3000	8.40	40.0	32.0
600	1.68	8.0	6.4	3500	9.80	46.7	37.4
630	1.76	8.4	6.7	4000	11.20	53.3	42.6
675	1.89	9.0	7.2	4500	12.60	60.0	48.0
750	2.10	10.0	8.0	5000	14.00	66.7	53.4
800	2.24	10.7	8.6	6000	16.80	80.0	64.0
825	2.31	11.0	8.8	7000	19.60	93.3	74.6
900	2.52	12.0	9.6	8000	22.40	106.7	85.4
975	2.73	13.0	10.4	9000	25.20	120.0	96.0
1000	2.80	13.3	10.6	10000	28.00	133.3	106.6
1050	2.94	14.0	11.2	15000	42.00	200.0	160.0
1125	3.15	15.0	12.0	20000	56.00	266.7	213.4
1275	3.57	17.0	13.6	30000 (c)	84.00	400.0	320.0
	a Minimum for 1 person lift (unchanged). b Minimum for 2 persons lift (unchanged). c Beyond 30000 kg, add 0.21 m^2 for each extra 75 kg/0.28 m^2 for each extra 100 kg. For intermediate loads, the area is determined by linear interpolation. All passengers have an average weight of 75kg Numbers of passengers are average values and are decimal						

6 A PROPOSAL FOR CHANGE

For a range of rated loads, Table 2 shows the maximum number of passengers permitted based on 75kg per passenger and the maximum available car area required based on 0.21m^2 per passenger is shown in Table 3. The commonly available rated loads are shown.

For consistency and clarity EN81-20 hydraulic lifts should also follow **Table 3** and EN81-20, Table 7 can then be deleted. Alternatively, as hydraulic lifts have other safety measures to avoid overload the concession of the extra floor area could still be included if desired.

As passenger numbers are now shown in Table 3, then EN81-20, Table 8 can also be deleted.

In simple terms the rated load is given in Table 3 as 360 multiplied by the available car area on the basis of live load intensity of 360kg/m^2.

A consequence of this proposal to transport more people in the larger lift cars, is energy can be saved and embodied carbon reduced as lifts will be selected with a lower rated load due to the larger available car area for passengers.

7 EXAMPLE 1

A lift with an available car area of 3.47m^2 is to be modernised.

A traffic designer determines the average number of passengers to be carried as 13.6. From Table 3 a lift with a rated load of 1275kg would be selected. The available car area is 3.57m^2.

What will the new rated load be and how many passengers can be transported?

With an area of 3.47m^2 then interpolating Table 3 the lift should have a rated load of 1240kg. It can then transport a maximum of 16.5 passengers and on average 13.2 passengers. This is smaller than required. As traffic design is not an exact science, in practice a lift with a rated of 1275kg would be selected.

8 IN SUMMARY

The car loading to effective (available) car platform area ratio started in the 1920s as a linear value at 60lb/ft^2, but as overloading was feared the ratio became nonlinear and was increased for larger cars to 127.5lb/ft^2 by the 1980s. It has remained so ever since as EN81-20, Table 6.

For a range of rated loads, Table 2 (extracted from Table 6) shows the maximum number of passengers permitted based on 75kg per passenger, but with reducing available car areas as the rated load increases.

EN 81-20, Table 6 shall be revised to reflect the reality of the 2020s bringing the elegance of the 1920s into the 2020s.

For a range of rated loads, Table 3 shows the car area required based on the maximum number of passengers permitted assuming an area of 0.21m^2 per passenger (360kg/m^2) and the corresponding rated load value (360A_c).

Traffic designers can specify a rated load with the confidence that the required number of passengers can be accommodated.

It may be some time before the standards reflect this proposal. However it can be implemented NOW using the current standards quite safely. A Design Examination Certificate would need to be obtained from an Approved/Notified Body for a deviation from a designated/harmonised standard citing the risk assessment evidence in this paper.

The weight of nations [15] should be considered when selecting a lift's rated load in various countries and regions of the world, see Addendum.

REFERENCES

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BIOGRAPHICAL DETAILS

Dr Gina Barney PhD, MSc, BSc, CEng, FIEE, HonFCIBSE, MAE, Principal of Gina Barney Associates, an independent vertical transportation consultancy, entered the lift industry two months after the 1935 COP and has been helping the lift industry ever since.

She and her research team at Manchester University developed the well-known Round Trip Time equation [18], made available an interactive Lift Simulation Design Suite of programs (PC-LSD and specified Adaptive Call Allocation (ACA). She later became involved in ISO work on energy efficient lift and escalator systems.

She is a member of BSI's lift committee MHE/4 and represents the UK on ISO/TC178/WG6/SG5 on traffic design and ISO/TC178/WG10 on energy efficiency. For more on Gina search "Dr Gina Barney."

ADDENDUM: DO ALL PASSENGERS WEIGH 75 kg?

The previous discussion has calculated the number of passengers in a lift by weight by assuming an average passenger weighs 75kg. This is according to EN81 standards and has now been adopted in ISO8100 standards. Do Europeans weigh on average 75kg? Do passengers all over the world all have an average weight of 75kg?

The absurdity of this statement is obvious.

There are nearly 200 countries in the world. Figure 4 shows the average body weights of adults for 177 countries. This figure is derived from seminal work by Walpole et al, *The weight of nations* (15). **Table 5** gives a selected range

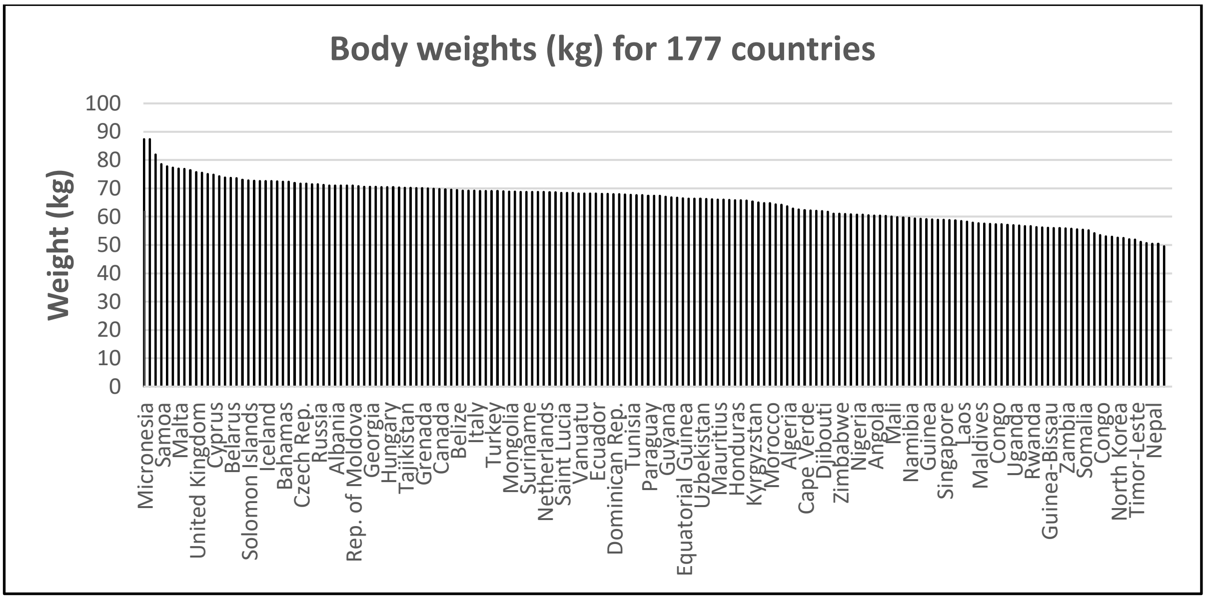

Figure 4 The weight of nations

Source: Walpole et al: The weight of nations: an estimation of adult human biomass. BMC Public Health 2012 12:439. [15]

The adult weight ranges from Bangladesh (50 kg) to Micronesia (87 kg), a 1.74 ratio. The world average is 62kg.

As a 75kg person occupies a space of 0.21m^2 then values for other occupied spaces can be linearly scaled to this body weight, in a similar manner to the BMI (Body Mass Index).

This is termed Body Area Index (BAI). A complete list of these can be found in CIBSE Guide D:2020, Table A2.1 [16] and range from 0.14m^2 to 0.24m^2. The world average is 0.17m^2 based on a world average body weight of 62kg. See Figure 5 for a full range of BAI values.

Table 5 Example range of BAI values.

Country/region	kg	BAI	Country/region	kg	BAI
Tonga	87	0.24	France	67	0.19
North America	82	0.23	China	61	0.17
Australia	77	0.22	Pakistan	59	0.17
Oceania	76	0.21	Singapore	59	0.17
United Kingdom	76	0.21	Africa	59	0.17
Germany	73	0.20	Asia	56	0.16

Russia	71	0.20	India	53	0.15
Switzerland	71	0.20	Vietnam	51	0.14
Europe	71	0.20	Bangladesh	50	0.14
WORLD AVERAGE	62kg		BAI	0.17	

This means a traffic designer who requires, say, an average passenger number of 13.6 persons giving a maximum passenger number of 17 persons would need a bigger lift in Tonga than one in Bangladesh.

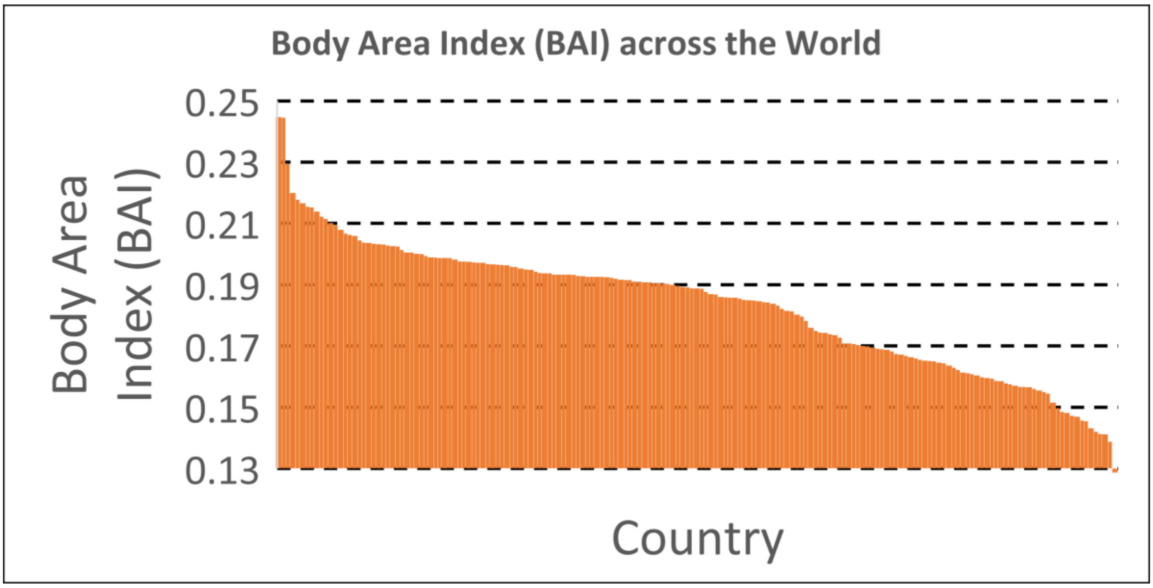

Figure 5: Body Area Index for 177 countries

EXAMPLE 2

Select a lift with a suitable rated load to accommodate a maximum of 17 passengers (a) using EN 81-20, Table 6, shown here as **Table 1**; and (b) using the proposed revision to EN81-20, Table 6 shown here are Table 3.

Table 6: Comparison of questions (a) and (b).

Country	Space required per passenger (m^2)	Total space required (m^2)	Nearest suitable lift rated load/car area (kg (m^2))	
			(a)	**(b)**
Tonga	0.24	4.08	2000 (4.20)	1600 (4.48)
UK	0.21	3.57	1600 (3.56)	1275 (3.57)
China	0.17	2.89	1275 (2.95)	1000 (2.80) *
Bangladesh	0.14	2.38	1000 (2.40)	1000 (2.24) *

- NOTE 9: These lifts are a few percent smaller than required. An advanced traffic designer would consider other factors and probably specify the next larger available rated load as this will accommodate larger non-domestic residents and visitors.

Except for the smallest lift in Bangladesh the rated loads are now smaller.

WARNING: Where lifts are installed in countries with BAIs less than 0.21 the lifts may need to be larger if a large number of overseas visitors are expected, eg: an airport.