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DCLG Final Research Report :

BD 2540

Economic impact of the inclusion of BDAG proposals for the provision of firefighting equipment and facilities in the revised Part B of the Building Regulations

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Fire Safety

BD 2530

Economic impact of the inclusion of BDAG proposals for the provision of firefighting equipment and facilities in the revised Part B of the Building Regulations

Final Research Report

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Executive Summary

This report is in response to a request from DCLG Buildings Division to an assessment of the potential economic impact of proposed changes to the provisions in Approved Document B (Fire safety) for firefighting shafts and discounting of stairs for phased evacuation.

A range of generic building types and building floor geometries (typically representative of common buildings of over 18m high), rectangular, square and L shape have been assessed at three different floor areas (1000, 2500 and 5000m^2).

The provisions for the use of dry fire mains, changes to the provisions of firefighting shafts and discounting of stairs for phased evacuation were then calculated for these nine permutations. Firstly; based on the current recommendations in Approved Document B; and secondly, using the revised recommendations from the BDAG research programme which fed into the proposed revision of AD B.

Discounting of Stairs

In each case it was found necessary to increase the number of exits by 1 in order to keep the stair width below 1400mm. In the case of 1000m2 building the stair width was governed by the minimum storey exit width which reduced when an additional exit was provided, as such the three stairs necessary to comply with the proposed change were each narrower than the two stairs required to comply with current guidance.

The increase in construction cost in the cases considered ranges from £23k to £27k per storey for the proposed amendment to Part B. Construction costs are four times the loss in rental but the loss in rental value will be incurred throughout the life of the building.

Firefighting Shafts and Additional Dry Fire Mains

In each case the number of fire fighting shafts required to meet the revised guidance is less than would currently be necessary. For the purposes of assessing the cost impact of this proposal on a national scale it may be more appropriate to assume a reduced efficiency.

The change in construction costs in the cases considered ranges from an increase of £5.3K (because of the additional dry fire mains) to a reduction of £52K. In the majority of cases there is a cost saving arising from the proposed amendment to Part B.

However, there were no architectural constraints on the location of the shafts for this exercise. In practice there will be aesthetic and functional constraints which would restrict where shafts and mains could be located and as such the actual provision in real buildings would probably be greater.

Notwithstanding these architectural constraints there is the potential, in some circumstances, for the proposed change to allow a significant reduction in the provision of firefighting shafts below what might be considered an acceptable level. As such it may be appropriate to consider incorporating a minimum number of shafts in the revised guidance.

Contents

Introduction and Objectives

This report is in response to a request from DCLG Buildings Division to an assessment of the potential economic impact of proposed changes to the provisions in Approved Document B (Fire safety) for firefighting shafts and discounting of stairs for phased evacuation.

A range of generic building types and building floor geometries (typically representative of common buildings of over 18m high), rectangular, square and L shape have been assessed at three different floor areas (1000, 2500 and 5000m^2).

The provisions for the use of dry risers, changes to the provisions of firefighting shafts and discounting of stairs for phased evacuation were then calculated for these nine permutations. Firstly; based on the current recommendations in Approved Document B; and secondly, using the revised recommendations from the BDAG research programme which fed into the proposed revision of AD B.

Discounting of stairs

In tall buildings over 30 to 35m in height, where phased evacuation is adopted, there is a potential that persons attempting to escape could be impeded by firefighters entering and operating within the building. This potential varies with the height of the building and with the number of escape stairs that are available (see appendix C). The proposed amendment to AD B, set out in DCLG's consultation paper, is discounting a stair in buildings with phased evacuation that are over 30m tall.

This has been proposed to overcome the potential conflict between persons escaping down a stair and firefighters undertaking firefighting and search and rescue operations over several levels within the same stair enclosure. As a consequence the width of stairs needs to be increased to accommodate additional persons.

The three floor areas were assessed as follows.

i) calculate design population of each floor, based on allowed space per person (systematic variable, 6 sq.m)

ii) calculate number of storey exits required (based on AD B table 4)

iii) determine widths of storey exits (AD B table 5, with one exit discounted); must exceed 0.75m

iv) if width of storey exit exceeds 1.4m, increase no. of stairs by 1, and return to stage (iii)

v) calculate stair population for phased evacuation, equals floor design population divided by number of stairs (or no. of stairs – 1, if discounting is being applied)

vi) calculate stair width (AD B table 8, note 2); must exceed 1.0m, and width of storey exit

vii) if width of storey exit exceeds 1.4m, increment no. of stairs by 1, and return to stage (iii)

Stages (iv) and (vii) are not actually required by AD B. However, for stairs above 30m in height and above 1.4m in width, there is a requirement for a central handrail. It was therefore decided to add extra stairs in to avoid the need for an extra handrail. The results are summarised in Table 1 below.

	i	Ii			iii	v	vi
Floor area (m2)	**Max persons per floor @ 6m^2/p**	**Min No of Exits**	**no of exits/stairs required**	**Persons per exit**	**Exit width**	**stair pop**	**stair width**
AD B 2000 – no discounting of stairs							
1000	167	2	2	167	1050	83.5	1050
2500	417	3	3	208.5	1050	139	1290
5000	834	3	6	166.8	1050	139	1290
Proposed amendment – 1 stair discounted							
1000	167	2	3	83.5	850	83.5	1000
2500	417	3	4	139	1050	139	1290
5000	834	3	7	139	1050	139	1290

Table 1. Number of exists, exit width and stair width for three example buildings to meet requirements of AD(B) 2000 and proposed amendment

In each case it was found necessary to increase the number of exits by 1 in order to keep the stair width below 1400mm. In the case of 1000m^2 building the stair width was governed by the minimum storey exit width which reduced when an additional exit was provided, as such the three stairs necessary to comply with the proposed change were each narrower than the two stairs required to comply with current guidance.

Costs

The proposed amendment will potentially have a significant impact. Offices are most likely to be affected by this proposal as these are generally the only buildings tall enough to be subject to such provisions. Other types of building could also be affected but it was considered that the nature of these buildings and the number built per annum was such that the impact of these proposals would be negligable. There are two key impacts arising from increasing stair width in buildings:

(i) Increase in building costs

(ii) Loss of floor space and hence reduction in the rateable floor area

Impact (i) is a one-off, but (ii) will continue throughout the life of the building and over the duration of a typical 10-year tenancy agreement could be considerable.

However, it is likely that a given building will only be subject to one of these two impacts. For example, if a building has a given footprint then to accommodate wider stairs there will be a reduction in rateable floor area, i.e. impact (ii). Alternatively, if the building were to maintain its rateable floor area then it would have to be constructed slightly larger leading to an increase in construction costs, i.e. impact (i). There may be a difference between the cost of constructing a section of floor compared to a section of stair but this is likely to be small. If this difference were to be considered then it would be a case of considering both impacts together.

Following the approach used in the partial draft RIA (that formed part of the public consultation package for Part B) we can estimate the cost impact of constructing additional stairs and the cost changes arising from differences in stair widths as shown in Table 1. The base figures required for this are the plan area of stairs which is taken to be 22.5m^2 for each storey together with, for impact (i), a gross building cost of £1.2k per m^2, or, for impact (ii), an average rental of £300 per m^2 per year. The results of this costing exercise are summarised in Table 2 below.

Building storey floor area (m^2)	Exits/stairs required		Exit width (mm)		Stair width (mm)		Cost impact per storey	
	AD(B) 2000	Proposed amendment	AD(B) 2000	Proposed amendment	AD(B) 2000	Proposed amendment	Construction cost (£k)	Rental loss (£k per year)
1,000	2	3	1,050	850	1,050	1,000	£23.1k	£5.8k
2,500	3	4	1,050	1,050	1,290	1,290	£27.0k	£6.8k
5,000	6	7	1,050	1,050	1,290	1,290	£27.0k	£6.8k

Table 2. Change in exits required, exit and stair width and associated costs for proposed amendment

Table 2 shows that the increase in construction cost in the three cases ranges from £23k to £27k per storey. Construction costs are four times the loss in rental but the loss in rental value will be incurred throughout the life of the building.

Firefighting Shafts and Rising Mains.

The proposed amendment to AD B is to replace the current guidance on the provision of firefighting shafts. The current guidance sets out a minimum number of shafts for a given floor area and also sets a minimum distance from any point on the floor to the fire main landing valve so as to limit the distance that firefighters would need to lay hose (hose distance) to 60m. The proposed performance based guidance is based entirely on a hose distance which is reduced to 45m.

A range of generic building types and building floor geometries have been considered rectangular, square and L shape at three different floor areas (1000, 2500 and 5000m^2). Each building was drawn to scale and assessed against the current and proposed guidance to establish the minimum number of shafts and risers required. For the current guidance the determining factor was the floor area however for the proposed guidance the location of the shafts was critical.

Table 3 below shows the comparison between the two approaches.

Case	**Approx Area**	**ADB 2000**	**Proposal**	
		F.F. Shafts	**F.F. Shafts**	**Fire Mains**
Square				
1	1000	2	1	
2	2500	2	1	
3	5000	4	1	4
Rectangular				
4	1000	2	1	
5	2500	2	1	1
6	5000	4	2	2
L Shape				
7	1000	2	1	
8	2500	2	1	
9	5000	4	1	3

Table 3. Number of FF shafts and mains needed to meet current and proposed provisions of AD B for nine building shapes and sizes

Costs

The costs to meet the two provisions in each of the 9 cases given in Table 3 have been developed from the individual components used to make up either a fire fighting shaft or fire mains as follows:

Fire fighting shaft	Fire mains
• Firefighting lift • Firefighting stairway • Fire fighting lobby • Fire resistant doors • Ventilation smoke shaft *[Only needed for a centrally located FF shaft – if shaft is located at a corner (i.e. partially bound by external walls) then windows can be used to provide ventilation]* • Dry rising main *[Required in buildings 18 to 30m in height. Above 30m a wet rising main is required]*	• Protected Stairwairs • Dry rising main

Table 4 – Costs of Firefighting Shafts and Fire Mains

The principle difference between the two approaches is that a FF shaft requires a fire fighting lift and higher standards of fire protection whereas as a fire main would be installed in a conventional escape stair does not. It is not straightforward to develop a cost per storey model built up from the above individual components because there is a fixed cost to provide a FF lift of £54k for the first four storeys of a building and then a subsequent cost of £5k per storey for buildings up to 16 storeys in height. Above 16 storeys the cost per storey rises as lift speeds need to increase, although most UK buildings are below 16 storeys[1]. Therefore, a nominal 8-storey building has been assumed which has a height of just under 30m (based on a typical storey height of 3.7m) and which keeps it within the limits of a dry rising main.

The other components can be costed individually on a per storey basis. Fire fighting stairs and a FF lobby can be costed on the basis of their typical area and a gross building cost of £1.2k per m^2 (per storey). The costs of fire resistant doors together with monitoring and alarms amounts to £1.2k per storey for each FF shaft/mains. A dry rising main costs about £2k per storey. As noted above a vertical ventilation smoke shaft is required for centrally located FF shafts: this can be of masonry construction the costs of which can be calculated from the unit cost of £55/m^2. For corner FF shafts windows can be used instead, the cost of which has been estimated from a unit cost of £200/m^2. Many of these costs have already been used in the draft partial RIA but have been developed for the purposes of this report[2].

On the basis of these costs and areas the cost of a single central FF shaft in the 8-storey building is £416k and that for a corner shaft is £372k (i.e. £44k less). The cost for a single fire main is much lower at £289k, but this is attributable to the absence of the FF lift. Tables 4a and 4b below summarises the cost per storey for the 8-storey building in each of the nine cases from Table 3 for the two sets of provision considered.

1 Information on FF lifts obtained from Otis.

2 Information on building costs and areas obtained from Spon's Architects' and Builders' Price book and through discussions with Buro Happold.

In practice stairs will have been needed to satisfy the provisons for means of escape in Part B 1 of the Building Regulations. However for the purposes of this comparison this has not been included.

	Cost per storey (£k)		
	AD(B) 2000	Proposal	Difference
Case 1	£103.9	£52.0	-£52.0
Case 2	£103.9	£52.0	-£52.0
Case 3	£207.8	£196.6	-£11.3
Case 4	£103.9	£52.0	-£52.0
Case 5	£103.9	£88.1	-£15.8
Case 6	£207.8	£176.2	-£31.6
Case 7	£103.9	£52.0	-£52.0
Case 8	£103.9	£52.0	-£52.0
Case 9	£207.8	£160.4	-£47.4

Table 4a. Cost per storey for 8-storey building to meet current and proposed Part B provisions *(__Central__ FF shafts)*

	Cost per storey (£k)		
	AD(B) 2000	Proposal	Difference
Case 1	£92.9	£46.5	-£46.5
Case 2	£92.9	£46.5	-£46.5
Case 3	£185.8	£191.1	£5.3
Case 4	£92.9	£46.5	-£46.5
Case 5	£92.9	£82.6	-£10.3
Case 6	£185.8	£165.2	-£20.6
Case 7	£92.9	£46.5	-£46.5
Case 8	£92.9	£46.5	-£46.5
Case 9	£185.8	£154.9	-£30.9

Table 4b. Cost per storey for 8-storey building to meet current and proposed Part B provisions *(__Corner__ FF shafts)*

The two sets of tables show that in the majority of cases there is a cost saving from the proposed amendment to Part B.

Discussion

In each case the number of fire fighting shafts required to meet the revised guidance is less than would currently be necessary. However there were no architectural constraints on the location of the shafts for this exercise. In practice there will be aesthetic and functional constraints which would restrict where shafts and mains could be located and as such the actual provision in real buildings would probably be greater. For the purposes of assessing the cost impact of this proposal on a national scale it may be more appropriate to assume a reduced efficiency.

For instance a single fire fighting shaft could provide cover to a square building of approximately 3,200m2. However, given the likely architectural constraints it may be more appropriate to adopt a 75% efficiency or 2800m2 per shaft. For buildings over 5000m2 it is likely that a combination of firefighting shafts and rising mains in escape stairs would be necessary.

Conclusion

Discounting of stairs

The increase in construction cost in the cases considered ranges from £23k to £27k per storey from the proposed amendment to Part B . Construction costs are four times the loss in rental but the loss in rental value will be incurred throughout the life of the building.

FireFighting Stairs

The change in construction costs in the cases considered ranges from an increase of £5.3K to a reduction of £52K. In the majority of cases there is a cost saving from the proposed amendment to Part B.

However there were no architectural constraints on the location of the shafts for this exercise. In practice there will be aesthetic and functional constraints which would restrict where shafts and mains could be located and as such the actual provision in real buildings would probably be greater.

Notwithstanding these architectural constraints there is the potential, in some circumstances, for the proposed change to allow a significant reduction in the provision of firefighting shafts below what might be considered an acceptable level. As such it may be appropriate to consider incorporating a minimum number of shafts in the revised guidance.

Appendix A – Fire Fighting Shaft Diagrams

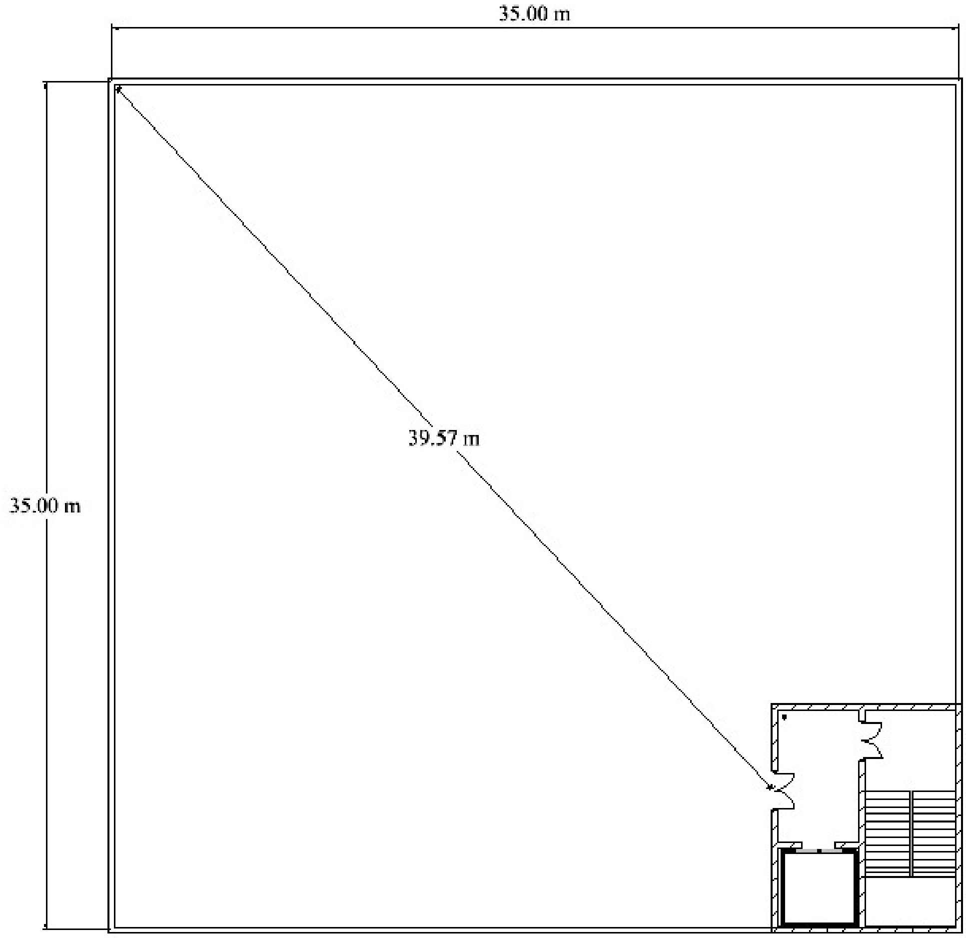

Figure 1 Square 1

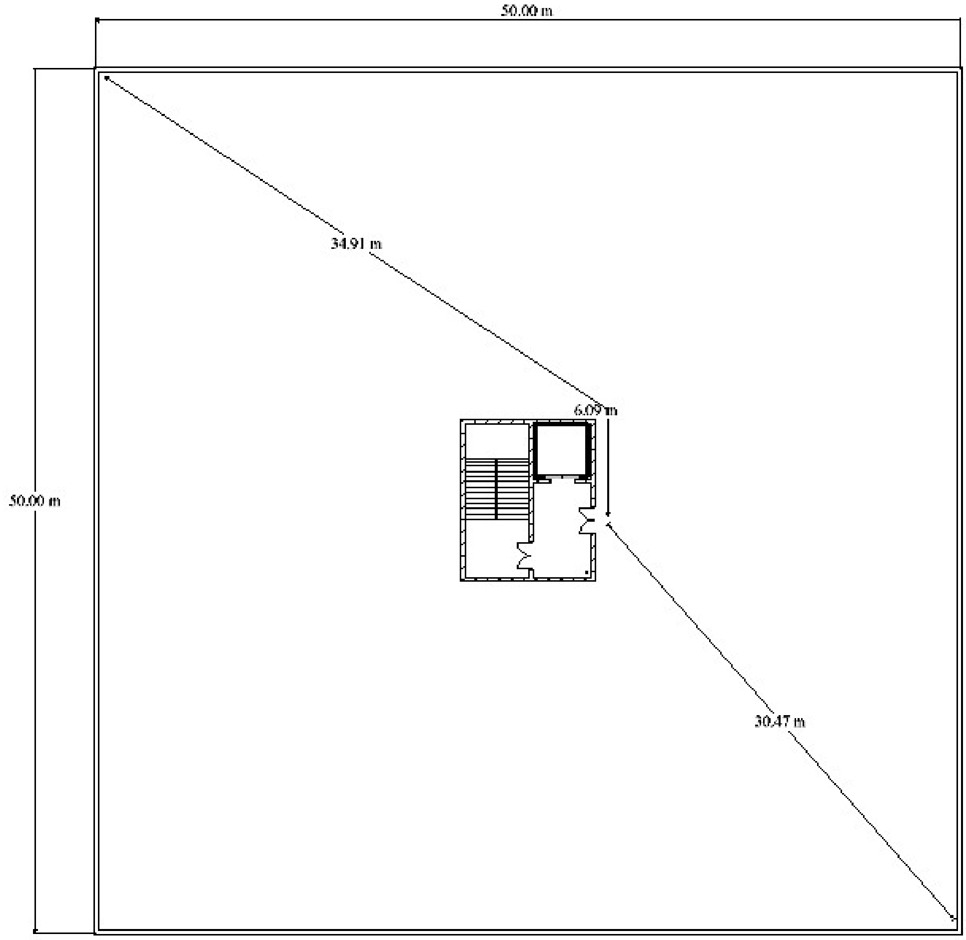

Figure 2 Square 2

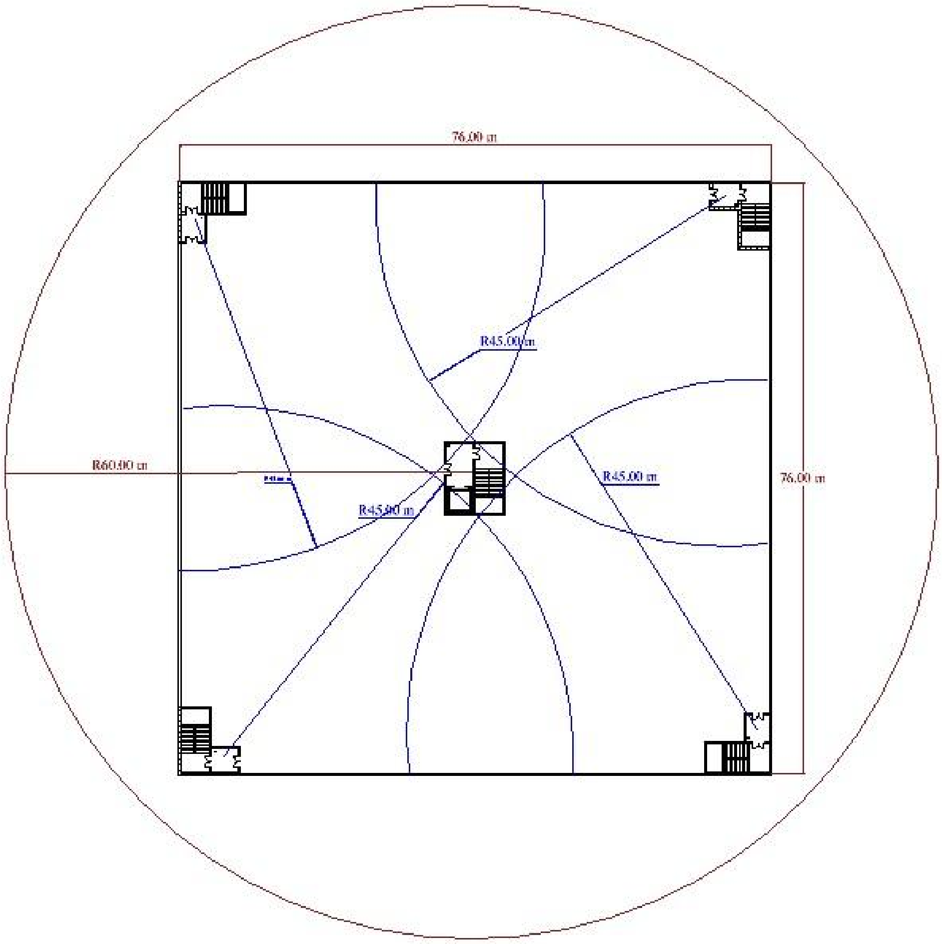

Figure 3 Square 3

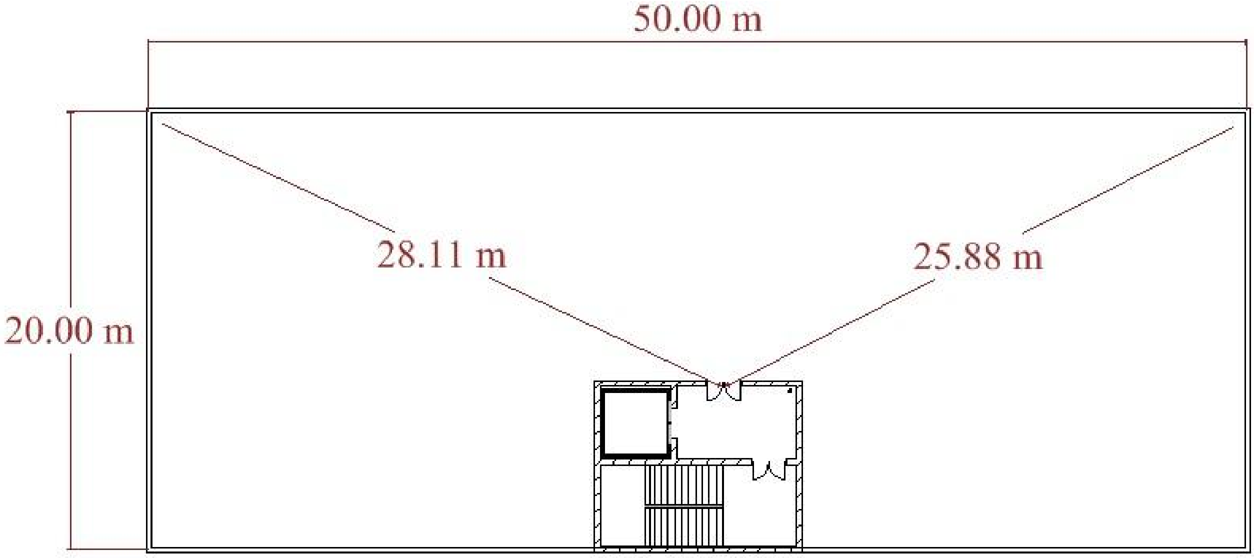

Figure 4 Rectangle 1

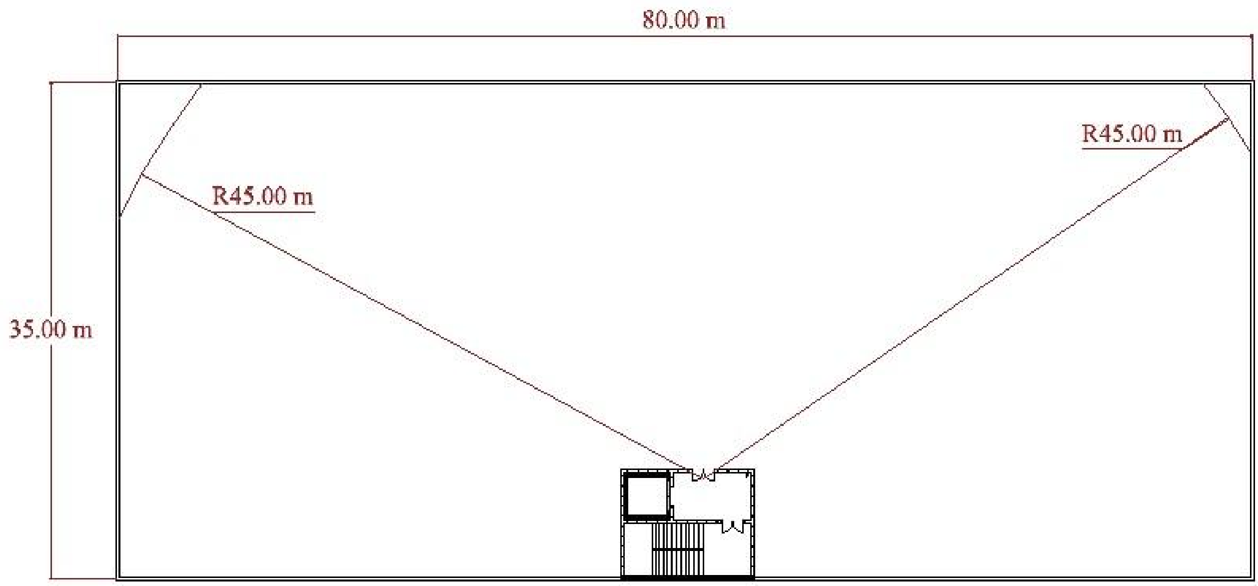

Figure 5 Rectangle 2 – Note that a single shaft would not be adequate. An additional rising main will be necessary.

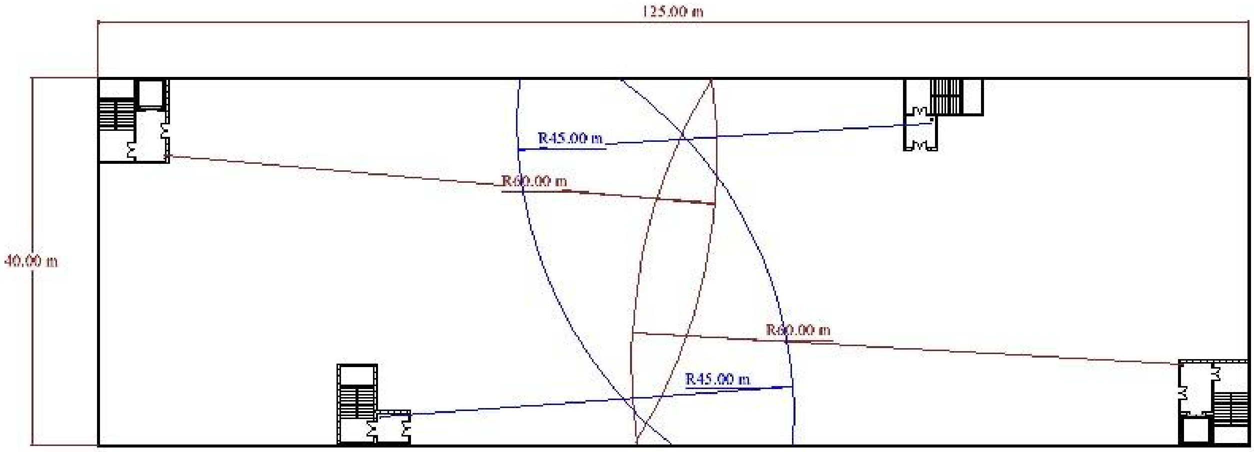

Figure 6 Rectangle 3

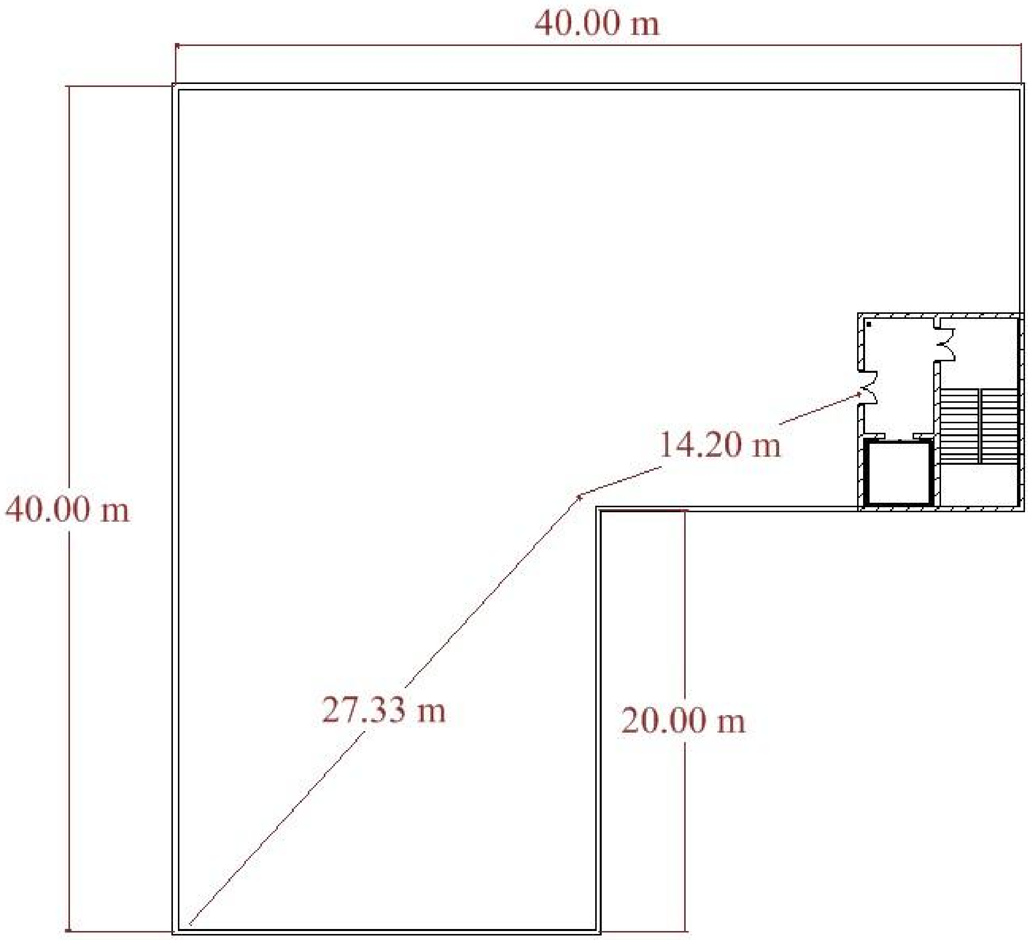

Figure 7 L Shape 1

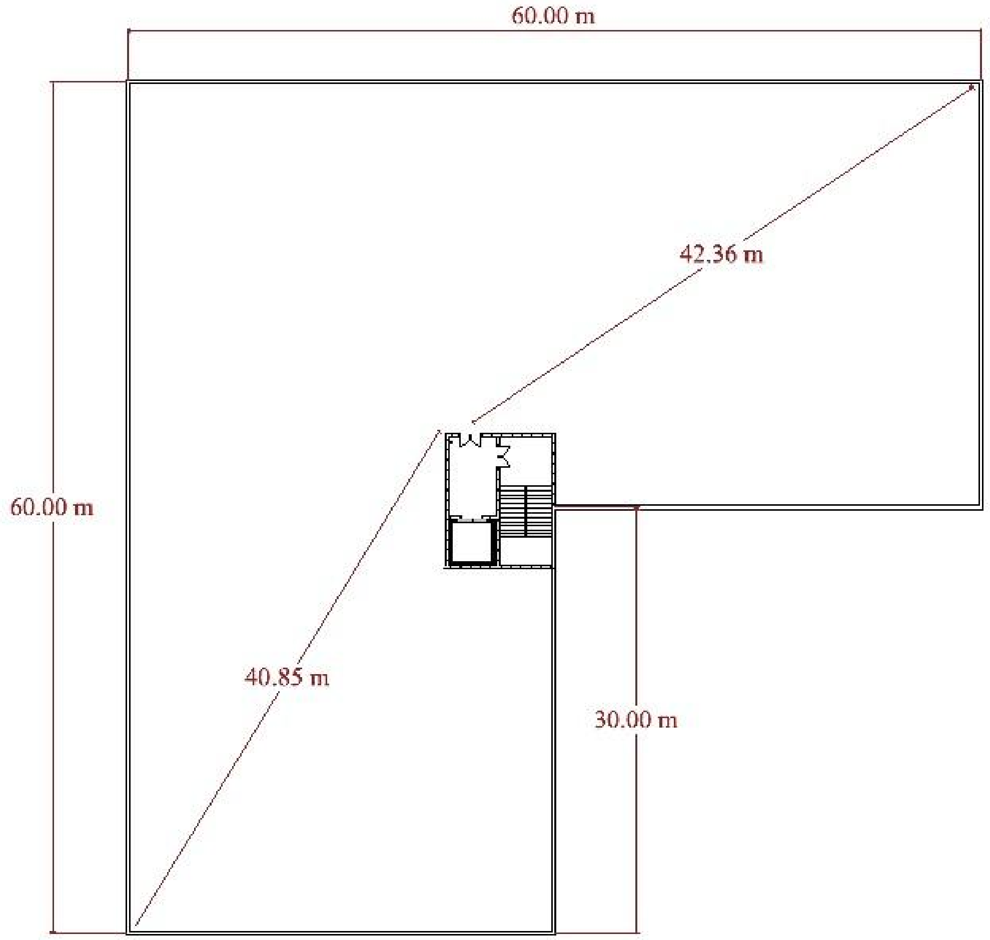

Figure 8 L Shape 2

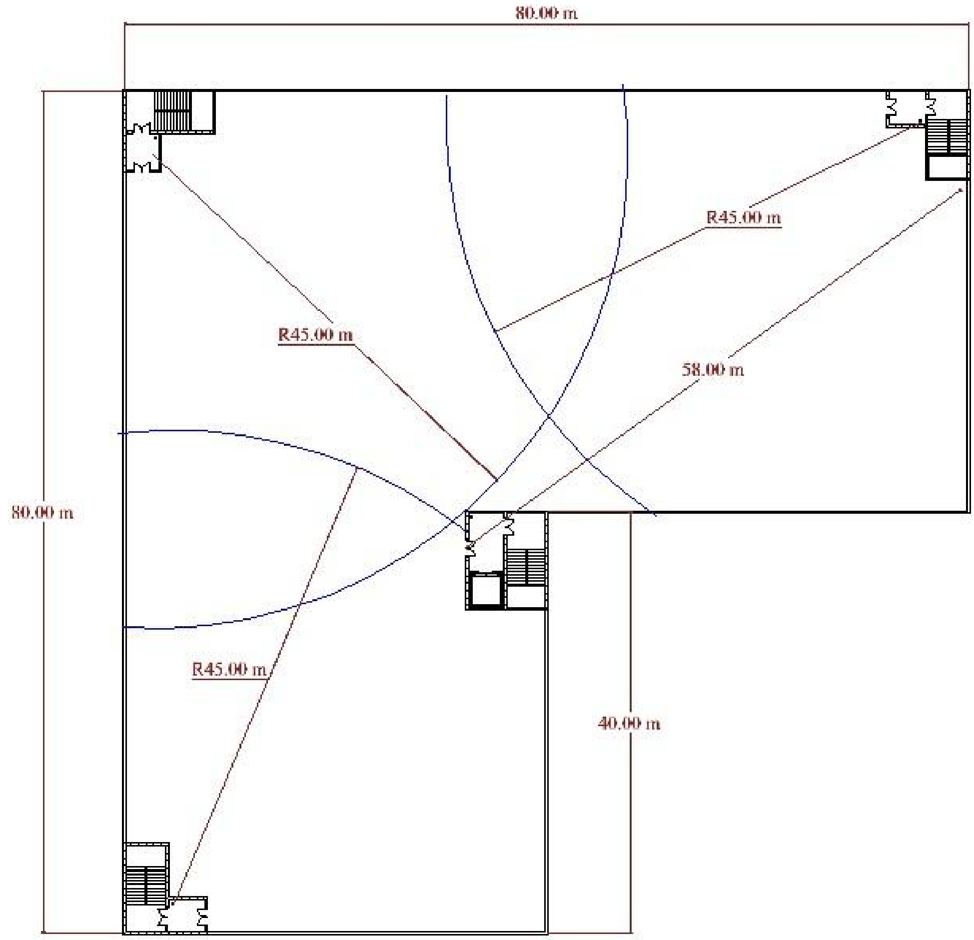

Figure 9 L Shape 3

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Appendix C - Probability of fire-fighters interacting with evacuees

It is assumed that when fire-fighters arrive at a building, after various activities outside the building, they will use a fire-fighting lift to set up a base for their operations on the stairs off the fire floor, the floor below, and the floor below that.

It is possible that evacuees may still be trying to use these stairs.

The StairFlow program [ref.1] has been used to derive probability distributions for the time when the stairs 2 floors below the fire floor are clear of evacuees.

Assumptions

1. Time t=0 is defined as the time when the fire is detected and the decision to evacuate part or all of the building has been taken. (The fire brigade may have been summoned either before or after t=0, most likely shortly after.)
2. The building is designed for phased evacuation
3. Determination of stair requirements assumes no stairs have been discounted
4. The design population is based on a floor space factor of 10 sq.m per person
5. The number of storeys is uniformly distributed between 3 and 23 storeys
6. The storey height is uniformly distributed between 3.0 and 3.6m
7. The floor area of each storey is uniformly distributed between 500 and 2500 sq.m.
8. The fire may occur on any of the floors, with equal probability for each
9. The actual number of people is determined firstly from a triangular distribution for the floor space factor, with a mode of 0.1 people per sq.m, a minimum of 0.1 people per sq.m and a maximum of 0.2 people per sq.m. It is then assumed that 80% of this building population is actually present – the Gaussian approximation to the Binomial distribution is used for the second stage.
10. A phased evacuation takes place
11. One of the stairs is inaccessible from the fire floor. All stairs are accessible from other floors. There are at least two stairs from every floor. The number and width of stairs has been determined according to the guidance in AD”B”.
12. Movement of smoke has been ignored (thus people are never “trapped” or worse)

Results

20,000 evacuations were simulated in a variety of different buildings (see assumptions above). The table below summarises the results for the subsets of these evacuations corresponding to different ranges of building height.

The values in the table are the times defining various fractiles of the distributions. For example, for buildings with heights in the range 20~25m, 10% of evacuations take longer than 15 minutes to clear the area in which the fire-fighters will wish to deploy. 5% of evacuations take longer than 18 minutes to clear this area, 2% of evacuations take longer than 21 minutes, and 1% take longer than 23 minutes. Table 1. Probability distributions for clearance time, for different building heights

Building height	**Time (minutes), for which the time taken to clear the fire-fighter deployment area is exceeded in X% of evacuations**			
	1%	**2%**	**5%**	**10%**
10 – 15m	15	12	11	9
15 – 20m	18	16	15	13
20 – 25m	23	21	18	15
25 – 30m	28	25	22	18
30 – 35m	32	29	26	21
35 – 40m	35	32	27	23
40 – 45m	46	39	32	27
45 – 50m	42	39	34	28
50 – 55m	46	42	36	30
55 – 60m	53	49	41	34

(Note: the accuracy of the values in the table above is not known precisely; it depends on the accuracy of the correlations used in the model to estimate various flow rates, as well as the validity of the assumptions above.)

Discussion

It has been suggested that fire-fighters would be seeking to deploy by approximately 20 minutes after they have been summoned.

The values in Table 1 suggest that once the building height exceeds 20 – 25m, the issue of fire-fighters interacting with evacuees should start to be considered, since in 1% - 2% of evacuations, there will be interaction between fire-fighters and evacuees.

Once the height exceeds 30 – 35m, the issue starts to become significant, affecting 5% - 10% or more of evacuations.

Note that these probabilities assume it is always necessary to continue the evacuation after the fire floor has been evacuated. If the probability of significant fire spread is included, the issue becomes less significant. For example, if only 1 in 10 evacuations need to involve people not on the fire floor, then for a building height of 30 – 35m only 1% (= 0.1 x 10%) of evacuations would fail to clear the evacuation zone in 21 minutes.

If we accept that the results in Table 1 only apply when the building is occupied, and the extent of fire spread requires a full evacuation, then for all fires the probability that the fire-fighters will interact with evacuees is much lower. Home Office fire statistics [ref.2] suggest 61% of fires occur during “office hours”, and of this fraction, 12% spread beyond the room of origin. If full evacuation is only required for fires which will spread, then this involves only 12% x 61% = 7.3% of all fires.

Table 2 below shows the proportion of fires where the fire-fighter deployment area is not cleared after 20 minutes

Table 2. Probability that fire-fighters will interact with evacuees

Building height	**Fraction of fires where fire-fighter deployment area is not cleared after 20 minutes**	
	Subset: full evacuations only	**All fires**
10 – 15m	-	-
15 – 20m	0.56%	0.04%
20 – 25m	3.8%	0.28%
25 – 30m	7.9%	0.58%
30 – 35m	13.6%	0.99%
35 – 40m	16.4%	1.20%
40 – 45m	22.0%	1.61%
45 – 50m	22.3%	1.63%
50 – 55m	28.6%	2.09%
55 – 60m	32.1%	2.34%

These probabilities are based on fire brigade deployment 20 minutes after the alarm sounds. Of course these times are not precise, but subject to uncertainty. A more prompt arrival by the Fire and Rescue Service would lead to a higher probability of interaction with evacuees.

An estimate of the numbers of people who might be affected by interaction between fire-fighters and evacuees can be made, based on the values in Table 1, and an approximate rule of thumb that each stair will experience a flow rate of about 1 person per second. Thus even 1 minute extra clearance time might result in 60 evacuees being affected by fire-fighters attempting to deploy.

In all of the evacuations simulated here, the population per floor was not sufficient to warrant more than two stairs. It might worth performing further simulations, with either or both of the following features:

- floor area greater than 2500 m^2
- design population is based on a floor space factor of 6 m^2 per person