ODPM Building Regulations Division Project Report :

Effect of Local Acts on Fire Risks

The authors of this report are employed by BRE. The work reported herein was carried out under a Contract placed by the ODPM. Any views expressed are not necessarily those of the by ODPM

Executive Summary

The objective of this study is to consider and compare fire losses, in terms of death, injury and property losses, experienced in those areas that have Local Act fire safety provisions in place and those that do not.

This report covers the statistical analysis, based on the UK Home Office Fire Statistics databases 1994-1999, and an analysis using the FRAME points scheme. In view of the difficulty encountered in relating the FRAME risk scores to absolute risk levels, conclusions have only been based on the analysis of the Home Office Fire Statistics databases.

Conclusions:

- Local Acts have no statistically significant impact as far as life safety aspects are concerned.
- For warehouses and car parks, Local Acts are beneficial in reducing property losses
- For tall buildings, there seems to be little benefit from Local Acts. The inherent degree of compartmentation is sufficient to prevent most fires getting “big”.

Recommendations:

- If it is intended that AD “B” is to remain driven purely by life safety considerations, the Local Acts could be repealed with no significant adverse effects.

Contents

Introduction

The “brief” for the project was:

> *“…we require a small piece of work to be carried out to build on the work of the BRAC Local Acts Working Party. The Working Party has recommended a number of repeals and modifications of Local Acts (including the London Building Acts). To this end a short piece of analysis work is needed whereby we will consider and compare fire losses, in terms of death, injury and property losses, experienced in those areas that have Local Acts in place and those that do not. The specific objectives of this task will be:*
>
> - *Undertake an analysis of the relevant fire safety aspects of the Local Acts in England and Wales - Consider and compare fire losses, in terms of death, injury and property losses, experienced in those areas that have Local Act fire safety provisions in place and those that do not.*
> - *On the basis of the analysis provide recommendations on possible provisions that may need to be placed within a revised Approved Document B and those that could be repealed with minimal impact.”*

This text was then added to as follows:

> *“… this study will need to be supplemented by an additional theoretical study using quasi-probabilistic techniques in order to estimate the benefits that may be attributable to the requirements of the Local Acts. The precise details of this approach would be dependent on the findings from the earlier statistical studies, but in essence would involve devising simplified building designs compliant with Local Acts and / or AD 'B', and then performing simple risk assessments using Points Scheme methods. Suitable methods might include FSES (Fire Safety Evaluation System) from the NFPA Life Safety Code (NFPA 101A), or FRAME (Fire Risk Assessment Method).”*

This report covers the initial statistical analysis, based on the UK Home Office Fire Statistics databases 1994-1999, and an analysis using the FRAME points scheme. The FSES scheme was not used, because it did not cover the appropriate occupancy classes.

Description of the project

Statistical Analysis

In addition to the UK Home Office databases 1994 – 1999, the published fire stats for 1998 [1] were used to get the interpretation of the 2-digit “BRIGNUM” code in terms of brigade area, and also the population of people in each brigade area.

Information supplied by Brian Martin [2] was used to determine which areas were affected by Local Acts. It is entirely possible that the brigade areas, and the areas affected by Local Acts, do not overlap precisely. For example, Bournemouth and Poole both have Local Acts, but not the rest of Dorset. Nevertheless, it was assumed for the purposes of the analysis that all fires reported by the Dorset brigade were affected by Local Acts. This will give reasonable results, without recourse to a GIS using postcode / grid reference information for each reported fire. (To complicate matters, fire records will have either postcode or grid reference, but not both.)

The analysis only considered warehouses, car parks, and tall buildings. These were identified by the type of property (“TOP”), namely TOP=891 for warehouses and TOP=882 for car parks. (Note: there is also a room use (“USEROOM”) for car parks: USEROOM=471. These were not included in the analysis, which only used the TOP code.) Tall buildings are identified in the Local Acts as over 18.3m (30m or 25m for parts of London). I used the number of floors (“FLOORS”) to identify tall buildings, with the same criterion used across the country: FLOORS>6.

Information on the numbers of buildings in each brigade area was not obtained. The fire risks have therefore been expressed in the following terms:

- Risks per thousand fires
- Risks per million population

The rationale behind the latter measure is an assumption that the number of buildings in an area is roughly proportional to its population. This assumption is probably better for car parks (no. car parks proportional to no. cars proportional to no. people) and tall buildings (no. of flats or offices proportional to no. people) than for warehouses.

Another important assumption behind the analysis is that the proportion of really large buildings (e.g. warehouses > 7000m^3) does not vary much across the country – this may well be invalid, and would need data from other sources to confirm or deny this.

FRAME Analysis

FRAME (Fire Risk Assessment Method) [3] is a development from the Gretener method [4,5], which concentrated on property protection. FRAME includes factors for life safety and business continuity as well, though not for environmental risks. Reduced to essentials, the FRAME points score is expressed by

$$R = \frac{P}{A.D}$$

where R is the Risk score, P is the score for risk Potential, A is the score for Acceptable risk, and D the Degree of protection provided. This is the same as the Gretener approach. However, different R factors are calculated for each of the separate risks. The calculations are performed for each of the compartments within a building, to indicate where the greatest problems are expected to lie.

Each of these factors is in turn a function of a number of other factors, gradually getting more specific. Some of the functions are very complex, involving logarithms, exponentials, etc. The functions seem to be arbitrarily chosen to give results that subjectively ‘feel right’. The functions are not directly related to statistical data, nor have they been derived as fitted curves describing the response of more complex models. However while the model may lack a rigorous theoretical justification, its results are in conformity with years of experience [3].

An acceptable balance between potential risk and fire protection is obtained for the compartment when the ratio R is less than one. The relationship between risk score and absolute level of risk is not specified, except for a rough correlation between R and the percentage of the fire “compartment” that is expected to be destroyed:

R value	< 1.0	1.0 ~ 1.3	1.3 ~ 1.5	1.5 ~ 1.7	1.7 ~ 1.9	> 1.9
% destruction	< 10%	10 ~ 20%	20 ~ 30%	30 ~ 50%	50 ~ 80%	> 80%

The method was applied to generic warehouse and car park buildings of different sizes, with and without the benefits of sprinkler protection, in order to estimate the likely impact of the Local Acts for these buildings. The assumptions that were made in calculating the FRAME risk scores are given in the following tables. In some cases the assumptions contain a random component, to reflect our uncertainty in the value of the appropriate variable. The FRAME equations were re-coded in Fortran, enabling Monte-Carlo runs to be performed in order to estimate the effects of the uncertainties on the overall risk scores. 100,000 FRAME risk calculations were performed for each building design.

Warehouse

Floor areas of 1,000m^2, 7,000m^2, 14,000m^2, 20,000m^2 and 40,000m^2 were examined, with roof heights of 7m and 14m. The aspect ratio of length to breadth was assumed to be 1.5, except where this would cause the breadth to exceed 90m. The other variables are listed below. Note, U(0,1) is a uniformly-distributed random number between 0 and 1.

Value	**Unit**	**Details**
0	-	Compartment level, storeys above or below ground
4	-	Number of egress directions (90 degrees angle separation)
Varies	-	No. of exits, one per 30m perimeter
Varies	-	Fire brigade access directions (90 degrees angle separation), based on AD "B" table 11. There will be one per 8,000m^2 of floor area, subject to a minimum of 1 and a maximum of 4
0.1	%	Ventilation area as a fraction of floor area
15	minutes	Fire resistance period for structure
15 x U(0,1)	minutes	Fire resistance period for ceiling / floor
15 x U(0,1)	minutes	Fire resistance for external walls
0	minutes	Fire resistance for internal walls
100 x U(0,1)	MJ/m^2	Fire load associated with the building construction
2,500 + 7,500 x U(0,1)	MJ/m^2	Fire load associated with the contents
1	M	Typical dimension of fuel packages
4 + U(0,1)	-	Flammable (=4) or highly flammable (=5) contents
100 + 200 x U(0,1)	K	Temperature rise required for ignition of contents
0	-	Easily-replaced building contents (difficult = 1, impossible / unique = 2)
Varies	£	Value of contents, 45 + 60 x U(0,1) per m^3 of building volume
Varies	-	No. people present, one per 30m^2 floor area, up to a maximum of 300 people
0.05 + 0.1 x U(0,1)	-	Ratio of {cost of outgoing products – cost of incoming materials} to total annual turnover. Typical value is 0.05 ~ 0.15 for warehouses.

Additional factors for warehouses are:

Activation factors	High fire load but low number of ignition sources; heat generator within compartment itself; gas heating; electric installations in compliance with rules but not regularly checked; possible uncontrolled smokers (multiply this last component by U(0,1))
Water supplies	Adequate: no points for “bad” factors
Normal protection	No guard service (no organised human presence, no manually operated alert system, no guaranteed notification to fire brigade, no alarm to occupants); adequate fire extinguishers; no hose reels; partial staff training in use of extinguishers; fire brigade arrival time between 10 ~ 20 minutes (this last component = 2 + 3 x U(0,1))
Special protection	No automatic detection*; no special water supply provision*; no sprinklers*; large permanent professional public fire brigade *Local Acts – add: detection by sprinklers; highly-reliable water supplies; sprinklers of varying standard (this last component = 11 + 9 X U(0,1))
Means of escape	Less than 300 people to warn; horizontal egress provision for 100% of occupants; large permanent professional public fire brigade Local Acts – add: full protection by sprinklers and automatic smoke venting
Salvage factor	Normal: no bonus points for “good” factors

Car Park

Floor areas of 1,000m^2 and 4,000m^2 per storey were examined, with roof heights of 3m per storey, and buildings of different sizes represented by different numbers of floors. The aspect ratio of length to breadth was assumed to be 1.5, except where this would cause the breadth to exceed 90m. The other variables are listed below. Note, U(0,1) is a uniformly-distributed random number between 0 and 1.

Value	**Unit**	**Details**
Varies (-2 to +4)	-	Compartment level, storeys above or below ground
4	-	Number of egress directions (90 degrees angle

		separation)
Varies	-	No. of exits, one per 30m perimeter
Varies	-	Fire brigade access directions (90 degrees angle separation), based on AD “B” table 11. There will be one per 8,000m^2 of floor area, subject to a minimum of 1 and a maximum of 4
Varies	%	Ventilation area as a fraction of floor area. For floors above ground, assume the entire perimeter provides ventilation (only the upper one-third of the “wall” is counted). Below ground, assume 0.1% as for warehouses
60	minutes	Fire resistance period for structure
60	minutes	Fire resistance period for ceiling / floor
0	minutes	Fire resistance for external walls
0	minutes	Fire resistance for internal walls
100 x U(0,1)	MJ/m^2	Fire load associated with the building construction
2,500 + 7,500 x U(0,1)	MJ/m^2	Fire load associated with the contents
1	M	Typical dimension of fuel packages
1 + 3 x U(0,1)	-	Hard to ignite (=1) through to flammable (=4) contents
100 x U(0,1)	K	Temperature rise required for ignition of contents
0	-	Easily-replaced building contents (difficult = 1, impossible / unique = 2)
Varies	£	Value of contents, 300 x U(0,1) per m^2 of floor area (note that each car requires more area – for manoeuvring – than it physically occupies, also car park not full all the time)
Varies	-	No. people present, between zero and one per 8m^2 floor area (two per car)
0.05 + 0.1 x U(0,1)	-	Ratio of {cost of outgoing products – cost of incoming materials} to total annual turnover. Assume same value as warehouses.

Additional factors for car parks are:

Activation factors	No special factors
Water supplies	Adequate: no points for “bad” factors
Normal protection	No guard service (no organised human presence, no manually operated alert system, no guaranteed notification to fire brigade, no alarm to occupants); inadequate fire extinguishers; no hose reels; no staff training in use of extinguishers; fire brigade arrival time between 10 ~ 20 minutes (this last component = 2 + 3 x U(0,1))
Special protection	No automatic detection*; no special water supply provision*; no sprinklers*; large permanent professional public fire brigade *Local Acts – add: detection by sprinklers; highly-reliable water supplies; sprinklers of varying standard (this last component = 11 + 9 X U(0,1))
Means of escape	Maybe less than 300 people to warn (check against actual number present in each Monte-Carlo run); protected staircases; large permanent professional public fire brigade Local Acts – add: full protection by sprinklers and automatic smoke venting
Salvage factor	Normal: no bonus points for “good” factors

Findings

Statistical Analysis

The results of the statistical analysis of warehouse fires are summarised in the table below.

WAREHOUSES		Local Acts			no Acts		
per thousand fires	deaths	0.0	+/-	0.0	0.0	+/-	0.0
	injuries	49.8	+/-	7.7	43.2	+/-	3.4
	"big" fires	29.4	+/-	5.9	58.3	+/-	3.9
per million pop	fires	15.4	+/-	0.5	12.5	+/-	0.2
	deaths	0.0	+/-	0.0	0.0	+/-	0.0
	injuries	0.8	+/-	0.1	0.5	+/-	0.0
	"big" fires	0.5	+/-	0.1	0.9	+/-	0.1

The statistically-significant differences are the proportion of fires that get “big” (>200m^2 in this case), which is much less in the areas where local acts apply. Also note the number of fires is greater where Local Acts apply – presumably the Local Acts are recognition that the (potential) problems are worse than normal, rather than encouraging for fires to start.

The results of the statistical analysis of car park fires are summarised in the table below.

CAR PARKS		Local Acts			no Acts		
per thousand fires	deaths	0.0	+/-	0.0	1.2	+/-	1.2
	injuries	15.7	+/-	6.4	17.3	+/-	4.6
	"big" fires	93.8	+/-	15.6	176.2	+/-	14.7
per million pop	fires	2.8	+/-	0.1	3.7	+/-	0.1
	deaths	0.0	+/-	0.0	0.0	+/-	0.0
	injuries	0.0	+/-	0.0	0.1	+/-	0.0
	"big" fires	0.3	+/-	0.1	0.8	+/-	0.1

The statistically-significant differences are the proportion of “big” fires (> 5m^2 in this case). Also the number of fires per million population, although in this case it is lower in the areas where Local Acts apply.

The results of the statistical analysis of fires in tall buildings are summarised in the table below.

TALL BUILDINGS		Local Acts			no Acts		
per thousand fires	deaths	3.6	+/-	1.0	4.6	+/-	0.5
	injuries	162.1	+/-	6.7	128.0	+/-	2.7
	"big" fires	15.8	+/-	2.1	15.1	+/-	0.9
per million pop	fires	47.6	+/-	0.8	63.5	+/-	0.5
	deaths	0.2	+/-	0.0	0.3	+/-	0.0
	injuries	7.7	+/-	0.3	8.1	+/-	0.2
	"big" fires	0.9	+/-	0.1	1.2	+/-	0.1

The statistically-significant differences are that the number of injuries per thousand fires is HIGHER for areas with Local Acts, but the number of fires per million people is lower. Other differences are not significant. (Note: the criterion for a “big” fire in this case is >20m^2).

FRAME Analysis

The results for the FRAME analysis are presented in the following graphs. As a result of the Monte-Carlo analysis, it was found that the uncertainties in the results arising from the input uncertainties was about:

- 10% of the risk score for property and business risks in unsprinklered buildings
- 15% of the risk score for property and business risks in sprinklered buildings
- 15~20% of the risk score for life safety risks in all buildings

Hence, the differences in risks for sprinklered and unsprinklered buildings are very significant.

The results for warehouses can be summarised as follows:

- The risks are significantly lower with sprinklers present
- The risks (especially property and business) increase with warehouse area
- Compartment height has little influence on the risk
- For areas up to 20,000m^2, the life risk with sprinklers is less than that for an area of 1000m^2 without sprinklers
- For areas of 40,000m^2, the life risk with sprinklers is less than that for an area of 7000m^2 without sprinklers
- Even with sprinklers, all risk scores are greater than 1.0, implying the compartment is inadequately protected

The results for car parks can be summarised as follows:

- The risks are significantly lower with sprinklers present
- The risks (especially property and business) increase with floor area

- Storey level above has little influence on the risk, although areas below ground are higher risk
- For a floor area 4,000m^2, the life risk with sprinklers is less than that for an area of 1000m^2 without sprinklers
- Even with sprinklers, most risk scores are greater than 1.0, implying the compartment is inadequately protected

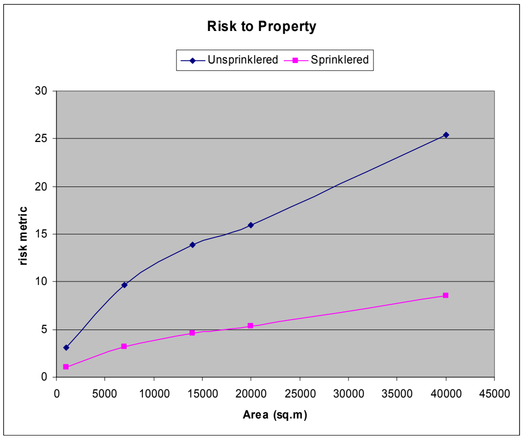
In most cases the values for the risk scores are greater than 1, sometimes very much greater. Although the correlation between risk score and absolute risk is not specified, the FRAME manual states that a risk score of 1.0 or less represents a well-protected compartment, and a value of 1.9 or more predicts an almost total loss in the event of a fire. This only applies to property risk, but it is implicit that the other risk scores follow a similar scale. On this basis, large warehouses and car parks should be death traps – even when sprinklered – but we know from the statistics that this is not the case.

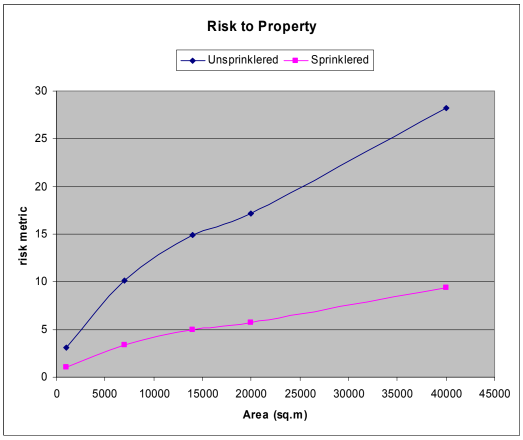
It is possible that some of the factors chosen were unduly pessimistic – the “normal protection” factors in particular are a major contributor to a high risk score. However, since the risk score is expressed as a ratio of potential hazard to protection, any errors in the components that are constant for all buildings should just change the risk score by a constant multiplying factor. The relative risks would remain unchanged (but note – the risk score is not directly proportional to absolute risk).

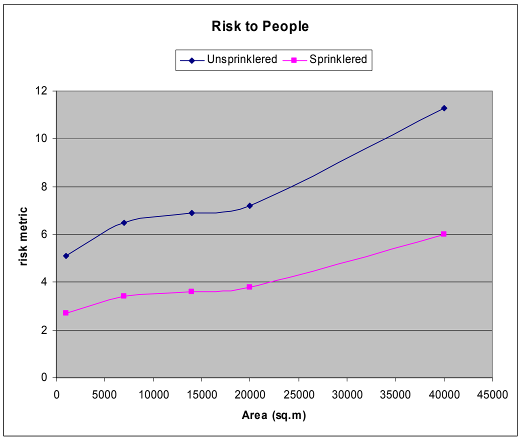
One of the criticisms levelled at points schemes approaches to risk assessment is that they implicitly pre-determine the “correct” fire safety strategy to be employed, as a consequence of the various weightings given to the different components. It may be that this is a significant factor in these examples. In FRAME, some “bonus points” are given for compartment sizes less than 1000m^2. This is clearly not applicable for any of the buildings considered in this report. However, it may be one of the implicit assumptions within FRAME that internal compartmentation is possible in order to reduce the risk to acceptable levels.

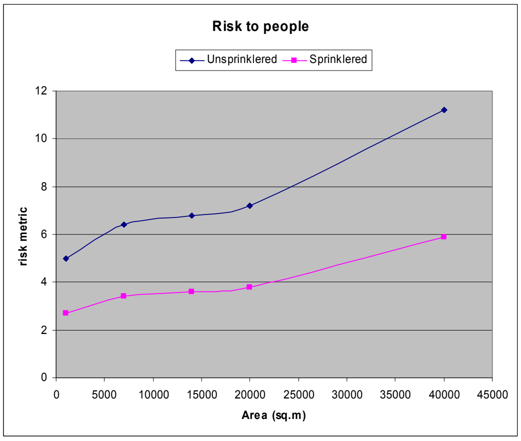
Perhaps a more serious problem with FRAME is that a “one size fits all” approach is not valid. As a test, a calculation representative of a domestic dwelling room was carried out. The results were: $R_{property} = 0.16$, $R_{people} = 0.64$, $R_{business} = 0.18$. All were less than 1.0, indicating adequate protection for the risk. We know from statistics that the risks for typical dwellings are about 6~10 deaths and 200~250 injuries per thousand fires [6], much higher than the risks for warehouses or car parks. However FRAME is predicting a score of R_{people} >>1 for such buildings. This strongly suggests that the FRAME risk score is not particularly well correlated with the absolute risk, at least for R_{people}.

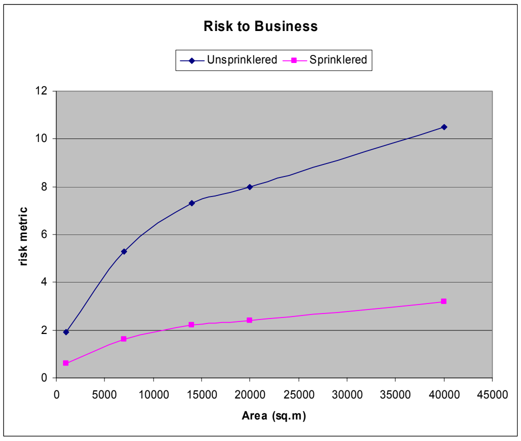
Warehouse results

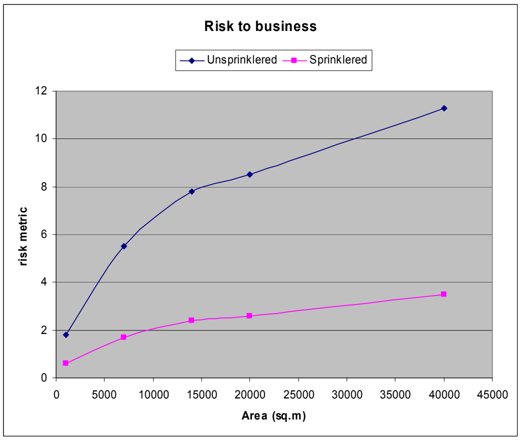
<table>
<tr><th>7m high</th><th>14m high</th></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>


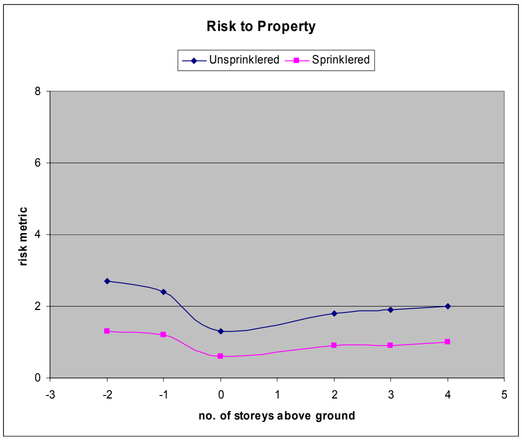
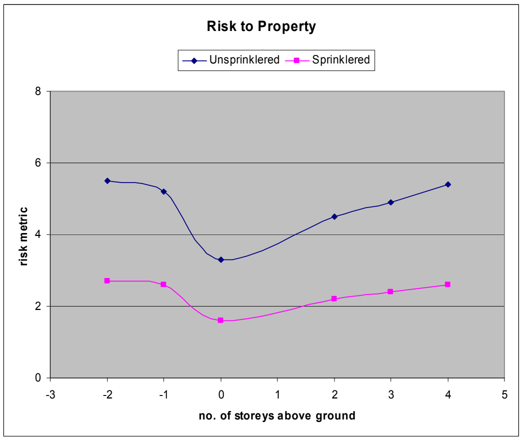
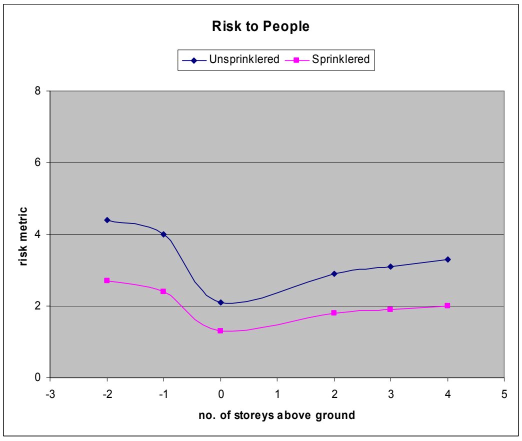
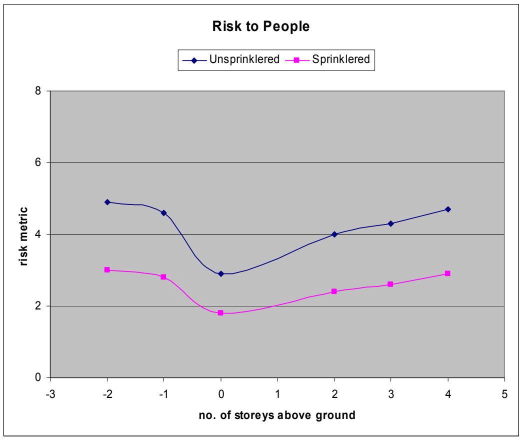
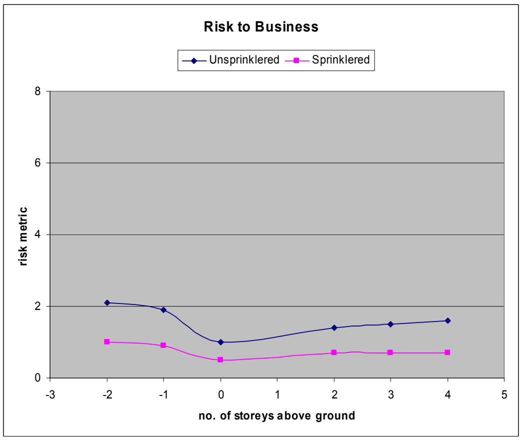
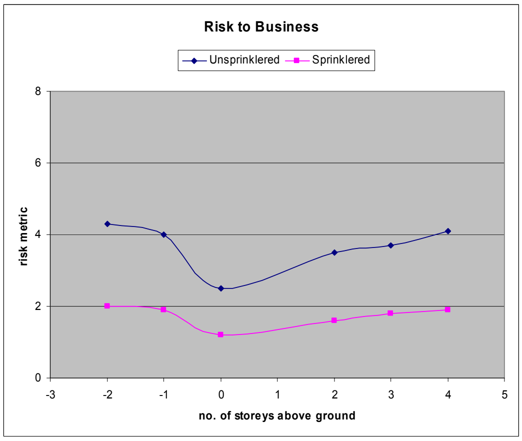
</td><td>


</td></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Car Park results

1000 m^2 area per storey	4000 m^2 area per storey
	
	
	

Conclusion and recommendations

In view of the difficulty encountered in relating the FRAME risk scores to absolute risk levels, conclusions have only been based on the analysis of the Home Office Fire Statistics databases.

Conclusions:

- Local Acts have no statistically significant impact as far as life safety aspects are concerned.
- For warehouses and car parks, Local Acts are beneficial in reducing property losses
- For tall buildings, there seems to be little benefit from Local Acts. The inherent degree of compartmentation is sufficient to prevent most fires getting “big”.

Recommendations:

1. If it is intended that AD “B” is to remain driven purely by life safety considerations, the Local Acts could be repealed with no significant adverse effects.

References

1. Watson,L & Gamble,J, *Fire Statistics United Kingdom 1998*, September 1999, ODPM
2. Martin,B, private communication, April 2004
3. De Smet,E, *Frame Manual, version 2*, 1999
4. *Rechenmethode der osterreichischen Brandverhutungsstellen zur Ermittlung der Brandschutz-Massnahmen*, Brandverhutung, April 1973
5. Kaiser,J, *Experiences of the Gretener Method*, Fire Safety Journal 2 (1979-80) p.213-222
6. Williams,C et al, *Effectiveness of sprinklers in residential premises*, BRE Project Report 204505, Feb 2004