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HOME OFFICE

The Value of Fire Protection in Buildings

Summary Report

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SCIENTIFIC RESEARCH & DEVELOPMENT BRANCH

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FIRE RESEARCH

THE VALUE OF FIRE PROTECTION IN BUILDINGS -SUMMARY REPORT

R.Rutstein
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SUMMARY

This summary report describes a study of the value of sprinklers, detectors and structural fire resistance in reducing the fire damage in buildings of different occupancies. The value is considered from the national economy point of view, and is determined by comparing the cost of providing fire protection with the benefits of the expected future reduction in fire damage. The value of fire protection from the firm's point of view is also considered briefly.

The method of analysis is outlined in this report and the main results are presented. Tables of the intermediate numerical results, the probability of a fire occurring, the average fire damage in protected and unprotected buildings, and the fire loss per unit area of fire damage, are included as an Appendix.

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1. INTRODUCTION

The Home Office Fire Department is currently undertaking a wide-ranging review of fire and fire protection and the study reported here is one of this series of studies. The objective of this particular study is:

-to assess the value of sprinklers, automatic fire detection and structural fire resistance in reducing fire losses in buildings.

Only the protection of property is considered here. The protection of life is the subject of a separate study.

This report contains a summary account of the study and includes an outline of the method of analysis as well as the main conclusions. The main numerical results are included in the Appendix. A full technical account of the study is given in Report 16/78,"The Value of Fire Protection in Buildings".

1.1 The requirements of the study

The particular requirements of this study which have dictated our approach to the problem are as follows:

1.The value of the fire protection measures is considered from the national economy point of view. The Home Office Fire Department, as a Central Government department, is concerned with the effects of fire and fire protection on the national economy. In this study the costs of providing fire protection and the direct and consequential fire losses are therefore measured in terms of the national economic effects. These costs and losses, and particularly the consequential losses, may be quite different from the costs and losses experienced by the owners or occupiers of the buildings.

While the primary objective has been to consider the national economic effects the problem has also been considered briefly from the point of view of the owners or occupiers of the buildings.

2.In this study the value of the fire protection measures has been assessed in quantitative terms. It was not sufficent to conclude, for example, that "sprinklers are very valuable". The study was designed to provide estimates of the value of each fire protection measure in monetary terms.

3.The study was intended to provide an overall picture of the value of fire protection. In order to provide this overall picture the analysis has been done for broad classes of buildings: industrial buildings as a single group, separate sectors of industry, storage buildings and shops. Other occupancies including offices, schools, hospitals and places of assembly (public houses, restaurants etc.) have also been considered but the results for these occupancies may be less accurate because of the scarcity of relevant data. The results of this analysis are therefore only applicable to each occupancy as a group, or to the typical buildings in the group. There may be many individual buildings in which the circumstances are different from the typical or average case and for which the results of the study do not hold. However, the objective of the study is the provision of an overall picture and general conclusions, rather than to attempt to produce a universal formula which is detailed and accurate enough to apply to any and every individual building.

1.2 The measurement of the value of fire protection

The value of fire protection is measured by comparing the costs of providing the protection with the reduction in fire losses resulting from the additional protection. Because the costs are mainly incurred in the initial year and the benefits accrue (in probability) in future years the costs and benefits must be compared using the standard accounting technique of Discounted Cash Flow.

If the initial cost of installing fire protection is C and the annual maintenance costs are c per year, then discounting at 10 per cent over 20 years, the total discounted cost of providing fire protection is;

$$C + 9.36c$$

The expected reduction in fire losses in any year is:

Reduction in fire losses =
Probability of fire x
(Fire loss if a fire occurs in an unprotected building
-
Fire loss if a fire occurs in a protected building)

The total discounted future benefits are equal to 9.36 times the expected annual reduction in fire loss.

If the discounted benefits are greater than the discounted costs then the provision of fire protection is considered cost-effective.

1.3 The approach to the problem

In order to estimate the value of fire protection, the costs and benefits must be calculated for each occupancy group. The separate items in this calculation are:

- the cost of providing fire protection
- the probability of a fire occurring
- the average amount of fire damage which would result if a fire occurred in an unprotected building.
- the average amount of fire damage which would result

if a fire occurred in a protected building.

This problem has been tackled as a statistical exercise. The separate elements of the problem have been estimated from the available fire data, and where data were not available additional data have been collected. A very important part of our study has been a special survey of fires. In the fire survey a total of 600 fires were examined by a forensic scientist, who has specialised in fire investigations, accompanied by a senior Fire Prevention Officer. About 100 of the fires were visited soon after the fire occurred, the fire scene was examined and the officer in charge at the fire and other witnesses were questioned. In the remaining fires, in which the circumstances were simpler, the fire report was examined and additional questions were asked of the officer in charge at the fire.

The fire survey not only provided information which could not have been obtained otherwise, but also gave a clearer understanding of fire data generally and thus enabled better use to be made of the other fire data.

Initially a fairly elaborate method of analysis was planned in order to produce the most accurate results and to avoid any misinterpretation of the fire data. In the event it turned out that there were insufficient detailed data to support the more sophisticated methods, and more importantly, it could be shown that the more complex methods would not make any significant difference to the answers. The final results were derived using simpler methods, but the experience of attempting to use more complex models has given us more confidence in the final results.

The analysis of the value of sprinkler protection is described in Sections 2 and 3, the analysis for detectors in Sections 4 and 5, and the effect of increased structural fire resistance is described briefly in Section 6. The final conclusions are summarised in Section 7.

2. THE VALUE OF SPRINKLERS- ANALYSIS

The estimation of each of the items in the calculation (listed in Section 1.3) can be regarded as a separate problem. Each of the items is discussed briefly in this section and the results are illustrated using the example of an industrial building with a floor area of 1500 square metres. The full results, for other occupancies and building sizes, are given in the Appendix.

2.1 The cost of a sprinkler system

The cost of the sprinkler heads and the associated pipework will depend on the size of the building which is to be protected. There will also be a fixed cost for each system for the control valves, alarms and the connection to the mains. The estimated cost of installing a sprinkler system in a building of simple, open construction and involving no special hazard and no additional water supplies, is £(2000 + 1.98 x Size of building(sq.m)). The costs of other sprinkler systems are given in Table A1.

The maintenance cost in future years is estimated to be about 1 per cent of the initial capital cost.

2.2 The probability of a fire occurring

The probability of a fire occurring will vary with the occupancy and the size of the building. The probability is estimated by relating the number of fires which occur in buildings of a given size and occupancy to the number of buildings of that size and occupancy at risk. The probability of a fire in a large building is greater than in a small building of the same occupancy, but the risk of a fire does not increase in direct proportion to the building size. The probability of a fire is of the form;

$$\text{Probability} = a.B^{c},$$

where B is the floorspace of the building and a and c are the estimated parameters for each occupancy.

The estimated probability of a fire in an industrial building is given by;

$$\text{Probability} = 0.0017B^{0.53},$$

which is equal to a probability of 0.082 in a 1500 square metre building, or, on average, one fire every 12 years.

Table A2 shows the probabilitity of a fire in other occupancies.

2.3 The expected fire damage in an unprotected building

The average area of fire damage which would occur in an unprotected building was estimated from an analysis of the fires in buildings which did not have sprinklers or detectors. The average area of fire damage is the average of many small fires and a few large fires, and the average depends on the size of the building, simply because large fires cannot occur in small buildings. The average area of fire damage is estimated in the form

$$\text{Fire size} = d.B^{e},$$

where B is the building floorspace and d and e are estimated parameters. For industrial buildings the estimated fire size is,

$$\text{Fire size} = 2.25.B^{0.45},$$

and the average fire size in an unprotected building of 1500 square metres is therefore 60 square metres.

The estimated areas of fire damage in buildings of other occupancies are given in Table A3.

2.4 The expected fire damage in a building fitted with sprinklers

The expected fire damage if a fire breaks out in a building in which sprinklers are installed has been estimated by considering four separate situations which might arise. There may be insufficient heat to activate the sprinkler heads; the sprinklers may not operate because the system has been turned off or because of a mechanical defect; the sprinklers might operate and control or extinguish the fire; or the fire may grow very large despite the operation of the sprinklers. These separate outcomes are not of interest in their own right, but subdividing the problem in this way provides more insight and produces a more reliable result.

For an industrial building of 1500 square metres the probabilities of each outcome and the average area of fire damage in each case are:

Sprinkler not activated	57%	5 sq.m.
Sprinkler failure	0.95%	130 sq.m.
Satisfactory operation	41%	18 sq.m.
Fire "out of control"	0.95%	500 sq.m.

The average damage if sprinklers are installed is therefore;

$$0.57\text{x}5 + 0.0095\text{x}130 + 0.41\text{x}18 + 0.0095\text{x}500 = 16 \text{ sq.m.}$$

Predicted performance in other occupancies is shown in Table A4.

2.5 The fire loss incurred

The relationship between fire losses and the area of fire damage has been investigated and it has been shown that the fire loss can be estimated simply by multiplying the area of fire damage by an average unit loss. For industrial buildings the direct loss (to the national economy) is estimated to be £140/sq.m. of fire damage. (The direct loss as estimated by insurance companies may be about 15 per cent higher.) Direct losses in other occupancies are shown in Table A5.

A study of consequential losses has shown that for manufacturing industry such losses are, from the national economy point of view, equal to about 60% of direct losses, although the consequential losses to the firm may be considerably greater.

2.6 The estimated value of sprinklers

For the example of an industrial building of 1500 square metres the initial capital cost of a sprinkler system would be £5000, and the total discounted cost of providing sprinkler protection, including future maintenance costs, £5500.

If a fire occurred and the building were not protected the average area of fire damage would be 60 square metres, involving a direct loss of 60x140=£8400, and a total loss of £8400x1.6=£13400. If the building were sprinklered the average area of fire damage would be 16 square metres, involving a direct loss of £2300, and a total loss of £3700. The provision of sprinklers will therefore have reduced the expected fire damage by 73%.

The probability of a fire per year is 0.082, and the expected reduction in fire losses per year is therefore 0.082x(£13400-3700)= £800. The total discounted benefit due to the reduced fire loss is thus £7400, which exceeds the (discounted) cost of providing the sprinklers. The provision of sprinkler protection in these buildings is therefore cost-effective from the national economy point of view.

The value of sprinklers can be calculated in this way for buildings of other occupancies and other sizes.

3 THE VALUE OF SPRINKLERS - RESULTS

3.1 The value of sprinklers to the national economy

The value of sprinkler protection, calculated from the national economy point of view, has been estimated for buildings of different occupancies and different sizes and the results are summarised in a graphical form in Figure 1. Figure 1 shows the Net Present Value of sprinkler protection (the discounted benefits minus the discounted costs) in different occupancies. Where the Net Present Value is greater than zero, sprinkler protection can be said to be cost-effective.

The results show that for the overall industrial group of buildings sprinklers are cost-effective in buildings larger than 800 square metres. When the different sectors of industry are considered separately the minimum building size above which sprinklers are of value is between 300 and 1000 square metres for most of the industries. The separate industries in which sprinklers appear to show the greatest economic value are Other Manufacturing (which includes rubber and plastic products), Chemicals, Food, Timber and Electrical Engineering. It is estimated that sprinklers would be cost-effective in about 50 per cent of the buildings in manufacturing industry, and these buildings account for about 90 per cent of the total floorspace in manufacturing industry.

Sprinklers also appear to be of value in the larger shops. Sprinklers do not appear to be of value (at least when only property protection is considered) in hospitals, offices, schools and pubs and restaurants.

One perhaps surprising result is that sprinklers do not appear to be cost-effective in storage buildings. Although the fires in storage buildings are large on average, and sprinklers are very effective in reducing this fire damage, the probability of a fire occurring is low and the expected reduction in fire damage is therefore not sufficient to offset the cost of providing sprinklers. This result, for all storage buildings considered as a single group, hides the fact that the circumstances in different types of storage buildings can be very different. If the storage group is subdivided it can be shown that sprinklers will be of net value in high risk, high value storage buildings.

Although the results of this analysis show that sprinklers are cost-effective in larger hotels there is reason to suspect that, because of the inadequacy of the data used in the analysis, these results overestimate the value of sprinklers in reducing property damage in hotels.

3.2 The present provision of sprinklers

The present provision of sprinkler protection in manufacturing industry has been estimated by a survey of manufacturing industry. The survey results show that 13 per cent of buildings have complete sprinkler protection and a further 4 per cent have partial sprinkler protection. Sprinklers tend to be installed in the larger buildings and it is estimated that a total of about 35 per cent of the floorspace in manufacturing industry is protected by sprinklers.

No estimates of the extent of sprinkler protection in other occupancies are available.

3.3 The value of sprinklers to the firm

The value of sprinklers to the firm has only been considered briefly in this study

Firms may install fire protection because of their awareness of the risks of fire and their wish to reduce these risks, or they may install protection mainly in order to secure more advantageous terms for fire insurance. Estimates have been made of the financial incentives to the firm to install fire protection.

Insurance companies offer premium discounts of between 60 per cent and 90 per cent for approved sprinkler systems. By making some assumptions to compensate for the lack of detailed information about insurance rates, it is possible to estimate the value to the firm of installing sprinklers in buildings of different sizes.

The estimates of the value to the firm of providing sprinklers in industrial buildings show that the value to the firm is broadly similar to the value to the economy, ie. where sprinklers are of value to the economy there is a financial incentive to the firm to install this protection. In development areas, where capital grants are available to firms who install sprinklers, the financial incentives to install sprinklers are much greater.

4 THE VALUE OF DETECTORS - ANALYSIS

4.1 The cost of detectors

It is estimated that the cost of installing either heat or smoke detectors in a building of simple, open construction is approximately £1.1 per square metre of floorspace. In addition there will be a cost of about £1500 for the control equipment. If a direct line system is installed there will also be a connection charge. The initial costs and the future maintenance and line rental charges for local alarm and direct line systems are given in Table A1.

4.2 The estimated reduction in fire damage

Detectors reduce fire damage by giving early warning of a fire and thus allowing people to intervene earlier. The effectiveness of detectors depends on where people are at the time the fire occurs, how rapidly the fire is growing, how people respond when they hear the alarm, and how capable people are of dealing with the fire when they first arrive on the scene. The effectiveness of detectors is therefore much more difficult to predict.

The basic factors which determine the effect of detectors in reducing fire damage cannot be deduced from the main fire statistics and we have therefore had to rely very heavily in this part of the analysis on the information derived in our own fire survey. For each of the fires examined in our survey an assessment was made of the amount of fire damage which might have occurred if detectors had been installed. This assessment was made in the light of the actual circumstances of each fire, and particularly the estimated rate of development of the fire in its early stages and the assumed ability of the people in the vicinity to respond to the alarm and deal with the fire.

This assessment of the damage which might have occurred, together with the record of the fire damage which actually occurred, could be used directly to estimate the possible reduction in fire damage due to detectors. However in order to widen the basis of the estimate an attempt has been made to generalise the survey results by reference to the complete sample of fires for which a K433/SAF2 fire report was available. The K433/SAF2 fire reports include a record of the location of the nearest person at the time of the fire. The possible reduction in fire damage can be estimated as a function of the cause of the fire, based on the detailed experience of the fire survey.

The estimation of the reduction in fire damage from the basic fire statistics is not entirely satisfactory, as it depends on a variety of assumptions, some of which are difficult to justify. Nevertheless, the general analysis has been used in this study because even though it may not provide an independent estimate, it does provide a better understanding of the estimate of the effectiveness of detectors.

For the example of an industrial building of area 1500 square metres the estimated effect of direct line detectors is as follows:

	Proportion of fires	Damage if unprotected	Estimated reduction
Person in room	55%	40 sq.m.	0%
Person in bldg.	18%	50 sq.m.	65-85%
Person not in building	27%	105 sq.m.	65-85%
All fires	100%	60 sq.m.	40-55%

The estimation of the reduction in damage due to direct line and local alarm detectors in buildings of different occupancies is shown in Table A6. This Table shows the estimates produced through the general analysis as well as the average assessed reduction in the fire survey. The generalised estimates cover a range of values, reflecting the degree of uncertainty in the estimation procedure, and are generally lower than the survey estimates, reflecting the cautionary nature of the generalised analysis.

4.3 The calculation of the value of detectors

Taking the example of a 1500 square metre industrial building again, the initial cost of a direct line detector system is about £3400 and the future annual running costs are £280 (see Table A1). The total discounted costs are thus £6000.

The average loss per fire in an unprotected building would be £13400 (from Tables A2 and A3 and including consequential losses of 60 per cent). If the fire damage is reduced by 40 per cent by the installation of automatic fire detection (Table A6), then the expected annual benefits would be 0.082x13400x0.4=£440. The discounted value of the total future benefits is then £4100. In this case the cost of providing direct line detectors is greater than the expected benefits, and from the national economy point of view the provision of detectors in these buildings is not cost-effective.

5 THE VALUE OF DETECTORS - RESULTS

5.1 The value of detectors to the national economy

The value of automatic fire detection, calculated from the national economy point of view, has been estimated for buildings of different sizes and different occupancies. The results for direct line alarm systems are summarised in Figure 2 and the results for local alarm systems in Figure 3.

In these Figures a range of values are shown for industrial buildings. This range reflects the alternative range of estimates of the reduction in fire damage. Only a single estimate of the economic value of detectors is shown for other occupancies, in order to simplify the graphs. The single line shown for the other occupancies is the mid-point of the range of values.

In industrial buildings larger than about 2000 square metres (22 per cent of the buildings in manufacturing industry exceed this size) direct line detectors appear to be of economic value. Somewhat surprisingly, detection systems with local alarms appear to be of equal or greater economic value than systems with direct line alarms. This result reflects the experience of the fire survey in which it was judged that in many cases a local alarm would have brought people to the fire promptly and that these people would have been able to extinguish, or at least to contain, the fire. Although direct line systems can achieve a greater reduction in fire damage, this additional benefit does not offset the higher cost of providing the direct line system.

The only other occupancy in which detectors appear to be of economic value is shops, and here it is the direct line systems which show the greater benefit.

5.2 The present provision of automatic fire detection

The results of the survey of manufacturing industry show that detectors are installed in about 5 per cent of buildings, covering a total of about 13 per cent of the total floorspace.

The industries with the proportionately highest degree of automatic fire detection are Electrical Engineering and Chemicals.

5.3 The value of detectors to the firm

Insurance companies offer discounts of up to 12.5 per cent for the installation of approved detector systems. Because of the way in which premiums are calculated this is equivalent to a discount of up to about 20 per cent on the premium payable.

Our estimates of the value to the firm of installing detectors suggest that even in the largest industrial buildings the costs of providing a detector system will exceed the benefits of the reduction in premiums. (Although there may of course be individual cases where this generalisation is not true.) In development areas where government grants are payable to firms for capital investment there may be a small financial incentive to firms to install detectors in larger buildings.

5.4 The reliability of detectors

Studies of the reliability of the present direct line fire detection systems have shown that for every genuine alarm signalled by the system there are more than 10 false and accidental alarms. A false alarm rate as high as this could cause serious problems for fire brigades if there was widespread use of direct line detector systems. However, the technology is changing rapidly in this area and the reliability of automatic fire detection systems may improve in the future.

6 THE EFFECT OF IMPROVED STRUCTURAL FIRE RESISTANCE

The effect of improved fire resistance in the internal structure of buildings can only be estimated from the information obtained in the examination of buildings in the fire survey. At each building visited in the survey an assessment was made of the amount of fire damage which might have occurred if all the internal surfaces (walls, doors, ceilings etc.) had a minimum of 30 minutes fire resistance.

Improved fire resistance would have reduced the amount of fire damage in some of the fires which spread beyond the room of origin. The survey assessments take into account the fact that in some of the larger fires improved fire resistance would have had no effect because, for example, doors were left open or because the fire was so severe and had burned for so long that even the more resistant compartment walls would have been penetrated.

No estimate was made of the cost of bringing the structure up to the higher standard, although it was clear that the cost would be substantial in many cases.

In the survey it was estimated that increased structural fire resistance would have reduced the average amount of fire damage by 45 per cent in industrial buildings, 50 per cent in storage buildings, and 55 per cent in shops.

7 CONCLUSIONS

Before presenting any conclusions the limitations of the study should first be reiterated. Firstly, only the protection of property has been considered in this study, and not the protection of life. Secondly, only complete sprinkler systems, complete detector systems and complete upgrading of the internal structural fire resistance have been considered. The value of partial fire protection systems (protecting only the most valuable parts of the building or the highest risks), or mixed systems (part sprinklers and part detectors), or other forms of fire protection (venting, CO_2 flooding etc.) have not been considered. Thirdly, a broad view of the problem has been taken and results have been derived only for the major occupancy groups. There may well be many special cases or individual buildings for which the general results are not valid.

The objective of this study was to derive an overall picture of the value of fire protection measures from the national economy point of view. This overall picture is presented in Figures 1-3. The main findings of the study are as follows:

1. Sprinklers are very effective in reducing fire damage, and the reduction in damage is estimated to be 70-90 per cent in buildings of different sizes and occupancies. When the cost of providing sprinklers is compared with the saving in fire losses the results of this study indicate that sprinklers are cost-effective in the medium and large industrial buildings, in large shops and in high value, high risk storage buildings.

2. From the firm's point of view there is a strong incentive to install sprinklers in order to benefit from the premium reductions offered by insurance companies. However far fewer firms have actually taken advantage of these incentives than would benefit from doing so. The question arises of why firms have been reluctant to take advantage of these financial incentives.

3. It is estimated that automatic fire detection can reduce fire damage by about 50 per cent on average in industrial buildings and even more in other occupancies. When these savings in fire losses are compared with the cost of providing detectors it appears that automatic fire detection is of economic value in the larger industrial buildings and the largest shops. However, if the present high false alarm rate is not improved, wider use of direct line detectors might cause serious problems for fire brigades.

It should be noted that the Fire Offices' Committee, representing fire insurers generally, have reported that their own estimates of the reduction in fire damage effected by detectors is well below the figure quoted here. Although the figures provided by FOC have not been supported by any detailed analysis, they are nevertheless based on many years' experience of underwriting fire risks. Only further detailed study could resolve which of the two estimates is closer to the true value, although the Home Office has no plans for such work to be carried out.

4. From the firm's point of view there is relatively little financial incentive to install detectors.

5. It is estimated that improved structural fire resistance might reduce fire losses by about 50 per cent. No estimate has been made of the cost of these structural improvements.

Figure 1 THE VALUE OF SPRINKLERS IN DIFFERENT OCCUPANCIES

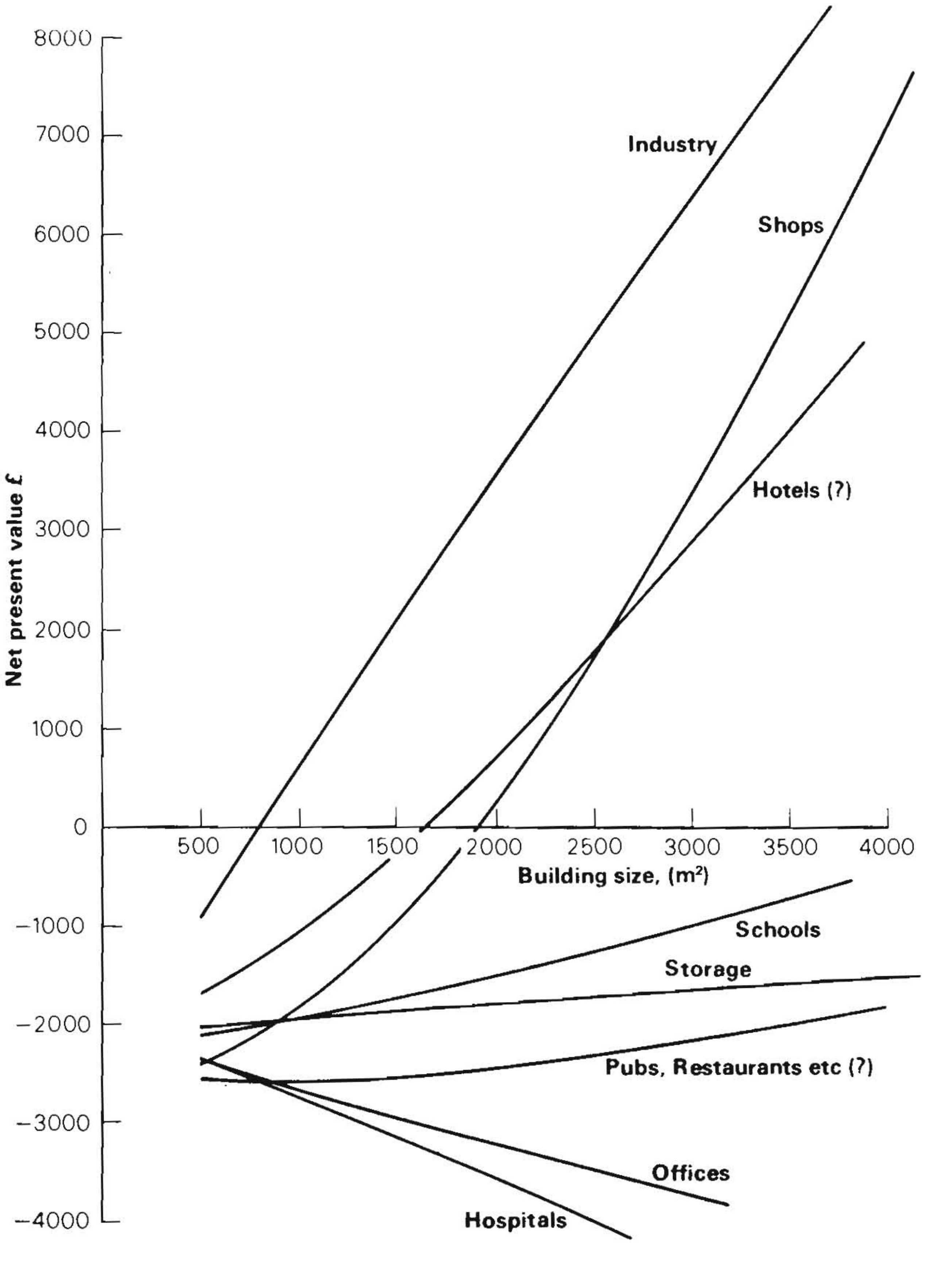


Figure 2 **THE VALUE OF DIRECT LINE DETECTORS IN DIFFERENT OCCUPANCIES**

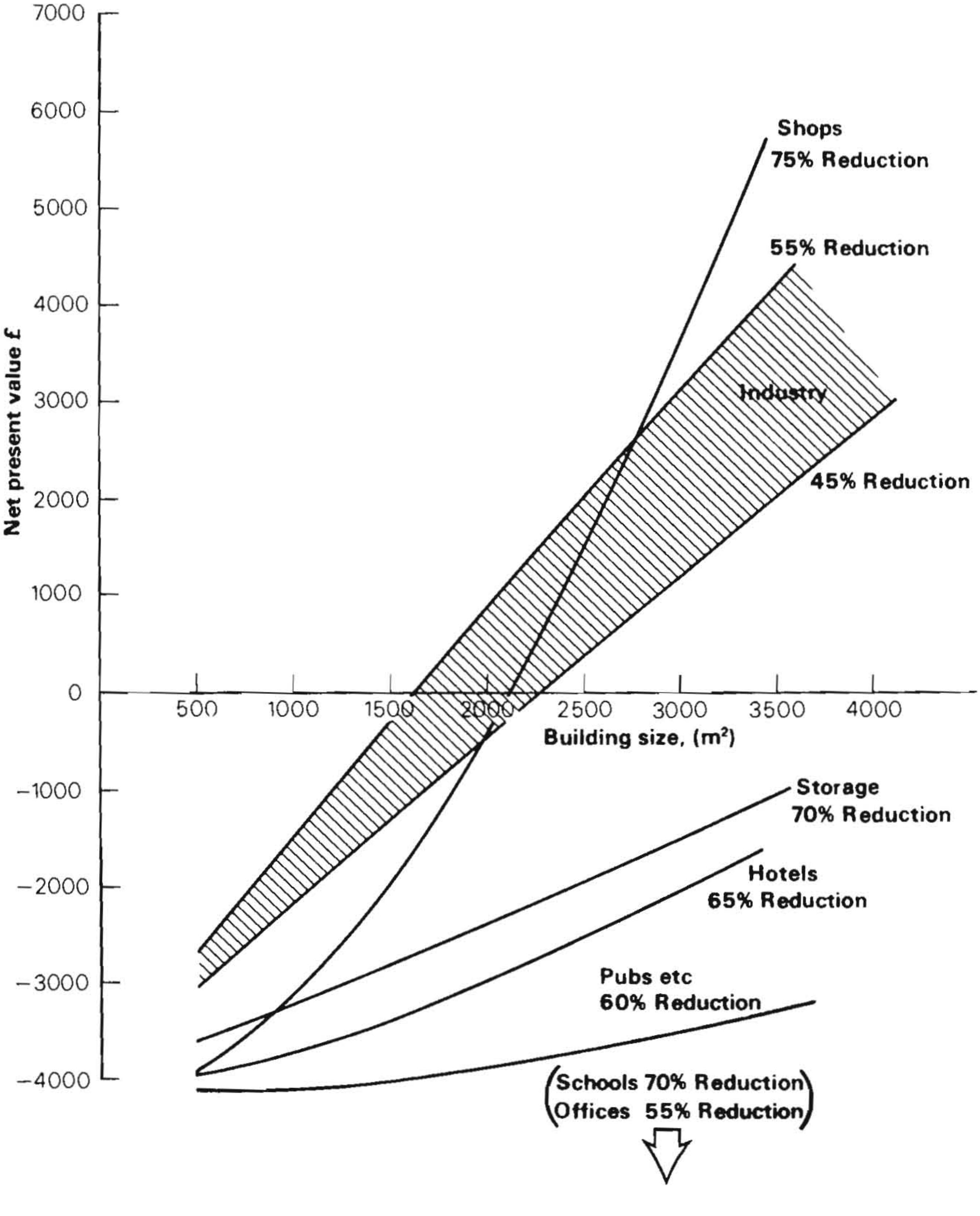
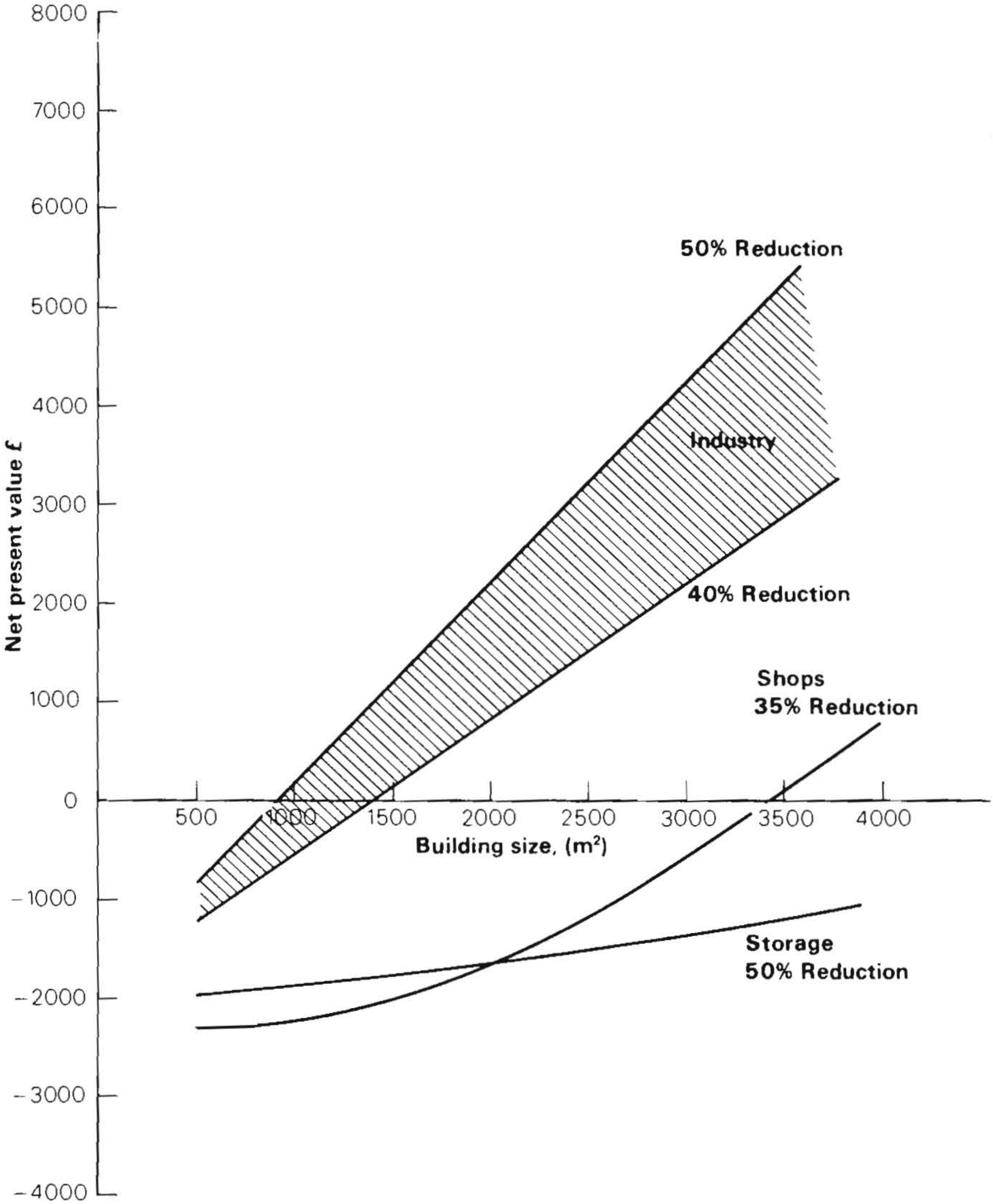


Figure 3 THE VALUE OF LOCAL ALARM DETECTORS IN DIFFERENT OCCUPANCIES



APPENDIX A

TABLES OF THE MAIN NUMERICAL RESULTS

TABLE A1 THE COST OF FIRE PROTECTION (1977 PRICES)

SPRINKLER SYSTEMS- in buildings of simple, open construction, not requiring pumps or additional water supplies

Initial cost

Extra low hazard	£2000 + 0.83 x size of building(m^2)
Ordinary hazard	£2000 + 1.98 x size of building(m^2)
Extra high hazard	£2000 + 2.67 x size of building(m^2)

Annual maintenance cost

Approximately 1% of initial cost.

AUTOMATIC DETECTION- in buildings of simple open construction.

Initial cost

Local alarm system	£1500 + 1.1 x size of building(m^2)
Direct line system	£1750 + 1.1 x size of building(m^2)

Annual maintenance and line rental costs

Local alarm system	£50 + 0.025 x size of building(m^2)
Direct line system	£240 + 0.025 x size of building(m^2)

TABLE A2 THE PROBABILITY OF A FIRE OCCURRING

OCCUPANCY (SIC ORDER)	PROBABILITY OF FIRE PER YEAR a. B^c		PROBABILITY OF FIRE IN $1500m^2$ BUILDING
	a.	c.	
INDUSTRIAL BUILDINGS:			
Food, drink and tobacco (III)	0.0011	0.60	0.086
Chemicals and allied (V)	0.0069	0.46	0.21
* Mechanical engineering (VII)	0.00011	0.75	0.027
Electrical engineering (IX)	0.00061	0.59	0.046
Vehicles (XI)	0.00012	0.86	0.062
* Metal goods not elsewhere specified (XII)	0.00158	0.54	0.082
Textiles (XIII)	0.0075	0.35	0.097
Timber, furniture (XVII)	0.00037	0.77	0.10
Paper, printing and publishing (XVIII)	0.000069	0.91	0.054
Other manufacturing (XIX)	0.0084	0.41	0.17
All manufacturing industry (III-XIX)	0.0017	0.53	0.082
OTHER OCCUPANCIES:			
Storage	0.00067	0.5	0.026
Shops	0.000066	1.0	0.099
Offices	0.000059	0.9	0.043
Hotels etc	0.00008	1.0	0.12
Hospitals etc	0.0007	0.75	0.17
** Pubs, restaurants etc	(0.00007)	(1.0)	(0.1)
Schools	0.0002	0.75	0.048

*Note: Some of the fires which should be included in the Mechanical engineering sector may have been classified as "Metal goods n.e.s." This would result in an underestimate of the probability of fire for Mechanical engineering and an overestimate for Metal goods. If the two groups are combined the estimated probability of fire is 0.00086 $B^{.56}$.

**Values for Assembly are assumed. There was insufficient information available to estimate the probability of fire in this occupancy group.

TABLE A3 THE ESTIMATED FIRE DAMAGE IF ONLY THE MINIMUM LEVEL OF FIRE PROTECTION IS PROVIDED

OCCUPANCY (SIC ORDER)	AVERAGE FIRE SIZE AS A FUNCTION OF BUILDING SIZE(m^2)	SAMPLE SIZE	AVERAGE FIRE SIZE IN A BUILDING OF 1500m^2 FLOORSPACE
INDUSTRIAL BUILDINGS:			
All industry	$2.25\ B^{.15}$	6496	60
Food, drink & tobacco (III)	$2.7\ B^{.45}$	313	73
Chemicals & allied (V)	$11.8\ B^{.12}$	516	28
Mechanical engineering (VII)	$0.17\ B^{.76}$	248	44
Electrical engineering (IX)	$18.5\ B^{.17}$	174	64
Vehicles (XI)	$0.80\ B^{.58}$	181	56
Metal goods not elsewhere specified (XII)	$6.4\ B^{.23}$	561	34
Textiles (XIII)	$2.6\ B^{.39}$	399	45
Timber, furniture (XVII)	$24.2\ B^{.21}$	393	112
Paper, printing & publishing (XVIII)	$6.7\ B^{.36}$	198	93
Other manufacturing (XIX)	$8.7\ B^{.38}$	228	140
OTHER OCCUPANCIES:			
Storage	$3.5\ B^{.52}$	1398	157
Shops	$0.95\ B^{.50}$	2662	37
Offices	15.0	622	15
Hotels etc	$5.4\ B^{.22}$	973	27
Hospitals	5.0	936	5
Pubs, restaurants etc	$7.6\ B^{.20}$	2908	33
Schools etc	$2.8\ B^{.37}$	906	42

TABLE A4 THE AVERAGE AREA OF FIRE DAMAGE IF SPRINKLERS ARE INSTALLED

OCCUPANCY (SIC ORDER)	SPRINKLERS NOT ACTIVATED		SPRINKLERS FAILED		SPRINKLERS OPERATED SATISFACTORILY		SPRINKLERS "COULD NOT COPE"	
	Propn.	Av. damage (m^2)	Propn.	Av. damage (m^2)	Propn.	Av. damage (m^2)	Propn.	Av. damage (m^2)
INDUSTRIAL BUILDINGS:								
All industry	.57	5	.022x.43	$5.23 B^{.45} - 6.63$	.956x.43	18	.022x.43	B/3
Food, drink & tobacco (III)	.69	3	.022x.31	$8.78 B^{.45} - 6.7$	.968x.31	2	.010x.31	B/3
Chemicals & allied (V)	.60	2	.022x.40	$29.5 B^{.12} - 3.0$	.942x.40	9	.032x.40	B/3
Mechanical engineering (VII)	.42	1	.022x.58	$0.29 B^{.76} - 0.72$	.968x.58	1	.010x.58	B/3
Electrical engineering (IX)	.47	1	.022x.53	$34.9 B^{.17} - 0.89$	.968x.53	3.5	.01x.53	B/3
Vehicles (XI)	.87	1	.022x.13	$6.2 B^{.58} - 6.7$	.966x.13	9	.01x.13	B/3
Metal goods not elsewhere specified (XII)	.42	1	.022x.58	$11.0 B^{.23} - 0.72$	.968x.58	6	.01x.58	B/3
Textiles (XIII)	.53	7	.022x.47	$5.5 B^{.39} - 7.9$	.960x.47	25	.018x.47	B/3
Timber, furniture (XVII)	.40	2	.022x.60	$40.3 B^{.21} - 1.3$	.963x.60	14	.01x.60	B/3
Paper, printing & publishing (XVIII)	.40	1	.022x.60	$11.2 B^{.36} - 0.7$	.956x.60	15	.019x.60	B/3
Other manufacturing (XIX)	.70	4	.022x.30	$29.0 B^{.38} - 9.3$	.915x.30	30	.065x.30	B/3
OTHER OCCUPANCIES								
Storage	.24	2	.022x.76	$4.6 B^{.52} - 0.63$	.928x.76	16	.05x.76	B/3
Shops	.55	1	.022x.45	$2.11 B^{.50} - 1.2$	.958x.45	1	.02x.45	B/3
Offices				27.5				
Hotels etc				$10.6 B^{.22} - 1.9$				
Hospitals etc				7.9				
Pubs, restaurants etc	.49	2	.022x.51	$14.9 B^{.20} - 1.9$	.973x.51	2	.005x.51	B/5
Schools etc				$5.5 B^{.31} - 1.9$				

TABLE A5 THE AVERAGE DIRECT LOSS PER UNIT AREA OF FIRE DAMAGE

OCCUPANCY (SIC ORDER)	UNIT LOSS (£/sq.m)
INDUSTRIAL BUILDINGS:	
All industry	140
Food, drink & tobacco (III)	270
Chemicals & allied (V)	300
Mechanical engineering (VII)	290
Electrical engineering (IX)	320
Vehicles (XI)	150
Metal goods not else-where specified (XII)	240
Textiles (XIII)	210
Timber, furniture (XVII)	130
Paper, printing & publishing (XVIII)	90
Other manufacturing (XIX)	120
OTHER OCCUPANCIES:	
Storage	120
Shops	160
Offices	150
Hotels etc	130
Hospitals etc	160
Pubs, restaurants etc	100
Schools	110

TABLE A6 THE ESTIMATED REDUCTION IN FIRE DAMAGE DUE TO DETECTORS - ALL FIRES

Occupancy	Survey sample size	Reduction in fire damage			
		With direct line alarm		With local alarm	
		Estimated from K433/SAF2	Estimated in Survey	Estimated from K433/SAF2	Estimated in Survey
Industry	210	-(40%-55%)	-55%	-(35%-50%)	-50%
Storage	30	-(60%-70%)	-80%	-(45%-55%)	-60%
Shops	50	-(65%-75%)	-85%	-(35%-40%)	-40%
Offices	17	-(55%-70%)	-45%	not estimated	-40%
Hotels	12	-(55%-65%)	-85%	not estimated	-85%
Pubs, restaurants	36	-(60%-75%)	-55%	not estimated	-40%
Schools	26	-(55%-70%)	-90%	not estimated	-85%