Effectiveness of sprinklers in residential premises:
Section 6: Cost benefit analysis

Project report number 204505

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February 2004

Contents

6	Cost benefit analysis	1
6.1	Introduction	1
6.2	Outline cost benefit calculation	2
6.3	Residential classification	3
6.4	Effectiveness of residential sprinklers	3
6.5	The components of the cost benefit calculation	4
6.5.1	Installation costs	4
6.5.2	Water supply costs	5
6.5.3	Capital recovery factor	6
6.5.4	Annual inspection and maintenance charges	7
6.5.5	Risks of death, injury and fires, in the absence of sprinklers	7
6.5.6	The value of each death prevented	8
6.5.7	The value of each injury prevented	8
6.5.8	The average value of property damage in unsprinklered domestic fires	9
6.5.9	Additional factors (not included in the analysis)	9
6.6	Uncertainty analysis	9
6.7	Confidence levels	11
6.8	Results of cost benefit calculations	12
6.9	Cost benefit calculations for ‘high-risk’ dwellings	13
6.10	Summary and conclusions of the cost benefit analysis	17
6.11	References	19
Appendix 6A – details of cost-benefit calculations		21
Appendix 6B – details of cost benefit calculations for HMO’s		28
Appendix 6C – details of cost benefit calculations for buildings of different heights		36

6 Cost benefit analysis

6.1 Introduction

The purpose of this stage of the overall project is to perform a cost benefit assessment of the expected impact of residential sprinklers. Naturally. this falls into two sections, an assessment of the costs and an assessment of the benefits. These two sections are more-or-less independent of one another.

The Pilot Study phase of this project looked at how the effectiveness of sprinklers (i.e. the benefits) might be estimated from UK fire statistics. In the Pilot Study, it was shown that a direct estimate of sprinkler effectiveness was not possible due to a scarcity of data. Therefore, an indirect method was proposed, to examine how the risk of death, injury, etc depended on the ultimate fire size. By making the assumption that sprinklers would restrict the ultimate fire size, and as a consequence reduce the risk to that corresponding to the smaller fire, the effects of sprinklers could be estimated.

The costs of residential sprinkler systems were mainly obtained from members of the Project Steering Group. As there are some variations in the cost values of various elements of the system, the overall costs would be expressed as a range of likely values, rather than just a single figure.

Similarly, the benefits of sprinklers were converted to monetary terms, using Government guidelines. Risks of fire, deaths and injuries were estimated from Government statistics, coupled with the estimate of sprinkler effectiveness from the Pilot Study to evaluate the benefits in terms of reduced risks.

During the Pilot Study, a number of cost benefit analyses performed outside the UK were reviewed. Different analyses considered a different range of factors for the costs and benefits. A complete list of these is given in Table 6.1, with the subset of factors that were considered in the analysis performed for this Project.

Table 6.1 Factors considered in cost benefit analysis

COSTS		BENEFITS	
❑ Installation	◄	❑ Lives saved	◄
❑ Water Supplies	◄	❑ Injuries prevented	◄
❑ Annual inspection & maintenance	◄	❑ Property loss savings	◄
❑ Accidental water damage		❑ Environment impact reduction	
		❑ Insurance Premium reduction	
		❑ Fire Brigade cost savings	
		❑ Other tradeoffs, eg more efficient use of building land	

(◄ = factor considered in this analysis)

Those factors not considered in this analysis were omitted because data were unavailable or they were considered too hard to quantify with any accuracy.

6.2 Outline cost benefit calculation

All costs and benefits need to be expressed in common units, namely for this analysis as cost per accommodation unit per year. Let

£S = System installation cost (one-off, per accommodation unit)
£W = Water supply cost (one-off, per accommodation unit)
K = Capital Recovery Factor
£M = Maintenance (annual, per accommodation unit)
£C = Cost (annual, total, per accommodation unit)

and

R = Risk (annual, per accommodation unit)
ε = Effectiveness of sprinklers in reducing risk
£V = Value of protection (e.g. each death prevented)
£B = Benefit (annual, per accommodation unit)

where the following subscripts refer to different components of the overall benefit:

d = deaths
i = injuries
p = property damage reduction
tot = total

The overall annual cost per accommodation unit is

$$£C = K(£S + £W) + £M \qquad \{6.1\}$$

The annual values of reducing deaths, injuries and property damage per accommodation unit are

$$£B_d = £V_d . R_d . \varepsilon_d \qquad \{6.2\}$$

$$£B_i = £V_i . R_i . \varepsilon_i \qquad \{6.3\}$$

$$£B_p = £V_p . R_p . \varepsilon_p \qquad \{6.4\}$$

The total annual benefit is

$$£B_{tot} = £B_d + £B_i + £B_p \qquad \{6.5\}$$

In order for residential sprinklers to be cost-effective, the following inequality needs to be satisfied:

$$\left(\frac{£B_{tot}}{£C} \right) \geq 1 \qquad \{6.6\}$$

6.3 Residential classification

It was decided, for the sake of consistency, to use the same classification of residential properties as that used by Hartless in his work [Hartless 2002]. These classifications, and the 'TOP' and 'OCCUP' codes in the UK Fire Statistics database [Gamble 1998] that define them, are given in Table 6.2.

Table 6.2 Classification of residential properties in this analysis

Residential classification	Fire statistics database codes
House, single occupancy	TOP = 411…416 and OCCUP = 1
House, multiple occupancy	TOP = 411…416 and OCCUP = 2…3
Flat, purpose-built	TOP = 421…422
Flat, converted	TOP = 471…472
Care Home, old person's	TOP = 311
Care home, children	TOP = 322
Care Home, disabled people	TOP = 359, 369

As the work progressed, it was decided to focus more closely on the properties having greater risks. Different types of houses of multiple occupancy (HMO) and different building heights (number of storeys above ground) were considered. Further details of these analyses are given in section 6.9.

6.4 Effectiveness of residential sprinklers

The Pilot Study established that is was not possible to determine the effectiveness of residential sprinklers directly from the UK fire statistics, due to paucity of data. An indirect method was proposed, based on a correlation between the risk of death, injury etc. per fire, and the size of the fire (the area damaged). Full details of this method are given in section 3.

The effectiveness of sprinklers in reducing the average property damage per fire could not be estimated from the UK statistics. Instead, a typical value of 50% was used, based on an examination of US statistics. The variability of this value is about ± 15% over different residential building types.

For the purposes of the cost-benefit analysis, the effectiveness of sprinklers was assumed to be independent of property type, and to lie in the following ranges:

- Reduction in the number of deaths 70% ± 15%
- Reduction in the number of injuries 30% ± 15%
- Reduction in the average property damage 50% ± 15%

6.5 The components of the cost benefit calculation

6.5.1 Installation costs

An attempt has been made to provide a cost estimate for residential sprinkler systems, based on figures provided by the Fire Sprinkler Association. These costs include the provision of water supplies, leading to the following overall cost estimates (2002 prices):

- Three-bedroom house, new build £1500 ~ £1800
- Three storey HMO, retro-fit £3000 ~ £5100
- Two-bedroom flat, new build £900
- Two-bedroom flat, retro-fit £1100
- Six-bedroom care home, new build £2100 ~ £4000
- Twelve-bedroom care home, new build £3000 ~ £5100.

Some information on overall costs has also been provided by other members of the Project Steering Group [Eady 2001; Kidd 2002]. These figures provide an indication of costs subject to variation, depending on factors such as cost of connecting up to the water supplies and local installation costs. Labour costs vary from region to region. A one-off installation designed and installed to DD 251 has also been assumed:

- Average three-bedroom house £1,500 to £3,000
- 3-storey HMO £6,500 to £8,000
- Residential home average 7 bed to 14-bed accommodation £8,000 to £15,000.

The following costs were all based on actual projects 2001~2002:

- $1m^3$ tank and pump (domestic system) £1,500
- $3m^3$ tank and pump (residential system) £2,500 ~ £3,000
- Town mains connection £600 ~ £1,500

- Three-bedroom house (one-off installation) £3,000 (£180 per sprinkler)
- Three-bedroom house (large estate) £2,000 (£110 per sprinkler)
- Four-bedroom house (one-off installation) £4,000 (£117 per sprinkler)
- Four-bedroom house (large estate) £3,000 (£90 per sprinkler)
- 35-bed hostel (retro-fit) £35,000 (£100 per sprinkler)
- 20-bed aged persons' home (retro-fit) £27,000 (£100 per sprinkler)
- 50-bed aged persons' home £50,000 (£110 per sprinkler)
- 7-bed student accommodation (retro-fit) £4,700 (£180 per sprinkler)
- 5-bed hostel (retro-fit) £7,000 (£120 per sprinkler)
- 6-bed children's home £12,000 (£140 per sprinkler).

Note that the figures quoted by Eady and Kidd are generally rather higher (much higher in some cases) than the estimates from the Fire Sprinkler Association (FSA). The FSA acknowledge that their figures are at the lower end of the cost range, assuming no unusual circumstances. However, for the time being it shall be assumed (until further information is available) that the FSA figures are the more representative of the two data sets. (There is agreement on the 3-bed house).

In an attempt to make a better estimate of the overall cost of providing a system, installation and water supply costs have been separated. The variation in water supply costs contribute a large fraction of the uncertainty in the total costs of the system. The FSA figures assumed that the care homes and the HMO's may require a pump and tank, costing between £0 ~ £1500, whereas the single occupancy houses and flats could use town mains supplies at no additional cost.

It was further assumed that the HMO counts as 6 accommodation units (each bedsit, etc is a separate entity), and thus the cost per unit was one-sixth of the cost per building. For the care homes, interpolation and extrapolation from the 6-bed and 12-bed estimates provided by the FSA has been employed. The average number of beds comes from the data in Table 6.1.

To illustrate this calculation, consider the case of the old person's care home. For a 6-bed home the FSA quoted total costs of £2100 ~ £4000, and for a 12-bed home total costs of £3000 ~ £5100. Much of the uncertainty (£0 ~ £1500) depends on whether of not a pump and tank is required. Installation costs were also assumed to be 20% higher for retrofit compared to new-build situations. Thus the costs for installation alone are £2100 (new) ~ £2520 (retro-fit) for a 6-bed home, and £3000 (new) ~ £3600 (retro-fit) for a 12-bed home. An equivalent way to express these figures is a baseline cost of £1200, plus £150 per room (sprinkler head) for new build, or £1440 plus £180 per room (sprinkler head) for retro-fit (an increase of 20%). By extrapolation, the lower cost bound is £1200 + 19 x £150 = £4050, and the upper cost bound is £1440 + 19 x £180 = £4860.

Hence, the values for installation costs that were used for the cost benefit analysis are as follows:

• House, single	£1500 ~ £1800	i.e.	£1650 ± £150
• House, multiple occupancy	£500 ~ £600		£550 ± £50
• Flat, purpose-built	£900		£900 ± £0
• Flat, converted	£1100		£1100 ± £0
• Care home (old persons, 19 bed)	£4050 ~ £4860		£4455 ± £405
• Care home (children, 9 bed)	£2550 ~ £3035		£2805 ± £255
• Care home (disabled people, 8 bed)	£2400 ~ £2880		£2640 ± £240

6.5.2 Water supply costs

Water supplies could either be provided by the town mains supply, or by the installation of a pump and tank. In some cases, the town mains supply could be used at negligible additional cost, in other cases there would be charges depending on the bore and length of additional pipes [Whittaker 2002]. For 25mm and 32mm bore pipes, the connection and first 2m of pipe would cost £410, up to a maximum for 10m of pipe (say) of £930. For 50mm bore, the connection and first 2m of pipe would cost £575, and extension to 10m of pipe would cost £1095. On the other hand, the costs for a pump and tank according to the RSA [Young 2002] range between £750 ~ £1500.

Generally speaking, the costs of providing town mains supply are less than the pump and tank option. As with the installation costs, it was assumed that the cost for each

accommodation unit in an HMO was one-sixth of the cost in the whole building. Also, it was assumed that flats would be able to share the costs of water supplies, again leading to a 1:6 per accommodation unit. Based on advice [Whittaker 2002], the likely range of costs (2002 prices) for different categories of residential buildings would be:

• House, single	£0 ~ £930	ie.	£465 ± £465
• House, multiple occupancy	£96 ~ £183		£140 ± £44
• Flat, purpose-built	£0 ~ £155		£78 ± £78
• Flat, converted	£68 ~ £155		£112 ± £54
• Care home (all types)	£0 ~ £1095		£835 ± £260

6.5.3 Capital recovery factor

In addition to the capital costs of the system, it is also necessary to consider how the yearly costs vary as a function of interest rates and the length of the loan. The Capital Recovery Factor [Ramachandran 1998] is defined as

$$K = r\frac{(1+r)^y}{(1+r)^y - 1} \qquad \{6.7\}$$

where r is the rate of interest expressed as a decimal fraction, e.g. 0.06 for 6%, and y is the length of the payback period in years. If the amount of capital to be repaid is C, the annual payment A is given by

$$A = C.K \qquad \{6.8\}$$

Substituting various values for r and y, a range for K can be estimated:

- r = 0.035 (i.e. interest rate of 3.5%); y = 25 years => K = 0.061
- r = 0.035 (i.e. interest rate of 3.5%); y = 50 years => K = 0.043
- r = 0.06 (i.e. interest rate of 6%); y = 25 years => K = 0.078
- r = 0.06 (i.e. interest rate of 6%); y = 50 years => K = 0.063.

The BRE preferred value for the repayment term is 50 years, the lifetime of the sprinkler system, as this is also the lifetime over which benefits will be provided. Government advice from the Treasury Green Book was to use an interest rate of 6% when performing cost-benefit analysis for large capital projects, although in 2001 the advice changed to use a value of 3.5% [HM Treasury 2003]. Current mortgage rates are about 5%. For the purposes of the cost benefit analysis, the following range shall be assumed:

• r = 0.035 (i.e. interest rate of 3.5%); y = 50 years	=> K = 0.043	±0.025

although the uncertainty will only be positive. (Note that for a 50-year repayment period, K cannot be less than 1/50 = 0.02, even with zero interest.)

An interest rate of 6% has been used throughout to inflate costs to 2002 prices where necessary.

6.5.4 Annual inspection and maintenance charges

The full annual cost includes not just the repayment on the loan, but also any inspection and maintenance charges incurred. The Fire Sprinkler Association [Young 2002] quotes a value of 1 man-hour per year, for houses. In the absence of other estimates, a value of £50 (2002 prices) will be used throughout the cost-benefit analysis for all accommodation units. A nominal uncertainty of £10 has been assumed.

- Annual Inspection and Maintenance £50 ± £10

6.5.5 Risks of death, injury and fires, in the absence of sprinklers

Table 6.3 gives the number of accommodation units of each type, derived from various sources including the English House Condition Survey, Local Authorities HMO Survey, etc [Hartless 2002], and also summarises the annual risks of death, etc. There are a number of ways in which the risks can be presented; for example Hartless calculates annual risks per person exposed, which is the normal approach for a Regulatory Impact Assessment when deciding what level of personal risk is acceptable. On the other hand, fire safety scientists often quote risks in terms of the average number of deaths, etc, per fire, since this provides a measure of the severity of individual fires (although it does not give any information on the relative frequency of fires in different cases). In Table 6.3, a third alternative has been chosen, which is the number of deaths, etc, per accommodation unit per year. This ties in with the cost benefit analysis later, where costs will also be calculated per accommodation unit per year.

This presentation of the risks also permits a rudimentary cost-benefit analysis to be made at a glance. If it is assumed that the value of a human life is approximately £1million, and the costs of injuries or rescues to be negligible in comparison. The amount each accommodation unit can afford to spend on fire safety each year (in £) is then the same figure as the number of deaths per million accommodation units each year.

Table 6.3 Number of accommodation units, and annual risks per million units

Property type	No. Units (000's)	People per unit	Fires	Death	Injury
House, single occ.	18,642	2.5	1616 ± 9	15 ± 0.4	367 ± 2
House, multiple occ.	1,337	1.9	1147 ± 29	13 ± 1	281 ± 6
Flat, purpose-built	3,605	2.0	4841 ± 37	27 ± 1	941 ± 7
Flat, converted	1,099	1.6	2561 ± 48	23 ± 2	664 ± 10
Care Home, old person's	16.3	19.0	66074 ± 2013	245 ± 50	6073 ± 249
Care Home, children	1.4	8.9	149286 ± 10326	143 ± 130	12857 ± 1237
Care Home, disabled persons	11.1	7.7	30990 ± 1671	72 ± 33	2523 ± 195

All uncertainties represent ± one standard deviation.

The effectiveness of sprinklers in reducing the number of deaths, injuries, and the extent of property damage, has already been mentioned. The remaining components of the

cost benefit analysis are the monetary values attached to each death and injury prevented, and the amount of damage per fire.

6.5.6 The value of each death prevented

Since 1988, the (then) Department of Transport has been using Willingness-To-Pay as the basis for its' assessments of how much money it is worth spending to prevent a road crash fatality. The same approach has been used [Hartless 2002] in making Regulatory Impact Assessments for ODPM (formerly DTLR). The main reasons for adopting Willingness-To-Pay, rather than an alternative measure such as legal compensation payments, are

- it is a 'statistical' life that is being valued, not a specific individual's life.
- the willingness of an individual to pay for small changes in their risk of loss of life can be used to infer the value of reducing the risk of death. The Department for Transport uses this willingness to pay measure and adds to it the value of lost output, medical and ambulance costs to arrive at the value of a prevented fatality.
- the value of a prevented fatality is the result of extensive research and the same methodology is used across government.

Previous estimates of the value of each life saved were reckoned as £0.8m [Hartless 2000] in 1994, and £1.14m [Dennison 2002] in 2000, an increase of about 6% per year. Assuming an average increase in GDP of 6% per year [Hartless 2002] since then, would give a value of £1.28m at 2002 prices. Other cost benefit analyses have had widely-different values for each life saved, even though also based on Willingness-To-Pay. A literature study referred to by Hartless had a range of values between £80k ~ £13.97m, with a mean of £2.76m, standard deviation £3m, and median £1.59m (all values at 1990 prices). A cost benefit analysis performed for smoke detectors [Spearpoint 1997] used a value of £960k (1996 prices), which was the same as that used by the United Nations Intergovernmental Committee on Climate Change.

Latest Government advice, where the value of each life saved was reckoned as £1.14m [Dennison 2002] in 2000, is to increase the value by the actual growth in GDP each year. Values of the UK GDP increase were 3.8% from 2000-2001, and 4.6% from 2001-2002 [Cruickshank 2004]. This gives a value of £1.243m at 2002 prices. A nominal uncertainty of 5% of this value has been assumed:

• Value of each life saved	£1,243,000	± £62,000

6.5.7 The value of each injury prevented

A recent study [Loweth 2002], quoting the Home Office fire statistics for HMO's in 1999 stated that there were 1112 serious injuries at a total cost of £130m (average cost £122k) and 1903 minor injuries at a total cost of £18m (average cost £9.5k). 37% of all injuries were serious.

The latest Department of Transport figures for 2000 are £128,650 for serious injuries, and £9,920 for minor injuries [Cruickshank 2004]. Converting these costs to 2002 prices (an increase of 3.8% in one year, and 4.6% in the other [Cruickshank 2004]), gives values of £140k for serious injuries, £11k for minor injuries, weighted average for all injuries £58k. This analysis has used this latter figure, and again assumed a nominal uncertainty of 5% of the value:

• Value of each injury prevented	£58,300	± £2,915

6.5.8 The average value of property damage in unsprinklered domestic fires

Finally, sprinklers will provide benefits due to the reduction in property damage. A recent Government publication [Dennison 2003] estimated the average property loss per fire at £7,100 (1999 prices), for domestic properties, and £22,600 per fire for commercial properties. This analysis has assumed that the "domestic" losses are the most representative value to use for the different building classes studied in this report. Converting to prices in 2002 requires increasing by the inflation rate rather than the GDP [Cruickshank 2004]. The inflation rate was 2.21% for 1999-2000, 1.29% for 2000-2001, and 2.61% for 2001-2002, hence the average property loss per fire is £7,540. This is for domestic properties without sprinklers. Yet again, a nominal uncertainty of 5% of the value is assumed:

• Unsprinklered property damage	£7,540	± £377

6.5.9 Additional factors (not included in the analysis)

The reduction of rescues required could result in lower fire brigade cover for an area, maybe fewer pumps sent to each incident or longer call-out times. However, for the purposes of this cost benefit analysis, the benefits will not be quantified. It will be assumed they are negligible in comparison to the other benefits.

In some countries, allowing 'trade offs' to be made when residential sprinklers have been fitted may have the effect of making the net cost of fitting the sprinklers almost zero, or maybe even a net saving. However, this mainly tends to apply where the country has a prescriptive building code. The sprinklers in this case are being used to maintain the risk at a uniform level, but at a lower cost than following the prescriptive regulation.

'Trade-offs' have not been investigated in this study since it is not possible to quantify the risk levels and cost implications of all the potential options.

6.6 Uncertainty analysis

The ratio of benefit to cost is defined as R, and is made up from various components for each of the benefits and costs. The benefit: cost ratio is simply

$$R = \frac{B}{C} \qquad \{6.9\}$$

where $B = \sum_i b_i$ and $C = \sum_j c_j$

Each component will make a contribution to the uncertainty

$$\Delta R_i = \frac{\partial R}{\partial b_i}\Delta b_i \text{ for a benefit,} \quad \{6.10\}$$

$$\Delta R_j = \frac{\partial R}{\partial c_j}\Delta c_j \text{ for a cost} \quad \{6.11\}$$

and the overall uncertainty in the ratio is given by adding each of the (independent) component uncertainties in quadrature:

$$\Delta R^2 = \sum_i \left(\frac{\partial R}{\partial b_i}\right)^2 \Delta b_i^2 + \sum_j \left(\frac{\partial R}{\partial c_j}\right)^2 \Delta c_j^2 \quad \{6.12\}$$

Expanding the derivatives

$$\frac{\partial R}{\partial b_i} = \frac{\partial R}{\partial B}\frac{\partial B}{\partial b_i} \quad \text{hence} \quad \frac{\partial R}{\partial b_i} = \frac{1}{C} \quad \{6.13\}$$

and

$$\frac{\partial R}{\partial c_j} = \frac{\partial R}{\partial C}\frac{\partial C}{\partial c_j} \quad \text{hence} \quad \frac{\partial R}{\partial c_j} = -\frac{B}{C^2} \quad \{6.14\}$$

since $\frac{\partial B}{\partial b_i} = 1$ and $\frac{\partial C}{\partial c_j} = 1$

Substituting, we have

$$\Delta R^2 = \sum_i \left(\frac{1}{C}\right)^2 \Delta b_i^2 + \sum_j \left(\frac{-B}{C^2}\right)^2 \Delta c_j^2 \quad \{6.15\}$$

which further simplifies to

$$\left(\frac{\Delta R}{R}\right)^2 = \sum_i \left(\frac{\Delta b_i}{B}\right)^2 + \sum_j \left(\frac{\Delta c_j}{C}\right)^2 \quad \{6.16\}$$

Each of the benefit and cost uncertainties may in turn be comprised of a number of sub-components. Consider for example the number of deaths prevented by sprinklers, given by

$$b_d = V_d . \varepsilon_d . \left(\frac{D}{N} \right) \quad \{6.17\}$$

where V_d is the value of each life saved, ε_d is the effectiveness of residential sprinklers at preventing deaths, D is the annual number of deaths and N is the number of properties of a particular type. As before, the individual component uncertainties add in quadrature, thus

$$(\Delta b_d)^2 = \left(\frac{\partial b_d}{\partial V_d} \right)^2 \Delta V_d^2 + \left(\frac{\partial b_d}{\partial \varepsilon_d} \right)^2 \Delta \varepsilon_d^2 + \left(\frac{\partial b_d}{\partial D} \right)^2 \Delta D^2 + \left(\frac{\partial b_d}{\partial N} \right)^2 \Delta N^2 \quad \{6.18\}$$

Evaluating the individual derivatives, substituting and simplifying gives

$$\left(\frac{\Delta b_d}{b_d} \right)^2 = \left(\frac{\Delta V_d}{V_d} \right)^2 + \left(\frac{\Delta \varepsilon_d}{\varepsilon_d} \right)^2 + \left(\frac{\Delta D}{D} \right)^2 + \left(\frac{\Delta N}{N} \right)^2 \quad \{6.19\}$$

A similar approach can be used for all the benefit and cost components, which can then be substituted into the general equation above for the overall uncertainty in the benefit: cost ratio.

6.7 Confidence levels

As all of the components of the benefit: cost ratio are uncertain, it is possible for the value of the ratio to exceed 1.0 “by chance”. In order to be reasonably certain that a benefit: cost ratio is genuinely in excess of 1.0, the ratio will have to be significantly larger than 1.0.

As there are many independent components of the overall uncertainty in the ratio, according to the Central Limit Theorem, the distribution of the uncertainty will be Normal (Gaussian). The mean of this distribution will be the calculated benefit: cost ratio, R, and the variance will be ΔR^2, using the notation from the previous section. The confidence level in the cost-effectiveness of residential sprinklers is therefore the probability that a Normally-distributed variate N(R, ΔR^2) exceeds a value of 1.0. This probability is given by the Cumulative Distribution Function for the Normal Distribution, $\Phi(z)$, where $0.5 < \Phi(z) < 1.0$ for $z > 0$, and

$$z = \frac{R - 1}{\Delta R} \quad \{6.20\}$$

Figure 6.1 is a graph showing the normal probability distribution of the benefit: cost ratio. The probability that this ratio exceeds a given value is related to the area under the curve. This Figure illustrates the confidence level, i.e. the probability that this ratio exceeds a value of 1.

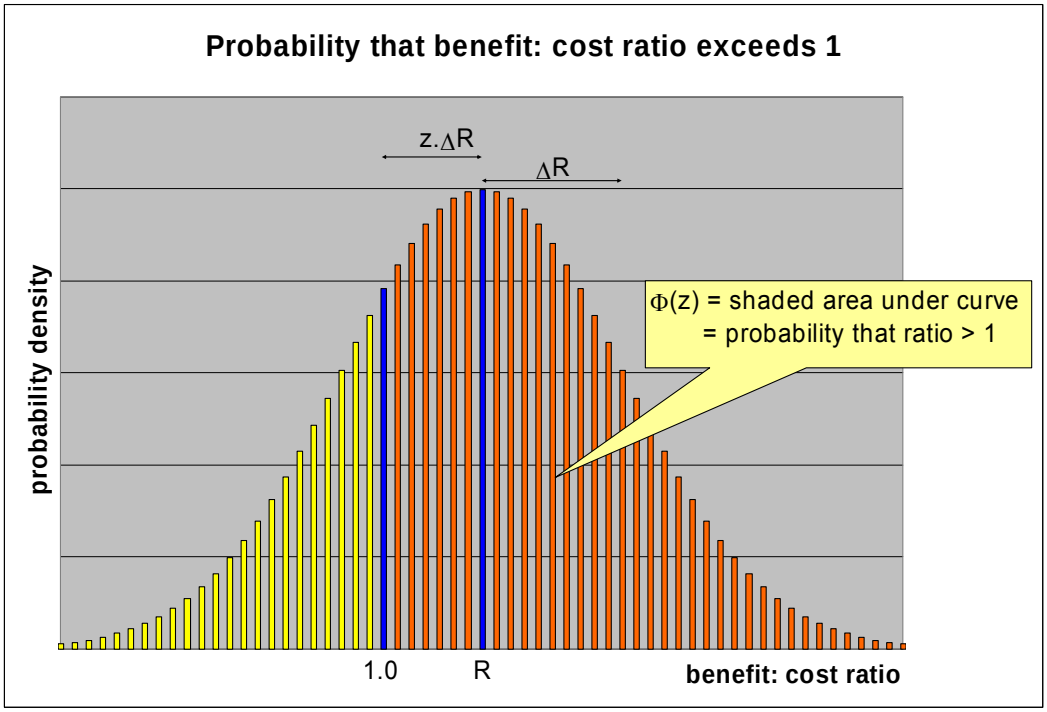

Figure 6.1 Confidence level; the probability that the (uncertain) benefit: cost ratio exceeds a value of 1

Note that it is possible for the benefit: cost ratio to exceed 1, even if the mean value of the distribution is less than 1. However, from the symmetry of Figure 6.1, it is clear that the confidence level will always be less than 50% in such cases.

It is common practice to require a confidence level of 95% in order to be "reasonably certain" an observed result did not arise by chance.

6.8 Results of cost benefit calculations

The detailed calculations for each domestic and residential property type are given in Appendix 6A. The summarised results are given in Table 6.4 and Figure 6.2.

Table 6.4 Results of cost benefit calculations

Property Type	Benefit:cost ratio			confidence
House, single occupancy	0.18	+/-	0.08	0%
House, multiple occupancy	0.26	+/-	0.08	0%
Flat, purpose-built	0.63	+/-	0.22	0%
Flat, converted	0.41	+/-	0.15	0%
Care Home, old person's	2.06	+/-	1.12	97%
Care Home, children	4.45	+/-	2.54	100%
Care Home, disabled persons'	1.13	+/-	0.63	66%

Note: the uncertainties associated with the benefit:cost ratios are all two standard deviations.

Although a confidence level of 95% is required in order to be “reasonably certain” an observed result did not arise by chance, a level of about 85% or more indicates a result that may merit more careful investigation.

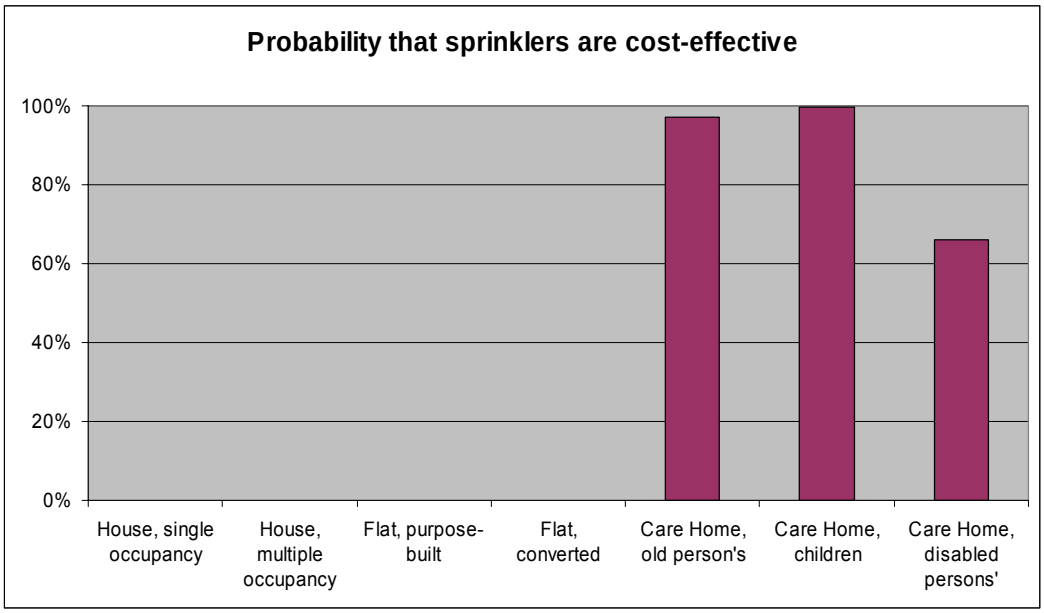

Figure 6.2 Probability that sprinklers will be cost-effective

6.9 Cost benefit calculations for ‘high-risk’ dwellings

From section 6.8, it appears that residential sprinklers may be cost-effective in care homes, but not in other types of property. However, the other categories are all quite broad in definition, and may contain a subset of high-risk properties whose effect on the cost-benefit ratio is not apparent when the ratio is calculated for the category as a whole.

A report by Entec [Wright 1997] showed that the risks from fire varied considerably over different types of HMO, and was also dependent on storey height. HMO’s of 3 storeys or more generally had much higher risks than their low-rise counterparts.

The UK fire statistics database contains insufficient detail for us to distinguish between different types of HMO’s, according to the classifications used in the Entec report. We must therefore rely on the Entec figures for the risks, combined with our estimates for the costs and sprinkler effectiveness, in order to perform the cost benefit analysis. Unfortunately, the Entec report only gives the risk of death, omitting the number of injuries and fires. The benefit: cost ratio that is calculated from the Entec figures is therefore on the low side (by about a factor of 1.5 ~ 2, if we compare the Entec ratios for

houses and flats with the ratios presented in section 6.8). The detailed calculations are given in Appendix 6B and summarised in Table 6.5.

Table 6.5 Cost benefit calculations for HMO's

Property Type	Benefit:cost ratio			confidence
1~2 storey				
Bedsit	0.15	+/-	0.09	0%
Shared House	0.11	+/-	0.10	0%
Lodgings	0.12	+/-	0.11	0%
Purpose-built	0.13	+/-	0.10	0%
Flat, converted	0.12	+/-	0.07	0%
Flat, purpose-built	0.21	+/-	0.10	0%
3+ storey				
Bedsit	0.66	+/-	0.44	6%
Shared House	0.20	+/-	0.25	0%
Lodgings	0.20	+/-	0.41	0%
Purpose-built	0.53	+/-	0.54	4%
Flat, converted	0.68	+/-	0.34	3%
Flat, purpose-built	0.47	+/-	0.20	0%
All properties				
Bedsit	0.25	+/-	0.13	0%
Shared house	0.13	+/-	0.11	0%
Lodging	0.13	+/-	0.11	0%
OAP PB	2.36	+/-	1.91	92%
other PB	0.50	+/-	0.73	9%
Hostel	0.91	+/-	0.82	41%
Flat, converted	0.26	+/-	0.12	0%
Flat, PB	0.32	+/-	0.13	0%
House	0.11	+/-	0.05	0%

Table 6.5 suggests, in common with section 6.8, that only old persons care homes are worth considering for residential sprinklers. However, not all the benefits have been included – the Entec study did not record the number of fires or injuries, only the number of deaths..

The UK Fire Statistics do record the number of storeys in the building. However in order to estimate the risks per accommodation unit, a detailed examination [White 2003] of the English House Condition Survey (EHCS) is required, in order to determine the number of units. As the EHCS only refers to the number of accommodation units in England, whereas the fire statistics refer to the whole of the UK, it follows that the risks (e.g. number of deaths divided by number of units) for the whole of the UK will be over-estimated slightly. Nevertheless, they will serve to illustrate the trend.

One of the problems with attempting a more detailed analysis is that as the categories become more precisely defined, the sample size becomes smaller and hence the relative

uncertainty in the statistics becomes larger. Eventually a point will be reached at which it is impossible to make firm conclusions because the uncertainties are too large. Therefore, although it is possible to look at houses, HMO's, purpose-built and converted flats with 1, 2, 3, … stories, the results do not enable conclusions to be drawn. Instead, categories gave been merged such that houses and HMO's are considered jointly, and likewise the two categories of flats are merged. Also, 1, 2, 3, … storeys are not considered as separate categories, but instead results have been merged for 1~2 storeys, 3~5, 6~10 and 11+ storeys. This is necessary because the size of the sample in the EHCS for individual storey heights is too small, as the number of storeys increases.

Table 6.6 Number of households, by property type and number of storeys

	Sample			Estimated population		
storeys	house	HMO	total	house	HMO	total
1	1,582	3	1,585	2,016,053	1,922	2,017,975
2	10,849	206	11,055	13,850,450	258,746	14,109,196
3	720	64	784	932,466	71,452	1,003,918
4+	25	4	29	27,342	5,052	32,394

	Sample			Estimated population		
storeys	flat, PB	flat, other	total	flat, PB	flat, other	total
1~2	1,619	263	1,882	1,416,052	328,430	1,744,482
3~5	1,604	309	1,913	1,495,213	362,547	1,857,760
6~10	166	0	166	173,756	0	173,756
11+	186	0	186	161,598	0	161,598

The detailed calculations are given in Appendix 6C and summarised in Table 6.7.

Table 6.7 Cost benefit calculation results

Property Type	Benefit:cost ratio			confidence
House, 1 storey	0.21	+/-	0.10	0%
House, 2 storey	0.20	+/-	0.09	0%
House, 3 storey	0.29	+/-	0.13	0%
House, 4+ storey	1.25	+/-	0.64	78%
Flat, 1~2 storey	0.49	+/-	0.18	0%
Flat, 3~5 storey	0.77	+/-	0.27	4%
Flat, 6~10 storey	1.00	+/-	0.37	50%
Flat, 11+ storey	1.99	+/-	0.73	100%

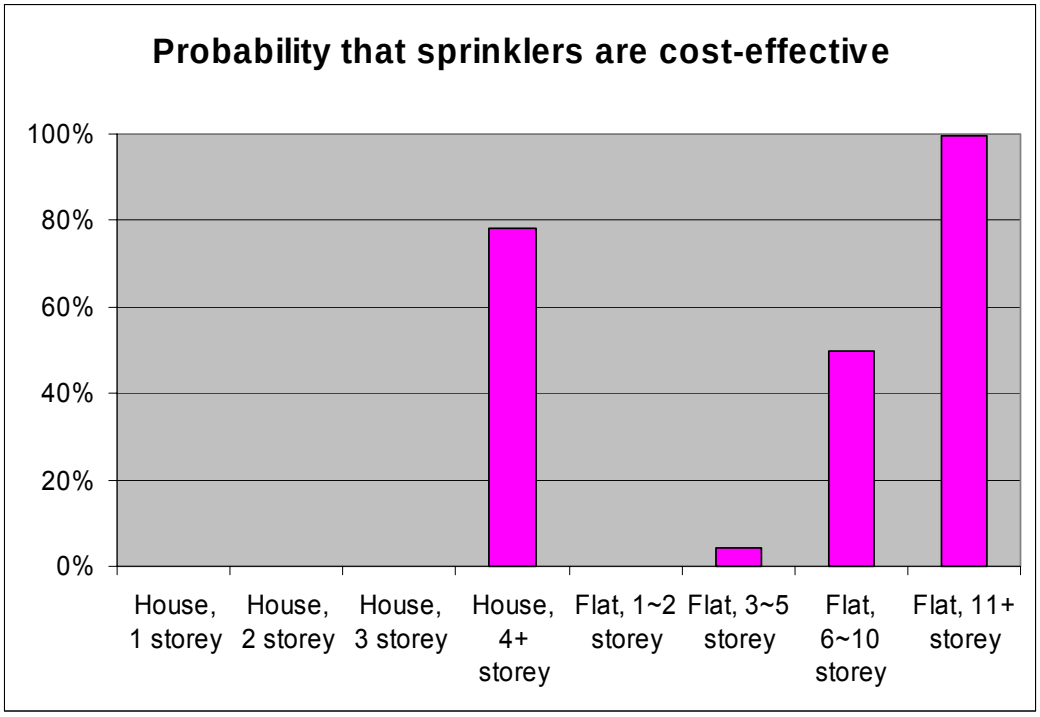

Figure 6.3 Probability that sprinklers are cost-effective in tall buildings

The results show that sprinklers are more likely to be cost-effective, the higher the risks of the building they are installed in. On the evidence of Table 6.7 and Figure 6.3, flats in blocks above 10 storeys high are worth consideration of fitting with sprinklers but houses and flats below 11 storeys are not.

It is worth re-iterating the finding from the Pilot Study (section 3.4), that the risks per fire do not vary much with building height. Taller buildings have greater risks per accommodation unit because they have relatively more fires per accommodation unit.

There have been other studies of the cost-effectiveness of residential sprinklers applied to high-risk buildings. Considerable caution must be exercised before accepting their conclusions.

For example, a recent examination of sprinklers in 3+ storey HMO's [Loweth 2002] concluded that the benefits in the first year would roughly match the total costs of provision, thus in 5 years the benefit: cost ratio would be 5:1, in 10 years 10:1, etc. This study contained a number of errors, in particular the annual charges for maintenance and inspection (which may be a considerable fraction of the total cost) were completely ignored, and (worst of all) the estimated risks apparently were based on the number of deaths etc. in HMO's as defined in the fire statistics (which includes flats in the definition) but the number of accommodation units was based on the EHCS 1991 (where flats were not included). As a result the risks were over-estimated by at least an order of magnitude. For 3-storey HMO's or higher, Loweth estimated 56 deaths in about 120,000 accommodation units (470 deaths per million units); compare this with 50 deaths (Entec figures, Appendix 6B) per million purpose-built flats (the most numerous category), or 34,

51 and 79 deaths per million flats in blocks 3~5, 6~10 and 11+ storeys high respectively (Appendix 6C).

Another study [Hutchinson 2000] looked at the effect of retro-fitting sprinklers to dwellings (e.g. council houses) in especially deprived/high-risk areas of about 200 ~ 300 households. While this report acknowledged that discounting for interest rates needed to be accounted for, this was not done; instead the capital cost was simply divided by the system lifetime (taken as 30 years) giving a capital recovery factor of 0.033 rather than 0.073 (6% interest rate). Also, the example quoted in the report assumed a particularly bad area, with risks roughly 20 times the national average (for ordinary homes in single occupation). It was assumed that the risk of death per fire was roughly the same for high and low risk properties, and thus the risk per accommodation unit depended on the number of fires. As the fire statistics show, this is a reasonable assumption. The risk of death was therefore estimated from the observed number of fires, which greatly exceeded the observed number of deaths for individual areas. The benefit: cost ratio was about 4:1. To be fair, the main thrust of this report was the identification of factors that led to high risks. However it is clear that an area has to be very much higher risk than the national average before sprinklers are cost-effective.

6.10 Summary and conclusions of the cost benefit analysis

Cost benefit analyses have been performed for a range of domestic and residential building types, including houses, flats, various types of houses of multiple occupation (HMOs), and various types of residential care homes. Further analyses were performed for different building heights, within certain of the broad categories listed above, in order to focus on properties that would be expected to have higher than average risks from fire.

The benefits of sprinklers include the prevention of deaths and injuries, and the reduction of property damage. The estimated effectiveness of sprinklers, in terms of the percentage reduction of deaths and injuries, was based on a correlation between fire size and risk of death and/or injury. Full details of this method are described in section 3. The other benefit considered was the reduction in property damage. Rather than assume the cost of the fire was directly proportional to the area damaged by the fire (which would neglect the larger area damaged by smoke), the estimated effectiveness from the US statistics was used.

The costs of providing residential sprinkler systems include installation, provision of water supplies, and annual maintenance. Estimates of these costs have been provided by members of the UK sprinkler and water industries. Government guidance was followed in assigning monetary values to deaths and injuries prevented, the average cost of property damage per fire, and the interest rate to use when calculating the capital recovery factor to convert initial costs into annual terms.

The costs and benefits all have uncertain values. An uncertainty analysis has been performed to estimate the overall uncertainty in the cost-benefit ratios, and the degree of confidence that the “true” ratio will have a value greater than 1. Note that a benefit: cost

ratio greater than unity may not be statistically significant, if the overall uncertainties are large. Also note, an estimated benefit: cost ratio of exactly 1.0 will always have a confidence level of only 50% that the true ratio is greater or equal to 1.0.

The results of the calculations for the generic domestic and residential building types are given in the following table.

Property Type	**Benefit: cost ratio**			**confidence**
House, single occupancy	0.19	+/-	0.09	0%
House, multiple occupancy	0.27	+/-	0.09	0%
Flat, purpose-built	0.67	+/-	0.24	0%
Flat, converted	0.43	+/-	0.16	0%
Care Home, old person's	2.21	+/-	1.20	98%
Care Home, children	4.85	+/-	2.75	100%
Care Home, disabled persons'	1.22	+/-	0.67	74%

Normally a confidence level of 95% or higher would be required before dismissing the possibility that a high benefit: cost ratio arose by chance. However as the estimates of the uncertainties used in the analysis are themselves rather uncertain, it is sensible to suggest that a confidence level of say 85% indicates promise, and merits further investigation with refined data.

From the table above, residential homes hold out the prospect of cost-effective sprinklers, but the other property types do not.

The influence of building height was also studied. In these analyses, single occupancy houses were combined with HMO's in a single category "house", and all types of flats were considered as a single category. The results are given in the table below.

Property Type	**Benefit:cost ratio**			**confidence**
House, 1 storey	0.22	+/-	0.10	0%
House, 2 storey	0.21	+/-	0.10	0%
House, 3 storey	0.30	+/-	0.14	0%
House, 4+ storey	1.32	+/-	0.68	83%
Flat, 1~2 storey	0.52	+/-	0.19	0%
Flat, 3~5 storey	0.81	+/-	0.29	10%
Flat, 6~10 storey	1.06	+/-	0.40	62%
Flat, 11+ storey	2.12	+/-	0.77	100%

On the basis of these calculations, flats in blocks 11 or more storeys high are worth considering for residential sprinklers.

The general conclusions are:

- Residential sprinklers are NOT cost-effective for most dwellings
- Residential sprinklers are PROBABLY cost-effective for residential care homes.
- Residential sprinklers are PROBABLY cost effective for tall blocks of flats (11+ storeys high)

The results and conclusions of this analysis are consistent with the experience of sprinklers in other countries (see section 3.8), which concluded that in order for sprinklers to become cost-effective (in a wider range of buildings),

- Installation and maintenance costs must be minimal, and/or
- Trade-offs may provide reduced costs by indirect means, and/or
- High risk buildings may be targeted, and justified on a case-by-case basis

6.11 References

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Appendix 6A – details of cost-benefit calculations

Note: all uncertainties in this Appendix are 2 standard deviations.

PROPERTY TYPE: House, single occupancy

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.03
Capital Recovery Factor	0.043	0.025	0.07
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	15	0.8	0.00
Sprinkler Effectiveness Factor	0.70	0.15	0.02
Deaths saved per Million Units	10.5		
Monetary Value per Death Saved	£1,243,000	£62,150	0.00
Monetary Benefit per Single Unit	£13.05		
Injuries per Million Units	367	4	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.02
Injuries saved per Million Units	110.1		
Monetary Value per Injury Saved	£58,300	£2,915	0.00
Monetary Benefit per Single Unit	£6.42		
Fires per Million Units	1616	18	0.00
Sprinkler Effectiveness Factor	0.50	0.15	0.01
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£6.09		
Total Monetary Benefit per unit	**£25.56**		
Benefit : Cost ratio	**0.18**	**+/-**	**0.08**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: House, multiple occupancy

	average	uncertainty	net effect
Capital Cost of System (per unit)	£550	£50	0.01
Water connection charge (per unit)	£140	£44	0.01
Capital Recovery Factor	0.043	0.025	0.06
Annual Cost of Loan	£29.42		
Annual Inspection Cost	£50	£10	0.03
Total Annual Cost	**£79.42**		
Deaths per Million Units	13	2	0.02
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	9.1		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£11.31		
Injuries per Million Units	281	12	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.03
Injuries saved per Million Units	84.3		
Monetary Value per Injury Saved	£58,300	£2,915	0.00
Monetary Benefit per Single Unit	£4.91		
Fires per Million Units	1147	58	0.00
Sprinkler Effectiveness Factor	0.50	0.15	0.02
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£4.32		
Total Monetary Benefit per unit	**£20.55**		
Benefit : Cost ratio	**0.26**	**+/-**	**0.08**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, purpose-buit

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.02
Capital Recovery Factor	0.043	0.025	0.17
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.07
Total Annual Cost	**£91.70**		
Deaths per Million Units	27	2	0.02
Sprinkler Effectiveness Factor	0.70	0.15	0.05
Deaths saved per Million Units	18.9		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£23.49		
Injuries per Million Units	941	14	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.09
Injuries saved per Million Units	282.3		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£16.46		
Fires per Million Units	4841	74	0.00
Sprinkler Effectiveness Factor	0.50	0.15	0.06
Unsprinklered property damage	£7,540	£377	0.01
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£18.25		
Total Monetary Benefit per unit	**£58.20**		
Benefit : Cost ratio	**0.63**	**+/-**	**0.22**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, converted

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,100	£0	0.00
Water connection charge (per unit)	£112	£54	0.01
Capital Recovery Factor	0.043	0.025	0.12
Annual Cost of Loan	£51.67		
Annual Inspection Cost	£50	£10	0.04
Total Annual Cost	**£101.67**		
Deaths per Million Units	23	4	0.03
Sprinkler Effectiveness Factor	0.70	0.15	0.04
Deaths saved per Million Units	16.1		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£20.01		
Injuries per Million Units	664	20	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.06
Injuries saved per Million Units	199.2		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£11.61		
Fires per Million Units	2561	96	0.00
Sprinkler Effectiveness Factor	0.50	0.15	0.03
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£9.65		
Total Monetary Benefit per unit	**£41.28**		
Benefit : Cost ratio	**0.41**	**+/-**	**0.15**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Care Home, old person's

	average	uncertainty	net effect
Capital Cost of System (per unit)	£4,455	£405	0.13
Water connection charge (per unit)	£835	£260	0.08
Capital Recovery Factor	0.043	0.025	0.99
Annual Cost of Loan	£225.53		
Annual Inspection Cost	£50	£10	0.07
Total Annual Cost	**£275.53**		
Deaths per Million Units	245	100	0.32
Sprinkler Effectiveness Factor	0.70	0.15	0.17
Deaths saved per Million Units	171.5		
Monetary Value per Death Saved	£1,243,000	£62,150	0.04
Monetary Benefit per Single Unit	£213.17		
Injuries per Million Units	6073	498	0.03
Sprinkler Effectiveness Factor	0.30	0.15	0.19
Injuries saved per Million Units	1821.9		
Monetary Value per Injury Saved	£58,300	£2,915	0.02
Monetary Benefit per Single Unit	£106.22		
Fires per Million Units	66074	4026	0.06
Sprinkler Effectiveness Factor	0.50	0.15	0.27
Unsprinklered property damage	£7,540	£377	0.05
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£249.10		
Total Monetary Benefit per unit	**£568.49**		
Benefit : Cost ratio	**2.06**	**+/-**	**1.12**
Confidence Level (ratio > 1)	**97%**		

PROPERTY TYPE: Care Home, children

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,805	£255	0.24
Water connection charge (per unit)	£835	£260	0.24
Capital Recovery Factor	0.043	0.025	1.97
Annual Cost of Loan	£155.19		
Annual Inspection Cost	£50	£10	0.22
Total Annual Cost	**£205.19**		
Deaths per Million Units	143	260	1.10
Sprinkler Effectiveness Factor	0.70	0.15	0.13
Deaths saved per Million Units	100.1		
Monetary Value per Death Saved	£1,243,000	£62,150	0.03
Monetary Benefit per Single Unit	£124.42		
Injuries per Million Units	12857	2274	0.19
Sprinkler Effectiveness Factor	0.30	0.15	0.55
Injuries saved per Million Units	3857.1		
Monetary Value per Injury Saved	£58,300	£2,915	0.05
Monetary Benefit per Single Unit	£224.87		
Fires per Million Units	149286	20652	0.38
Sprinkler Effectiveness Factor	0.50	0.15	0.82
Unsprinklered property damage	£7,540	£377	0.14
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£562.81		
Total Monetary Benefit per unit	**£912.10**		
Benefit : Cost ratio	**4.45**	**+/-**	**2.54**
Confidence Level (ratio > 1)	**100%**		

PROPERTY TYPE: Care Home, disabled people

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,640	£240	0.06
Water connection charge (per unit)	£835	£260	0.06
Capital Recovery Factor	0.043	0.025	0.49
Annual Cost of Loan	£148.15		
Annual Inspection Cost	£50	£10	0.06
Total Annual Cost	**£198.15**		
Deaths per Million Units	72	66	0.29
Sprinkler Effectiveness Factor	0.70	0.15	0.07
Deaths saved per Million Units	50.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£62.65		
Injuries per Million Units	2523	390	0.03
Sprinkler Effectiveness Factor	0.30	0.15	0.11
Injuries saved per Million Units	756.9		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£44.13		
Fires per Million Units	30990	3342	0.06
Sprinkler Effectiveness Factor	0.50	0.15	0.18
Unsprinklered property damage	£7,540	£377	0.03
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£116.83		
Total Monetary Benefit per unit	**£223.61**		
Benefit : Cost ratio	**1.13**	**+/-**	**0.63**
Confidence Level (ratio > 1)	**66%**		

Appendix 6B – details of cost benefit calculations for HMO's

Note: all uncertainties in this Appendix are 2 standard deviations.

PROPERTY TYPE: Bedsit, all

	average	uncertainty	net effect
Capital Cost of System (per unit)	£721	£66	0.01
Water connection charge (per unit)	£183	£57	0.01
Capital Recovery Factor	0.043	0.025	0.06
Annual Cost of Loan	£38.54		
Annual Inspection Cost	£50	£10	0.03
Total Annual Cost	**£88.54**		
Deaths per Million Units	25	10	0.10
Sprinkler Effectiveness Factor	0.70	0.15	0.05
Deaths saved per Million Units	17.5		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£21.75		
Total Monetary Benefit per unit	**£21.75**		
Benefit : Cost ratio	**0.25**	**+/-**	**0.13**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Bedsit <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£721	£66	0.00
Water connection charge (per unit)	£183	£57	0.00
Capital Recovery Factor	0.043	0.025	0.04
Annual Cost of Loan	£38.54		
Annual Inspection Cost	£50	£10	0.02
Total Annual Cost	**£88.54**		
Deaths per Million Units	15	8	0.08
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	10.5		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£13.05		
Total Monetary Benefit per unit	**£13.05**		
Benefit : Cost ratio	**0.15**	**+/-**	**0.09**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Bedsit 3+ stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£721	£66	0.02
Water connection charge (per unit)	£183	£57	0.02
Capital Recovery Factor	0.043	0.025	0.17
Annual Cost of Loan	£38.54		
Annual Inspection Cost	£50	£10	0.07
Total Annual Cost	**£88.54**		
Deaths per Million Units	67	38	0.37
Sprinkler Effectiveness Factor	0.70	0.15	0.14
Deaths saved per Million Units	46.9		
Monetary Value per Death Saved	£1,243,000	£62,150	0.03
Monetary Benefit per Single Unit	£58.30		
Total Monetary Benefit per unit	**£58.30**		
Benefit : Cost ratio	**0.66**	**+/-**	**0.44**
Confidence Level (ratio > 1)	**6%**		

PROPERTY TYPE: Shared house, all

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.02
Capital Recovery Factor	0.043	0.025	0.05
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	21	14	0.09
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	14.7		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£18.27		
Total Monetary Benefit per unit	**£18.27**		
Benefit : Cost ratio	**0.13**	**+/-**	**0.11**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Shared house <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.00
Water connection charge (per unit)	£465	£465	0.01
Capital Recovery Factor	0.043	0.025	0.04
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	17	14	0.09
Sprinkler Effectiveness Factor	0.70	0.15	0.02
Deaths saved per Million Units	11.9		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£14.79		
Total Monetary Benefit per unit	**£14.79**		
Benefit : Cost ratio	**0.11**	**+/-**	**0.10**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Shared house 3+ stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.03
Capital Recovery Factor	0.043	0.025	0.08
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	33	38	0.24
Sprinkler Effectiveness Factor	0.70	0.15	0.04
Deaths saved per Million Units	23.1		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£28.71		
Total Monetary Benefit per unit	**£28.71**		
Benefit : Cost ratio	**0.20**	**+/-**	**0.25**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Lodgings, all

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.02
Capital Recovery Factor	0.043	0.030	0.06
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	20	14	0.09
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	14		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£17.40		
Total Monetary Benefit per unit	**£17.40**		
Benefit : Cost ratio	**0.12**	**+/-**	**0.11**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Lodgings <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.02
Capital Recovery Factor	0.043	0.030	0.05
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	19	14	0.09
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	13.3		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£16.53		
Total Monetary Benefit per unit	**£16.53**		
Benefit : Cost ratio	**0.12**	**+/-**	**0.11**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Lodgings 3+ stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.03
Capital Recovery Factor	0.043	0.030	0.09
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	32	64	0.40
Sprinkler Effectiveness Factor	0.70	0.15	0.04
Deaths saved per Million Units	22.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£27.84		
Total Monetary Benefit per unit	**£27.84**		
Benefit : Cost ratio	**0.20**	**+/-**	**0.41**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: other purpose-built HMO's, all

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,720	£320	0.03
Water connection charge (per unit)	£835	£260	0.03
Capital Recovery Factor	0.043	0.025	0.22
Annual Cost of Loan	£151.56		
Annual Inspection Cost	£50	£10	0.02
Total Annual Cost	**£201.56**		
Deaths per Million Units	115	160	0.69
Sprinkler Effectiveness Factor	0.70	0.15	0.11
Deaths saved per Million Units	80.5		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£100.06		
Total Monetary Benefit per unit	**£100.06**		
Benefit : Cost ratio	**0.50**	**+/-**	**0.73**
Confidence Level (ratio > 1)	**9%**		

PROPERTY TYPE: other purpose-built HMO's <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,720	£320	0.01
Water connection charge (per unit)	£835	£260	0.01
Capital Recovery Factor	0.043	0.025	0.06
Annual Cost of Loan	£151.56		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£201.56**		
Deaths per Million Units	29	18	0.08
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	20.3		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£25.23		
Total Monetary Benefit per unit	**£25.23**		
Benefit : Cost ratio	**0.13**	**+/-**	**0.10**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: other purpose-built HMO's 3+ stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,720	£320	0.04
Water connection charge (per unit)	£835	£260	0.03
Capital Recovery Factor	0.043	0.025	0.23
Annual Cost of Loan	£151.56		
Annual Inspection Cost	£50	£10	0.03
Total Annual Cost	**£201.56**		
Deaths per Million Units	122	110	0.47
Sprinkler Effectiveness Factor	0.70	0.15	0.11
Deaths saved per Million Units	85.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.03
Monetary Benefit per Single Unit	£106.15		
Total Monetary Benefit per unit	**£106.15**		
Benefit : Cost ratio	**0.53**	**+/-**	**0.54**
Confidence Level (ratio > 1)	**4%**		

PROPERTY TYPE: Flat, self-contained, all

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,100	£0	0.00
Water connection charge (per unit)	£112	£44	0.00
Capital Recovery Factor	0.043	0.025	0.08
Annual Cost of Loan	£51.67		
Annual Inspection Cost	£50	£10	0.03
Total Annual Cost	**£101.67**		
Deaths per Million Units	30	8	0.07
Sprinkler Effectiveness Factor	0.70	0.15	0.06
Deaths saved per Million Units	21		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£26.10		
Total Monetary Benefit per unit	**£26.10**		
Benefit : Cost ratio	**0.26**	**+/-**	**0.12**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, self-contained <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,100	£0	0.00
Water connection charge (per unit)	£112	£44	0.00
Capital Recovery Factor	0.043	0.025	0.04
Annual Cost of Loan	£51.67		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£101.67**		
Deaths per Million Units	14	6	0.05
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	9.8		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£12.18		
Total Monetary Benefit per unit	**£12.18**		
Benefit : Cost ratio	**0.12**	**+/-**	**0.07**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, self-contained 3+ stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,100	£0	0.00
Water connection charge (per unit)	£112	£44	0.01
Capital Recovery Factor	0.043	0.025	0.20
Annual Cost of Loan	£51.67		
Annual Inspection Cost	£50	£10	0.07
Total Annual Cost	**£101.67**		
Deaths per Million Units	79	26	0.22
Sprinkler Effectiveness Factor	0.70	0.15	0.14
Deaths saved per Million Units	55.3		
Monetary Value per Death Saved	£1,243,000	£62,150	0.03
Monetary Benefit per Single Unit	£68.74		
Total Monetary Benefit per unit	**£68.74**		
Benefit : Cost ratio	**0.68**	**+/-**	**0.34**
Confidence Level (ratio > 1)	**3%**		

PROPERTY TYPE: Flat, purpose-built

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.01
Capital Recovery Factor	0.043	0.025	0.09
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.04
Total Annual Cost	**£91.70**		
Deaths per Million Units	34	6	0.06
Sprinkler Effectiveness Factor	0.70	0.15	0.07
Deaths saved per Million Units	23.8		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£29.58		
Total Monetary Benefit per unit	**£29.58**		
Benefit : Cost ratio	**0.32**	**+/-**	**0.13**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, purpose-built <3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.01
Capital Recovery Factor	0.043	0.025	0.06
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.02
Total Annual Cost	**£91.70**		
Deaths per Million Units	22	6	0.06
Sprinkler Effectiveness Factor	0.70	0.15	0.04
Deaths saved per Million Units	15.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£19.14		
Total Monetary Benefit per unit	**£19.14**		
Benefit : Cost ratio	**0.21**	**+/-**	**0.10**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, purpose-built >3 stories

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.02
Capital Recovery Factor	0.043	0.025	0.13
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.05
Total Annual Cost	**£91.70**		
Deaths per Million Units	50	10	0.09
Sprinkler Effectiveness Factor	0.70	0.15	0.10
Deaths saved per Million Units	35		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£43.51		
Total Monetary Benefit per unit	**£43.51**		
Benefit : Cost ratio	**0.47**	**+/-**	**0.20**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: OAP Rest Home, purpose-built

	average	uncertainty	net effect
Capital Cost of System (per unit)	£4,455	£405	0.15
Water connection charge (per unit)	£835	£260	0.09
Capital Recovery Factor	0.043	0.025	1.13
Annual Cost of Loan	£225.53		
Annual Inspection Cost	£50	£10	0.09
Total Annual Cost	**£275.53**		
Deaths per Million Units	747	454	1.43
Sprinkler Effectiveness Factor	0.70	0.15	0.51
Deaths saved per Million Units	522.9		
Monetary Value per Death Saved	£1,243,000	£62,150	0.12
Monetary Benefit per Single Unit	£649.96		
Total Monetary Benefit per unit	**£649.96**		
Benefit : Cost ratio	**2.36**	**+/-**	**1.91**
Confidence Level (ratio > 1)	**92%**		

PROPERTY TYPE: Hostel

	average	uncertainty	net effect
Capital Cost of System (per unit)	£2,720	£320	0.06
Water connection charge (per unit)	£835	£260	0.05
Capital Recovery Factor	0.043	0.025	0.40
Annual Cost of Loan	£151.56		
Annual Inspection Cost	£50	£10	0.04
Total Annual Cost	**£201.56**		
Deaths per Million Units	210	158	0.68
Sprinkler Effectiveness Factor	0.70	0.15	0.19
Deaths saved per Million Units	147		
Monetary Value per Death Saved	£1,243,000	£62,150	0.05
Monetary Benefit per Single Unit	£182.72		
Total Monetary Benefit per unit	**£182.72**		
Benefit : Cost ratio	**0.91**	**+/-**	**0.82**
Confidence Level (ratio > 1)	**41%**		

PROPERTY TYPE: House, single occupancy

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.00
Water connection charge (per unit)	£465	£465	0.01
Capital Recovery Factor	0.043	0.025	0.04
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	17	2.2	0.01
Sprinkler Effectiveness Factor	0.70	0.15	0.02
Deaths saved per Million Units	11.9		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£14.79		
Total Monetary Benefit per unit	**£14.79**		
Benefit : Cost ratio	**0.11**	**+/-**	**0.05**
Confidence Level (ratio > 1)	**0%**		

Appendix 6C – details of cost benefit calculations for buildings of different heights

Note: all uncertainties in this Appendix are 2 standard deviations.

PROPERTY TYPE: Bungalow

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.03
Capital Recovery Factor	0.043	0.025	0.08
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	22	2.6	0.02
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	15.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£19.14		
Injuries per Million Units	294	9.8	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.02
Injuries saved per Million Units	88.2		
Monetary Value per Injury Saved	£58,300	£2,915	0.00
Monetary Benefit per Single Unit	£5.14		
Fires per Million Units	1374	258	0.01
Sprinkler Effectiveness Factor	0.50	0.15	0.01
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£5.18		
Total Monetary Benefit per unit	**£29.46**		
Benefit : Cost ratio	**0.21**	**+/-**	**0.10**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: House, 2 floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.03
Capital Recovery Factor	0.043	0.025	0.08
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.01
Total Annual Cost	**£140.17**		
Deaths per Million Units	16	0.8	0.00
Sprinkler Effectiveness Factor	0.70	0.15	0.02
Deaths saved per Million Units	11.2		
Monetary Value per Death Saved	£1,243,000	£62,150	0.00
Monetary Benefit per Single Unit	£13.92		
Injuries per Million Units	421	4.4	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.03
Injuries saved per Million Units	126.3		
Monetary Value per Injury Saved	£58,300	£2,915	0.00
Monetary Benefit per Single Unit	£7.36		
Fires per Million Units	1845	114	0.00
Sprinkler Effectiveness Factor	0.50	0.15	0.01
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£6.96		
Total Monetary Benefit per unit	**£28.24**		
Benefit : Cost ratio	**0.20**	**+/-**	**0.09**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: House, 3 floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.01
Water connection charge (per unit)	£465	£465	0.04
Capital Recovery Factor	0.043	0.025	0.11
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.02
Total Annual Cost	**£140.17**		
Deaths per Million Units	26	4.2	0.03
Sprinkler Effectiveness Factor	0.70	0.15	0.03
Deaths saved per Million Units	18.2		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£22.62		
Injuries per Million Units	521	18.4	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.03
Injuries saved per Million Units	156.3		
Monetary Value per Injury Saved	£58,300	£2,915	0.00
Monetary Benefit per Single Unit	£9.11		
Fires per Million Units	2186	464	0.01
Sprinkler Effectiveness Factor	0.50	0.15	0.02
Unsprinklered property damage	£7,540	£377	0.00
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£8.24		
Total Monetary Benefit per unit	**£39.98**		
Benefit : Cost ratio	**0.29**	**+/-**	**0.13**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: House, 4+ floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£1,650	£150	0.06
Water connection charge (per unit)	£465	£465	0.18
Capital Recovery Factor	0.043	0.025	0.47
Annual Cost of Loan	£90.17		
Annual Inspection Cost	£50	£10	0.09
Total Annual Cost	**£140.17**		
Deaths per Million Units	93	42	0.26
Sprinkler Effectiveness Factor	0.70	0.15	0.12
Deaths saved per Million Units	65.1		
Monetary Value per Death Saved	£1,243,000	£62,150	0.03
Monetary Benefit per Single Unit	£80.92		
Injuries per Million Units	2686	230	0.03
Sprinkler Effectiveness Factor	0.30	0.15	0.17
Injuries saved per Million Units	805.8		
Monetary Value per Injury Saved	£58,300	£2,915	0.02
Monetary Benefit per Single Unit	£46.98		
Fires per Million Units	12375	6034	0.16
Sprinkler Effectiveness Factor	0.50	0.15	0.10
Unsprinklered property damage	£7,540	£377	0.02
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£46.65		
Total Monetary Benefit per unit	**£174.55**		
Benefit : Cost ratio	**1.25**	**+/-**	**0.64**
Confidence Level (ratio > 1)	**78%**		

PROPERTY TYPE: Flat, 1~2 floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.02
Capital Recovery Factor	0.043	0.025	0.13
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.05
Total Annual Cost	**£91.70**		
Deaths per Million Units	22	2.8	0.03
Sprinkler Effectiveness Factor	0.70	0.15	0.04
Deaths saved per Million Units	15.4		
Monetary Value per Death Saved	£1,243,000	£62,150	0.01
Monetary Benefit per Single Unit	£19.14		
Injuries per Million Units	749	19	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.07
Injuries saved per Million Units	224.7		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£13.10		
Fires per Million Units	3433	444	0.02
Sprinkler Effectiveness Factor	0.50	0.15	0.04
Unsprinklered property damage	£7,540	£377	0.01
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£12.94		
Total Monetary Benefit per unit	**£45.18**		
Benefit : Cost ratio	**0.49**	**+/-**	**0.18**
Confidence Level (ratio > 1)	**0%**		

PROPERTY TYPE: Flat, 3~5 floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.03
Capital Recovery Factor	0.043	0.025	0.20
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.08
Total Annual Cost	**£91.70**		
Deaths per Million Units	34	3.4	0.03
Sprinkler Effectiveness Factor	0.70	0.15	0.07
Deaths saved per Million Units	23.8		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£29.58		
Injuries per Million Units	1154	20.2	0.00
Sprinkler Effectiveness Factor	0.30	0.15	0.11
Injuries saved per Million Units	346.2		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£20.18		
Fires per Million Units	5451	538	0.02
Sprinkler Effectiveness Factor	0.50	0.15	0.07
Unsprinklered property damage	£7,540	£377	0.01
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£20.55		
Total Monetary Benefit per unit	**£70.32**		
Benefit : Cost ratio	**0.77**	**+/-**	**0.27**
Confidence Level (ratio > 1)	**4%**		

PROPERTY TYPE: Flat, 6~10 floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.04
Capital Recovery Factor	0.043	0.025	0.27
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.11
Total Annual Cost	**£91.70**		
Deaths per Million Units	51	14	0.13
Sprinkler Effectiveness Factor	0.70	0.15	0.10
Deaths saved per Million Units	35.7		
Monetary Value per Death Saved	£1,243,000	£62,150	0.02
Monetary Benefit per Single Unit	£44.38		
Injuries per Million Units	1106	65.2	0.01
Sprinkler Effectiveness Factor	0.30	0.15	0.11
Injuries saved per Million Units	331.8		
Monetary Value per Injury Saved	£58,300	£2,915	0.01
Monetary Benefit per Single Unit	£19.34		
Fires per Million Units	7373	2058	0.08
Sprinkler Effectiveness Factor	0.50	0.15	0.09
Unsprinklered property damage	£7,540	£377	0.02
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£27.80		
Total Monetary Benefit per unit	**£91.52**		
Benefit : Cost ratio	**1.00**	**+/-**	**0.37**
Confidence Level (ratio > 1)	**50%**		

PROPERTY TYPE: Flat, 11+ floors

	average	uncertainty	net effect
Capital Cost of System (per unit)	£900	£0	0.00
Water connection charge (per unit)	£78	£78	0.07
Capital Recovery Factor	0.043	0.025	0.53
Annual Cost of Loan	£41.70		
Annual Inspection Cost	£50	£10	0.22
Total Annual Cost	**£91.70**		
Deaths per Million Units	79	18	0.17
Sprinkler Effectiveness Factor	0.70	0.15	0.16
Deaths saved per Million Units	55.3		
Monetary Value per Death Saved	£1,243,000	£62,150	0.04
Monetary Benefit per Single Unit	£68.74		
Injuries per Million Units	2827	108	0.02
Sprinkler Effectiveness Factor	0.30	0.15	0.27
Injuries saved per Million Units	848.1		
Monetary Value per Injury Saved	£58,300	£2,915	0.03
Monetary Benefit per Single Unit	£49.44		
Fires per Million Units	17080	3248	0.13
Sprinkler Effectiveness Factor	0.50	0.15	0.21
Unsprinklered property damage	£7,540	£377	0.04
Reduced property damage per fire	£3,770		
Monetary Benefit per Single Unit	£64.39		
Total Monetary Benefit per unit	**£182.57**		
Benefit : Cost ratio	**1.99**	**+/-**	**0.73**
Confidence Level (ratio > 1)	**100%**		