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Cost-Effective Fire Safety Measures for Residential Buildings in New Zealand

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Preface

This is a report on the cost-effectiveness of smoke alarms and sprinkler systems installed in dwellings in New Zealand.

Acknowledgements

This work was funded by the New Zealand Building Research Levy.

Note

This report is intended for regulatory bodies, the fire protection industry and other researchers.

COST-EFFECTIVE FIRE SAFETY MEASURES FOR RESIDENTIAL BUILDINGS IN NEW ZEALAND

BRANZ Study Report SR 93 (2000) **C A Wade and C R Duncan**

REFERENCE

Wade, C.A and Duncan, C.R (2000). Cost-Effective Fire Safety Measures for Residential Buildings in New Zealand. Study Report No 93. Building Research Association of New Zealand, Judgeford, New Zealand.

ABSTRACT

A study was carried out which investigated the cost effectiveness of the installation of smoke alarms and domestic sprinklers in New Zealand dwellings in order to reduce injury and property losses, and to save lives. The study followed methodology used for a similar study in Australia, with similar conclusions resulting from both studies. A number of different smoke alarm installation options were considered. Sprinkler systems to current Standards (NZS 4515: 1995) and also to a recent proposed revision of this Standard (DZ4515/CD3). Specifically domestic sprinklers, installed to current and proposed New Zealand Standards, are not considered to be cost-effective at this time. On the other hand, stand-alone battery-powered smoke alarms are considered to be a cost-effective measure.

The report gives a brief historical record of the domestic fire problem in New Zealand. An analysis of statistical fire records and risk profiles in New Zealand is undertaken, and comparisons with similar overseas data are made. The statistical analysis includes data on the causes and locations of fires in residential buildings. The approach to the cost-effectiveness methodology is outlined, with comparison made to a similar Australian study. The details of the cost/benefit study for a variety of configurations of smoke alarms and for domestic sprinkler systems form the basis of recommendations relating to the cost-effectiveness of these types of fire protection for dwellings.

Contents

2.1.2 Location

Statistics collected by the New Zealand Fire Service (NZFS, 1999a) show that 72% of the reported fires in dwellings start in the kitchen, lounge or bedroom as shown in Figure 2. The most frequent area of fire origin is the kitchen (34%), but the most frequent area for the origin of fires which cause fatalities (refer Figure 3) is the bedroom (38%), followed by the lounge/dining room (26%), and the kitchen (24%).

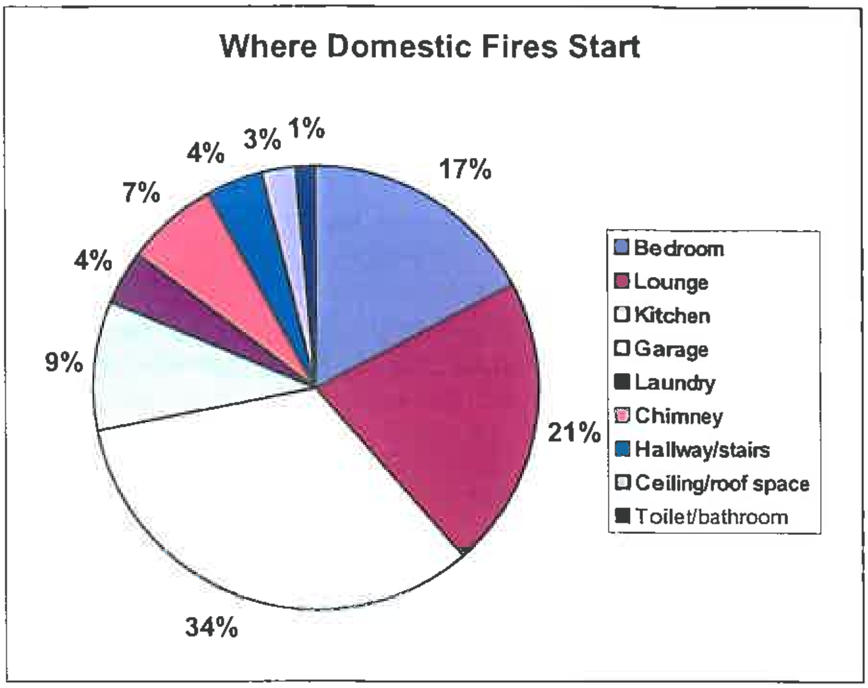

Figure 2: Where New Zealand domestic fires start (NZFS, 1999a)

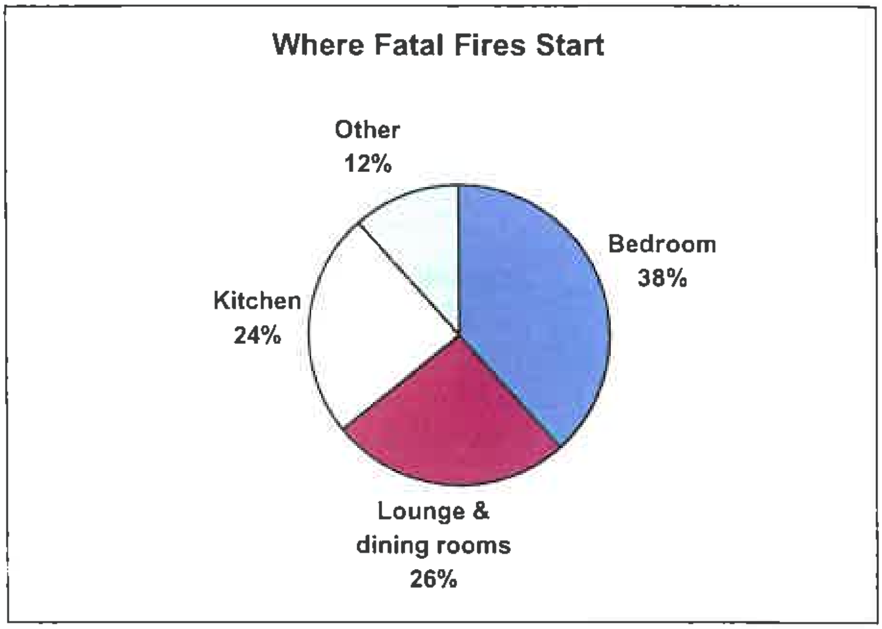

Figure 3: Where fatal fires start – New Zealand (Irwin, 1997)

2.1.3 Severity

In New Zealand, domestic fires contribute to the majority of fire deaths. The annual average number of fire deaths in houses and flats in New Zealand from 1986 – 1998 is 23 (Grieve, 1999).

Figure 4 shows the number of deaths caused by fire each year. "Residential" refers to fires in houses and flats. The number of fire deaths are small enough that variations from year to year can be significant and any overall trends are difficult to determine.

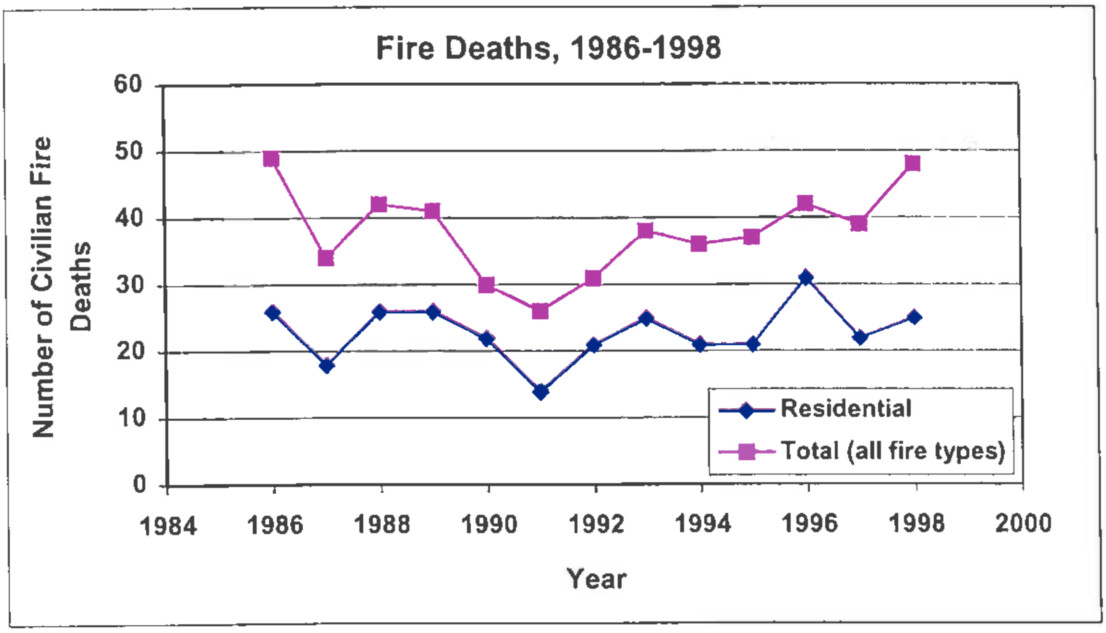

Figure 4: Fire deaths in houses and flats compared to all fire types (New Zealand) 1986-1998

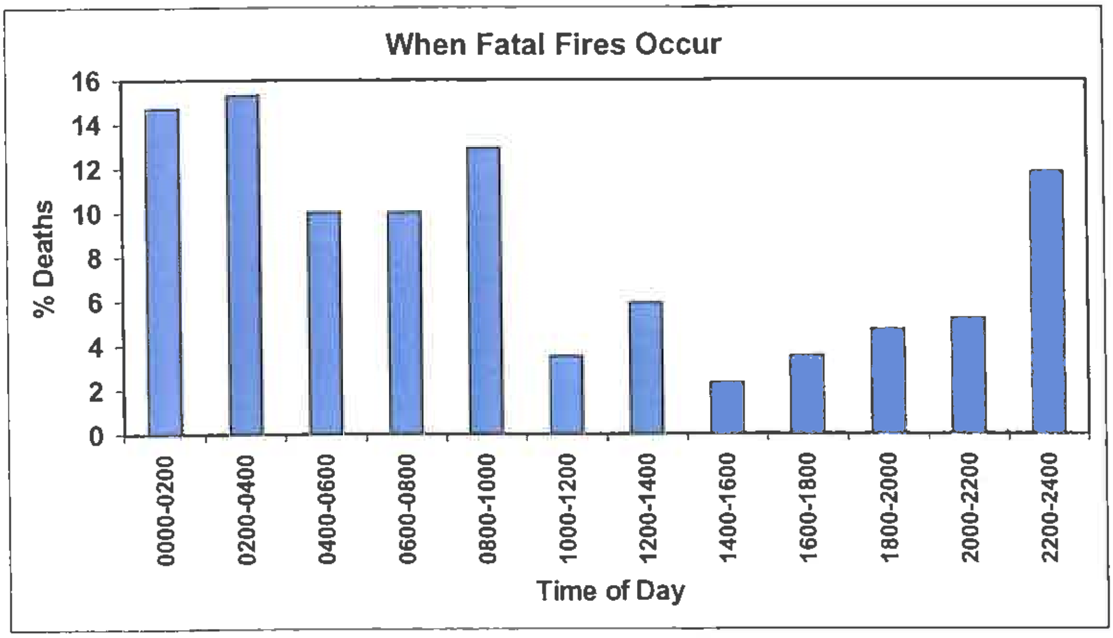

Figure 5: When fatal fires occur – New Zealand (Irwin, 1997)

Figure 5 graphs a distribution of the time of day when fatal fires occur. The graph indicates that fires resulting in fatalities are more likely to occur between 10 pm and 10 am, during the most common sleeping hours. These statistics suggest that sleeping occupants are more at risk from fire.

2.2 International Statistics

Figure 6 and Figure 7 show a comparison of fire death rates between a variety of countries (FEMA, 1997a; Beever and Britton, 1999; Irwin, 1997). The number of New Zealand fire deaths per million population is low by world standards but is about equal to the average for all the developed countries. The rates shown apply to the 1992 year, except for Australia, which is the average over the period 1990-1992, and for New Zealand, which is the average over the period 1986-1994.

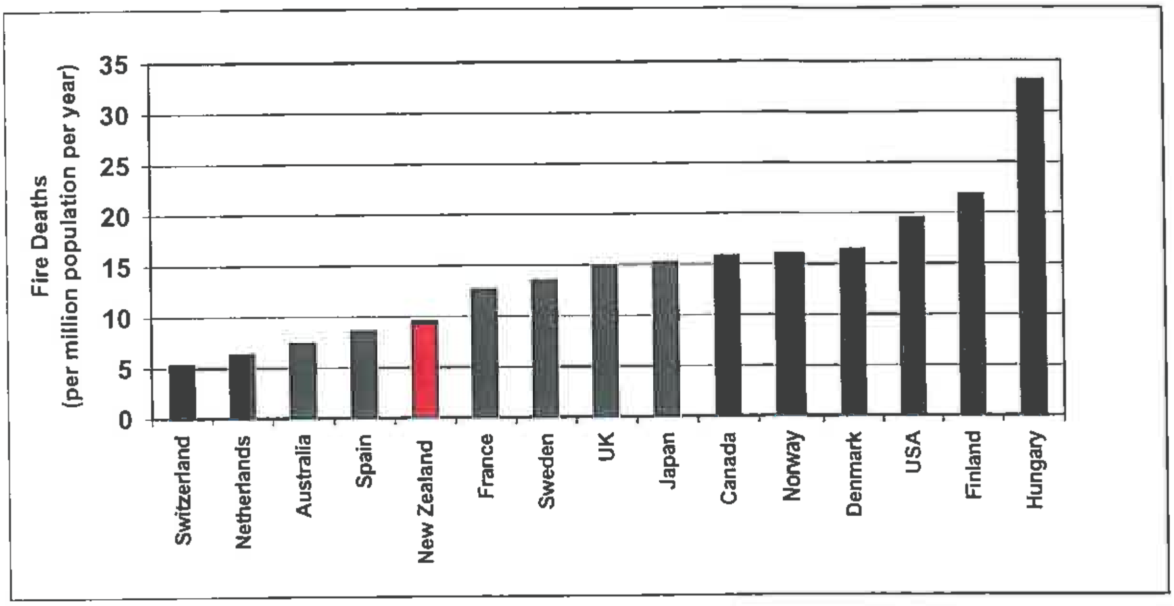

Figure 6: Comparison of fire death rates

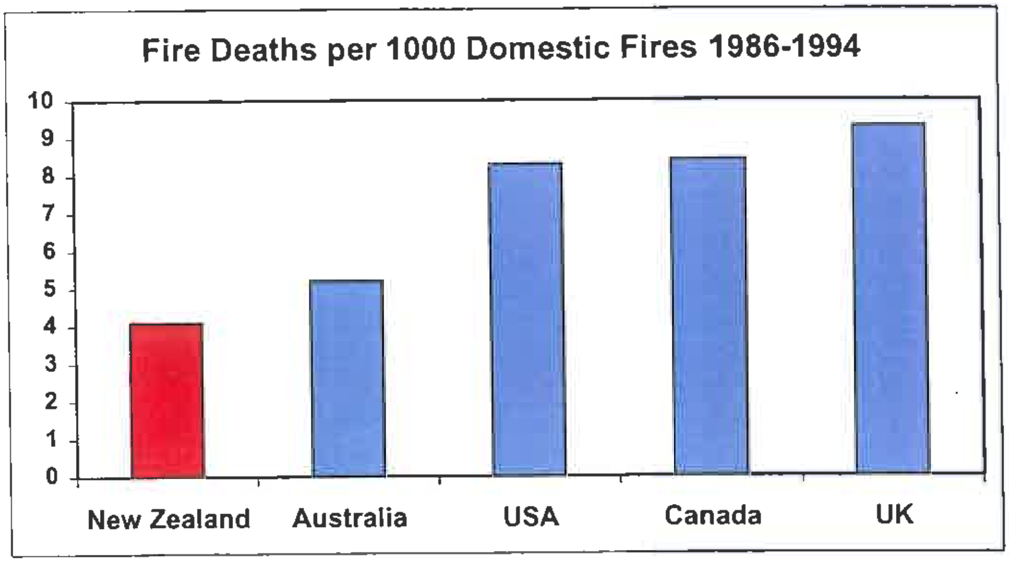

Figure 7: Comparison of international fire death rates (Irwin, 1997)

In New Zealand, close to 40% of fatal fires begin in the bedroom (Figure 3), with the majority occurring during sleeping hours, between 10 pm and 10 am (Figure 5). Statistics from the United States show trends for domestic fires to be similar to those of New Zealand, with 8 out of 10 fire deaths occurring in the home (Home Fire Sprinkler Coalition, 1999). The kitchen, bedroom and living room (den) feature as the top three areas of fire origin (refer Figure 8).

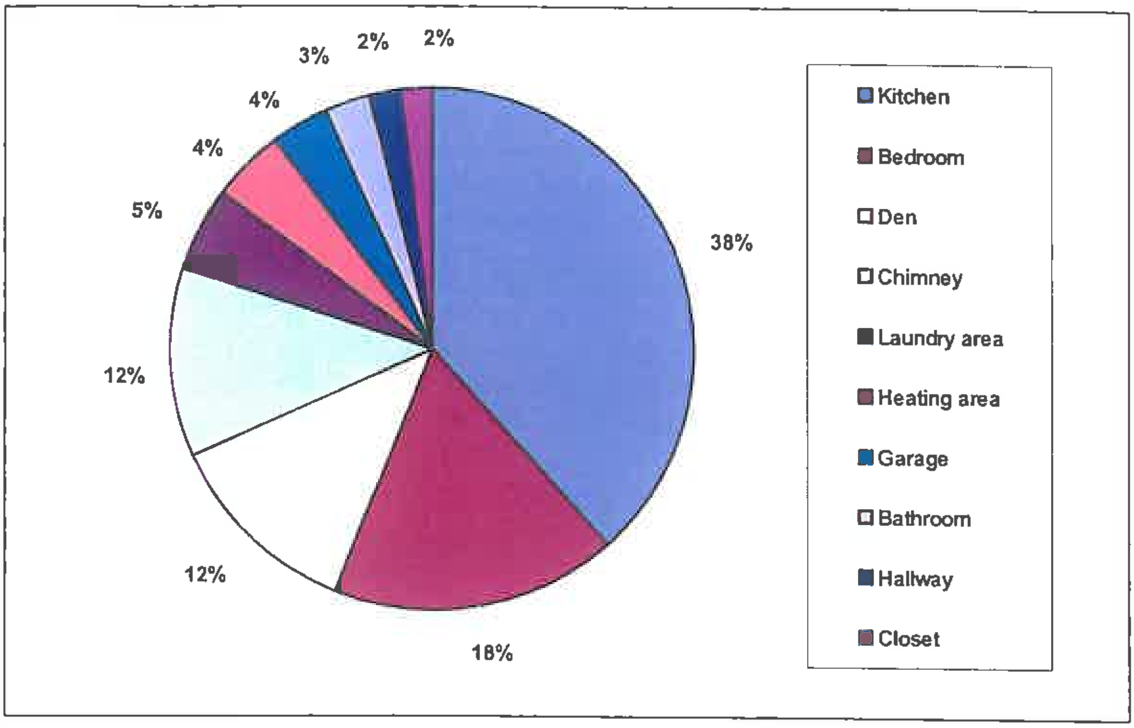

Figure 8: Area of domestic fire origin – United States (Edison, 1999)

According to the United States Fire Administration (USFA, 1998b), statistics show:

- Cooking is the leading cause of home fires in the United States; it is also the leading cause of fire injuries.
- Careless smoking is the leading cause of fire deaths.
- Heating is the second leading cause of residential fires and ties with arson as the second leading cause of fire deaths.
- Arson is the third leading cause of residential fires and a second leading cause of residential fire deaths.

In the United States, about 5000 people die every year as the result of fire, and another 25,500 are injured. At least 80% of all fire deaths occur in private homes. Direct property loss due to fires is estimated at $US 9 billion annually (USFA, 1998b).

Approximately 86% of United States homes have at least one smoke alarm (Edison, 1999). About 64% of the residential fire deaths occur in the 14% of the United States homes which have no smoke alarms (and presumably no sprinkler system) installed (Edison, 1999). In the United Kingdom, smoke alarm ownership has increased from under 10% in 1988 to 82% in

1998. Over the period 1994 to 1997, 71% of the fire deaths in dwellings occurred where there was no smoke alarm (Watson and Gamble, 1999).

There are cities in the United States where laws have been passed to make residential sprinkler systems compulsory. In approximately 90% of all documented sprinkler activations in residences in these cities, one sprinkler head has been sufficient to control the fire (USFA, 1998).

3. COST-EFFECTIVENESS METHODOLOGY

The methodology for the cost/benefit modelling follows that described by Beever and Britton (1999) where the cost per life saved is determined for the installation of a specified fire safety measure. For each analysis, a nominal discount rate and an inflation rate are used. A sensitivity analysis for these and other variables is included in the study. An analysis period of twenty years is considered for all fire safety measures, and where components have a different working life, the replacement costs are included at the appropriate time.

For each fire safety measure, a net present cost is calculated by subtracting the net present value of savings (such as injuries avoided and direct loss of property) from the net present value of the purchase, installation and maintenance costs. The net present value per household is calculated using the formula:

$$\text{NPV} = \sum_{t=1}^{n} \frac{\text{Net yearly cost}}{(1 + \text{discount rate})^t} \qquad \text{where } t = \text{time (years)}$$

4. ASSUMPTIONS

4.1 Rate of Fire Incidents

Beever and Britton (1999) used a fire incident rate of 0.00187 fires per year per household for Australia. This was based on data from the Australian Fire Incident Reporting system and Country Fire Authority data. The comparable fire incident rate for the USA (FEMA, 1997b) was 0.00270 fires per year per household.

New Zealand Fire Service statistics show that over the five-year period from 1993 to 1997, the average number of fires in 1- and 2-family dwellings each year is 5967. Assuming the average number of dwellings (SH and SR purpose groups) to be 1,269,000 (BIA, 1999) over the same period provides an estimate of 0.0047 reported fires per year per household.

Irwin (1997) also analysed New Zealand Fire Service data for the period 1986 to 1994, and determined the average number of reported fires in domestic structure buildings (1- and 2-family dwellings, apartments, flats) to be 4668 per year. Again, based on an average number of dwellings of 1,152,000 over that period, this provides an estimate of 0.0041 reported fires per year per household.

Therefore, a fire incident rate of 0.004 fires per year per household is used in this study, based on current New Zealand data from NZFS Statistics 1993-1997 and Irwin's analysis. Although higher than the equivalent Australian or USA data, this is still expected to provide a conservative estimate of the actual fire incident rate due to the number of fires that are discovered and extinguished without a call to the Fire Service (i.e. not reported).

4.2 Cost of Fire Injuries

Beever and Britton (1999) assumed a value of A$21,100 as the cost per fire injury. This amount included estimates for pain and suffering, patient and visitor transportation, and estimated lost earnings.

Earlier cost/benefit studies from the USA (Ruegg and Fuller, 1984) used US$20,000. This USA study was also the basis for the studies done by Rahmanian (1995) and Strategos (1989).

A value of $30,000 for the average cost of a fire injury is used in this study which is of the same order as the Australian value after accounting for exchange rates and inflation.

4.3 Death Rates in the Absence of Fire Protection Systems

The death rate per 1000 fires shown in Figure 7 is an average value assuming a certain proportion of smoke alarms and a negligible number of fire sprinkler systems to be present. However, for this study, we require the fire deaths (per 1000 fires) to be estimated in domestic structure buildings with and without these fire protection systems.

Beever and Britton (1999) used a figure of 12 deaths per 1000 house fires where no smoke alarms were present. This value was based on examination of 1994 NFIRS (USA) data by Beever and Britton (1999) as they considered the AFIRS data in this area to be unreliable. They also used 7 deaths per 1000 house fires where no sprinklers were present, but presumably this lower value accounted for the presence of smoke alarms in some of these cases. This value was based on AFIRS data showing 6.66 deaths per year over the period 1989-1993.

FEMA (1999) indicates that in the United States in 1996, there were 11.6 deaths per 1000 fires where no smoke alarm was present. This rate is similar to that presented by Hall (1996) for USA data from 1984-1994 indicating that on average, there were 10.2 deaths per 1000 fires where no smoke alarm was present. The overall average fire death rate in the USA for the years 1987 to 1996 was 9.0 deaths per 1000 fires.

Similar figures for the United Kingdom (Home Office, 1995) for the years 1988-1993 gave 10.2 deaths per 1000 fires when no alarm was present.

Irwin (1997) also carried out a study and found there were 170 domestic fire deaths over a nine-year period (1986-1994) in New Zealand, giving a figure of 4.05 deaths per 1000 fires. As noted previously, this rate does not distinguish between houses with and without smoke alarms or sprinklers. It is also considerably lower than the equivalent USA rate for 1- and 2-family dwellings – about 50% lower.

In the absence of better information, the estimated death rate without smoke alarms or sprinklers is taken as approximately one-half of the equivalent USA rate (10-12 deaths per 1000 fires) based on Irwin's analysis. Therefore for this study. 6 deaths per 1000 fires for the case where no smoke alarm or sprinklers were present was considered to be a conservative estimate and was used in the analysis.

4.4 Injury Rates in the Absence of Fire Protection Systems

New Zealand data for the period 1993-1997 (NZFS, 1998) gave 1455 injuries to the public and 977 injuries to fire fighters, with a total of 85,024 fires (in all occupancies) giving 28.6 injuries per 1000 fires. Irwin (1997) compares injury rates in domestic fires between different countries (Table 1). As for the reported death rates, the reported injury rate for New Zealand is also significantly less than for other countries. It is also about seven times the fire death rate.

Table 1: Reported injury rate per 1000 fires (Irwin 1997)

Country	Injury Rate per 1000 fires
New Zealand	26.6
Australia	48.2
United Kingdom	170.0
USA	44.6
Canada	59.8

FEMA (1999) reported that in the USA for the 1996 year, the average injury rate per 1000 fires was 40.8 (about 4.5 times greater than for the fire death rate for the same year). Again this does not account for the presence or absence of any fire protection systems. FEMA (1999) also reported the fire death rate without smoke alarms as 11.6 deaths per 1000 fires. If the same ratio between deaths and injuries were applied, the fire injury rate in USA fires without alarms could be estimated as 52 injuries per 1000 fires.

Home Office (1995) data for the United Kingdom (1988-1993) reports 168 injuries per 1000 fires without detectors present. Beever and Britton (1999) reported that AFIRS showed 80 injuries per 1000 fires where no alarm was present.

For the purpose of this study, 40 injuries per 1000 fires was used for houses with no alarms or sprinklers.

4.5 Discount Rate

An 8% nominal discount rate (related to the average mortgage interest rate payable by a homeowner) was selected for use in this study. This represents the return on investment that could be made elsewhere, or the opportunity value of the investment.

4.6 Inflation Rate

An inflation rate of 2% was used in this study. This is used in determining the replacement cost of the smoke alarm system after 10 years. It is also used in conjunction with the discount rate to determine the net present value of costs incurred and savings made at some time in the future.

4.7 Analysis Period

An analysis period of 20 years was used in this study.

5. SMOKE ALARM COST BENEFIT MODEL

5.1 Smoke Alarm Installation Options

The analysis for smoke alarms considered the following options:

1. Single battery-powered smoke alarm (with 1-year battery)
2. Single battery-powered smoke alarm (with long-life 10-year battery)
3. Single mains-wired smoke alarm (with backup battery)
4. Four battery-powered smoke alarms (with 1-year battery)
5. Four battery-powered smoke alarms (with long life 10-year battery)
6. Four interconnected battery-powered smoke alarms (with 1-year battery)
7. Four interconnected mains-wired smoke alarms (with backup battery)

The installation was assumed to take place in both new and existing buildings, and all alarms were assumed to be of the ionisation type.

5.2 Costs Associated with Smoke Alarms

It is assumed that the installation and testing of interconnected alarms is undertaken by a qualified tradesman. The Australian Standard for smoke alarms AS 3786:1993 (SA, 1993) states that batteries shall be capable of powering the smoke alarm without a fault signal for at least one year, and allow for routine testing once per month. In this analysis, the annual maintenance costs associated with single alarms are estimated on monthly testing and annual replacement of batteries (except for the long-life batteries).

5.2.1 Labour rates for installation of alarms

Installation of alarms was assumed to be carried out by a qualified electrician. Charge-out rates for electricians are given in *Consumer* magazine (Consumers' Institute, 1998). A typical rate of $40 per hour (including GST) was used in the analysis.

5.2.2 Installation time

Beever and Britton (1999) allowed 1 hour for the installation of a single battery-powered smoke alarm and 2 hours for a single mains-wired smoke alarm. They also allowed 7 hours for the five interconnected battery-powered smoke alarms and 8 hours for five interconnected mains-wired smoke alarms. For battery-operated smoke alarms, this study uses 1 hour for the first alarm and 15 minutes for every subsequent smoke alarm installed. For interconnected battery-operated smoke alarms, 45 minutes per alarm is used, and for interconnected mains-powered alarms, 1 hour per smoke alarm is assumed. Longer installation times are assumed for existing buildings. These estimates are less conservative than the Australian values but considered to be more realistic. The estimates take into account a likely difference between the time taken to install a single smoke alarm (by a home owner, for example) and the minimum chargeable time by an electrician (which includes callout/travel). The installation times given in Table 2 were therefore assumed in this study.

Table 2: Smoke Alarm Installation Time

Installation Option	Installation Time Charged by Electrician (hours)	
	New Building	Existing Building
Single battery-powered smoke alarm (with 1-year battery)	1.00	1.00
Single battery-powered smoke alarm (with long-life 10-year battery)	1.00	1.00
Single mains-wired smoke alarm with backup battery	2.00	3.00
Four battery-powered smoke alarms (with 1-year battery)	1.75	1.75
Four battery-powered smoke alarms (with long-life 10-year battery)	1.75	1.75
Four interconnected battery-powered smoke alarms	3.00	4.50
Four interconnected mains-wired smoke alarms with backup battery	4.00	6.00

5.2.3 Material costs

The unit costs (NZFS, 1999b) per smoke alarm shown in Table 3 were used.

Table 3: Cost of Smoke Alarms

Option	$ total
Single battery-powered smoke alarm (with 1-year battery)	20
Single battery-powered smoke alarm (with long life 10-year battery)	45
Single mains-wired smoke alarm with backup battery	70
Four battery-powered smoke alarms (with 1-year battery)	80 (4 @ $20)
Four battery-powered smoke alarms (with long-life 10-year battery)	180 (4 @ $45)
Four interconnected battery-powered smoke alarms	120 (4 @ $30)
Four interconnected mains-wired smoke alarms with backup battery	280 (4 @ $70)

5.2.4 Annual maintenance costs

Maintenance is to be carried out by the householder and is assumed to comprise testing and cleaning of each smoke alarm on a monthly basis. The cost of the time involved is not a direct cost but a small allowance is made here to cover the inconvenience caused to the householder. Time costing is on the basis of 2 minutes per month per alarm unit @ $40/hr giving $16 per alarm per year.

A replacement battery (where required) is taken as $5 per year for the stand-alone alarms, and $1 per year where the battery acts only as back-up power source (assuming in this case the battery need only be replaced once every five years).

The annual maintenance costs are given in Table 4.

Table 4: Smoke Alarm Annual Maintenance Costs

Option	$
Single battery-powered smoke alarm (with 1-year battery)	16 + 5 = 21
Single battery-powered smoke alarm (with long-life 10-year battery)	16
Single mains-wired smoke alarm with backup battery	16 + 5/5 = 17
Four battery-powered smoke alarms (with 1-year battery)	4(16 + 5) = 84
Four battery-powered smoke alarms (with long-life 10-year battery)	4(16) = 64
Four interconnected battery-powered smoke alarms	4(16 + 5) = 84
Four interconnected mains-wired smoke alarms with backup battery	4(16 + 5/5) = 68

5.3 Benefits of Smoke Alarms

5.3.1 Reduction in fire death rates with smoke alarms present

Beever and Britton (1999) used 12 deaths per 1000 house fires where no smoke alarms were present, and between 3 and 4 deaths per 1000 house fires where smoke alarms were present, depending on the installation type. This was based on examination of 1994 USA data as they considered the AFIRS data in this area to be unreliable.

FEMA (1999) indicates that in the United States in 1996, there were 11.6 deaths per 1000 fires where no smoke alarm was present and 5.0 deaths per 1000 fires where smoke alarm(s) were present. This represents an average reduction in the death rate of 57% through the presence of a smoke alarm(s). These rates are similar to those presented by Hall (1996) for USA data from 1984-1994, which indicated that on average, there were 10.2 deaths per 1000 fires where no smoke alarm was present and 5.7 deaths per 1000 fires where a smoke alarm(s) was present. The overall average fire death rate in the USA for the years 1987-1996 was 9.0 deaths per 1000 fires.

A previous BRANZ study (Narayanan and Whiting, 1996) of New Zealand Fire Service data for the years 1986-1993 gave 8.6 deaths per 1000 fires when no alarm was present and 5.7 deaths per 1000 fires when an alarm was present. However, the number of cases recorded in the latter case was small and probably unreliable.

Fire death rates presented in this way will change over time depending on the proportion of homes with fire protection systems installed. For example, as the number of smoke alarms in houses increases, it might be expected that the number of reported fires would drop due to more fires being detected at an earlier time, requiring a lesser number of Fire Service callouts.

Similar figures for the United Kingdom (Home Office, 1995) for the years 1988-1993 gave 10.2 deaths per 1000 fires when no alarm was present and 3.8 deaths per 1000 fires when an alarm was present. However, more recent data for the United Kingdom is less conclusive (Watson and Gamble, 1999). Over the four-year period 1994-1997, there were 7.6 deaths per 1000 fires in dwellings where a smoke alarm was not present, and 7.8 deaths per 1000 fires in dwellings where a smoke alarm was reported as being present. When the smoke alarm operated and raised the alarm, the rate was reduced to 4.2 deaths per 1000 fires. One of the difficulties with interpreting this data is that if the smoke alarm is present and has raised the alarm, then a number of fires may be extinguished at an early enough time that the fire never develops to a point at which it becomes a "reported" fire, and therefore the number of fires would be underestimated, and the death rate per 1000 fires would be overestimated by the statistics.

Section 4.3 concluded that a death rate of 6.0 per 1000 fires was appropriate to use in this analysis. Considering all the above information relating to the effect of smoke alarms, the following fire death rates were used to account for the presence of a smoke alarm system in this study. The assumed reduction in death rate is in the range 42-67%, depending on the type and reliability of the smoke alarm system installed.

Table 5: Assumed Fire Death Rate per 1000 Fires with Smoke Alarms

Installation Option	Fire Death Rate per 1000 Fires
Single battery-powered smoke alarm (with 1 year battery)	3.5
Single battery-powered smoke alarm (with long-life 10-year battery)	3.3
Single mains-wired smoke alarm with backup battery	3.0
Four battery-powered smoke alarms (with 1-year battery)	2.8
Four battery-powered smoke alarms (with long-life 10-year battery)	2.5
Four interconnected battery-powered smoke alarms	2.2
Four interconnected mains-wired smoke alarms with backup battery	2.0
No alarm	6.0

5.3.2 Reduction in the fire injury rate with smoke alarms present

Beever and Britton (1999) assumed that there will be an alarm in the room of origin for the interconnected or multiple alarms, and that the alarm will be outside the room of origin for single alarms. The same assumption is made in this study. They reported that AFIRS showed 20 injuries per 1000 fires where the smoke alarm was in the room of origin and operated; 80 injuries per 1000 fires where no alarm was present; and 35 injuries per 1000 fires when the alarm was not in room of origin.

Due to a lack of detailed information on the effect of different types of fire protection system (e.g. stand-alone battery smoke alarms versus interconnected main-powered alarms), it was necessary for Beever and Britton to estimate the expected death and injury rates by considering the failure probabilities for each system.

They determined the following:

- One battery-powered ionisation smoke alarm – 40 injuries per 1000 house fires
- One mains-powered ionisation smoke alarm with battery backup – 30 injuries per 1000 house fires
- Five interconnected battery-powered ionisation smoke alarms – 20 injuries per 1000 house fires
- Five interconnected mains-powered ionisation smoke alarms with battery backup – 20 injuries per 1000 house fires
- No alarms – 80 injuries per 1000 house fires.

The Home Office (1995) reported that for the United Kingdom during 1988-1993, there were 168 injuries per 1000 fires without detectors present and 147 injuries per 1000 fires with detectors present. Watson and Gamble (1999) note that more that one third of non-fatal casualties are due to chip pan fires. In general, "reported" injuries rates in the United Kingdom are high compared to USA and Australian rates, and there may well be differences in the reporting mechanisms which contribute toward this.

Fire incident records in New Zealand for fires with alarms present is too uncertain to determine appropriate input values here, so overseas data is utilised. Since the fire injury rate without smoke alarms present for New Zealand (26.6 per 1000 fires) is about one-half the Australian rate (48.2 per 1000 fires – see Table 1), it is also assumed that the fire injury rate with smoke alarms present for New Zealand would still be about one-half the Australian rate with smoke alarms present. So, for the purposes of this study, the fire injury rates shown in Table 6 were used.

Table 6 : Assumed Fire Injury Rate per 1000 Fires with Smoke Alarms

Installation Option	Fire Injury Rate per 1000 Fires
Single battery-powered smoke alarm (with 1-year battery)	20
Single battery-powered smoke alarm (with long-life 10-year battery)	18
Single mains-wired smoke alarm with backup battery	15
Four battery-powered smoke alarms (with 1-year battery)	12
Four battery-powered smoke alarms (with long-life 10-year battery)	12
Four interconnected battery-powered smoke alarms	10
Four interconnected mains-wired smoke alarms with backup battery	8
No alarm	40

5.3.3 Reduced property losses

Data supplied by the Insurance Council of New Zealand (Gravestock, 1999) indicated that the average fire insurance claim over a recent 12-month period to be $13,300. This comprised both contents ($4,700) and building ($8,600) claims. However, the extent of smoke alarm coverage (if any) associated with these claims was not known.

Rahamanian (1995) analysed New Zealand insurance data applicable between 1990-1994. He estimated that the average property loss due to domestic fires in New Zealand to be $74 million per year. Assuming the average number of reported fires in domestic buildings to be 4668 fires per year (Irwin, 1997), this gives the average property loss per fire as approximately $16,000. This is of the same order of magnitude as the estimate from Gravestock (1999).

A 1996 survey of 786 homes distributed throughout New Zealand by Decision Analysis Limited (DAL, 1997) found that smoke alarms were installed in 48% of homes. The survey also found that the proportion of working alarms was 95%.

A survey by BRANZ in 1999 of 461 randomly selected owner-occupied houses in Wellington, Christchurch and Auckland showed that 71% of houses had one or more smoke alarms installed (see Figure 9). This study also found that the proportion of working alarms to be 95%.

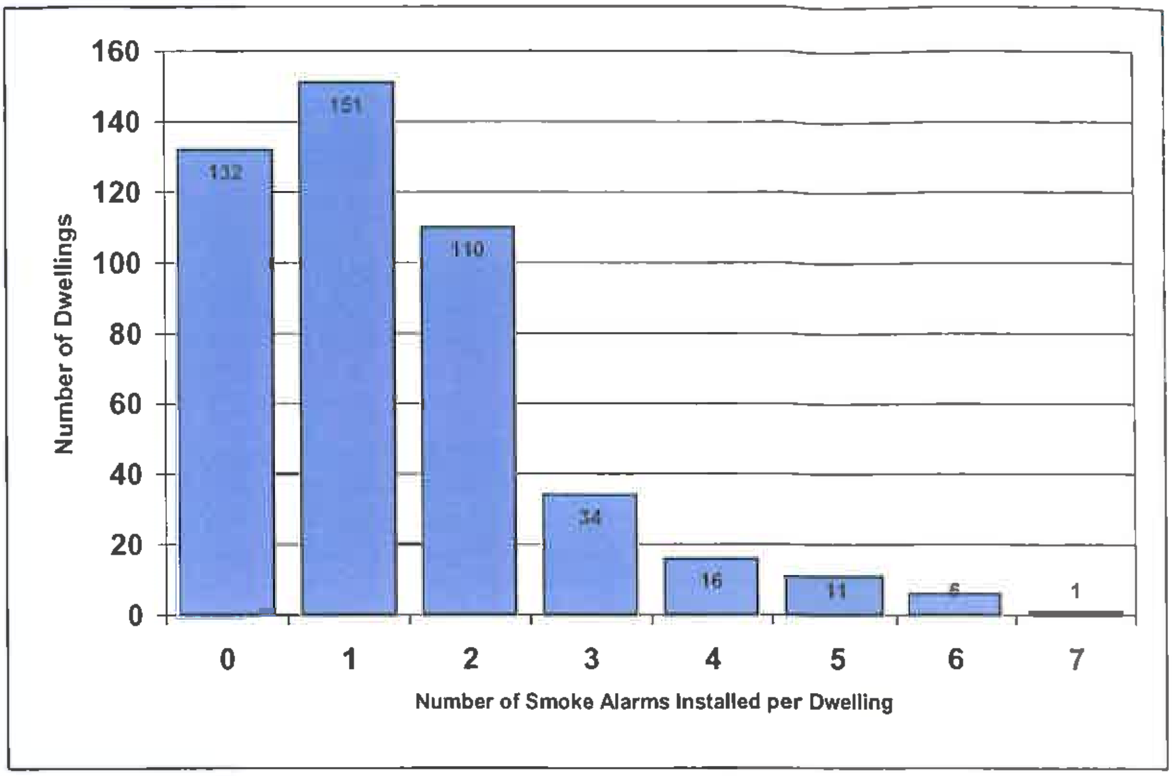

Figure 9: Dataframe BRANZ house condition survey 1999

An analysis by the New South Wales Fire Brigade (Nicolopoulas, 1996) into smoke alarm effectiveness suggests a reduction in property loss of 53% is achieved through the installation of smoke alarms. However, it is noted that the data and this estimate has a large uncertainty associated with it, therefore for this analysis we have used a lesser reduction (35%) and have assumed that 65% of houses have at least one smoke alarm installed.

We then estimate the average property loss with and without smoke alarms present as $11,200 and $17,200 respectively as follows.

x \$A+(1-x) \$B = \$13,300

1-\$A/\$B = 0.35

Where

x = 0.65 = proportion of homes with smoke alarm(s)

\$A = average loss with smoke alarm(s) present

\$B = average loss without a smoke alarm present

(0.65)\$A + (1-0.65)\$A/0.65 = 13300, therefore \$A = 11,200 and \$B = 17,200.

To estimate the losses associated with the installation of a specific smoke alarm installation option, a linear relationship between the dollar loss and the probability of a smoke alarm detecting the fire was assumed, based on the probabilities for success in detecting the fire given by Beever and Britton (1999).

Therefore it is assumed that, with no smoke alarm protection, the probability of a smoke alarm giving a warning is 0, and the average property loss per household fire is $17,200.

With a single battery-operated alarm not in the room of fire origin, the probability of a smoke alarm giving a warning is 0.59, and the average property loss per household fire is $11,200.

For smoke alarm installations offering a higher probability of detecting a fire, the relationship between the loss and the probability of detection is expressed as:

$$\$ \text{ Loss} = \$17{,}200 - [10{,}169 \times (\text{probability of detecting fire})]$$

It must be noted that these figures are based on reported fires. It is a reasonable assumption that average property savings with smoke alarms are much greater than this due to the significant number of fires that are detected and extinguished at an early stage without Fire Service involvement. The property losses per household in Table 7 were used for each installation option.

Table 7: Effect of Smoke Alarms on Property Losses

Installation Option	Probability of Detecting the Fire	Property Loss
Single battery-powered smoke alarm (with 1-year battery)	0.59*	$11,200 per fire per household
Single battery-powered smoke alarm (with long-life 10-year battery)	0.65	$10,600 per fire per household
Single mains-wired smoke alarm with backup battery	0.73	$9,800 per fire per household
Four battery-powered smoke alarms (with 1-year battery)	0.78	$9,300 per fire per household
Four battery-powered smoke alarms (with long-life 10-year battery)	0.80	$9,100 per fire per household
Four interconnected battery powered smoke alarms	0.84	$8,700 per fire per household
Four interconnected mains-wired smoke alarms with backup battery	0.87	$8,400 per fire per household
No alarm	0	$17,200 per fire per household

*source – Beever and Britton (1999)

5.4 Smoke Alarm Life

The smoke alarm life is taken as 10 years.

5.5 Results

Table 8 shows the cost per life saved determined for each installation option. It shows that in new domestic construction, the installation of a single battery-powered smoke alarm fitted with a long-life 10-year battery provides a net benefit to the community, and may be considered a cost-effective means of reducing fire deaths, injuries and property loss due to fires in domestic dwellings. The results for installation into existing construction are similar.

The option expected to save the greatest number of lives is the mains-wired multiple interconnected alarms at a cost of $3 million per life saved. This is the same cost per life saved as for the battery-powered multiple stand-alone alarms. However, the latter system is expected to save a fewer number of lives overall. The mains-wired multiple interconnected alarms have a higher initial installation cost, but the ongoing maintenance costs are lower.

Table 8: Cost per Life Saved for Installation of Smoke Alarms

Installation Option	Estimated Fatalities per year	Cost per Life Saved	
		New Building	Existing Building
None	30.5		
Single battery-powered smoke alarm (with 1-year battery)	17.8	$128,000	$128,000
Single battery-powered smoke alarm (with long-life 10-year battery)	16.8	-$142,000 (net benefit)	-$142,000 (net benefit)
Single mains-wired smoke alarm with backup battery	15.2	$143,000	$404,000
Four battery-powered smoke alarms (with 1-year battery)	14.2	$3.0 million	$3.0 million
Four battery-powered smoke alarms (with long-life 10-year battery)	12.7	$2.4 million	$2.4 million
Four interconnected battery-powered smoke alarms	11.2	$2.9 million	$3.2 million
Four interconnected mains-wired smoke alarms with backup battery	10.2	$3.0 million	$3.3 million

In evaluating the cost effectiveness of each option, regard could be made to the value of a single human life such as used by the Land Transport Safety Authority (LTSA) in New Zealand (Miller and Guria, 1991). This is taken as $2 million or $2.3 million when adjusted for inflation over the period 1991-2000 (Page, 2000).

All of the single alarm installations meet this 'cost-per-life-saved' criteria, although the number of lives expected to be saved are not as high compared with the installation of multiple alarms.

The installation of multiple stand-alone alarms fitted with long-life ten-year batteries has a cost per life saved of $2.4 million dollars, close to the LTSA value, and therefore would appear to be a worthwhile option.

While the cost per life saved for other options are greater than the $2.3 million (inflation adjusted) used by the Land Transport Safety Authority, they may still be low enough to warrant further consideration as an effective means of reducing fire deaths, injuries and property loss in residential buildings.

5.6 Sensitivity Analysis

A sensitivity analysis was carried out to determine how dependent the cost per life saved estimates were on key input data and assumptions. The variables investigated were maintenance costs, the analysis period, fire injury costs, inflation rate, discount rate and the fire incident rate. Figures 10-17 show the changes in the estimated cost per life saved as the changes to the input variable are made. In the case of Figure 16 and Figure 17, the fire injury and fire death rates in the absence of any alarm system are assumed to remain unchanged, and the effect of a change in the injury and death rates with the alarm system is examined. The results appear to be very sensitive to assumptions about maintenance costs as shown in Figure 10. For example consider the four stand-alone alarms with 1-year batteries – if the cost of a householder's time for the installation, cleaning and testing of alarms was disregarded, the cost per life saved of $3 million dollars becomes a net benefit of $276,000 per life saved, significantly increasing the apparent cost-effectiveness of this option.

The cost/benefit model is less sensitive to changes in inflation rate, discount rate, cost per fire injury and analysis period. The model is also not particularly sensitive to fire incident rates above 0.004 fires per household per year (see Figure 15). However, for fire incident rates of less than 0.004, the cost per life saved increases. This suggests that alternative efforts to reduce the numbers of fires in dwellings (e.g. more education) will reduce the cost-effectiveness of smoke alarm installations.

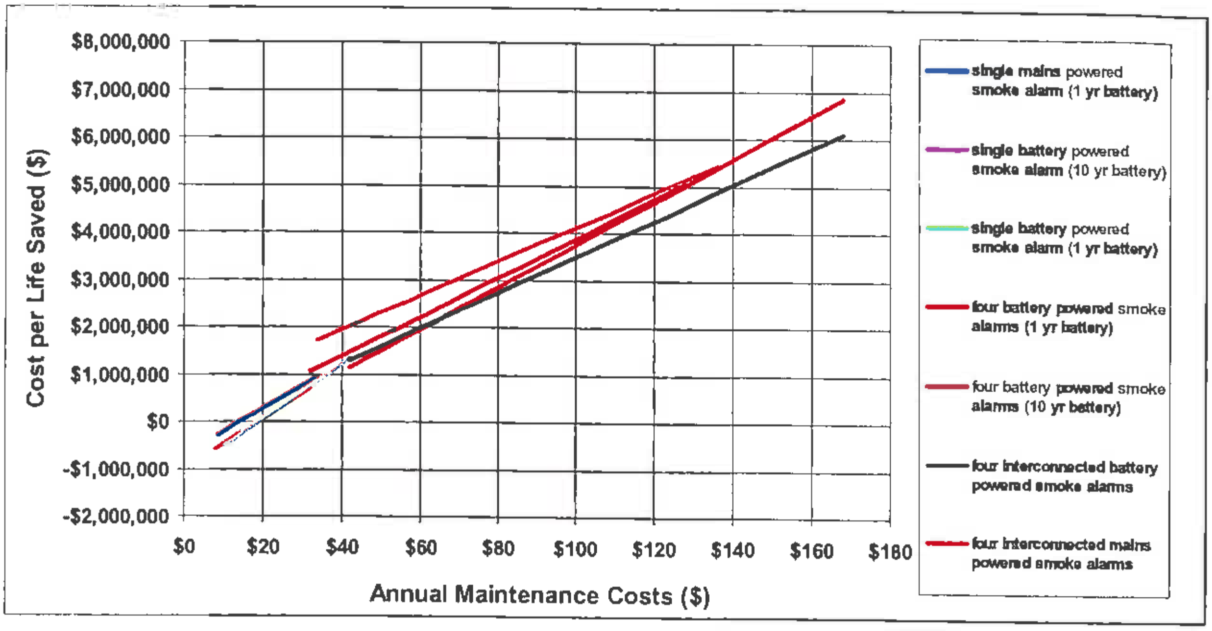

Figure 10: Smoke alarms – sensitivity to annual maintenance costs

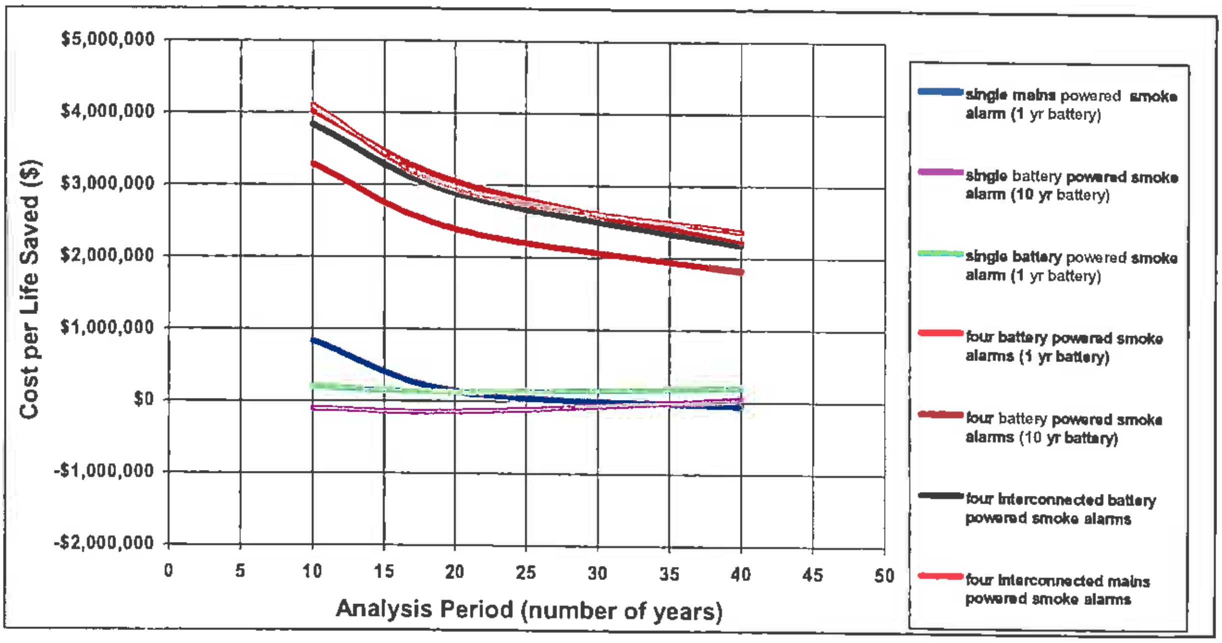

Figure 11: Smoke alarms – sensitivity to analysis period

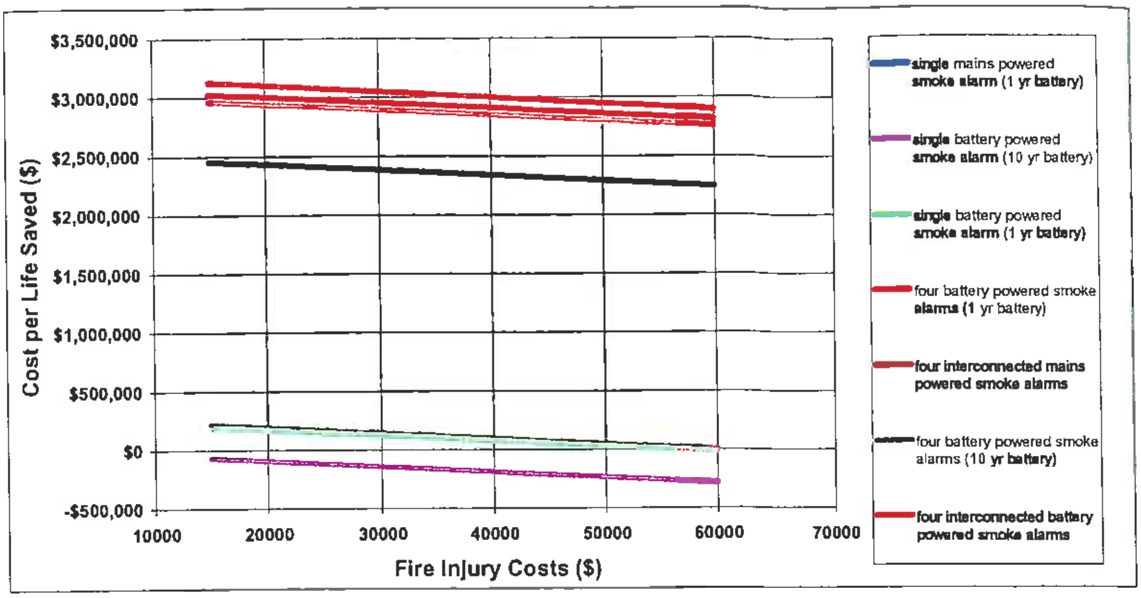

Figure 12: Smoke alarms – sensitivity to fire injury costs

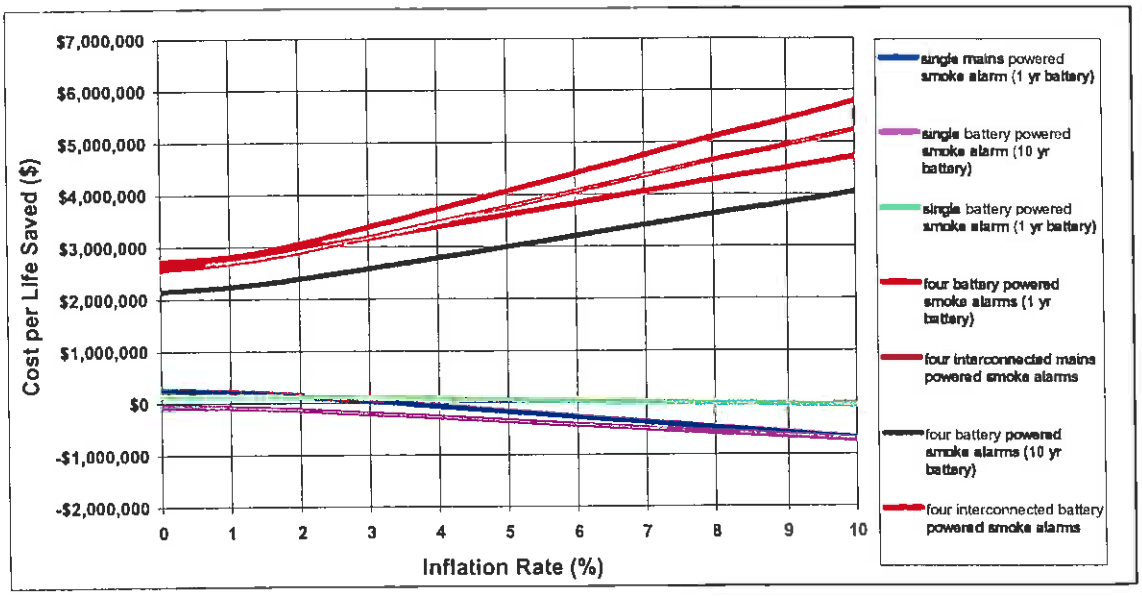

Figure 13: Smoke alarms – sensitivity to the inflation rate

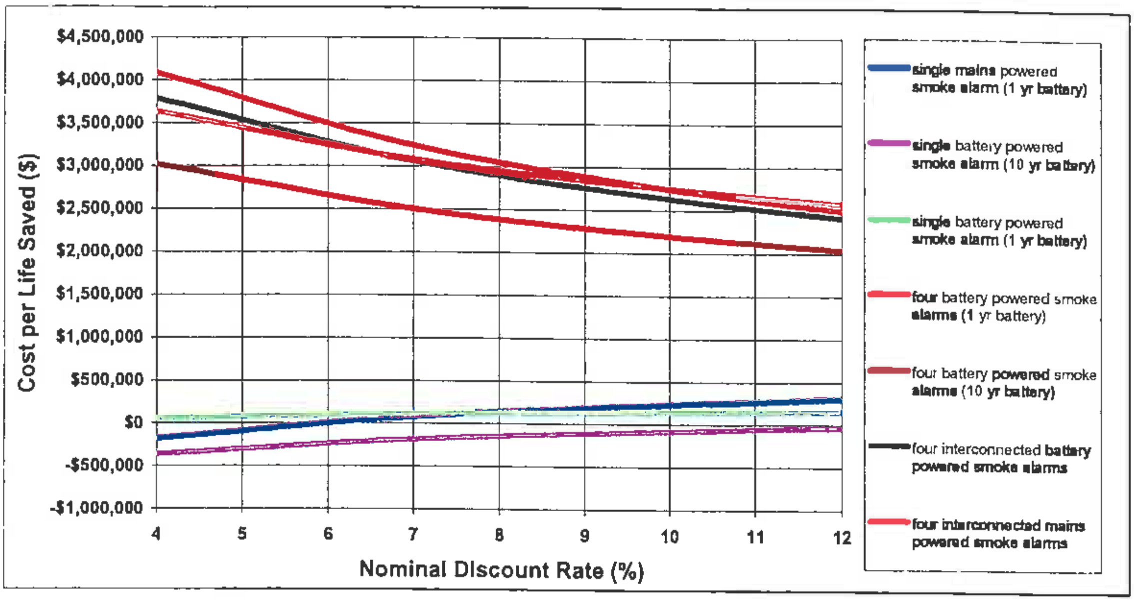

Figure 14: Smoke alarms – sensitivity to the discount rate

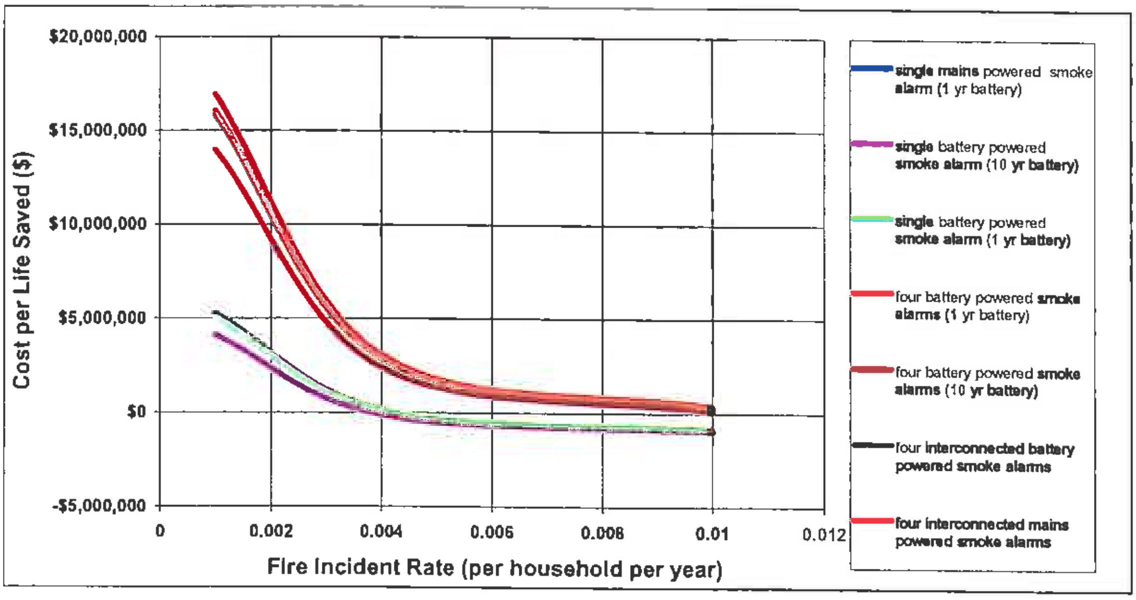

Figure 15: Smoke alarms – sensitivity to fire incident rate

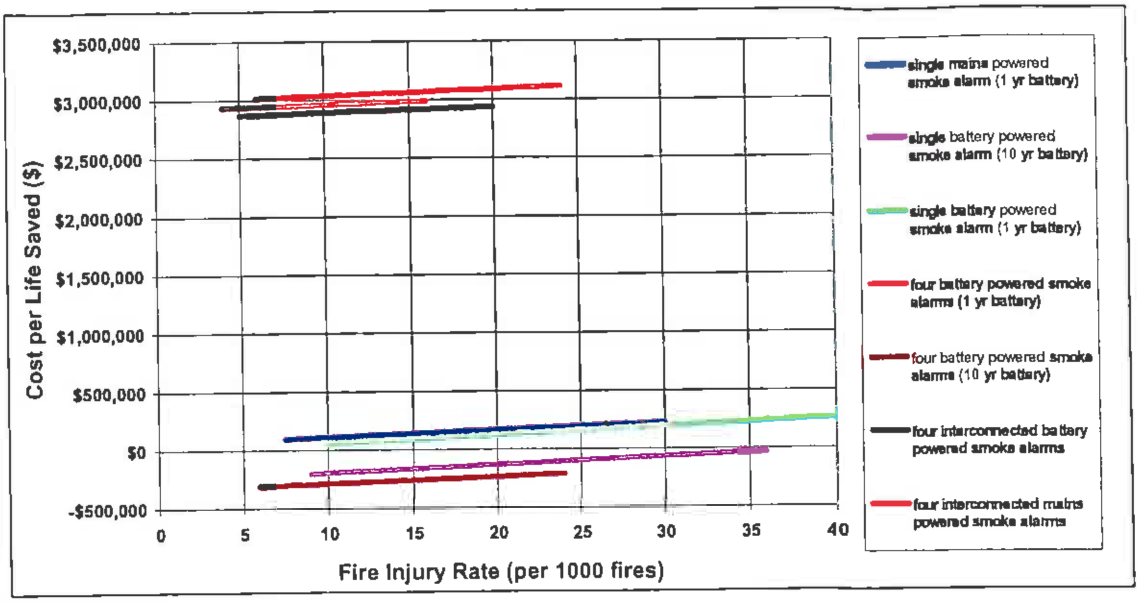

Figure 16: Smoke alarms – Sensitivity to the fire injury rate with alarms present

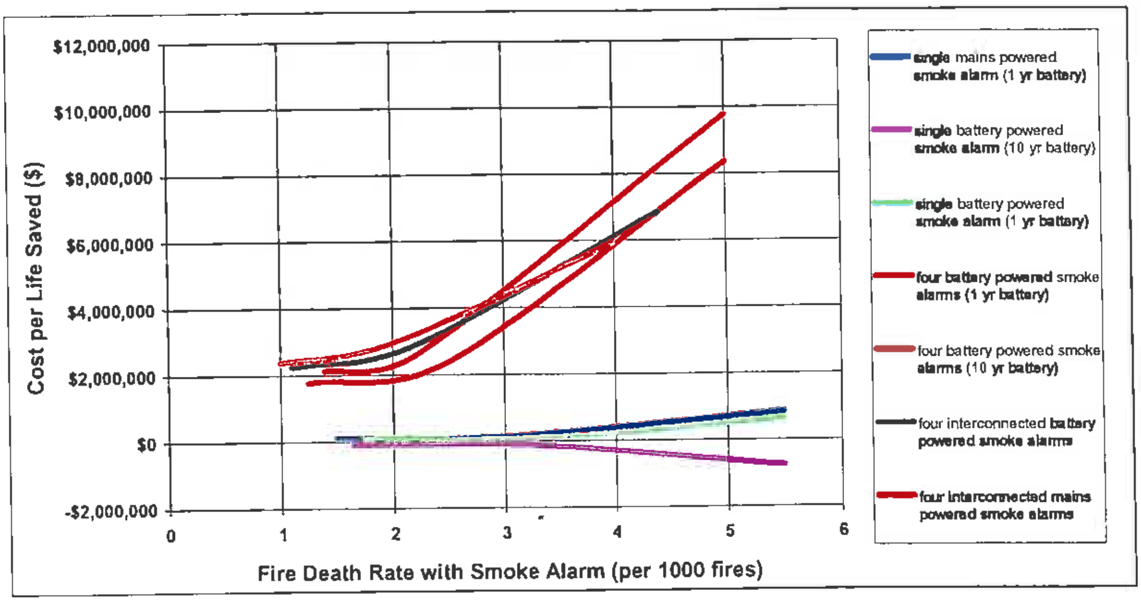

Figure 17: Smoke alarms – Sensitivity to the fire death rate with alarms present

6. FIRE SPRINKLER SYSTEM ANALYSIS

The methodology for the cost/benefit analysis of the domestic fire sprinkler system follows that carried out for the domestic smoke alarms. A dollar cost per life saved is used to assess the cost-effectiveness of the system. Each variable for the 'cost per life saved' equation is derived from New Zealand Fire Service statistics and commercial costs. For annual costs, a net present value (NPV) is calculated using a nominal discount rate of 8% and an inflation rate of 2% for an analysis period of 20 years. The fire sprinkler systems analysed have a life span of 30 years.

6.1 Fire Sprinkler System Installation Options

A cost/benefit analysis was carried out for three options of fire sprinkler system:

- a fire sprinkler system installed in a new dwelling
- a fire sprinkler system retrofitted for an existing dwelling
- a fire sprinkler system designed to the requirements of the proposed draft revisions to the sprinkler standard DZ 4515/CD3 (SNZ, 1999)

A low-cost three-bedroom home was used as the design home for the sprinkler installations (refer Figure 19 for the floor plan of the building). The three-bedroom design home was used as being representative of a standard, low-cost family home. It was assumed that the home is located in the suburbs, with access to water services and public amenities such as fire hydrants. The home is a single-level dwelling constructed of timber frame with corrugated galvanised steel roof, weatherboard exterior walls, aluminium windows and interior lining of gypsum plasterboard walls with particleboard-finished floors. Costs for the fire safety measures were market value, with in-situ prices provided by appropriate contractors.

6.2 Costs Associated with Fire Sprinkler Systems

In order to evaluate the cost per life saved, values for the installation costs, maintenance costs, injury costs, property losses, expected number of lives saved and the rate of fire incidents were required. The following describes the input 'cost' variables used in the cost-benefit analysis.

6.2.1 Installation costs

Installation costs for the sprinkler system were taken from quotes provided by sprinkler contractors. The quotes were for installation of the sprinkler system into the three-bedroom design home, and were based on the requirements of NZS 4515:1995 (SNZ, 1995). Each quote itemised costs for materials, labour and maintenance. Average values from the quotes were used for the input value of installation costs (refer Table 9).

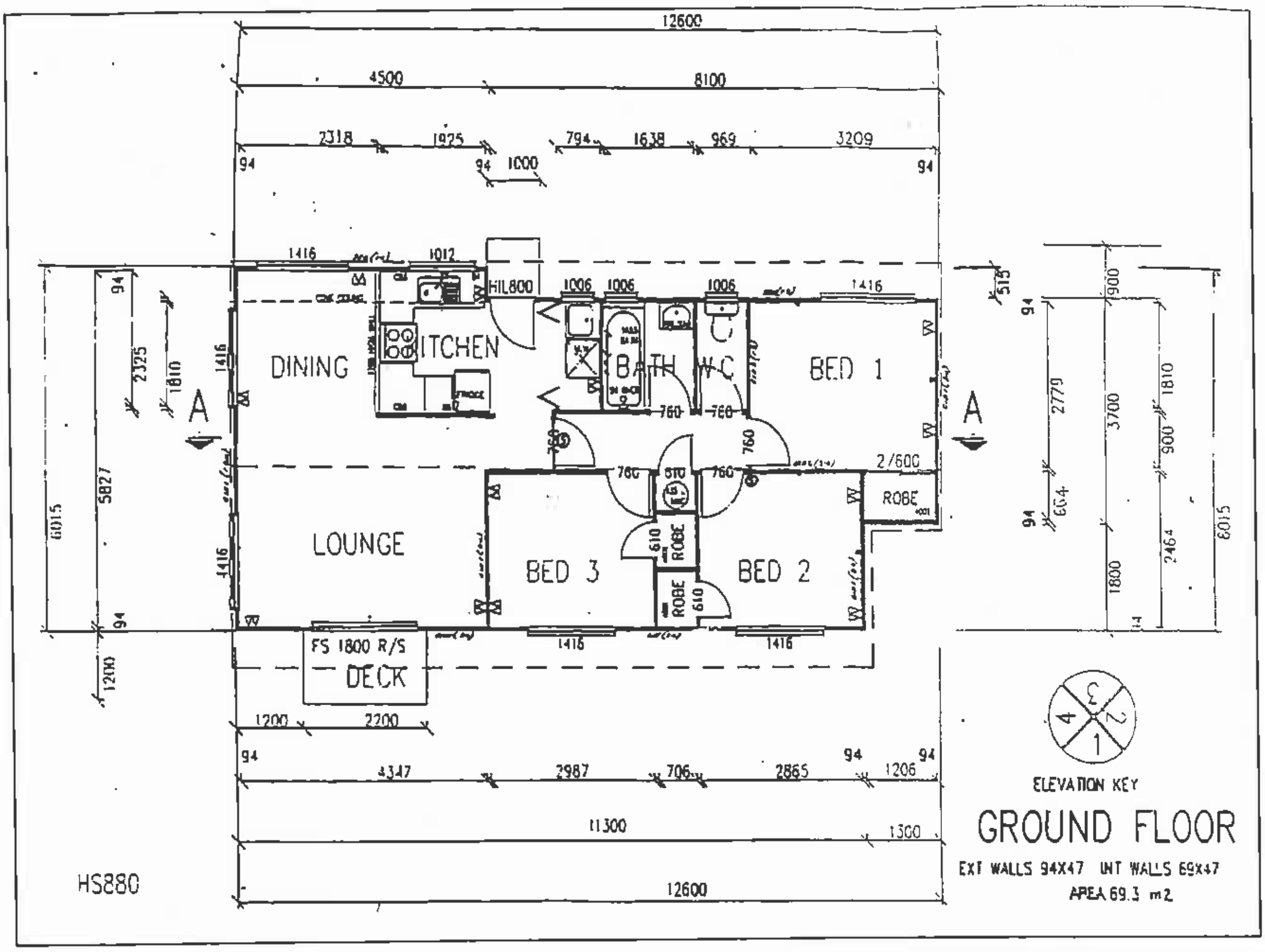

Figure 18: Floor plan of house used for sprinkler system design

6.2.2 Maintenance costs

The annual maintenance was assumed to be undertaken by a sprinkler contractor at contractor labour rates. A value of $635 was used to cover annual maintenance, survey, inspections and replacements of parts. The value was derived from the average of the quoted prices for the annual maintenance inspections.

Table 9 is a summary of the installation and maintenance input values used for the cost/benefit analysis of the new and retrofit fire sprinkler systems.

Table 9: Sprinkler – Installation and Maintenance Input Values

Sprinkler Option	Design, Installation and Material Costs ($)	Connection to Street Mains ($)	Annual Maintenance and Survey Costs ($)
New (to NZS 4515:1995)	6500**	200*	635
Retrofit (to NZS 4515:1995)	6750**	2300	635
New (to DZ 4515/CD3)	4070	200*	280

* Marginal cost of upsizing pipes and water meter
** Includes residential valve set ~ $3000

6.3 Assumptions made for Sprinkler System Analysis

Assumptions made for the input costs in the analysis for the domestic sprinkler system were:

- Analysis period for the study of 20 years, with a sprinkler system life of 50 years.
- The sprinkler system is not connected directly to the fire service.
- Annual maintenance is undertaken by a sprinkler contractor at a cost of $350 (for the NZS 4515:1995 systems only).
- The sprinkler system is required to have an annual survey at a cost of $285.
- There is a water connection fee charged by the territorial authority of $2300 for a retrofit sprinkler system only. This value of this fee is quoted from that charged for connection to the water mains in Wellington, New Zealand; prices may vary depending on the local authority. It is assumed the domestic water connection charge for a new home would incorporate the sprinkler connection so only the marginal cost of upsizing the pipes and water meter is included.
- The system does not incorporate a separate backflow prevention device. Backflow prevention is provided by the check valves in the main sprinkler valve set.
- It is assumed that the dwelling is supplied with adequate mains water pressure to operate the sprinkler system to design conditions. With adequate mains pressure, no pump or storage tank is required to boost the pressure to operate the sprinkler system.

6.4 Benefits of Fire Sprinkler Systems

6.4.1 Reduction in fire death rates with fire sprinkler system present

Beever and Britton (1999) used 7 deaths per 1000 house fires where no sprinkler systems were present, and between 1.46 and 3.89 deaths per 1000 house fires where sprinkler systems were present. The figures representing the expected reduction in death rates are based on examination of 1994 USA data. The value of 7 deaths per 1000 house fires when no sprinkler system is present is based on AFIRS data for the period of 1989 to 1993 as presented by Beever and Britton (1999).

A study by Rahmanian (1995) suggests that sprinklers in domestic dwellings can reduce the number of deaths by 50% or more. Ruegg and Fuller (1984) estimated 1.46 deaths per 1000 house fires for houses with sprinklers and alarms.

The case study of the installation of domestic sprinkler systems in homes in Scottsdale, Arizona, indicates that the sprinkler systems have the potential to reduce the number of domestic fire fatalities by 80-90 % (Home Fire Sprinkler Coalition, 1997).

The fire death rates shown in Table 10 were used in the cost/benefit analysis to account for the presence of a fire sprinkler system. It was estimated that the presence of a fire sprinkler system would reduce the number of deaths caused by domestic fires by 80%.

Table 10: Sprinkler – Reduction in Fire Death Rates

Option	Deaths per 1000 House Fires
New Sprinkler System (to NZS 4515:1995)	1.2
Retrofit Sprinkler System (to NZS 4515:1995)	1.2
New Sprinkler System (to DZ 4515/CD3)	1.2
No System Installed	6.0

6.4.2 Reduction in fire injury rates with fire sprinkler system present

Beever and Britton (1999) used 70 injuries per 1000 house fires where no sprinkler systems were present. Injuries were defined as those recorded at the scene of the fire. For the number of injuries in sprinklered fires, Beever and Britton (1999) found the data they used from the NFIRS database for 1995 to be inconsistent, stating 100 injuries per 1000 fires which is greater than that for unsprinklered fires in Australia. A study by Ruegg and Fuller (1984) estimated civilian injury rates to be 14 per 1000 fires for 1- and 2-family houses protected by sprinklers and smoke alarms (Beever and Britton, 1999). Beever and Britton (1999) consider fire injury rates in the range of 15 to 30 per 1000 fires for sprinklered 1- and 2-family dwellings.

The following fire injury rates were used in the cost/benefit analysis to account for the presence of a fire sprinkler system.

Table 11: Sprinkler – Reduction in Fire Injury Rates

Option	Injuries per 1000 House Fires
New Sprinkler System (to NZS 4515:1995)	15
Retrofit Sprinkler System (to NZS 4515:1995)	15
New Sprinkler System (to DZ 4515/CD3)	15
No System Installed	40

It was estimated that the presence of a fire sprinkler system would reduce the number of injuries caused by domestic fires by approximately 63%.

6.4.3 Reduced property losses with fire sprinkler system installed

Beever and Britton (1999) state that direct losses arising from property damage for unsprinklered 1- and 2-family dwelling fires average at approximately $A 10,000 per fire. according to AFIRS data for the period 1992/93 published in Beever and Britton (1999). According to NFIRS data for the 1995 period, as published in Beever and Britton (1999), domestic property damage as a result of fire averages at $US 8,100. In their analysis, Beever and Britton (1999) use values of $A 24,000 for property loss in an unsprinklered home and $A 3,900 for property loss in a sprinklered home.

With no sprinkler system installed, the average value of property loss is established to be $17,200 from statistics provided by the Insurance Council of New Zealand (Gravestock, 1999) – refer section 5.3.3.

The following property loss values were used in the cost/benefit analysis to account for the presence of a fire sprinkler system. They are based on the experience of installing domestic sprinkler systems in homes in Scottsdale, Arizona, where houses with sprinklers achieved an 84% reduction in average fire losses (Ford, 1997).

Table 12: Sprinkler – Reduction in Property Losses

Option	Property Loss
New Sprinkler System (to NZS 4515:1995)	$3,000
Retrofit Sprinkler System (to NZS 4515:1995)	$3,000
New Sprinkler System (to DZ 4515/CD3)	$3,000
No System Installed	$17,200

6.5 Sprinkler System Life

The life span of the fire sprinkler system is taken to be 50 years.

6.6 Results

Table 13 displays the results of the cost/benefit analysis undertaken for the three designs of fire sprinkler system.

Table 13: Sprinkler – Cost-Benefit Analysis Results

Option	$ Cost per Life Saved
New Sprinkler System (to NZS 4515:1995)	$34.8 million
Retrofit Sprinkler System (to NZS 4515:1995)	$40.9 million
New Sprinkler System (to DZ 4515/CD3)	$17.8 million

All options for the domestic fire sprinkler system are shown to be not cost-effective. The cost per life saved for each option ranks in the tens of millions of dollars. Ranking of the results shows the sprinkler system designed to the requirements of the draft new standard DZ 4515/CD3 (SNZ, 1999) to be the most cost-effective of the three options, being approximately one half of the cost per life saved of the current Standard. The sprinkler system designed to the requirements of the current NZS 4515:1995 (SNZ, 1995) and retrofitted to the design home is shown to be the least cost-effective due particularly to the estimated $2300 charge for connection of the sprinkler system to the water mains.

6.7 Sensitivity Analysis

To determine which components of the sprinkler system critically influence the cost effectiveness of the system, a sensitivity analysis was undertaken. The sensitivity analysis looks particularly at the response of the system to variations in annual maintenance costs, analysis period, cost per fire injury and fire incidence probability.

6.7.1 Annual maintenance costs

A value of $635 was used as the input figure for maintenance when the cost effectiveness of the domestic sprinkler system was assessed. The cost is inclusive of annual inspections, certificates and testing of the system, which are assumed to be undertaken by a qualified tradesperson.

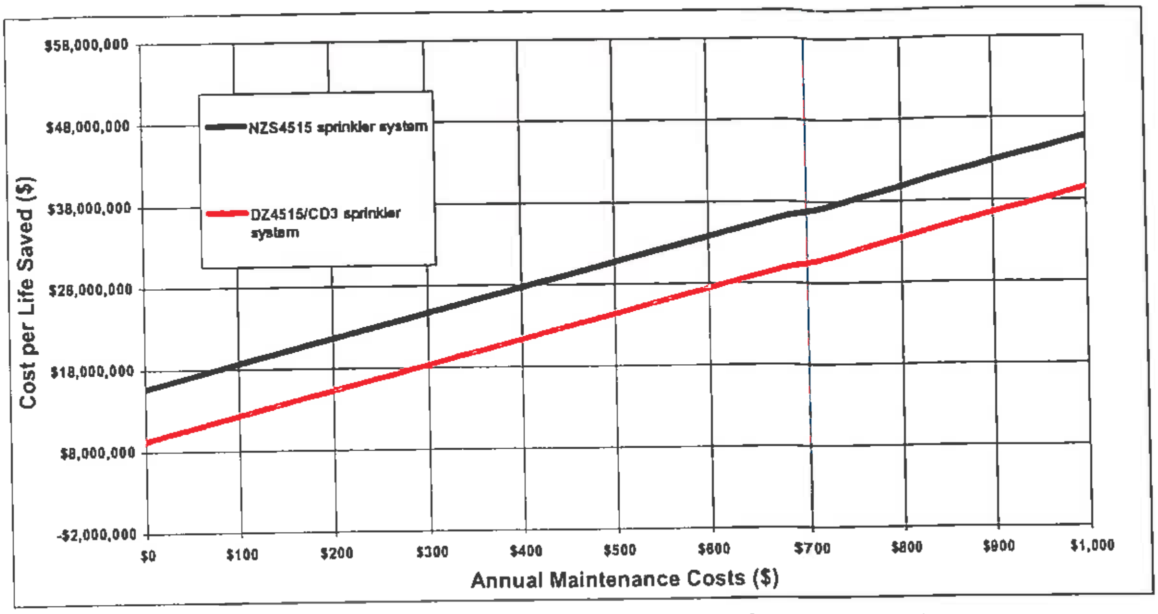

Figure 19: Sprinklers – sensitivity to annual maintenance costs

6.7.2 Cost per fire injury

An input value cost of $30,000 per fire injury was used for the cost/benefit analysis of the domestic sprinkler system (see section 4.2). **Figure 20** indicates that the cost effectiveness of the domestic sprinkler system is not significantly influenced by an increase or decrease in the cost for treatment per fire injury.

6.7.3 Fire incidence probability

A fire incidence probability of 0.004 (fires per year per household) was derived from statistics for use in the cost/benefit analysis of the domestic sprinkler system. Figure 21 indicates that the system is particularly sensitive to an increase in fire incidence probability. The more frequent the occurrence of a fire, the more cost effective the system becomes.

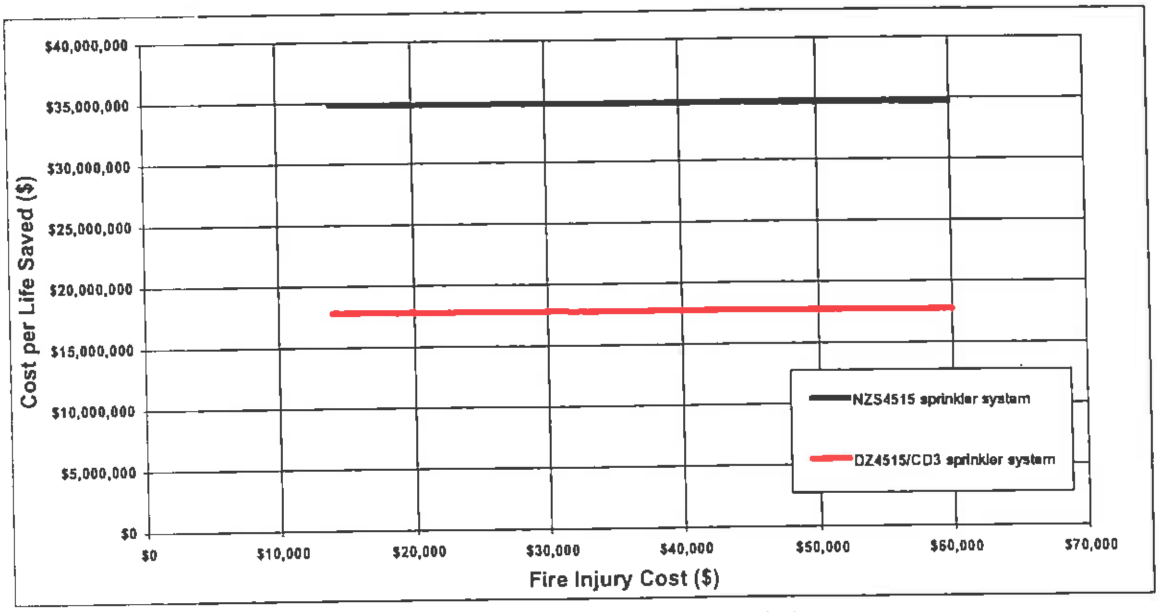

Figure 20: Sprinkler – sensitivity to fire injury costs

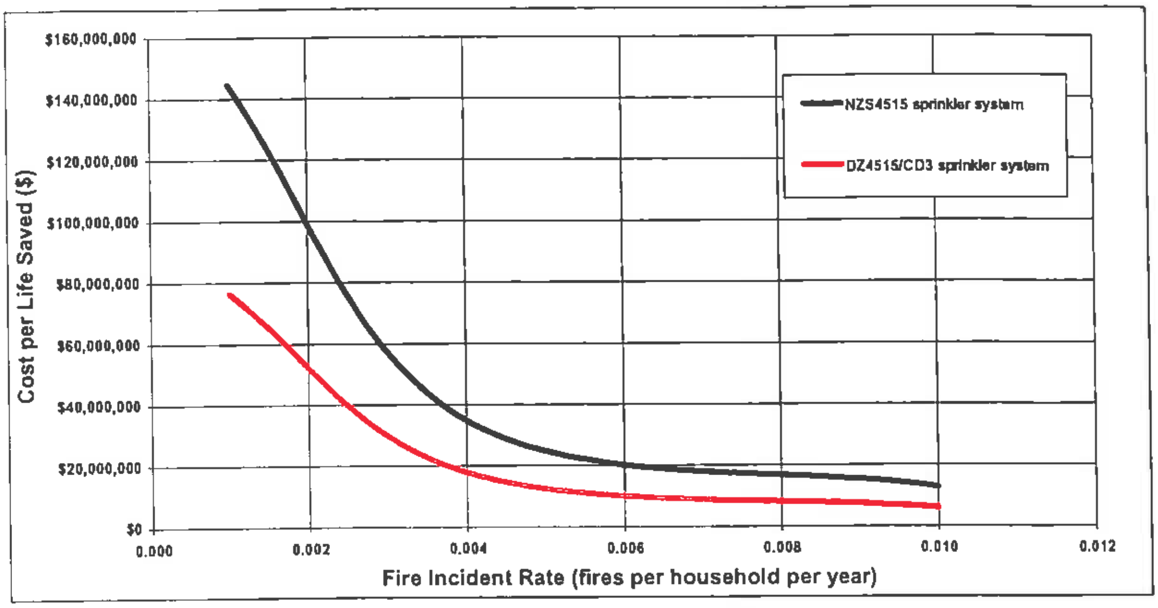

Figure 21: Sprinkler – sensitivity to fire incident rate

6.8 Discussion of Fire Sprinkler System Analysis

6.8.1 Comparison with Australian study

The cost/benefit analysis has shown that fire sprinkler systems installed in the home to current New Zealand Standards are not cost-effective. These findings agree with Australian findings as shown by the Beever and Britton (1999) study.

Table 14 is a summary of the findings from the Australian study (Beever and Britton, 1999).

The cost/benefit analysis for the domestic fire sprinkler system built to current New Zealand Standards produced results evaluating the cost per life saved as between $18 million and $41 million (refer Table 13). These results are at the lower end of the ranges estimated by the Australian study, showing domestic sprinkler systems built to current Standards to be not cost-effective.

Amendments to the existing domestic sprinkler Standard have begun to address issues of cost. Comparison of the cost per life saved for the current NZS4515 complying system with the cost per life saved of the system built to the requirements of the proposed draft Standard, show the amendments to the Standard have achieved close to a 50% reduction in the cost per life saved (refer Table 13). This reduction has been achieved mainly through changes to the requirements for annual maintenance and changes to the configuration of the control valve system. The sensitivity of the cost per life saved to the input variable of maintenance cost show this to be a factor significantly influencing the cost effectiveness of the system. Moves by the draft Standard to reduce the annual maintenance cost are directing the system towards becoming more cost-effective.

Table 14: Australian cost-benefit results for domestic fire sprinkler systems (Beever and Britton, 1999)

Protection Scenario	Cost per life saved ($AUD)
Sprinkler System Designed to the Australian Standard (AS 2118.5)	
Production house (built to a standard specification (150 m^2))	$53 million to $30 million
Custom-build house (built to the client's requirements (210 m^2))	$60 million to $34 million
Existing house (retrofit option)	$60 million to $34 million
Alternative Design Sprinkler System from Domestic Supply	
Production house	$46 million to $26 million
Production house, maintenance-free system	$5 million to $3 million
Custom-built house	$48 million to $27 million
Custom-built house, maintenance-free system	$7 million to $4 million
Existing house	$50 million to $28 million
Existing house, maintenance-free system	$10 million to $6 million
Throughout a new medium-density housing estate	$16 million
New medium-density housing estate – $100 maintenance/year	$2 million

6.8.2 Sensitivity analysis

A sensitivity analysis was undertaken for the aspects of maintenance, cost per fire injury, probability of fire occurrence and analysis period for the cost/benefit analysis of the domestic fire sprinkler system. The sensitivity analysis identified that the cost effectiveness of the domestic sprinkler system is particularly sensitive to maintenance costs and fire incident probability.

Results from the sensitivity analysis indicate there are scenarios where the installation of a domestic fire sprinkler system becomes more cost-effective. Two possible scenarios where the option of fire sprinkler systems may be more cost-effective are for high-cost rural homes and low-cost housing.

In the event of a fire in a high-cost rural home, there would be slow or no fire service intervention due to the location and perhaps isolation of the property. There is also the possibility that the house does not have mains supplied water and relies on storage tanks for potable water and supply for fire service facilities. The claims for insurance for high-cost rural properties would be significantly greater than the average insurance claim. With these factors considered for the particular fire scenario, the domestic sprinkler system becomes more cost effective.

The fire sprinkler system becomes more cost-effective where there is low-cost housing with a high probability of fire occurrence. As shown by Figure 21, the cost per life saved is sensitive to the probability of fire occurrence; the higher the probability of fire occurrence, the more cost-effective the domestic fire sprinkler system. In the case of low-cost housing where there is an increase in the probability of fire occurrence, domestic sprinkler systems become more cost-effective.

7. ALTERNATIVE FIRE PROTECTION SYSTEMS

In addition to domestic smoke alarms and sprinkler systems, there are other fire protection systems and precautions for use in the home. These fire protection features include: fire extinguishers, furniture flammability legislation, passive fire protection, heat detection and education programs. Analysis of these features were undertaken by Beever and Britton (1999) and it is believed that the results from this cost/benefit analysis undertaken for the Australian situation are comparable to the results which would be achieved if the analysis were to be done for the New Zealand situation.

7.1 Fire Extinguishers

Beever and Britton (1999) investigated the cost effectiveness of installing dry powder hand-held fire extinguishers. The results of the study found the fire extinguishers to have a benefit to cost ratio of 2.5:1. This result is based on:

- The cost of the 2 kg dry powder extinguisher being $A 35
- One extinguisher installed per house
- Maintenance of the extinguisher not required
- Replacement life of the extinguisher equal to 20 years with the reliability of the unit assumed to decrease from 99% to 50% over that duration
- Aesthetic disbenefit equivalent to $AS 10 per year
- Increase in injury rate per fire of 5%

The analysis assumes there is no reduction in the number of fatalities as a result of installation of hand-held fire extinguishers, hence a cost per life saved cannot be calculated. Alternatively, a benefit to cost ratio of 2.5:1 was calculated.

The results of the cost/benefit analysis of the fire extinguisher conclude that the installation of dry powder extinguishers into kitchens is recommended.

7.2 Furniture Flammability Legislation

Beever and Britton (1999) conclude that with regards to furniture flammability legislation:

> *'At this time, no recommendation can be made for upholstered furniture and mattress flammability regulations in Australia. However it is recommended that research into the development of suitable low-cost materials be promoted and that information on the flammability of combinations of fabrics and fillings is distributed to the furniture industry. The public should also have access to information that allows the purchase of furnishings that will not create potentially hazardous situations.'*

This conclusion is derived from the assumptions that:

- Future developments in technology for fire-retardant furnishings will result in cost reductions and legislation can be introduced for a cost of between $A 20-100 per household.
- Fire losses resulting from fires involving upholstered furniture are 25% greater as compared to all fires. Based on this statistic, an average loss of $A 30,000 per household fire

involving upholstered furniture is assumed. If furniture flammability legislation was introduced, it is assumed that the average loss per household would reduce to $A 20,000.

Results from the cost/benefit analysis for the introduction of furniture flammability legislation by Beever and Britton (1999) show:

- Cost per life saved equal to $A 30 million due to the introduction of mattress flammability legislation costing $A 50 per household.
- Cost per life saved equal to $A10 million due to the introduction of upholstered furniture flammability legislation costing $A 50 per household.

7.3 Education Programme

The Australian study undertaken by Beever and Britton (1999) concludes that:

'Though not directly considered within their study, review of other work suggests that safety education programmes offer the greatest level of reduction in fire accidents by a very cost-effective means'

This New Zealand study also does not consider the cost-effectiveness of implementation of education programmes, but does recognise that they could have a significant impact on the reduction of fire incidents.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Domestic Smoke Alarms

- It is concluded that the installation of stand-alone battery-powered or mains-wired smoke alarms is a cost-effective measure to reduce injury and property losses, and to save lives in residential dwellings. While the installation of a single smoke alarm is expected to result in a lower cost per life saved, the expected number of lives saved is also less. The installation of multiple (4) battery-powered stand-alone smoke alarms should also be considered as worthwhile with an estimated cost per life saved in the range $2.4 – 3.0 million.
- Installing interconnected multiple (4) battery-powered smoke alarms increased the cost per life saved to be in the range of $2.9 – 3.2 million.
- Installing interconnecting multiple (4) mains-powered smoke alarms increased the cost per life saved to be in the range $3.0 – 3.3 million.
- The analysis also showed that the cost per life saved will be significantly reduced if the allowance for the cost of a householder's time for regular cleaning and testing of alarms were disregarded.
- Based on the findings of this study, it is concluded that it is cost/effective for new and existing households to have (at least) stand-alone, long-life 10-year-battery operated alarms in all bedrooms and living areas. A case may also be made for interconnected mains-powered smoke alarms depending on the acceptability of the calculated cost per life saved ($3 million).

8.2 Domestic Fire Sprinkler System

- Domestic fire sprinkler systems constructed to current Standard (i.e. NZS 4515:1995 (SNZ, 1995) installed in new homes and retrofitted in existing homes, are not cost-effective.

- Statistics show that domestic fire sprinkler systems would significantly reduce the number of fatalities, injuries and the amount of property loss in homes in the event of a fire.

- Draft amendments to the current New Zealand Standard, NZS 4515:1995 (SNZ, 1995), for the installation of domestic fire sprinkler systems attempt to reduce the cost of the system. This reduction has been achieved mainly through changes to the requirements for annual maintenance and changes to the configuration of the control valve system. Further reductions in the cost of the domestic fire sprinkler system could be achieve from further refinement of sprinkler design and installation requirements.

- There are scenarios, such as for high-cost rural properties and low-cost homes with a high probability of fire occurrence, where the installation of domestic fire sprinkler systems become more cost-effective.

- Based on the findings of this study, no recommendation can be made for changing the New Zealand Building Code to require sprinklers (to NZS 4515:1995) to be installed in domestic dwellings at this time. The adoption of sprinklers should, however, be reassessed in the future because their cost effectiveness is expected to improve as the population ages, and as design and installation efficiencies reduce their cost.

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