TASK 5: COST/BENEFIT ASSESSMENT METHODOLOGY TO SUPPORT POLICY DECISIONS

EU FireStat - Closing data gaps and paving the way for pan-European Fire Safety Efforts

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EXECUTIVE SUMMARY

This report presents the results of Task 5 in the project: “EU FireStat - Closing data gaps and paving the way for pan-European Fire Safety Efforts”. The purpose of the task is to review previously conducted cost-benefit analyses used to evaluate various fire safety measures, and to present an overview of how such analysis can be performed. Furthermore, the report proposes an appropriate method for cost-benefit assessment to be used by the Member States and/or the European Commission.

The review of previous studies gives an overview of the application of cost-benefit analysis to various fire safety measures. The installation of different kinds of water sprinkler systems is a measure that has been examined at in several countries. Due to high costs water sprinkler systems are seldom seen as cost-beneficial in general; however, for specific types of buildings or for certain risk groups the benefits can out-weigh the costs. Another measure that has been analysed in several countries is the installation of smoke alarms, often seen to be cost-beneficial due to the low cost. Other measures that are described in the overview include stove guards, fire extinguishers and combustible cladding.

Cost-benefit analysis represents a common method of socio-economic analysis. The procedure of performing such an analysis varies but it will always include an estimate of all the costs of introducing the measure and an estimate the benefit due to risk reduction as well as other benefits associated with the introduction of the measure. A cost-benefit analysis is considered to provide a structured and explicit way to create basis for decision making regarding fire safety measures and it has shown to work well in several EU countries.

This report presents a proposal for a calculation procedure to conduct a cost-benefit analysis together with a description of the most important input variables. Based on the overview of previous studies, it is evident that there can be a substantial uncertainty associated with some the input variable values; consequently, it is strongly recommended that a cost-benefit analysis should be complemented with a sensitivity analysis to present the variation in the result due to uncertainty in the inputs. The input data in the proposed calculation procedure includes several of the statistical parameters proposed in pervious tasks within the project. A next step will be to apply this procedure in a set of case studies.

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1. INTRODUCTION

The nature and format of fire data varies significantly across the EU Member States. Naturally, this poses an obstacle to data comparison and thereby to effectively assessing potential best practices and successful safety approaches. The current project therefore addresses the need for common European terminology regarding fire statistics in buildings. Data collected from fire incidents can be used as an input for decisions. Cost-benefit analysis is a method that can be used for applying fire-related data to safety interventions.

1.1. Scope and goal Task 5

The scope of Task 5 is to review previously conducted cost-benefit analyses in order to present an overview of how this type of analysis can be performed and used for regulatory and/or other policy decisions on fire safety. Based on this overview, a general method for cost-benefit assessment to be used in by the Member States and/or the European Commission is suggested. The method should be able to be used by the Member States and/or the European Commission to evaluate potential future fire safety regulations or other policy decisions at national/EU level. The method should be presented and explained in a thorough manner. The input and data needed for the method should be presented and explained.

1.2. Method

The literature review is based on material provided by partners in the consortium and through a search in Google Scholar, Google and Scopus during the summer of 2021. The principal method used in the search of previous analysis and suitable methods has been a so-called "snowball" approach, where reference lists of interesting papers and reports on cost-benefit analysis of fire safety measures has been reviewed to find other interesting sources.

The review is not exhaustive but is sufficiently comprehensive to provide a good picture of the field and to inform the application of cost-benefit analysis to various fire safety measures.

1.3. Limitations

Due to variations between the Member States regarding regulations on fire safety measures, how statistics are collected and the previous use of cost-benefit analysis, it is difficult to present generic input of important variables like the value of a statistical life, risk reduction due to installation of a certain system, and interest rates. Consequently, it is not considered possible to present input values for an immediate application of the proposed method. Appropriate context-specific input values will often need to be chosen at the start of the cost-benefit analysis.

Regarding the application of the method, the reader is encouraged to study the work in Task 6 to gain a fuller understanding of the use of the proposed method.

1.4. LIST OF ABBREVIATIONS

BRANZ - Building Research Association of New Zealand
BRE - Building Research Establishment
CBA - Cost-benefit analysis
CEA - Cost-effectiveness analysis
CUA - Cost-utility analysis
COI - Cost-of-illness
LCA – Life-cycle analysis
LQI – Life quality index
MSB - Swedish Civil Contingencies Agency
QALY - Quality-adjusted life-year
SCBA - Social cost-benefit analysis
VSL – Value of statistical life
WTP – Willingness to pay

2. SOCIO-ECONOMIC ANALYSIS

The methods that can be used in a socio-economic cost-benefit analysis are divided into normative and descriptive methods. In the normative methods, the purpose is to provide a basis to say whether a project or investment is "good" for society or not. These methods compare the benefits (or effects) and the costs to society. Descriptive methods, on the other hand, describe the consequences in the form of costs to society [2].

The definition of “society” is important for all methods. It should include all sectors, i.e., not just the public sector, but also the private business sector, all households, and the environment. Consequently, the analysis is not just for an individual authority, hospital, company or similar entity; all societal effects must be included in the analysis. “Society” also needs to have a geographical dimension, and it is most common that a study encompasses a specific country.

2.1. Normative methods

Normative methods include cost-benefit analysis, cost-effectiveness analysis, and cost-utility analysis.

2.1.1. Cost-benefit analysis

A cost-benefit analysis (CBA) includes three main steps. Firstly, the benefit and the costs associated with the action are identified. Secondly, the effects are converted to monetary units. Finally, the benefit (in monetary units) is weighed against all costs (valued in the same monetary units). The analysis should include all the benefits to society, e.g., not only the direct but also indirect positive effects. As far as possible, all these benefits should be valued in monetary terms. The costs should encompass all of society's costs, e.g., not only the project's direct costs but also negative external effects. A societal cost-benefit analysis (SCBA) is an approach that is sometimes mentioned as an extension of economic cost-benefit analysis. A SCBA should account for all possible costs and benefits (including social and environmental) borne by society due to an intervention.

The most common way of expressing the results in a cost-benefit analysis is to use a “net benefits” calculation If the benefit is greater than the cost, the conclusion is that the measure is socio-economically profitable. The cost-benefit can also be expressed as a ratio (or so-called cost-benefit ratio) by dividing the benefit by the cost. If this ratio is greater than 1, it is considered profitable. CBA makes it possible to compare very different type of measures through the inclusion of several variables are included in both the advantages and disadvantages [1].

The benefits in this analysis come in the form of saved lives, reduced injuries, reduced property losses and reduced environmental damage. In general, it is difficult to assign the effects of increased fire protection because it is a very uncertain factor. An example of this is given in a literature review by MSB [2] where several studies of the effect of smoke alarms and hand-held fire extinguishers on fire protection in homes are cited. The diverging results of the different studies show how sensitive the results are to different assumptions regarding the effects of the different measures. In general, it is very important to carefully study the assumptions and simplifications made before the results of a cost-benefit analysis are invoked.

The benefits and costs of a measure that arises at different times must be considered. Because events that occur at different times are not directly comparable, they must be recalculated to a specific time. With the present value method, costs that arise at different times can be compared by being recalculated back in time (discounted) with a certain interest rate.

The main criticism of this method relates to the assumption that income is assumed to be a substitute for happiness or satisfaction, the fact that it willingly ignores distributional effects, and its lack of objectivity when it comes to the selection of certain parameters (e.g. discount rate) [1].

As a part of the “Better regulation ‘Toolbox’” the European commission has issued procedural guidelines on performing cost-benefit analysis for policy decisions [1]. Among other things, the guideline includes a list of “10 steps to complete a Cost Benefit Analysis”.

2.1.2. Cost-effectiveness analysis

In a cost-effectiveness analysis (CEA) [3], a benefit measure is compared with the cost to society. In most cases, a single measure of the benefit is included and is not normally valued in monetary terms. Examples include cost per saved life or cost per ton of carbon dioxide emitted. The result of a CEA cannot be interpreted as socio-economic profitability, but on the other hand it is possible to compare the cost-effectiveness of several different projects .

2.1.3. Cost-utility analysis

Cost-utility analysis (CUA) [4] is sometimes called cost-benefit analysis in the health sector, and it is a special variant of CEA. In a CUA the benefits are measured as health improvements in terms of quality-adjusted life-year (QALY). A QALY = 1 represents one year of life for a fully healthy person, while QALY = 0 represents a deceased person [2].

2.2. Descriptive method

Cost-of-illness (COI) analysis [5] is a so-called descriptive method. In a COI analysis the societal burden of diseases or accidents is measured in the form of a monetary sum. It includes direct costs such as care costs and indirect costs such as loss of production. However, this value is not linked to any measure to reduce the diseases or accidents. The result of COI describes the size of a problem, but it cannot be used to decide whether or not a particular measure should be taken. A COI analysis can supplement other metrics like the number of fatalities or injuries in a specific type of accident [2].

2.3. Analysis on different levels

Even though socio-economic analysis should include all the effects on society there are several examples where this methodology is applied within a certain context. For example, a cost-benefit approach can be applied to compare to different systems to see which system that is more beneficial. In such a case it is the relative comparison between the systems that is of interest rather than absolute values in terms of e.g., a cost-benefit ratio.

Socio-economic analysis can be performed on a general societal level to motivate the introduction of new general rules or recommendations, e.g. requirements on smoke alarms in the building code. However, an analysis can also be useful on a smaller scale, e.g., for a single scenario in a specific building type or for a specific group of people identified to be at high risk. How the analysis is performed and the uncertainty associated with the different input variables needed can vary greatly depending on how specific an analysis is.

3. OVERVIEW OF PREVIOUSLY CONDUCTED COST-BENEFIT ANALYSES OF FIRE SAFETY MEASURES

Fire safety measures to reduce fatalities, injuries and damage from fires can include technical or non-technical measures. Here, technical measures relate to different types of fire protection systems (like water sprinkler and smoke alarms) while non-technical measures relate to e.g., organizational issues and information campaigns to reduce the consequences of fires. The focus of this review is on cost-benefit analyses of technical fire safety measures.

3.1. WATER SPRINKLER SYSTEM IN RESIDENTIAL BUILDINGS

In the conducted review, several different examples of cost-benefit analysis of water sprinkler systems in residential buildings have been identified. In this section, a selection of some of these studies are presented and summarised. For additional examples, the reader is referred to Appendix A in the BRE report [6].

3.1.1. BRE study

In 2012, the British Research Establishment (BRE) [6] did an update of a cost-benefit analysis of water sprinkler systems in residential buildings from 2004 [7]. The update includes a thorough review of data on sprinkler system reliability and effectiveness. It also contains a review of sprinkler costs and benefits (value of life and injury estimates) as well as a review of property damage costs in cases without sprinkler systems.

The value of each death prevented used in the BRE report was £1,692,000 and the average value of each injury prevented was estimated with a Monte Carlo calculation to be £50,450 (with a standard deviation of £2,870). The average property damage in dwellings was estimated to be £8,800 (standard deviation of £460) and for care homes it was £33,600 (standard deviation of £1,700). All these values are in the monetary value of 2010.

The sprinkler system effectiveness (i.e., the risk reduction due to installation) was calculated with an estimated fire area at the time of sprinkler activation and a statistical correlation between risk and fire area. The resulting sprinkler system effectiveness (calculated with a Monte Carlo methodology) is presented in Table 1.

Table 1: Values of sprinkler system effectiveness in reducing deaths, injuries and damage used in the BRE study [6].

Building type	Deaths (%)	Injuries (%)	Damage[1] (%)
House (single occupancy)	90 ± 4	64 ± 11	93 ± 2
House (multiple occupancy)	100 ± 0	66 ± 10	93 ± 2
Flat (purpose-built)	90 ± 3	61 ± 12	88 ± 4
Flat (converted)	95 ± 4	66 ± 11	92 ± 2
Care home (elderly people)	62 ± 19	73 ± 9	86 ± 4
Care home (children)	97 ± 9	56 ± 18	99 ± 2
Care home (disabled people)	30 ± 32	51 ± 25	99 ± 3

[1] Including the 95% confidence interval

Fire statistics from the UK were used to estimates the number of fires, deaths and injuries, and the extent of fire damage in various domestic and residential building types [8]. Estimated numbers of different building/dwelling types as well as the number of residents per building were retrieved from various data sources.

The lifetime of a water sprinkler system was taken to be uniformly distributed between 40 and 50 years. Furthermore, an average interest rate of 3.5% with a standard deviation of 0.2% was used in the analysis to compare costs that occurred at different times. The cost of installation, water supply and maintenance of water sprinklers were estimated with the help of a questionnaire sent to sprinkler installers. Finally, Monte Carlo calculations were performed to find the cost-benefit ratio for different building types, and the results from different building types are presented in Table 2.

Table 2: Cost-benefit ratios calculated in the BRE study [6].

Building type	Cost-benefit ratio[2]
House (single occupancy)	0.14 ± 0.02
House (multiple occupancy - shared)	0.43 ± 0.07
House (multiple occupancy – bedsit type)	1.96 ± 0.49
Flat (purpose-built)	2.36 ± 0.69
Flat (converted)	1.51 ± 0.48
Care home (elderly people)	2.82 ± 1.35
Care home (children)	13.33 ± 91.40
Care home (disabled people)	1.86 ± 0.86

As seen in Table 2, an installation of water sprinkler is cost beneficial for several different building types. However, there are large uncertainties (illustrated by a large confidence interval) connected the results large in some cases. In addition to this BRE report on the UK, BRE has also presented a specific report for Wales [9]

3.1.2. Swedish study

In a Swedish study, Lundborg and Martinsson [10] studied the cost-benefit of installing several different types of fire protection systems in Swedish apartment buildings, and one of these was a residential water sprinkler system. Lundborg and Martinsson used a scenario analysis in their estimate of the benefit and to reduce uncertainties. A total of six scenarios, based on statistics from MSB on the most fatal residential fires in apartment buildings, were analysed in the report (see Table 8).

Table 3: Scenarios analysed by Lundborg and Martinsson [10].

	Fire Cause	First object ignited
Scenario 1	Smoking	a. Bed
		b. Sofa/armchair
		c. Furnishing
		d. Cloths
Scenario 2	Forgotten stove	Stove
Scenario 3	Candles	Furnishing

[2] Including the 95% confidence interval

The benefit of the installation was estimated as the number of saved lives due to the installation of water sprinkler systems. The risk-reducing effect regarding saved lives was based on previous studies and set to 53%. The reliability of the sprinkler system was set to 92%. The benefit was then calculated to monetary units using values of a statistical life and injury (see Table 4).

Table 4: Value of life and injury in monetary terms used within the Swedish transport sector[3].

Statistical life	€2,336,500
Severe injury	€434,000
Slight injury	€20,800

The cost consisted of the installation, operating, and maintenance costs per apartment. The lifetime of the sprinkler system was assumed to be 25 years and the interest rate used was 4%. A cost benefit ratio was calculated for each one of the scenarios in Table 8 and these were used to calculate a total ratio for three different age categories (see Table 5).

Table 5: CBA of residential water sprinklers in apartment buildings [10].

	Cost-benefit ratio[4]
All age groups	0.17 (0.34)
Age 65-79	0.36 (0.52)
Age 80+	0.62 (0.79)

Based on the results from the study, it cannot be argued that a general introduction of residential sprinklers is motivated in Sweden, and it cannot even be motivated for the oldest people (80+) in society. Even though the context and area of analysis is different to the BRE analysis, it is obvious that there are large differences in the inputs used. The lifetime of the system as well as the effectiveness is taken as much higher in the BRE analysis, while the value of life is higher in the Swedish study.

3.1.3. Norwegian study

A third, similar study for installing water sprinkler was performed in Norway in 2012 [11]. In the study, both normal housing (detached or terraced houses) and apartment buildings were included. Cost-benefit ratios were calculated for different groups in the population. In general, the ratio was below 1; however, for elderly with high risk (defined by having home care) and living in apartment building, it was calculated to be above 1. The calculated ratios in this Norwegian study are somewhat higher than what was found by Lundborg and Martinsson [10] and a possible reason for this is that the Norwegian study used a value of statistical life that was about 20% higher than that used by Lundborg and Martinsson.

3.1.4. NIST study

In 2007 the National Institute of Standards and Technology (NIST) [12] in the USA performed a CBA on installation of residential sprinkler systems according to NFPA 13D in three different types of single-family houses. The different houses varied in size, which affected the estimated costs. The

[3] Costs in Swedish currency are re-calculated to Euros in the table (€1 = 10.2 SEK).
[4] Including property damage

cost of maintenance was not included, since it was argued that that the system could be inspected and maintained by the homeowner. NIST estimated the benefits of the sprinkler systems to include reductions in civilian fatalities and injuries, homeowner insurance premiums and property losses (insured and uninsured). The risk reduction values used in the study were based on findings over a 3-year period. The risk reduction applied for fatalities was 100%, 57% for civilian injuries, and 32% for property loss. A 30-year period was studied and an interest rate of 4.8% was used in the calculation. The value of each life saved was estimated at US$7.94 million (in 2005 dollars) and the value of each injury avoided was estimated to be US$171,620. The conclusion of the NIST study was that residential sprinkler systems in which homeowners can perform regular maintenance are cost-effective. Based on this study, NIST created a web-based tool. The tool "Sprinkler Use Decisioning" (SPUD) can be used to estimate the benefits and costs of a residential sprinkler system under a particular set of conditions. It is however up to the user to provide the inputs, and it has been illustrated that the result is strongly driven by the assigned value of a statistical life, the period of the analysis, and the upfront cost of the system [13].

3.1.5. BRANZ study

Research undertaken by BRANZ [14] investigated the cost-effectiveness of domestic sprinkler systems in New Zealand, installed in compliance with existing standards. The summary here is an adaption of the abstract and executive summary of the report. The methodology for the cost-effectiveness study followed that carried out by Beever and Britton [15] for the Building Control Commission of Victoria, Australia. The study involved cost benefit modelling to determine a dollar cost per life saved for the installation of specified fire safety measures. The cost per life saved was determined by using the following formula:

$$\text{cost per life saved} = \frac{\left(\begin{array}{c}\text{installation cost+maintenece cost}\\ \text{- savings in injury cost - savings in property losses}\end{array}\right)}{\text{expected number of lives saved}}$$

The total cost of installing this system into a simple, single-level three-bedroom new house was found to be approximately NZ$1000 (€600). Each variable for the cost per life saved equation was derived from New Zealand Fire Service statistics and commercial costs. The cost-benefit analysis showed that the proposed system achieves a cost per life saved competitive with that of domestic smoke alarms, but would be more effective in saving lives and property. The cost per life saved was found to be less than NZ$900,000 (€540,000).

In a follow up study [16], a life cycle assessment approach according to ISO 14040 was used to evaluate sustainability issues focusing on environmental impacts. The model for the cost-effectiveness analysis for home sprinklers was revised to account for input parameter uncertainty by including input distributions instead of single value inputs, and by conducting simulations that sampled the input distributions. Overall, incorporation of sustainability issues into the cost effectiveness analysis for home sprinkler systems provided a broader insight into the overall costs and benefits, including aspects that currently have no monetary equivalent.

3.1.6. Studies using the life quality index

It is difficult to compare the above-mentioned studies in this section due to the specific contexts in different countries, the varying scope of analysis, and the use of different input values. Still, the fundamental methods in performing the calculations are rather similar.

An alternative approach to using the value of statistical life approach is to apply the so-called Life Quality Index (LQI) method [17]. In short, the index gives the present value of lifetime quality, *Q*. *Q* is assumed to be proportional to societal wealth, to the power *q*, multiplied by discounted life expectancy. Where *q* represents the work-life balance. The life quality index can be calculated for countries where reliable statistical data is available. Hasofer and Thomas [18] used the method to perform cost-benefit calculations of installing sprinkler systems in one- and two-family dwellings in Australia. They found that installation of sprinklers in these dwellings was not cost-effective.

In a recent study, Hopkin et al. [19] discusses the shortcomings of applying a value for a statistical life in this type of study and instead favor the benefit of increased life expectancy (through the LQI concept [17]) and the associated societal capacity to commit resources (SCCR). Hopkin et al. state that SCCR places a value on risk reduction instead of needing to place a value on a statistical life (a discussion on drawbacks of the statistical life approach is available in Section 4.1.2). Hopkin et al. performed calculations based on previous studies and concluded that residential sprinkler installations in houses in the US and apartments in Wales will likely be beneficial, while residential sprinkler installations in houses in Wales, Australia and New Zealand will not be beneficial.

3.2. WATER SPRINKLER SYSTEMS IN NURSING HOMES

In 2010, MSB in Sweden [20] performed an update of previous cost-benefit analysis on water sprinkler systems in nursing homes [21, 22]. An effort was also made to review the literature on how an installation of water sprinkler affects deaths, injuries, and property losses in fires.

The baseline scenario in the study was that there were no sprinkler systems installed in nursing homes, and that was compared to a scenario where water sprinklers were installed. The analysis was based on a scenario with a 2000 m^2 nursing home with 40 apartments of 50 m^2 each, and that each apartment was occupied by one resident.

Costs and benefits were calculated for each nursing home place. The costs included installation and maintenance, and it was calculated for both a newly-built and a refurbished nursing home. The benefit included the risk reductions in terms of fewer fatalities, fewer seriously injured, fewer slightly injured and less property damage. Jaldell used a risk reduction effect of 70% on property damage, fatalities and other personal injuries after a water sprinkler system was installed. To quantify the benefit, values of statistical life and injury from Table 4 were used. No account was taken of the negative effect due to water damage. The statistical data collected by MSB on fatalities and injuries was used in the analysis.

The results clearly showed that the benefit exceeded the cost of sprinklers in both refurbished and new buildings. The conclusion was that all sprinkler types are socio-economically profitable in both refurbished and new buildings.

Table 6: CBA of water sprinklers in nursing homes [20].

	Cost-benefit ratio
Refurbished building	2.1
New building	2.7

3.3. Portable water sprinkler systems

Runefors and Frantzich [22] studied the cost-benefit of a portable, smoke detector-activated, water sprinkler system. This type of system will automatically detect and extinguish the fire, and a major advantage of the system is that it can be located anywhere in a room without major installations.

The efficiency (risk reduction) of the system varied between 60-70% depending on age group and the reliability was set to 90%. The benefit was then calculated, based on values of statistical life. The benefit due to reduced property damage was ignored in the study due to the small contribution to the total benefit of the installation. The benefit was also calculated for smokers, since it has been seen that the risk of dying from fire amongst smokers is significantly greater than the general population. In the case of smokers, the risk reduction estimate was modified somewhat.

Cost estimates were provided by the supplier and included installation and maintenance/running costs. Since the analysis was done on the elderly population (65+), the lifetime of the system was set as an expected remaining life span of the resident; however, analysis was also performed where account was taken of reusing the system for later residents.

Table 7: CBA of portable water sprinkler system by Runefors and Frantzich [22].

	Cost-benefit ratio		
	65+	**75+**	**85+**
All, no reuse of system	0.14	0.14	0.13
All, reuse of system	0.27	0.28	0.35
Smokers, no reuse of system	1.57	1.80	1.82
Smokers, reuse of system	2.41	3.62	4.92

The analysis for the entire elderly population ("All" in Table 7), show the economic benefit did not exceed the cost. However, for particularly vulnerable groups, it was found that the benefit exceeded the cost of the installation. This was especially true for older people who are smokers.

In a similar Norwegian study [11] the cost-benefit ratios for portable sprinkler systems were calculated to be somewhat higher for the elderly (0.3-0.5), but the ratio did not exceed 1. No specific study of smokers was undertaken in the Norwegian study.

3.4. Smoke alarms in residential buildings

Just as for water sprinkler systems, there are several examples of cost-benefit analysis conducted on smoke alarms. In this section, a selection of some of these studies are presented and summarised.

Several studies have observed a clear effect of installing smoke alarms on the number of fatalities in a country. For example, during a 10-year period there was a dedicated campaign in Estonia with a home visit and fire alarm give-away program [26]. This campaign resulted in a dramatic decrease (60-70%) of fire fatalities in the country.

Regarding the economic efficiency of smoke alarms, MSB performed a study on Swedish homes in 2011 [27]. In the analysis the benefit of installing smoke alarms was expressed as the risk reduction on fatalities, severe injury and property damage. To calculate this risk reduction, the authors needed to establish what the risk would have been if the protection factor had not existed. It was then necessary to know how many households in Sweden have smoke alarms and their reliability.

MSB conducted a survey and found that 96% of detached or terraced houses and 90% of the apartments in apartment buildings had fire alarms. The survey also found that 79% of households in detached or terraced houses and 73% of apartment buildings had working smoke alarms. This results in a reliability of 82% and 81% for detached or terraced houses and apartments respectively. When it comes to the risk reduction of installing smoke alarms there are several studies with somewhat diverging values. MSB used values from a previous study, where the risk reduction effect on property damage was 26%, 45% on fatalities and 10% on other personal injuries. The number of fatalities and injured where retrieved from the MSB statistics and similar values as in the study of water sprinkler systems were used to value life and personal injury (see Table 4). Insurance company data were used to estimate the property damage and the marginal effect could be calculated with the risk reduction value and the likelihood of a fire.

The cost of the actual smoke alarm as well as an assumed installation cost were included in the cost estimate. Furthermore, it was assumed that two smoke alarms are needed in detached or terraced houses and one in apartments to achieve the full benefit of the installation. A lifetime of 10 years and an interest rate of 4% were used in the cost calculation. The analysis included both battery-operated smoke alarms and connected to the electrical mains. In the case of the battery-driven alarm both “one-year” and “multi-year” batteries were analysed. The “multi-year” battery was assumed to have a lifetime of at least 10 years. The cost-benefit ratios calculated in the study are presented in Table 8.

Table 8: CBA of fire alarms in residential buildings [27].

	Cost-benefit ratio	
	Detached or terraced houses	**Apartments**
One-year battery	10.0	13.3
Multi-year battery	9.2	12.5
Connected to mains	2.3	3.1

All the scenarios in Table 8 have a cost-benefit ratio above 1. It is interesting to note that the battery-powered smoke alarms are at least three times as effective as the mains-driven alarms, even when considering the higher reliability of the mains power supply.

In a consequence analysis performed in connection with a review of the Swedish building code in 2010, a similar analysis was performed by the National Board of Housing, Building and Planning (Boverket) [24]. In the first analysis, a new requirement on smoke alarms connected to the mains in new residential buildings was found to be motivated. However, after further analysis, it was concluded that the initial assumption on the reliability of this type of smoke alarms were over-estimated. Consequently, the current requirement in the Swedish building code is that smoke alarms, which still can be battery driven, should be installed in new residential buildings.

Lundborg and Martinsson [10] also performed an analysis of fire alarms in residential apartment buildings and found the cost-benefit ratio to be 9.46 (12.19[5]) for the general population, 14.64 (17.37) for the age group 65-74 years and 25.75 (28.48) for the age group 80+. They used the same risk reduction effect as MSB (45%) and a reliability of 81%.

[5] Including property damage

The benefit of smoke alarm installations has also been studied with a different approach in Dallas, Texas, by observed reductions in fire deaths and injuries after a community smoke alarm installation program [25]. A total of 28,570 households were included in the program, along with a reference group comprised of a similar number of households. The total cost of the installation over the observation 5-year was US$1,483,618 and an estimated 8.3 fire injuries (2.5 non-fatal and 5.8 fatal) were averted in terms of 100 000 person-years. From a societal perspective, the installation was estimated to have saved US$3.8 million (or a US$3.21 return on investment for every dollar spent on the program) and appears to have been highly cost beneficial. The study claims to be the longest directly observed documentation of injury outcomes and the costs associated with a smoke alarm installation program in the literature.

3.5. FIRE EXTINGUISHERS

MSB examined the economic efficiency of handheld fire extinguishers in Swedish homes in 2011 [27]. To be able to express the benefit it was necessary to estimate how many households in Sweden that had fire extinguishers at that time and the possible effect that they can have. In a previous survey performed by MSB it was found that 57% of detached or terraced houses and 14% of apartments had fire extinguishers and it was assumed that all of them were functional. The benefit of the fire extinguishers was based on values from a previous study where it was expected that they reduce property damage by 26% in detached or terraced houses and 16% in apartments. No risk reduction in fatalities or injuries were assumed. It is mentioned in the analysis that there is a possible difference in the effect between different types of extinguishers (i.e. powder and foam); however, this was not taken into account in the study.

The cost of a fire extinguisher was set to €49, the lifetime to 20 years and the interest rate used in the calculations were 4%. The resulting cost-benefit ratios are presented in Table 9.

Table 9: CBA of fire extinguishers in residential buildings [27].

	Cost-benefit ratio
Detached and terraced houses	4.8
Apartments	1.4

The values calculated by MSB are close to similar calculations made by Mattson [22] in 2004. Mattson found the ratio for detached or terraced houses to be 5 and 1.3 for apartments. In a sensitivity study, MSB added a possible effect on fatalities and injuries to the benefit and found that cost-benefit ratios then would be 4-7 times as large as in Table 9.

In their work, Lundborg and Martinsson [10] also performed an analysis of fire extinguishers in apartment buildings. They assumed that 11% of apartments have a functional fire extinguisher and the authors did not account for any risk reduction effect on fatalities and injuries. The final cost-benefit ratio was found to be 1.97 which is close to what was found by MSB (Table 9).

3.6. STOVE GUARDS

Runefors and Frantzich [22] performed a cost-benefit analysis of stove guards in 2017. They took the benefit of installing stove guard as the reduction in deaths and injuries, reduction in property damage and the reduced cost due to fewer dispatches of the fire service. Fire incident statistics from MSB's databases were used to retrieve the number of fatalities and injured in stove fires, and values similar to those in Table 4 were used to convert the benefit of reduced fatalities and injuries into monetary terms. Data from Swedish insurance companies were used to get the property damage from stove fires. The reduced cost due to fewer fire service dispatches only included the time for the part-time fire service since the cost of a fulltime fire service was fixed and independent of the number of dispatches. The proportion of dead and injured that could have been saved if the installation had been in place was set to 75%. This value was also used for the reduction in property damage and the reduced cost due to fewer dispatches. Runefors and Frantzich states that a reduction of 75% is most likely a high value and they investigate other reduction values in a sensitivity analysis. In their calculation of the benefit Runefors and Frantzich differentiated between detached or terraced houses and apartments.

The cost estimates were made based on data from two different suppliers and included the hardware cost, installation cost and the running cost. One of the suppliers gave information on installation in a new building and in an existing building. The specified lifetime was 10 or 20 years depending on supplier. Runefors and Frantzich used an interest rate of 4% in the calculation. The calculated cost-benefit ratio is presented in Table 10. The span in ratios that can be seen in Table is due to differences in the suppliers' cost estimates.

Table 10: CBA of stove guards by Runefors and Frantzich [22].

	Cost-benefit ratio
Detached or terraced houses	0.09-0.13
Apartments	0.19-0.24

Lundborg and Martinsson [10] also studied the cost-benefit of installing stove guards in Swedish apartment buildings. The only scenario that Lundborg and Martinsson include in this analysis was Scenario 2 (see Table 8). The cost estimates were slightly lower than those used by Runefors and Frantzich and the risk-reducing effect was set to 100%. Consequently, Lundborg and Martinsson got higher ratios than Runefors and Frantzich, see Table 11.

Table 11: CBA of stove guards in apartment buildings by Lundborg and Martinsson [10].

	Cost-benefit ratio
All age groups	0.28 (0.99) [6]
Age 65-79	0.43 (1.14)
Age 80+	0.41 (1.12)

In a somewhat different context, a Norwegian study [11] found the cost-benefit ratio for stove guards to be 1.5 for elderly with home care and 1.0 for disabled men in the age 30-49. The results are difficult to compare since this Norwegian study is conducted on other types of groups than the two Swedish studies. There findings would indicate that even though stove guards might not be cost-beneficial in general, they may well be appropriate it for specific groups.

3.7. EXTERIOR DETECTION FOR SCHOOL BUILDINGS

[6] Including property damage

A paper by Johansson et al. [28] analyses four technical systems for detecting exterior fires that are intended to reduce the consequences of arson fires in Swedish school buildings. Previous studies have shown that exterior fires around schools during evenings and weekends can cause large destruction and costs. Therefore, the study focused on this type of scenario.

The research studied two types of linear heat detectors (maximum temperature detection and differential heat detection), smoke detectors and thermo sensors. The authors used two case buildings in the study and did a comparative cost-benefit analysis of the four systems. The benefit was estimated based on a correlation, derived from fire statistics, between fire damage and fire service response time. However, to use this correlation, it was necessary to perform experimental full-scale tests to quantify the detection time of each system. No account was taken of the reduction in personal injuries since these types of fires very seldom cause injuries. The costs were estimated as the material cost, installation cost and running cost. The lifetime of all systems was assumed to be 20 years. The costs of de-commissioning a system was not considered in the analysis. As in the previously mentioned studies, the present value method was used to compare costs that occurred at different times and the interest rate was set to 5%.

Statistics from MSB were used to find the frequency of exterior school fires and to calculate the possible damage reduction per second saved due to earlier detection. As can be seen in Table 12, the result showed that the maximum temperature detection cable had the highest cost-benefit ratio of the studied systems. The analysis also illustrated that it would not be beneficial to install these types of systems in all schools in Sweden. However, there were clear cost-benefit advantages for installation in areas where exterior school fires occur more frequently (such as in the larger Swedish cities).

Table 12: Result of CBA of exterior detection systems by Johansson et al. [28].

Technical System	Stockholm	Gothenburg	Malmö	Sweden
Maximum temperature detection cable	2.69	5.06	3.73	0.65
Differential linear heat detector	2.40	4.52	3.33	0.58
Smoke detectors on attic	0.71	1.33	0.98	0.17
Thermo sensor	0.46	0.86	0.64	0.11

3.8. Use of flame retardants in TV-sets

A cost-benefit model was developed to evaluate the financial impact from regulatory and voluntary initiatives for removing flame retardants [29]. The model was based on the Fire-LCA model which is a LCA model including fires as an end-of-life scenario. TV-sets were the case study for this analysis and included costs for flame retardants in the product and costs for disposal of the product. Benefits in form of lives saved, injuries avoided, and capital costs avoided are also included.

The model is based on previous work using LCA analysis to evaluate the environmental impact from products with different fire performance called Fire-LCA. In the Fire-LCA study, emissions were associated with each part of the life cycle. In the CBA study, costs were set to each part of the life cycle (production, use, end-of-life/recycling).

The fire statistics used for the work were primarily derived from a study conducted in a regional area in Sweden where each TV-set fire was investigated by specialists over a 14-month period. This was then extrapolated to a European level. The data from the 14-month period was detailed enough to determine how many of the TV-set fires were big enough to breach the enclosure, spread to the room, were cause by external ignition etc. This type of data is in general difficult to receive from normal fire statistics.

The report [29] gives an overview of the different values available for a statistical life ranging from US$ 1.7 million to US$7.3 million. A value of US$5 million was used in the calculations. The model also utilizes a discounting rate for saving of future lives due to choices made today, two different values were used, 3 and 10%. Yearly costs for burns were also included in the analysis. No cost was set regarding exposure to flame retardants, as it was not possible to find any results indicating any damage due to the exposure levels achieved.

For recycling, an overview was made of the fees in different countries. A variation was made between cheapest country (Sweden €0.87) and most expensive country (Belgium €11).

The cost of firefighting and post-fire clean-up were not included in the study, and neither were costs for replacing damaged equipment. The only replacement cost included is the cost for building up a new home/room based on economic statistics from Sweden. In one scenario, this was replaced by insurance cost.

A set of eight scenarios were studied, where the discounting rate and costs used were varied (such as insurance cost in one scenario). The study showed that using flame retarded TVs were beneficial for all the scenarios. It also showed that the results were very dependent on the discounting rate used.

It should be noted that this study was conducted in early 2000 and based on data from 1990. Technical innovations since then have led to the introduction of flat-screen TVs which are much less likely to cause a fire than the cathode ray TVs of the period. Fires starting in TVs are now extremely rare events, and TV is no longer a specific item of origin in the Swedish fire service incident report.

3.9. Societal cost-benefit analyses performed in the Netherlands

Two different reports commissioned by the ministry of Safety and Justice were issued in the Netherlands [31, 32]. They focus on societal cost-benefit analysis (SCBA) for different aspects of house fires and include studies on smoke detectors, community safety projects, residential sprinklers, and increased regulations on furniture. The texts are adapted from the abstracts and executive summaries and in some cases translations of the Dutch text.

A societal cost-benefit analysis (SCBA) compares all related effects with government measures or policies. These are not just economic effects such as income and prices, but also environmental effects or social goals that have no market price. The target of the SCBA is to attach a monetary value to these non-economic effects so that effects are mutually comparable, and an integral analysis is possible of the effect of a policy on the well-being of citizens and companies in a broad sense.

In the first report [31], three different alternatives were studied:

- a stimulation package scheme for smoke detectors involving subsidy of 50% for purchase and installation of the smoke detectors.
- a community safety project aimed at high-risk neighbourhoods: This is the “Fire Safe Living” project that focuses on multiple aspects of fire safety awareness among risk groups such as residents of deprived neighbourhoods, the elderly and students. For the SCBA, the major element

at the heart of the “Fire Safe Living” initiative is to influence safety awareness among residents in high-risk neighbourhoods through home visits with information material and other measures. Neighbourhoods and target groups are selected on the basis of risk assessments. A smoke detector is offered free of charge during the control visit if it is not yet present. This study assumes a national implementation of this concept, where Fire Safe Living is still mainly carried out regionally. The research assumes that the Fire Safe Life reaches approximately 150,000 households every year.
- mandatory installation of residential sprinklers in new-build homes. This requires adjustment of the Building Decree.

Of the possible measures, the “Fire Safe Living” project has the most positive balance of social costs and benefits. This balance amounts to €40 million plus the positive value of a number of PM items. These are items such as the value of possible savings on firefighting, the value of which cannot be quantitatively calculated. The most important benefits of this project are the prevention of fatalities and the prevention of material damage.

The SCBA residential fire project was the first concrete elaboration of the guidelines on Cost-benefit analyses based on the work of Poort, Koopmans et al. [33]. The report concludes that fire safety is a policy area that lends itself well to SCBAs. It is important to note that in some cases, input data from other countries were used in this study.

A SCBA is a systematic method of assessing the costs and benefits of government policy. If, when a policy measure is implemented, the total benefits for society are greater than the total costs, the result is a net societal benefit. Subtracting all costs from benefits results in a benefit/cost balance, with a positive balance indicating a project that increases prosperity and a negative balance indicating a project that lowers wealth. It is also customary to divide the benefits by the costs: the benefit/cost ratio. A ratio greater than 1 then indicates prosperity gain.

The method is composed of 8 steps comprising:
1. Problem analysis
2. Determination of the project and the baseline scenarios (zero alternatives)
3. Picturing the project effects (cause-consequence)
4. Measuring the effects
5. Evaluation the effects
6. Determine the costs
7. Setup of the cost benefit
8. Presentation and interpretation.

In a follow up study [32] there were two types of policy measures selected, each with two variants, i.e. four policy measures in total. A first type was the obligation to install home fire sprinklers, the second type concerns fire safety requirements for upholstered furniture such as sofas. With respect to mandatory home fire sprinklers, two different variants were examined: an obligation for new build homes (variant A) and an obligation for existing homes (variant B).

Regarding fire safety requirements for upholstered furniture and mattresses/beds, two variants were explored as well. Variant A is based on the current fire safety requirements that apply in the United Kingdom. Variant B explicitly prohibits the use of chemical flame retardants, which means that fire safety must be achieved through other techniques or methods.

The outcome the SCBA analysis are the following:

1. The social costs of both variants of the policy measure ‘mandatory home fire sprinklers’ (new build and existing homes) are higher than their benefits to society.
2. Analyses regarding the policy measure ‘fire safety requirements for upholstered furniture and mattresses/beds’ do not have an unambiguously positive or negative outcome. The reason is that the outcome of the SCBA depends upon specific assumptions made in the calculations.

In both cases, further research is needed so it would be unwise to accept or reject these fire safety requirements.

3.10. COMBUSTIBLE CLADDING

A study ordered by the Department of Environment, Land, Water and Planning in Australia conducted by Regulatory Impact Solutions in Victoria, Australia [34]. The background for this study was the 2014 fire at the Lacrosse apartment building in Melbourne’s Docklands and the tragic Grenfell fire in London in June 2017. These fires highlighted the fire safety risks arising from the non-compliant use of combustible cladding in Victoria and other jurisdictions.

The study found that the proposal to ban ACP (aluminum composite panels) with less than 93% of inert mineral filler would have a material net benefit. This was based mainly on the estimated savings to insurance costs as a result of reduced risks to property damage attributable to combustible cladding. It is important to note that the study focused on property losses and did not quantify avoided deaths or injuries. The ban would therefore provide even further benefits over and above the quantified net benefit.

However, based on the analysis of the authors, several concurrent steps should be taken in the implementation of the proposal to ensure that these benefits are achieved:

- The insurance industry, and the market, would need a high level of assurance that the proposal to ban the insulation material is being complied with in practice.
- Further attention is needed to improve the capacity and availability of professional indemnity insurance for practitioners.
- Official bodies such as national/regional governmental departments could list cladding products on a website that are compliant for construction applications. During consultation, industry highlighted considerable market uncertainty concerning product compliance.

While property and professional indemnity insurance premiums are driven by many factors, there would be benefits in liaising with the insurance industry to let them know that combustible cladding is no longer being used for Type A and B buildings in Australia. This may allay some concerns the insurance industry has with all cladding.

4. METHOD FOR COST-BENEFIT ANALYSIS OF FIRE SAFETY MEASURES

In Chapter 2 different possible methods for socio-economic analysis were described, but the review in Chapter 3 clearly illustrates that the most common method applied in these studies is a cost-benefit method that more or less corresponds to the description given in Section 2.1.1. The cost-benefit analyses in Chapter 3 give examples of calculations on both the general population in a country or for specific groups of people. The analysis applied to a general group can be performed to motivate the introduction of new general rules or recommendations (see Section 2.3). A more specific analysis can be performed when investigation measures that can be recommended for certain vulnerable areas (like the elderly or buildings in high-risk areas) to find better tailored and cost-beneficial fire safety measures. From these reviews a calculations procedure is proposed as well as the input data needed.

4.1. THE CALCULATION PROCEDURE

The methods to perform the different analyses presented in Chapter 3 varies somewhat, e.g. BRE [6] performed Monte Carlo calculations and Lundborg and Martinsson [10] used specific scenarios and then extrapolated the results. The analyses can also differ depending on the type of problem studied. Even so, the general principles for the analyses are similar, and this section is devoted to giving an overview of a possible calculation procedure that can be used when performing a cost-benefit calculation of fire safety measures. The analysis consists of the following two major steps:

- Estimate all the costs associated with the introduction of the measure
- An estimate of the benefit due to risk reduction as well as other benefits associated with the introduction of the measure

4.1.1. Cost estimate

It is necessary to study the costs during the whole lifetime of the measure (technical system) introduced. This is done by using a life-cycle cost analysis. In such an analysis, both the initial investment costs (e.g., cost of planning, materials, and labour[7]) and future costs (e.g., cost of repairs, service, running and maintenance) are included.

Costs incurred at various times during the economic lifetime of the system are not directly comparable, and it is important to know when the costs occur to be able to take this into account. The net present value method is one method that can be used to compare costs that have occurred at different times [30]. The net present value method assumes that the running costs are not tied up when the system is installed and thus can be used for other investments. Costs at different times are moved in time by the aid of an interest rate to compare them by considering them at the point in time when the system was installed. The interest rate for discounting future values, *r*, reflects the potential income and inflation (see Equation 1).

$$r = \left(\frac{1+r_c}{1+I}\right) - 1 \qquad \text{Equation 1}$$

[7] An in-depth discussion of different possible costs is provided by the European Commission [1]

Where r_c is the interest rate calculated for costing purposes and I is the rate of inflation. It is often difficult to find an interest rate suitable for these purposes, and as can be seen in Chapter 3 the real interest rate, r, varies between different studies (from 3.5% to 5%). A too low or high value can have a large effect on the results, especially if the lifetime of the intended technical system is long. Even so, when an interest rate is quantified, the following equation is used to calculate the life-cycle cost (LCC) of each technical system:

$$LCC = I_{in} + \sum_{i=0}^{n} \frac{R_i}{(1+r)^i} \qquad \text{Equation 2}$$

Where I_{in} is the initial investment cost (e.g., material and installation) and R_i is the running costs in year i. Costs of reinvestments and liquidation are not considered in Equation 2 but can also be included. The estimated annual cost, A, is then calculated as the annuity of the life-cycle cost with the following equation:

$$A = LCC \cdot \frac{r}{1-(1+r)^{-i}} \qquad \text{Equation 3}$$

4.1.2. Benefit estimate

The benefit estimate is more dependent on the measure taken and the type of benefit (e.g., reduced number of fatalities, reduced property losses). In a case where the measure will have a potential to reduce the number of fatalities, the following procedure could be applied. In many situations a part of the population might already have introduced the measure. In such a case it is needed calculate the consequence if no measure had been taken. In Equation 5 this is exemplified with the number of fatalities per year.

$$Number\ of\ fatalities\ (corr) = \frac{Actual\ number\ of\ fatalities\ per\ year}{((1\text{-}risk\ reduction\ of\ measure)\cdot x+(1\text{-}x))} \qquad \text{Equation 5}$$

Where x is the proportion of the population (e.g., number of households) that have the measure in place already. As an example, in a country with 100 fatalities per year, a measure with a risk reducing effect of 50% will be introduced; however, this measure is already in place amongst 10% of the population. This means that the corrected number of fatalities will be $\frac{100}{((1-0.5)\cdot 0.1+(1-0.1))} = 105$. Following this calculation, the number of saved lives if the entire population would have the system installed can then be calculated with Equation 6.

$$Number\ of\ potential\ saved\ lives = Number\ of\ fatalities\ (corr) \cdot risk\ reduction\ of\ measure \qquad \text{Equation 6}$$

Finally, the benefit can be calculated with Equation 7.

$$Benefit = \frac{Number\ of\ potential\ saved\ lives \cdot (VSL + indirect\ costs)}{Population} \qquad \text{Equation 7}$$

where VSL is the value of a statistical life, and the indirect costs are costs that will not occur when lives are saved (e.g., cost of ambulance and hospital costs). The calculation procedure will be similar when estimating the benefit of reduced number of injured as an effect of the introduction of a measure. When property damage is analysed, the value saved needs to be estimated, which can be done with fire statistics and insurance company data. Still the reliability and efficiency of the measure needs to be included when deriving the benefit. For more information on costs associated with fire damage, Lam and Robbins [36] have reviewed different international approaches to categorize key cost components (like e.g., property loss, business interruption, fire service).

The VSL is a crucial component of the benefit-cost analyses as can be seen in Equation 7, and it is derived by investigating individuals' willingness to pay (WTP) for a lower risk of mortality, divided by that risk reduction. This means that VSL does not measure an actual value of a life, but instead it should be seen as a monetary value on the willingness to accept slightly higher or lower levels of risk [1].

It should be acknowledged that VSL is a somewhat controversial concept. Firstly, the values of a healthy life have been suggested to be depended on individual preferences [35]. At the same time, it has been observed that there are variations in the valuing of a prevented fatality depending on gender, race, and social status. It is impractical to take account of such discrepancies when forming a basis for societal decision-making on safety [19]. Secondly, an issue that has been raised is that the stated preferences cannot be considered independent from the specific scenario that is used when investigating the preferences. This means that the VSL obtained in a study should not be applied in other fields [37]. Finally, a safety measure that is of benefit of all its users will need a societal VSL, that would represent how much the society is willing to pay to prevent the fatality of an undefined member of the society [38].

An alternative method to applying the concept of VSL is the so-called J-value method [39]. The J-value estimates the maximum it is reasonable to spend on a measure by balancing the costs against the increase life expectancy that the measures will result in. The concept is related to the LQI [17]. When an investment is made in a measure the idea is that the lifetime quality, Q will increase with ΔQ to Q'. Hopkin et al [38] adopted the J-value method for applications in fire safety engineering and demonstrates how the J-value provide a basis for assessing whether a proposed fire safety measure should be implemented. As presented in Section 3.1 Hopkin et al [19] used this method to revisit several previous CBA studies related to the installation of residential sprinkler systems in single-family dwellings

4.1.3. Cost-Benefit ratio

When the annual cost and benefit is calculated the cost benefit ratio can be derived by dividing the benefit with the cost, see Equation 8. A measure that has a ratio above 1 will be cost-beneficial.

$$Cost\ benefit\ ratio = \frac{Benefit}{Cost} \qquad \text{Equation 8}$$

4.1.4. Sensitivity analysis.

It is of great importance to check the robustness of the results from a CBA [1] and based on the overview of previous studies presented in Chapter 3, it is evident that there can be great variation associated with some of the input parameters to a cost-benefit analysis. The general purpose of a sensitivity analysis is to investigate how the result of a calculation varies, when changes are made in the input variables. For variables with great influence, even a small change can have a large effect on the results. Variables that are found to have a large influence needs to be studied carefully to reduce the uncertainty in the variable value. If the uncertainty cannot be reduced, several calculations with different values for the uncertain variable can be conducted to illustrate the possible span in the result.

It is strongly recommended that a sensitivity analysis of some kind be performed when conducting a cost-benefit analysis. There are several examples of sensitivity analyses in Chapter 3. In one of these, Runefors and Frantzich [22] investigated the influence of some individual variables by varying them by ±50% and in the BRE study [6] a Monte Carlo approach was applied in the calculation procedure, in order to illustrate the probability distributions for the outcome.

4.2. SUMMARY OF REQUIRED DATA FOR COST-BENEFIT CALCULATIONS

Examples of the type of data needed for the cost-benefit analysis of fire safety measures are presented in Table 13 and Table 14. These tables provide an example of the input data that may be needed for a CBA; however, no claim is made that these tables are comprehensive. It is not considered appropriate to present any quantitively input values for an immediate application of the method proposed in Section 4.1. An analysis of the necessary input variables and their values need to be conducted for each specific analysis.

It should also be pointed out that in some cases there are valid alternatives to the variables presented in the tables. As an example, it might be considered more appropriate to use the benefit of increasing life expectancy (through the LQI) and the associated SCCR as suggested by Hopkin et al. [19] instead of applying values of a statistical life.

When statistical data on fires is used, it is important that the data reflect the situation it is intended for. For example, the number of fires can change due to other changes in society such as the introduction of new types of consumer products or a downward trend in smoking.

Table 13: Variables normally needed to estimate the benefit of a measure.

Variable for benefit calculation	Typical data source
Possible number of fatalities	Fire incident statistics / hospital records
Possible number of injuries	Fire incident statistics / hospital records
Value of lives and injuries saved	Data from other studies or investigations. This value can vary as can be seen in the review of studies in Chapter 3. The VSL in EU has been proposed to range from US$1.8 million – 5.4 million (in 2005), with a base value of US$3.6 million [1].
Property loss /damage for fires with no installation	Insurance company, economic statistics

Other costs associated with fire with no installation (e.g., fire service dispatch, environment etc)	Specific source associated with the cost
Current number of installations	Relevant statistics / review of literature
Unit of interest e.g., number of affected apartments	Relevant statistics / review of literature
Efficiency associated with the measure	Review of literature, fire statistics, detailed studies in a certain area
Reliability of the measure	Review of literature, fire statistics (e.g., operation and effectiveness of fire safety measures)

Table 14: Variables normally needed to estimate the cost of a measure.

Variable for cost calculation	**Typical data source**
Hardware cost	Supplier /manufacturer
Installation cost	Supplier /manufacturer
Running cost / maintenance cost	Supplier /manufacturer
Lifetime	Supplier /manufacturer
Interest rate for discounting future values	Estimated based on interest rate and inflation, this can also be calculated, see Equation 1. In Chapter 3 the values vary between 3 and 10% in the different studies.

5. CONCLUSION

This report provides an overview of cost-benefit analysis for evaluating fire safety measures and summarises the results obtained and a proposal for a general procedure.

The installation of various kinds of water sprinkler systems has been studied in several countries and is not seen as cost-beneficial in general; however, for specific types of buildings or for certain risk groups, the benefits can outweigh the costs. Another measure that has been analysed in several countries is installation of smoke alarms and it is often found to be cost-beneficial in general, primarily due to its low cost. Other measures that have been reviewed in this work include stove guards, fire extinguishers and combustible cladding.

Cost-benefit analysis is a common methodology for performing an economic analysis of fire safety investments seems to be through cost-benefit analysis, and CBA is considered to provide a structured and explicit way to create basis for decision making regarding fire safety measures. The actual procedure when performing a CBA varies between the examples given in Chapter 3, but it always includes an estimate of the cost of introducing the measure and an estimate of the benefit due to risk reduction as well as other benefits associated with the introduction of the measure. Based on the overview in Chapter 3, it is evident that there can be a substantial uncertainty connected to some of the input variable values; consequently, it is strongly recommended that a cost-benefit analysis should be complemented with a sensitivity analysis to present the variation in the result due to uncertainty in the inputs.

An overview of a proposal for a calculation procedure to conduct a cost-benefit analysis, together with a description of the most important input variables, is presented in Chapter 4. Important input variables to CBA calculations can include basic fire statistics, such as the number of fires, number of fire fatalities, number of injured, fire cause and type of building. These are variables that have been suggested in previous tasks to be included in the EU FireStat project. One of the motivations for including these variables specifically mentioned in the previous tasks has been the need of data for conducting CBA. For information on the presence, operation, and reason for failure of different technical systems (like automatic extinguishing systems and smoke alarms), which can be needed as a part of a CBA analysis of such systems, more detailed fire statistics is needed. It is also important to point out that there are several other input variables needed for a CBA that cannot be obtained from fire service statistics, for example the risk reduction of installing a certain measure and the cost of installation and maintenance of a certain measure. Accordingly, for a Member State and/or the European Commission to be able to conduct a CBA for a policy decision, fire statistics is a prerequisite, but it does not provide the complete dataset needed for the analysis.

The calculation procedure presented in this task is proposed to be used in the case studies that will be performed in Task 6. The case studies in Task 6 are important for a further explanation and illustration of the calculation procedure, since the type of data needed, and its availability varies between areas of study, both in terms of type of system and country studied.

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