TASK 6: CASE STUDIES USING COST/BENEFIT ASSESSMENT METHODOLOGY

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

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EXECUTIVE SUMMARY

The methodology for cost-benefit analysis of fire protection measures presented in Task 5 is demonstrated in this report with three case studies. The three case studies are covering three types of possible actions i.e., implementing technical installations, improving materials/products through legislation and prevention campaigns. The topics of the case studies are:

- Smoke detectors in residential buildings
- Introduction of a minimum fire regulation on upholstered furniture/matrasses in Sweden for residential fires.
- Home visits as a prevention measure.

The actual procedure when performing a cost-benefit analysis varies somewhat between the different case studies but they are all based on the same methodology which was an output from Task 5 of the project. 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 are included in all case studies. A rather detailed calculation was possible for Case study 1 since there have been several studies in the area and data is available for most of the important input variables. It was also seen that the measure (smoke alarm) is cost-effective. The results of Case study 2 and 3 are considered more uncertain and harder to interpret since the benefit-cost ratio is close to 1. Several important input variables are also associated with great uncertainties which makes it especially important to include a sensitivity analysis in these cases.

The conducted case studies underpin that good fire statistics are crucial in order to conduct this type of analysis. Data on number of fatalities, number of fires, item first ignited etc. have been used in the case studies. However, it is also important to point out that there are several input variables needed for a cost-benefit analysis that cannot be obtained from fire service statistics, for example the risk reduction and cost of implementing and maintaining a certain measure. Accordingly, for a Member State and/or the European Commission to be able to conduct a cost-benefit analysis for a policy decision, fire statistics is a prerequisite, but it does not provide the complete dataset needed for the analysis.

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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 for data comparison and thereby to effectively assessing potential best practices and successful safety approaches for fire safety. The current project therefore addresses the need for common European terminology and data collection 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 assessing the cost effectiveness of fire safety measures by applying such fire-related data.

1.1. SCOPE AND GOAL TASK 6

The goal of this task was to provide three case studies where the cost/benefit assessment methodology/approach proposed in Task 5 was applied to show how the proposed method can be used to support regulatory and/or other policy decisions/choices.

1.2. METHOD

The methodology for the case studies is presented in Chapter 3. It is based on the methodology for cost-benefit analysis that was developed in Task 5 [1].

1.3. LIMITATIONS

The reader must keep in mind that the purpose of this task is to demonstrate a methodology. In many cases the input data to the case studies have been scarce. Due to the limited time and extent of this task, it has not been possible to make detailed investigations into to all input variables. However, the authors have made their best efforts to make use of the data available to make reasonable estimates of input values to the three conducted case studies. Still the outcome of the analyses is prone to large uncertainties and decisions should not be made based on that outcome, the cases studies should only be considered as examples of how such analysis can be conducted.

The authors of this report are all located in Sweden, this means that there is a focus on Swedish conditions in this report. Even so, this is not considered to affect the possibility to demonstrate the methodology presented in Task 5 which was the main objective of task 6. Due to this limitation, the outcome of the results in this report should not be used at this stage for policy decisions or choices at European, national or regional level.

2. DESCRIPTION OF CASE STUDIES

The three case studies have been developed by the members of Task 6 and discussed with the project consortium. Feedback on the three cases have also been received by the European Commission Services. The three cases studies cover three different possible approaches for policy decisions namely: installation of technical systems, improved material and or products and prevention campaigns.

2.1. CASE STUDY 1: SMOKE DETECTORS IN RESIDENTIAL BUILDINGS

The focus of the first case study is on smoke alarms in Sweden. There have been several studies in this area previously including a study conducted by the Swedish Civil Contingencies Agency (MSB) in 2011 [2] and a study by Lundborg and Martinsson in 2014 [3].These studies are used as a starting point for the analysis conducted here.

2.2. CASE STUDY 2: INTRODUCTION OF A MINIMUM FIRE REGULATION ON UPHOLSTERED FURNITURE/MATRASSES IN SWEDEN FOR RESIDENTIAL FIRES.

The second case study concerns the introduction of regulations on upholstered furniture in Swedish residential buildings. This is a measure that is not in place in Sweden and data from the UK is used to derive risk reduction rates.

2.3. CASE STUDY 3: HOME VISITS AS A PREVENTION MEASURE.

In this case study home visits as a fire prevention measure are studied. This is a measure that has been applied in for example Estonia and the Netherlands. The study will be carried out on a local level in Sweden where data from a conducted campaign of home visits is available.

3. METHODOLOGY FOR COST-BENEFIT ANALYSIS

The methodology for cost-benefit analysis used in the case studies in Chapter 5-7 has been presented in the Task 5 report [1], but is presented here as well for clarity.

3.1. THE CALCULATION PROCEDURE

The cost-benefit analysis methodology used in this report 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

3.1.1. Cost estimate

It is necessary to study the costs during the whole lifetime of the measure 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 [5]) 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 [4]. 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).

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

Where r_c is the interest rate calculated for costing purposes and *I* is the rate of inflation. 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:

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

3.1.2. 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 one needs to calculate the consequence if no measure had been taken. In Equation 5 this is exemplified with the number of fatalities per year.

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

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, i.e. the number of fatalities that would occur if no one had taken the measure, 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.

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

The benefit due to lives saved can be calculated with Equation 7.

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

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 population (e.g., number of households) depends on the type of study conducted.

The calculation procedure (Equation 5-7) 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. The probability of a fire occurring is calculated with Equation 8.

$$Probability\ of\ fire = \frac{Number\ of\ fires}{Population} \quad \text{Equation 8}$$

However, account must be taken to if any households already have the measure present; therefore, a corrected probability must be calculated. This corrected probability represents the probability of fire if there would be no measure present in the population at all. This calculation is performed using Bayes' theorem and according to Equation 9.

$$Probability\ of\ fire = x\cdot(1\text{-}risk\ reduction\ of\ measure)\cdot proportion\ with\ risk\ measure\ in\ place+$$

$x \cdot (1\text{-proportion with risk measure in place})$ Equation 9

where x is the corrected probability, and *the probability of fire* is calculated with Equation 8. The benefit due to reduced property losses is then calculated according to:

$$\text{Benefit due to reduced property losses} = \text{risk reduction of measure} \cdot \text{corrected probabilty of fire} \cdot \text{cost associated with fire}$$ Equation 10

The cost associated with fire can be estimated based on e.g. insurance company data.

3.1.3. Benefit-cost ratio

When the annual cost and benefit is calculated the benefit-cost ratio can be derived by dividing the benefit with the cost, see Equation 11. A measure that has a ratio above 1 will be cost-beneficial.

$$\text{Benefit-cost ratio} = \frac{\text{Benefit}}{\text{Cost}}$$ Equation 11

3.1.4. Sensitivity analysis.

It is of great importance to check the robustness of the results from 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.

4. GENERAL INPUT VALUES OF CASE STUDIES

The case studies in Chapter 5-7 include several input values that are common for all three studies. These general input values are presented in this chapter.

4.1. VALUE OF STATISTICAL LIFE

The value of statistical life (VSL) is a crucial component of the cost-benefit analysis as can be seen in Equation 7, and it is derived by investigating individuals' willingness to pay 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.

VSL is a somewhat controversial concept. Firstly, the values of a healthy life have been suggested to be dependent on individual preferences [6]. 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 [7]. 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 [8]. Finally, a safety measure that is of benefit to 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 [9].

Table 1: Value of life and injury in monetary terms used within the Swedish transport sector [10] from 2006[1]. The values for 2021 is calculated based on a discount rate of 4%.

Parameter	2006	2021
Statistical life	€2,188,500	€3,941,500
Severe injury	€407,000	€732,000
Slight injury	€19,500	€35,000

The values of VSL in Table 1 are taken from the Swedish transport sector, and similar numbers have been used by MSB in previous studies. The reason why these values are used in this analysis is that the traffic area has been subjected to the most studies regarding the value of statistical life. Therefore, the numbers are considered to be the most reliable that can be found for the country. However, as mentioned above, this type of values can be context dependent. It could be that the fire area differs from the traffic area due to differences regarding the frequency of accidents, risk perception, psychological factors such as anxiety and fear, and that fire affects other groups in the society (e.g. in terms of age, income and other demographic, socio-economic and fire-specific factors). For example, in a study by Carlsson, Daruvala and Jaldell [11] it was found that the monetary value for life was 1/3 lower for fire than for road traffic, and it was also found that children were valued higher than 40-year-olds and 40-year-olds higher than those even older.

[1] Costs in Swedish currency are re-calculated to Euros (€1 = 10.2 SEK).

4.2. Discount rate

A discount rate to account for costs at different times are used in the calculations (Equation 1). This rate should reflect potential changes in prices. A discount rate of 4% is used as a baseline value in all three case studies. This value has been recommended for Sweden [10] and has been applied in previous cost-benefit analyses in the country [2].

4.3. Fire statistics

Fire statistics are used to different degrees in the three case studies. The number of fires in residential buildings in Sweden are taken from two sources, the fire service [12], and insurances companies[2] (see Table 2). The average damage cost is based on data from insurance companies and the cost profile of furnishing.

Table 2: Number of fires, fatalities, and injuries in residential buildings

Type of residence	Number of fires		Average damage cost (€)
	Fire service	Insurance	
Apartment buildings	3,300	13,213	5,100
Detached or terraced houses	2,700	16,554	5,500
Total	6,000	29,767	-

A weighted average damage cost can be calculated with information from Table 2 to €5,300. The number of fatalities in different types of occupancies is used in all three cases studies and this data is based on Swedish fire service response statistics (see Table 3).

Table 3: Number of fatalities and injuries in residential buildings [2].

Type of residence	Fatalities	Severe injuries	Light injuries
Apartment buildings	38.2	69	515.2
Detached or terraced houses	41.2	30.4	225.7
Total	79.4	99.4	740.9

4.4. Statistics on residential buildings

The main population that is used in the case studies is the number of households in Sweden. This data is retrieved from Statistics Sweden [13].

Table 4: Number of residences in residential buildings [13].

Type of residence	Number of homes
Homes in apartment buildings	2,585,221
Detached or terraced houses	2,104,946
Total	4,690,167

[2] Data from insurance companies have been retrieved from a previous MSB analysis [2].

The residences in Table 4 accounts for 93% of all residences in Sweden. The remaining 7% are in so-called special housing, which includes homes for elderly and disabled, student housing and other types of special housing. Special housing is not included in this analysis.

5. CASE 1 - SMOKE DETECTORS IN RESIDENTIAL BUILDINGS

The analysis includes two types of battery-operated smoke alarms: a "1-year" and a "10-year" battery. A lifetime of 10 years and a discount rate of 4% are used in the calculation.

5.1. COST ESTIMATE

The cost of the actual smoke alarm as well as an assumed installation cost are included in the cost estimate. The cost of installing and maintaining smoke alarms are based on values previously used by MSB [2] and are presented in Table 4. These values are from 2011; however, based on the current pricing in Sweden the costs in Table 4 are considered to still be reasonable.

Table 5: Smoke alarm costs

Type of cost	Cost (€)	
	1-year battery	10-year battery
Material cost	7	19
Installation cost	5	5
Running cost per year	1	0

There are different recommendations on how many smoke alarms that are needed in residential buildings in different countries. NFPA [14] states that smoke alarms should be installed in each bedroom, outside each sleeping area and on every level of the home, including the basement. In England and Wales [15] the minimum requirement is to have a at least one smoke alarm on every floor in homes. In Sweden [16] the recommendation is to have at least one smoke alarm per floor, and that the coverage area should not exceed 60 m^2. This case study is based on Swedish conditions; therefore, the recommendation of 60 m^2 coverage area is applied.

Table 6: Size of residences in residential buildings [13].

Type of residence	Size of residence		
	<60 m^2	60-120 m^2	>120 m^2
Apartment buildings	39.7%	58.2%	2.1%
Detached or terraced houses	4.7%	48.1%	47.2%

In Sweden there are statistics on the size of different residences available (see Table 6). Based on the values in Table 6 the expected number of smoke alarms needed in apartments and in detached or terraced houses can be calculated to 1.62 and 2.43 respectively.

The initial investment, I_{in} will, according to Table 5, be €12 for a 1-year battery alarm and €24 for a 10-year battery alarm. There is no running cost for the 10-year battery alarm but a running cost of €1 for the 1-year battery alarm due to the yearly exchange of battery.

Equation 2 is applied to calculate the *LCC* over the 10-year lifespan for the 1- and 10-year battery alarm to €20.44 and €24 respectively. The yearly cost is then calculated with Equation 3 to €2.52 and €2.96. These costs are used in Table 7 to calculate the cost based on the expected number of smoke alarms needed in the different types of residences.

Table 7: Annual smoke alarm costs

Type of residence	Cost (€)	
	1-year battery	10-year battery
Apartment buildings	4.08	4.79
Detached or terraced houses	6.12	7.19
Average for all residences	5.20	6.11

5.2. Benefit estimate

The benefit estimate is dependent on the measure taken and the type of benefit (e.g., reduced number of fatalities, reduced property losses).

MSB conducted a survey in 2011 and found that 96% of detached/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. Here values from previous studies in Sweden [2] are applied, where the risk reduction effect on fatalities were 45%, 10% on personal injuries and 26% on property damage.

Table 8: Reliability and risk reduction related to smoke alarms.

Type of residence	Reliability	Risk reduction		
		Fatalities	Severe/light injuries	Property damage
Apartment buildings	81%	45%	10%	26%
Detached or terraced houses	82%	45%	10%	26%

5.2.1. Saved lives and injuries

Since a large proportion of the population has the measure already in place it is necessary to calculate a corrected number of fatalities/injuries per year. Equation 5 is applied to perform this calculation. The number of potentially avoided fatalities or injuries is then be calculated with Equation 6 (see Table 9).

Table 9: Number of potentially avoided fatalities and injuries.

Type of residence	Fatalities	Severe injuries	Light injuries
Apartment buildings	25.6	7.4	55.6
Detached or terraced houses	28.8	3.3	24.5
Average for all residences	54.4	10.7	80.1

Finally, the benefit can be calculated with Equation 7, where values of the potential number of avoided fatalities and injuries are calculated with data from Table 1 and Table 9 (no indirect costs are included). The benefits due to avoided fatalities and injuries are given in Table 10.

Table 10: Benefit of avoided fatalities and injuries (€/year).

Type of residence	Fatalities	Severe injuries	Light injuries
Apartment buildings	39.0	2.1	0.8
Detached or terraced houses	53.9	1.1	0.4
Average for all residences	45.7	1.7	0.6

5.2.2. Reduced property costs

Insurance company data is used to estimate the property damage and the probability of a fire occurring. The fire probability is calculated by dividing the number of fires with the population (see Equation 8) and the corrected fire probability is then calculated with Equation 9, see Table 11.

Table 11: Calculated fire probabilities

Type of residence	Fire probability	Corrected fire probability
Apartment buildings	$5.1 \cdot 10^{-3}$	$6.3 \cdot 10^{-3}$
Detached or terraced houses	$7.9 \cdot 10^{-3}$	$9.9 \cdot 10^{-3}$
Average for all residences	$6.4 \cdot 10^{-3}$	$7.9 \cdot 10^{-3}$

The benefit is then derived by multiplying the average damage reduction (Table 2) with the risk reduction regarding property damage for smoke alarms and the probability of a fire (see Equation 10). The resulting benefits are presented in Table 12.

Table 12: Benefit of avoided property damage (€/year).

Type of residence	Avoided property damage
Apartment buildings	8.4
Detached or terraced houses	14.2
Average for all residences	11.0

5.3. BENEFIT-COST RATIO

The total benefit (see Table 13) is calculated by adding the benefit of avoided fatalities and injuries (Table 10) to the benefit of avoided property damage (see Table 12).

Table 13: Total cost and benefit (€/year).

Type of residence	Cost (€)		Total benefit (€)
	1-year battery	10-year battery	
Apartment buildings	4.1	4.8	50.2
Detached or terraced houses	6.1	7.2	69.7
Average for all residences	5.2	6.1	59.0

A benefit-cost-ratio can be calculated based on the data in Table 13. And as can be seen in Table 14 the ratio will exceed 1 with a good margin for all types of residences.

Table 14: Benefit/cost ratio for smoke alarms (€/year).

Type of residence	Benefit/Cost	
	1-year battery	10-year battery
Apartment buildings	12.3	10.5
Detached or terraced houses	11.4	9.7
Average for all residences	11.3	9.6

5.4. SENSITIVITY ANALYSIS

A sensitivity analysis is performed to see the possible effect of some input variables considered to be associated with a high degree of uncertainty.

5.4.1. Discount rate

The discount rate is varied ±50% to demonstrate its influence on the results. Based on the results in Table 15 it can be seen that a decrease of 50% in discount rate will increase the ratio with 7-10% and an increase of 50% will decrease the ratio with 6-9%.

Table 15: Influence on benefit/cost ratio when discount rate is change ±50%.

Type of residence	Benefit/Cost (discount rate 2%)		Benefit/Cost (discount rate 6%)	
	1-year battery	10-year battery	1-year battery	10-year battery
Apartment buildings	13.2	11.6	11.5	9.5
Detached or terraced houses	12.2	10.7	10.7	8.8
Average for all residences	12.1	10.7	10.6	8.8

5.4.1. Material and installation cost

The material and installation costs are increased by 100% to demonstrate its influence on the results. The ratio will decrease by 37% and 50% for the 1-year and 10-year battery smoke alarm, respectively as seen in Table 16.

Table 16: Influence on benefit/cost ratio when cost is increased by 100%.

Type of residence	Benefit/Cost (cost +100%)	
	1-year battery	10-year battery
Apartment buildings	7.8	5.2
Detached or terraced houses	7.2	4.8
Average for all residences	7.1	4.8

5.4.1. Risk reduction of the measure

The risk reduction of installing smoke alarms is based on a previous Swedish study and is considered to be associated with some uncertainty. To demonstrate the sensitivity in the result to this input variable the ratios are re-calculated with a 25% and 50% reduction in the risk reduction values in Table 8 the results from this calculation are provided in Table 17.

Table 17: Influence on benefit/cost ratio when the risk reduction value is reduced.

Type of residence	Benefit/Cost (risk reduction -25%)		Benefit/Cost (risk reduction -50%)	
	1-year battery	10-year battery	1-year battery	10-year battery
Apartment buildings	8.4	7.1	5.1	4.3
Detached or terraced houses	7.6	6.5	4.6	3.9
Average for all residences	7.6	6.5	4.6	3.9

5.5. DISCUSSION

The results in this case study demonstrates that the battery-driven smoke alarms are cost-effective in Swedish residential buildings, and this is in line with several previous studies [2,3]. The sensitivity analysis also demonstrates that these results are rather robust.

It should be noted that the ratio for the 1-year battery alarm will always result in a ratio that is higher than the 10-year battery alarm. This is due to the fact that the 10-year battery alarm is more expensive and that no account has been taken to any differences in reliability[3].

[3] It could be argued that the 10-year battery alarm will be more reliable since no maintenance is required.

6. CASE 2 - FIRE REGULATION ON UPHOLSTERED FURNITURE/MATRASSES

Upholstered furniture is known to be the item first ignited in many fatal fires [12,17] and one way to reduce the number of fatalities could be to increase the fire requirements on upholstered furniture as was done in UK in 1988. The effectiveness of this regulation was studied by the Department of Trade and industry in 2000 [18] and the number of lives saved in UK due to that regulation was estimated to be 11-20 per million population yearly once all furniture had been replaced. The UK legislations required the upholstered furniture to pass the match and cigarette test and an additional mass loss requirement was put on the foam in the upholstered furniture. This resulted in furniture that had a fire performance similar to withstanding crib 5-7.

Based on the statistic in the report from Department of Trade and Industry [18] combined with Swedish fire statistics [12] a statistical fire model was set up by Andersson, Simonson, Rosell, Blomqvist and Stripple [19] in order to make a fire-LCA analysis of the environmental impact should this regulation be introduced in Sweden and EU. This work was focused on the emissions due to the furniture production and fires in them and no cost-benefit analysis was conducted.

Here the statistical fire model developed in the Fire-LCA study together with Swedish fire statistics is used to instead make a cost benefit analysis that includes lives saved and property saved should this regulation be introduced. It is here assumed that a crib 5 requirement is put on the upholstered furniture rather than having a requirement on separate parts, this allows i.e. interliners to be used to achieve the fire performance.

6.1. COST ESTIMATE

As most people would have a sofa and bed regardless of whether there are any fire requirements or not, the cost estimate in this case is the additional cost of the higher fire performance. This is a cost that is not known and a baseline value of €100 is assumed. This number is associated with a high uncertainty, and therefore a sensitivity study is conducted on this value (Section 6.4).

With an initial cost of €100, a lifetime of 10 years and an interest rate of 4% the annual cost is calculated with Equations 1-3 to €12.3.

6.2. BENEFIT ESTIMATE

The benefit consists of saved lives and reduced property cost due to fires being avoided or reduced substantially due to the higher requirements on upholstered furniture.

6.2.1. Saved lives and avoided injuries

In this case the number of potential saved lives cannot not be based on all fatalities in residential buildings (Table 2), instead the number of fatalities due to fires that have started in upholstered furniture is used. Swedish fire statistics give that 35% of fatal residential fires start in furnishing and 85% of these are upholstered furniture. Table 2 gives that there is an average of 79.4 fire fatalities in

Swedish residential buildings, so the expected number of fatalities from fires in upholstered furniture becomes 23.6.

Since there is no regulation on improved fire performance on upholstered furniture in Sweden today the number of households that have fire improved upholstered furniture already in place is assumed to be zero. This means that the corrected number of fatalities is the same as the expected number.

The number of lives saved is estimated based on the UK study [18], the exact numbers are however difficult to estimate from the diagrams in that report and the risk reduction is therefore set to 0.9 as a baseline value. This means that the potential number of people saved becomes 0.9·23.6 = 21.3. The value of a statistical life is 3,941,500 (see Table 1) and no account is taken to indirect costs. This results in the following calculation of the benefit per household according to Equation 7:

$$\text{Annual benefit due to saved lives} = \frac{21.3 \cdot (3{,}941{,}500 + 0)}{4{,}690{,}167} = €17.9$$

Injuries are not considered in this case as too little data is available to make any reasonable assumption.

6.2.2. Reduced property costs

The benefit due to reduced property loss when the measures are in place is split into three different categories.

- Fires confined to the item ignited. This is a small fire where it is only the item first ignited that is consumed in the fire, in this case it is the item that needs to be replaced, together with some other things in the room that are damaged due to smoke. It is assumed that the average cost associated with category is €5,000.
- Fires confined to the room of fire origin. Most or the entire room is consumed in the fire. Again, more things probably need to be replaced and the average associated cost for this is set to €25,000.
- Fire spread outside the room of origin. This is a large fire where the entire apartment is consumed in the fire. The associated cost is set to €2,000,000.

To estimate the number of fires in each category Swedish fire statistics [12] on the extent of fires is used. In this case only fires to which the fire service has responded are used for the calculation (see Table 2) and given that 2% of these start in upholstered furniture, according to Swedish fire statistics [12], the total number of fires per year is 120. Swedish fire statistics include data on size of fires [12, 17], for fires starting in upholstered furniture the size of the fires 50% are confined to room, 41% confined to item and 9% spread outside the room of origin.

Table 18: Estimated number of fires and associated cost.

Fire extent	**Estimated % of fires**	**Estimated number of fires**	**Estimated cost/fire (€)**
Confined to item	41%	49	5,000
Confined to room	50%	60	25,000
Spread outside room of origin	9%	11	2,000,000

With increased fire performance requirements on upholstered furniture the number of fires will decrease to 12, and the distribution of the type of fire extent will change [17]. According to Andersson et.al. the numbers of fires can be estimated to be as presented in Table 19.

Table 19: Estimated number of fires and associated cost with measures in place

Fire extent	Estimated % of fires	Estimated number of fires	Estimated cost/fire (€)
Number of fires		12	
Confined to item	55%	6.6	5,000
Confined to room	36%	4.3	25,000
Spread outside room of origin	9%	1.1	2,000,000

The probability for each category is calculated by dividing the number of fires with the population according to Equation 8 (see Table 20). Since there are no fire requirements on upholstered furniture today in Sweden there is no need to calculate a corrected fire probability. The benefit is then calculated with Equation 10.

Table 20: Fire probability and benefit.

Fire extent	Fire probability without measure	Benefit (€/year)
Confined to item	$1.04 \cdot 10^{-5}$	0.05
Confined to room	$1.28 \cdot 10^{-5}$	0.24
Spread outside room of origin	$2.35 \cdot 10^{-6}$	0.42
Total	$2.56 \cdot 10^{-5}$	0.71

The annual benefit due to reduced property losses will be €0.71 per household in the baseline case.

6.3. BENEFIT-COST RATIO

The total annual benefit per household will be €18.6, this means that the benefit/cost ratio in this the baseline case is 1.5 (18.6/12.3)

6.4. SENSITIVITY ANALYSIS

A sensitivity analysis is performed to see the possible effect of some input variables that are considered to be associated with a high degree of uncertainty.

6.4.1. Cost of the measure

In the baseline scenario it was assumed that the average cost of the measure, in terms of protection of upholstered furniture, is set to €100 per household. To test the sensitivity on the benefit/cost ratio of this input variable it is increased by 50% and 100% (see Table 21). The lifetime is kept at 10 years.

Table 21: Influence on benefit/cost ratio when the cost of the measure is increased.

Increase in cost	Annual cost (€)	Benefit/cost
50%	18.5	1.00
100%	24.6	0.75

The measure will still be cost-effective if the average cost is increased by 50% to €150.

6.4.1. Risk reduction of the measure

The baseline risk reduction of implementing regulation on upholstered furniture (0.9) is based on estimates and data from the UK. To demonstrate the sensitivity in the result to this input variable the ratios are re-calculated with a 25% and 50% reduction in the risk reduction values (see Table 22).

Table 22: Influence on benefit/cost ratio when the risk reduction value is reduced.

Risk reduction value	Benefit/cost
0.675	1.13
0.45	0.75

The measure will still be cost-effective if the risk reduction value is decreased by 25% to 0.675.

6.5. DISCUSSION

The case study clearly illustrates that input data such as the lifetime of furniture, the cost of introducing certain measures, costs of fires and the risk reduction of the measure are needed to perform the analysis. This type of data will not be acquired with fire statistics, instead they need to be found with dedicated studies. Even so, detailed fire statistics are also needed to perform this type of analysis.

The conducted case study illustrates that it is possible to show that a regulation on upholstered furniture can be cost-effective in Sweden. However, some of the input values are uncertain and a more detailed analysis is of course needed. In this case the cost of the increased fire performance had a large impact on the result. On the other hand, one could consider to what extent this cost should be included as the cost will probably be reduced once this is something included in all upholstered furniture and sofas/beds.

7. CASE 3 – HOME VISITS AS A FIRE PREVENTION MEASURE

In this case study prevention campaigns in the form of home visits as a fire prevention measure are studied. Home visits can be arranged in many different ways and how they are performed will of course have a strong influence on the cost and the potential effect of the measure. There are examples of how home visits have been used as a fire prevention measure in several European countries (e.g. Estonia, the Netherlands and Sweden). A difficulty of analysing this type of measure in terms of cost and benefits is that it is hard to determine its effect as there can be a combination of effects.

Home visits are a measure that has been applied in for example Estonia and the Netherlands. However, this study will be based on a series of home visits conducted by Räddningstjänsten Syd in Sweden. Räddningstjänsten Syd provides the fire and rescue service for five municipalities (Burlöv, Eslöv, Kävlinge, Lund and Malmö) with more than 500,000 inhabitants in the southern part of Sweden.

Räddningstjänsten Syd has used home visits as a preventive method, with the inspiration from the UK[4]. An analysis has been conducted by researchers from Malmö University and Lund University on the home visits carried out by Räddningstjänsten Syd during 2010-2016 [20]. During these years Räddningstjänsten Syd conducted 70,000 home visits. The home visits were rather straightforward, each visit took 5-10 minutes and during that time information about the importance of different fire safety measures (e.g., smoke alarm, fire blanket and fire extinguisher) was provided to the household. The effect of the measure was, according to Räddningstjänsten Syd, clear and a reduction of 30% in the number of residential fires was seen during these years. It is important to mention that many of these visits were conducted in high risk areas as stated in the report.

7.1. Cost estimate

The cost of home visits would include the time of the visit, transport costs associated to the visit and training of the people performing the home visit. The actual visit performed by Räddningstjänsten Syd lasted 5-10 minutes. Here this time is increased to 15 minutes to include time for training and transport. The hourly cost (including social fees) for an informant is assumed to be €75, and here it is assumed that two informants are engaged in each visit. This results in that the cost per visit will be €37.5.

7.2. Benefit estimate

The benefit consists of saved lives and reduced property cost due to that the fires will be avoided due to increased knowledge in the population after having received a home visit from the fire and rescue service.

[4] The fire and rescue service in Merseyside, Liverpool conducted more than 100,000 home visits per year during 2007-2010.

7.2.1. Saved lives and avoided injuries

The average number of fire fatalities per year in the five municipalities prior to 2010 (when the home visits were introduced) were 2.7 according to Swedish fire statistics. According to Räddningstjänsten Syd there was a reduction of 30% in the number of fires during the years when the home visits were conducted. However, during the six-year period 70,000 households were visited which accounts for 30%[5] of the households in the area. A higher number of visits would most likely result in a higher risk reduction value. Therefore, it is assumed that the risk reduction is 50% given that all households are visited.

It is assumed that there were no home visits conducted prior to the 2010, which means the measure was not in place to any degree in the population. This means that the corrected number of fatalities according to Equation 5 will be the same as the actual number of fatalities, 2.7/year. This means that the potential number of people saved becomes 0.5·2.7 = 1.35. The value of a statistical life is 3,941,500 (see Table 1) and no account is taken to indirect costs. This results in the following calculation of the benefit per household according to Equation 7:

$$\text{Annual benefit due to saved lives} = \frac{1.35 \cdot (3{,}941{,}500 + 0)}{230{,}000} = €23.1$$

Injuries are not considered in this case as too little data is available to make any reasonable assumption.

7.2.1. Reduced property costs

Insurance company data is used to estimate the property damage and the probability of a fire occurring. The fire probability is calculated by dividing the number of fires with the population (Equation 8) and the corrected fire probability is then calculated using Equation 9. There is no insurance company data available on the average number of fires in the region. However, it is assumed that it is proportional to the number of households[6], which results in 0.049 · 29,767 = 1,459 fires. The probability of fire can then be calculated with Equation 8 to $6.3 \cdot 10^{-3}$, and the benefit can be calculated with Equation 10, using the weighted average damage cost of €5,300 from Table 2.

$$\text{Annual benefit due to reduced property losses} = 0.5 \cdot 6.3 \cdot 10^{-3} \cdot 5{,}300 = €16.8$$

7.3. BENEFIT-COST RATIO

The total annual benefit per household will be €39.9 (23.1+16.8), this means that the benefit-cost ratio in this the baseline case is 1.07 (39.9/37.5).

[5] According to Statistics Sweden, there were roughly 230,000 households in the area in 2013.
[6] The proportion of the total number households in Sweden is calculated as 230,000/4,690,167 = 0.049

7.4. Sensitivity analysis

A sensitivity analysis is performed to see the possible effect of some input variables that are considered to be associated with a high degree of uncertainty.

7.4.1. Cost of the measure

If the cost of the home visits would increase to €40 (increase by 7%) the cost benefit ratio would be below 1. However, in the baseline scenario it was assumed that the average annual cost of home visits is €37.5. By assuming this it is implicitly assumed that the effect of the measure is only 1 year. If it instead would be assumed that the effect of a visit would last three years, the annual cost would decrease to €12.5, and the benefit-cost ratio would increase by a factor 3.

7.4.2. Risk reduction of the measure

The baseline risk reduction of implementing home visits (0.5) is based on the home visits conducted by Räddningstjänsten Syd. To demonstrate the sensitivity in the result to this input variable the ratios are re-calculated with a 25% and 50% reduction in the risk reduction values (see Table 22).

Table 23: Influence on benefit/cost ratio when the risk reduction value is reduced.

Risk reduction value	Benefit/cost
0.375	0.8
0.25	0.53

The benefit-cost ratio will be below 1 for both cases in Table 23, and it is even so that a reduction by 85% in the risk reduction value (to 0.46) will yield in a ratio below 1. So, the baseline value (0.5) results in a borderline case.

7.5. Discussion

There are several input values, just as in case study 1 and 2, that are hard to estimate in this case study. The most uncertain variable is the risk reduction value. The 30% risk reduction that is presented in the referred study [20] was achieved when 30% of the households were visited over a 6-year period. In the baseline calculations it is assumed that all households are visited during one-year and that the risk reducing effect only holds for one-year (i.e., each household needs to be visited each year to receive the assumed risk reducing effect). Consequently, if the actual total effect of the home visits is in the order of 30% when only 30% of the households are visited (as argued for in the referred study [20]) the calculation performed here will most likely underestimate the benefit.

Furthermore, it is worth noting that the benefit does not include the cost for rescue service attending fires. In this case where it is the rescue service that has the cost for the measure it could be useful to also include their benefit from the measure.

8. CONCLUSION

The methodology for cost-benefit analysis of fire protection measures presented in Task 5 has been demonstrated in this report with three case studies. The three case studies are covering three types of possible actions i.e. implementing technical installations, improving materials/products and prevention campaigns.

The actual procedure when performing a CBA varies somewhat between the different case studies but they are all based on the methodology presented in Chapter 3. 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 is included in all case studies. A rather detailed calculation was possible for Case study 1 (Chapter 5) since there have been several studies in the area and data is available for most of the important input variables. It was also seen that the measure (smoke alarm) is cost-effective. The results of Case study 2 and 3 are consider much more uncertain and harder to interpret since the benefit-cost ratio is close to 1. Several important input variables are also associated with large uncertainties which makes it important to include a sensitivity analysis.

As can be seen when studying the conducted case studies, good fire statistics is crucial to conduct this type of analysis. Data on the number of fatalities, number of fires, item first ignited etc. have been used in the case studies. However, it is also important to point out that there are several input variables needed for a cost-benefit analysis that cannot be obtained from fire service statistics, for example the risk reduction and cost of implementing and maintaining a certain measure. Accordingly, for a Member State and/or the European Commission to be able to conduct a cost-benefit analysis for a policy decision, fire statistics is a prerequisite, but it does not provide the complete dataset needed for the analysis.

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