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Cost-Benefit Analyses of Sprinklers in Nursing Homes for Elderly

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Abstract:

The risk of dying in fires in nursing homes is six times the risk of dying in fires at home in Sweden. The risk of being injured in nursing homes is even higher. The reason is that fire alarms do not help if people have problems moving around, or have dementia and do not understand what is going on. One way to reduce this risk is to install fire sprinklers. The benefits depend on the value we put on elderly people living in nursing homes. Their life expectancy is 3.2 years. This study measures the benefits and compares them in terms of the monetary value of full lives, life years and quality adjusted life years (QALYs) for deaths and injuries. The results show that sprinklers are cost-effective in newly built nursing homes no matter what value of life is used. However, if sprinklers are installed in already existing buildings, they are cost-effective only if the value of a statistical life is used.

Highlights:

- A cost-benefit analysis of fire sprinklers in nursery homes for the elderly.
- The elderly have a short expected lifetime, 3.2 years, and poor quality of health.
- A comparison of valuing benefits in monetary units using full lives, remaining life years or quality adjusted life years.
- For newly built homes sprinklers are cost effective regardless of the value set on the elderly.
- For installation in already built homes, sprinklers are cost effective only when using a full life valuation.

Keywords:

QALY, value of statistical life, nursing home, fire safety, sprinklers, elderly

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H75, I11, J14, K32,

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Cost – benefit analyses of sprinklers in nursing homes for elderly

1. Introduction

The risk of dying in fires in nursing homes is six times the risk of dying in fires at home in Sweden. The risk of being injured in nursing homes is even higher. The reason is of course that fire alarms do not help if people have problems moving around or have dementia and do not understand what is going on. The residents will take longer to detect the fire, have slower reaction time, have longer movement time, have a problem getting out using e.g. windows or stairs, cannot themselves help in suppressing the fire, and cannot expect to get help from their fellow residents. In 2.5-3 minutes the condition may be critical, and in this short period the fire and rescue service will not have arrived in normal cases, and nor will the nursing home personnel have time to get everybody out (Mostue and Stensaas 2002). One way to reduce this risk is to install fire sprinklers. However, from an economic point of view sprinklers should not be installed if their benefits do not exceed their costs. The benefits depend on the value we put on elderly people living in nursing homes. One interesting, and hard to answer, question then is what explicit value should be set on this group. Should we value the elderly individual in the same way as an average individual, or should we use quality adjusted life years, which drastically discounts the value of this specific group with low health and few years to live?

The purpose of this study is to find out whether it is economically efficient to install sprinklers in elderly homes, both newly built and existing, in Sweden. The benefits of installing sprinklers are that more lives will be saved, fewer people will be injured and less property will be damaged. Since these benefits are measured in different physical values, we will convert these savings into monetary values to make it possible to compare the benefits with the monetary value of installation costs. The methodology used is thus an economic cost-benefit analysis. Another question that will be answered is how sensitive the results are to what value we set on the elderly people in nursing homes.

In economic cost-benefit analyses it is customary to treat lives in “full units”, that is “a life is a life” irrespective of age, income or other socio-economic factors. The standard approach is to use the value of a statistical life, VSL. In most evaluations this is not a problem. For example, in traffic safety projects there is normally no reason not to value saved lives on the basis of an average individual in society. However, when it comes to nursing homes the target group is really a special group. They are elderly and in poor health, both of which lead to the fact that they will live a very short time. We can

think of two ways of dealing with this: Reduce the VSL-figure according to an age effect, and use the value of statistical life years, VSLY, instead of VSL. Using VSLY in cost-benefit analysis has been proposed by some (Sunstein 2004), but still cannot be considered a common recommendation for use in cost-benefit analyses (Viscusi 2009).

Nursing homes in Sweden can be run by municipalities or private firms, and in both cases the money comes from the taxpayers via the city council. Should the managers of the nursing homes improve fire safety instead of improving the quality of health care? When it comes to evaluations of health care using health economic measures, the standard procedure is to use the change in quality adjusted life years (QALYs) as a measure of utility change. In this study we will therefore measure the monetary value of benefits using VSL, VSLY and QALYs for deaths and injuries. We will thus compare how these three measures affect the benefit side and the conclusions.

This study makes three main contributions. First, not many cost-benefit analyses of fire safety, especially sprinklers, have been done on nursing homes. Second, not many cost-benefit analyses compare the three methods of valuing saved lives, VSL-VSLY-QALY, and how this affects the results. Third, to be able to set the quality of life weight for the QALYs, we conduct a thorough discussion of the problems of finding such a value for the elderly in nursing homes and burn patients.

Considering the cost side, modern sprinkler equipment has become much cheaper than older equipment, since a completely separate sprinkler water supply system has to be built into older sprinkler systems, but the existing water supply system can be used for modern sprinkler systems. With the modern system it is now possible to install sprinklers for a reasonable cost in already built elderly nursing homes.

The results show that sprinklers are cost-effective in newly built nursing homes no matter what value of life is used. However, if sprinklers are installed in already existing buildings, they are cost-effective only if the value of a statistical life is used. For VSLYs the results show that costs are nearly equal to benefits, but for QALYs they are not. So one conclusion of the paper is that cost-effectiveness depends not on the value we could put on the different affected groups, but on the value we should put on them.

Section 2 discusses the empirical findings on how to value the elderly in nursing homes when it comes to the physical and monetary values of VSL, VSLY and QALY. Section 3 provides evidence of

fire sprinkler effectiveness. Section 4 presents the data, the calculations and the results. Section 5 contains various sensitivity analyses using Monte Carlo simulations, including varying the discount rate, the effectiveness rate and the cost figures. Section 6 concludes the paper with a discussion of the findings.

2. Valuing elderly people in nursery homes

Several studies show that people in general value age groups differently. Most studies find that children are valued higher and the elderly are valued lower than middle-aged people. Considering stated preference studies where the respondents have to prioritize between different age groups in different choice sets, Johannesson and Johansson (1997), in a study on health investments, found that the lives of forty 70 year olds were equivalent to that of one 30 year old. The corresponding figure was around 2.5 in a stated preference study by Johansson-Stenman and Martinsson (2008) on traffic safety projects. Carlsson et al. (2010), in a similar stated preference study on fire and traffic safety, reveal that 10 year old children are worth 3.3 times as much as 70 year olds, and that 40 year olds are worth 2.3 times as much as 70 year olds. All these three studies find that the relative value of a saved life decreases with age, but Cropper et al. (1994) show that the utility attached to saving an anonymous life is a hump-shaped function of the age of the person saved. Saving the lives of eight, eleven and seven 60 year olds are considered equivalent to saving the life of a 20-year old, a 30-year old and a 40 year-old, respectively.

The literature on the relationship between age and value of a statistical life (VSL) is extensive, both in terms of theoretical models (e.g. Jones-Lee 1989; Johansson 2002) and empirical investigations (e.g. Evans and Smith, 2006; Aldy and Viscusi 2007, Krupnick et al. 2002, Alberini et al. 2004). Two recent surveys came to different conclusions about the value of the elderly compared to other adults depending on the method used. Krupnick's (2007) review of stated preference studies concludes that: "The fact that the studies that focus on this issue are split in their findings is further evidence that the senior discount effect, if it exists, is not robust." (p. 275). Aldy and Viscusi's (2007) review of revealed preference labor market studies concludes that: "The labor market VSL increases with age, peaks in mid-life, and subsequently declines." (p. 257). Pearce (2000 p. 23), surveying three UK and one Canadian stated preference studies, concludes that "--- WTP falls with age, but only after age 70", which is highly relevant for this study. Leiter (2011, in a recent stated preference study of snow avalanche risks in Austria, shows that VSL varies with age if the hazard rate is age specific, but not if it is not age specific. The age specific effect, which is lower for those aged 63+, and higher for those

aged 18-24 and 55-62, comes from focusing on the individual skiers, while the age-independent effect comes from focusing on non-skiers.

However, these studies have not led to many policy implications, and the reason is probably that it is very hard for decision-makers to explicitly state that some people are worth less. For example, a negative public reaction was received when the US Environmental Protection Agency discounted the life of the elderly by 37 %, and therefore later abandoned this discounting (OECD 2011). However, no such reaction was provoked by the European Commission's (2001) recommendation of an age-adjustment factor of 0.7 for valuing elderly people in environmental cost-benefit analyses, or by the factor of 0.75 for the elderly in Canada (OECD 2011).

As a first alternative we will exercise caution and not explicitly state a lower value for people in elderly homes. But what monetary value should we choose? The only official value in Sweden is the one used for the transportation sector where the risk value was SEK 21 million in 2006 (SIKA 2009). The OECD (2011) lists different official values for some countries. The Swedish value is higher than the value used by the UK Department of Transport (£ 1 million) and the European Commission recommendation of € 1-2 million, lower than the official values used by different US agencies ranging from US\$ 5-7.5 million and the values used in Canada of C\$ 6.5 million, but quite close to the value used in Australia of A\$ 3.5 million and to the value of US\$3.5 million for the EU-27 recommended by the OECD study in question.¹ The differences in values can hardly be explained by different income levels and different risk levels.²

There are also reasons to believe that VSL should vary depending on different objective risk levels for different contexts, but also subjective risk perceptions when it comes to feelings such as dread, fear, knowledge, familiarity, voluntariness and control. Should we, then, use the official Swedish VSL which is derived mainly from studies in road traffic environments, and not in fires? Unfortunately, avoiding fire risk has not been studied much, and the few studies points in different directions. Savage (1993) discovered differences in the relative WTP for reducing risk in the hazard contexts

¹ Of course the different country values fluctuate with the exchange rates. The exchange rates for January 2012 are: 1 € = SEK 8.8 = 1.3 US\$ = 1.3 C\$ = 1.2 A\$

² The risk of a traffic accident for example is quite similar considering per capita and per vehicle-km for the UK and Sweden, but the average EU risk is higher, and Australia and Canada have similar risk levels and income levels, all according to IRTAD (2010). Another factor not taken into account here, and rarely in international comparisons, is that the VSLs normally are given in consumer prices (since revealed and stated preference studies consider consumers' willingness to pay), that is including taxes. The consumer tax levels are quite different between countries; Sweden has a normal value-added-tax of 25 %, while some states in the USA have no sales tax at all.

domestic fires, stomach cancer and road and aviation accidents in a study where respondents were supposed to divide \$100 among the four risk contexts. He found that, due to a lower perception of dread and other unknown aspects, respondents had a statistically significantly lower WTP for fire safety projects than for highway safety projects.³ In a stated preference study using repeated contingent valuation questions, Carlsson et al. (2010b) found that the VSL for risk of fatalities in fires was only 2/3 of that for fatalities in road traffic. However Chilton et al. (2002) detected no major differences in risk valuation for risks of railways, domestic fires, fires in public places, and roads. Carlsson et al. (2010a) found no difference in risk priorities between fire and traffic risks in a choice experiment taking age effects and difference between saving lives and reducing injuries into account.

An alternative to using the value of a statistical life is to use the value of a statistical life year (VSLY) instead. VSLYs may be estimated directly from revealed and stated preference studies, but this has not been done in many studies.⁴ Instead, it is more reasonable, today, to calculate VSLYs from official VSLs, since there are many more VSL-studies and the official VSL-values therefore should be more reliable. The standard approach to calculating VSLY is to assume that the VSL is true for the average age of the fatalities, and then treat the VSL as a sum of the expected life years. Assuming a discount factor and taking the yearly fatality rate into account, the VSLY can be calculated as:

$$VSLY = \frac{r * VSL}{[1 - (1+r)^{-L}]}$$

where r is equal to the discount rate and L is equal to life years saved (Aldy and Viscusi, 2007).⁵ The implicit assumptions here are that the discount rate is constant for a full lifetime, and that it is reasonable to assign an equal value of VSLY for every year lost. The choice of the size of the discount rate is important. For example, using 2 % instead of 4 % for the Swedish VSL of 21 million, changes VSLY from SEK 1.1 to 0.8 million, or by more than 25 %. However, economic theory suggests that the interest rate consists of two parts, where one part is due to the diminishing marginal rate of

³ Savage explains the perhaps intuitively surprising finding that a lower degree of knowledge of the risk leads to a lower WTP, by arguing that people may be more willing to spend money on things that they know will have an effect.

⁴ One rare recent example is Desaiques et al. (2011) that estimated VOLY directly from WTP surveys on reducing air pollution in nine European countries. They conclude that a reasonable value for Western Europe is €40000. (Using an interest rate of 4 % and a life expectancy of 40 years, this corresponds to a VSL of about €1.1 million.)

⁵ Mason et al. (1999) argue that if a declining VSL over age is assumed such information should be incorporated in the calculations. However, this is not regarded here, firstly because the evidence on declining VSL is not clear, and secondly that Mason et al. find that taking this fact into account does not in a substantial way.

consumption over time and the other part is a pure time preference. Mason et al. (2009) suggest that it is only the pure time preference rate that should be used in these calculations, since it can be assumed that the VSLY will increase by the marginal rate of consumption over time.⁶ It should also perhaps be relevant to assume a decreasing interest rate over time instead of a constant interest rate, i.e. use hyperbolic discounting. However, the relevance of these proposals for people in nursing homes with few expected life years can be questioned, and therefore we will assume a constant interest rate here. Since we cannot take for granted that VSL is independent of age, VSLY could also be dependent of age. Hammit (2007 p. 238) concludes from Krupnick (2007) that “---suggests that VSLY increases with age.” and from Aldy and Viscusi (2007) that “--- over the older ages during which VSL decreases, the rate of decrease in VSL appears to be somewhat more rapid than the rate at which life expectancy decreases, suggesting that VSLY decreases with age.” Hammit also notes that the revealed preference studies using labor market data do not include elderly retired people, and that the choice is arbitrary between VSL and VSLY. This is not true when it comes to the elderly living in nursery homes, since the life expectancy in elderly homes is very short, only about three years.

However, in health economics it is standard procedure to use quality adjusted life years, QALYs, as measures of benefits. That is, not only expected saved life years, LY, are considered, but also how the quality of life changes, QoL⁷. The average QoL in Sweden is somewhere around 0.8 (see references below), but considering elderly people living in nursery homes the QoL value should be lower, due to being older and having reduced physical and mental health. Using the EQ-5D, Burström et al. (2001a) estimated health-related QoLs for different diseases, age and socioeconomic groups in Sweden. For the age group 70-79 the index was found to be 0.79, and for the age group 80-88 it was 0.74. For all age groups the index for those classifying their health as “rather poor” was 0.46, and for those classifying it as “very poor” it was 0.17. Using their regression results (ibid, p. 631, table 7), the indices for the age group 70-79 with “poor health” and “very poor health” were calculated to be 0.46 and 0.23, respectively, while for the age group 80-88 the corresponding indices were 0.45 and 0.21. (The youngest age group 16-19 had the highest index with 0.91 and the group including the average age of a Swede had an index of 0.86. The index was lower for females than for men.) In another similar study by Burström et al. (2001b) the index for the age group 70-79 was 0.71 and for the age group 80-84 it was 0.61. For all ages the index for those reporting “rather poor” was 0.33 and for those reporting “very poor” 0.20. Using their regression results (ibid, p. 65, table 7) the indices for

⁶ In the UK it is assumed that the social discount rate is 3.5 %, of which 1.5 % is due to pure time preferences.

⁷ The scale goes from 0 (=dead) to 1 (=full health). This scale is presented here even if some authors have used a scale from 0 to 100.

the age group 70-79 with “poor health” and “very poor health” were 0.32 and 0.20, respectively, while for the age group 80-88 the corresponding indices were 0.27 and 0.14. In a Finnish study on the quality of life for elderly critically ill patients, Kaarlola et al. (2006) found that the Quality of life-index decreased from 0.68 for 65-69 year olds down to 0.61 for 80-94 year olds. The index was about 0.15 points higher for the same age groups in the general population.⁸ Sullivan et al. (2002) used the SF-36 to find norms for physical and mental health quality indices for the Swedish population. For physical health the quality index could be standardized to 0.54 for people in the age group 75-79 and 0.48 for people 80 and over. The mental health quality indices were higher by 0.68-0.69. In a German study of quality of life in the older population, Hunger et al. (2011) found the mean EQ-5D index to be 0.76 with a mean age of about 74 years. The mean index was found to be decreasing (non-linearly) up to the age of 87 (about -0.14), and then somewhat increasing. Borglin et al. (2005; 2006), in two postal surveys of the quality of life among older people in Sweden, found a Quality of life-index of 0.75 in the first. In the second, the index for present life was 0.52-0.60 and for life span 0.86-0.89 (females-males), showing a decrease over time. The mean ages were 85 and 83, respectively. Another Swedish survey used a sample recruited from a politically affiliated organization for seniors (Retired People’s Organisation, PRO), but found a fairly high current quality of life-index of 0.74 (Hagberg et al. 2002). It can be compared to a life span quality of 0.75 and an outlook-of-life-index of 0.69. Unfortunately, none of these Swedish surveys made adjustments for where the older people lived. However, measuring health using a quality of life index may not be straightforward. Nord (1996) summarized health state scores for different QoL- index models. For people with severe problems the index value varied between 0.20 (EuroQoL) and 0.77 (15 D). Nord’s conclusion is that none of the models are appropriate and he adds that a rule-of-thumb-model (with values of 0.67-0.85) may also be used.

So what about people living in nursing homes? Using a postal survey, Hellström, Andersson and Persson(2004) found no difference in the quality of life-measure QoL (both mental and physical) when comparing older people in Sweden living at home and receiving help to those living in special accommodation. However, they found lower values for those needing help compared to those not needing help in the same age group. In another postal survey, Hellström, Persson and Hallberg (2004) showed that the total score for quality of life, QoL, was about 15 % lower for older people needing

⁸ Halvorsrud and Kalfoss (2007) reviewed measurements of quality of life in older adults. They listed different methods used and tried to set a quality mark on each study, but unfortunately they did not list and compare the absolute value of quality of life from each study. (Many studies do not list the absolute value, but they just compare correlations between different methods used.)

help compared to those not needing help. Tseng and Wang (2001) found that the standardized score for quality of life among the elderly in nursing homes in Taiwan was 0.53.

So is it fair to use lower QALYs for the elderly, due to shorter expected life and worse health? Nord et al. (1999) list four arguments. The first is the fair innings argument, which says that all people should have a standard life time of about 70-75 years (not more). The second is a severity argument, which says that it would be better to increase people from low QALY indices to high. The third is the realization-of-potential argument, which says that you should not be punished for not being able to reach a high QALY. The fourth is an inequality aversion argument, which says that QALYs among people should be as equal as possible. Having lower priority preferences for the elderly may also be attributed to a productivity argument according to Tsuchiya (1999). When it comes to sprinklers in homes for the elderly, the severity argument and the realization-of-potential argument are valid. They have lower QoL-indexes on average, but they also have no possibility of attaining a high QoL-index. So we could therefore argue that a larger weight should be given to people in elderly homes. The empirical evidence also points in this direction (Dolan et al. 2005), but choosing specific weights is hard (Lancsar et al. 2011). One suggestion is to set the weight to 1 for all life saving programs, but whether this corresponds to people's preferences is a matter of discussion (Nord et al. 1999; cf. Johannesson 2001). The fair innings argument instead works in the opposite direction for people living in elderly homes, since it is reasonable to assume that they have had their "fair" share of life already. As discussed below, some, but not all, empirical evidence also points in this direction. Ubel et al. (1999), however, argue that the public anyway have sympathy for the disabled because they have *not* had their fair quality of life. That death is the worst state, as shown by Ebrahim et al. (1991), is also questionable. They let people value different health statuses on a scale between 0 (best) and 12 (worst). For those older than 75, death was given a valuation of 9.0, which was the same valuation given to a health status described by "Confined to bed. Has slight pain which is relieved by aspirin." The health status described as "Unconscious, but not aware or in pain" got a valuation of 10.5. These health statuses are very likely not uncommon in elderly homes and can be interpreted as a QoL-index with negative numbers.

Having discussed the average weight for people living in nursing homes, we must also discuss how many QALYs will be lost if there is a fire and people get injured. Unfortunately, there have not been many studies of this, even if burn treatment can be very hard to undergo. McMillan (2002) uses burn treatment as an example of negative QoL-weights "The possibility of a negative quality of life is important in QALY theory. Some medical treatments (e.g. for severe burns) have recovery periods

during which (arguably) the patient's quality of life is worse than being dead. In such situations, the first QALYs produced may be negative." (ibid, p. 19). Baker et al. (2008) compared two different ways of measuring quality of life: Quality of Life Questionnaire (QLQ) and SF-36, for young adults burned as children. The results showed that for SF-36 the value was the same as for non-burned, but for QLQ the results showed lower quality of life for burned than for non-burned. Bron and Hay (2001) analyzed whether artificial skin substitute (Transcyte) is more cost-effective than traditional human cadaver allograft (HCA), for patients with total body surface burns. The interesting result here is that, while still in hospital the quality of life is 0.65, but directly after hospital treatment it is 0.54. Sanchez and Bastida (2007) calculated QALYs for burn patients in Valencia, Spain. The QoL-index gain with treatment was 0.26 measured with VAS and 0.36 with TTO. These measures can be seen as the minimum levels of a loss in the QoL-index when burned. The average QoL-index after treatment was 0.87, which means that a maximum level for getting burned could be a loss of around 0.3 - 0.5. Miller et al. (2000) calculated a QoL loss for children suffering from burns to be 0.11.

The empirical evidence above is not clear, not for elderly people in general, people living in nursing homes, or for burn treatments, so it is hard to choose specific QoL-weights. In this study the chosen QoL-weights are 0.6 for the mean value for the elderly in nursing homes. A severe injury is measured by a reduced QoL-weight by 0.5 for 2 months, and a slight injury by a reduced QoL-weight by 0.1 for 2 weeks. Since these reduction numbers can be discussed, a sensitivity analysis of these weights have been performed using Monte Carlo-simulations.

If we have decided upon a QALY for the elderly in nursing homes, what monetary value should we attach to this figure? One way, as for life years, is a direct approach using stated preference willingness to pay questions to find monetary values of QALYs. So far there have not been many studies directly estimating a WTP for QALYs, especially not in Sweden. One recent study incorporating many European countries including Sweden, is the EuroVaQ-project (Donaldson et al. 2010). They estimated the WTP for a QALY both indirectly by first stating standard game and time-trade-questions and then letting respondents value the answers in monetary units and directly answer different WTP questions for different QALY-changes and risk levels. Unfortunately, the project did not sum up the estimations to one specific monetary number for Europe or for the countries involved. The (trimmed) mean results for Sweden from the indirect method vary between US\$19000 and 63000, and from the direct methods between US\$4000 and 58000. The variation in the results seems to reflect the non-linear preference scale for QoL-changes, which is reflected in the discussion on QoL above. There seem to be non-linearities when it comes to both the absolute and

the relative QoL-changes. The WTP for a 0.1 QoL-change is not the same when the change goes from 0.4 to 0.5 compared to 0.7 to 0.8, and the WTP for a 0.2 change is not twice as high as a 0.1 change. Similar difficulties of finding a monetary value for QALYs using stated preference techniques is the conclusion by Pinto-Prades et al. (2009) when trying to estimate a WTP for QALY in Spain.⁹

Another way is to use the value of a VSL and recalculate this into QALYs in the same way as VSLYs are calculated but also taking into consideration that the average QALY is lower than 1 VSLY. Donaldson et al. (2010) used this method to calculate the value of one discounted QALY to SEK 1.02 million, which is considerable higher than both the direct study results above and higher than the (unofficial) Swedish threshold of SEK 500000 (NBHW, 2010). This is the method that will be used in this study.

3. Evidence of sprinkler efficiency

Hall (2010) recently analyzed American fire department statistics from 2003 to 2007 to study the size of the impact of sprinklers and other automatic fire control equipment. He found a very large effect on the number of fatalities. For example, restaurants and bars decreased the number of deaths down to 0, i.e. by 100%, hospitals by 72%, homes by 80%, warehouses and offices by 75% and industrial buildings by 25%. The effect of saved property is also very large when buildings with functioning sprinklers were compared to buildings without sprinklers (or without a functioning sprinkler). For example, sprinklers reduced lost property value by 63% for school and healthcare buildings, by 68% for residential buildings and by 22% for industrial buildings. The problem with this study is that it does not hold other factors affecting the saved value constant, such as response time and strength and size of the fire service and the fire and other fire protective equipment.

Similar effects to those found by Hall were obtained earlier from U.S. data. Butry (2009) used in his cost-benefit analysis of American sprinklers, effect relationships, derived from data for 2002 to 2005, to show a 100% decrease of fatalities in homes with sprinklers, 57% fewer people with injuries and 32% less property damage. However, there is a disclaimer that "part of the estimated sprinkler benefit could in fact be due to the increased performance smoke detectors in dwellings with sprinkler systems." (Ibid., p. 126). Thus, smoke detectors were not controlled for. Butry found that the benefit-cost difference was positive, so sprinklers were economically viable even for "smaller" houses (colonial-style houses). Thomas (2002) also discovered similar positive results in an analysis of

⁹ A theoretical analysis of the problem (impossibility?) of finding a societal WTP for a QALY is discussed by Dolan and Edlin (2002).

U.S. fire data from 1983 and about 10 years onwards. For example, for hotel / motel the effect was 100% in terms of fatalities in fires of sprinklers, and 54% for apartments.

Similar positive results in terms of sprinklers were obtained by Melinek (1993) in a study of British fires in 1987. The conclusion was that if all houses used sprinklers, fatalities would be reduced by half and the number of injuries reduced by 20%. Mostue and Stensaas (2002) conducted a fire experiment and concluded that with sprinklers at least 50 % fewer people will die from fires in nursing homes. Nystedt (2003) shows that residential sprinklers reduce the risk of death by 53% in Sweden. A study by Duncan, Wade and Saunders (2000) from New Zealand takes into account whether the building has smoke detectors or not. The results show that sprinklers only in buildings could reduce fatalities by 80%, and in combination with smoke detectors by 84% (only smoke detectors reduce the number of fatalities by 53%). A Canadian study by Richardson (2009) shows that the number of deaths from fires in care homes for the elderly is 65 % lower with sprinklers installed compared to care homes without sprinklers. Property damages are 40 % lower, but personal injuries are larger in care homes with sprinklers installed. Ramachandran (1998) quotes British and Australian studies to show a mortality risk of about 0.001 for homes with sprinklers, which can be compared with the average risk of 0.01 for a rescue operation in home fires in general, which then implies that sprinklers are very efficient in reducing mortality.

Despite the positive effect of the sprinklers, it is not certain that it is economically efficient to install sprinklers in buildings because the cost is too high. As we saw above, however, Butry (2009) found that installing private homes with sprinklers was economically efficient, whereas a previous study by Harmathy (1988) did not find it profitable. A Swedish cost-benefit study by Juås (1994) used American and Canadian results for the early 80s showing a 44% reduction in deaths and 65% reduction in property damage when sprinkler were used. The costs of sprinkler installation in newly built residential houses (both detached and apartments) were generally too large compared to benefits. Juås also examined the economic efficiency of sprinklers in various industrial buildings, and revealed that sprinklers were only economically efficient in the chemical industry. For hospitals and nursing homes the costs were roughly equal to benefits. Mostue and Stensaas (2002) estimate that the ratio between benefits and costs is between 1 and 4.5 for nursing homes in Norway. All of these studies used the average value of statistical life for valuing saved lives.

Williams et al. (2004) found that benefit- cost ratios in the UK for detached houses and apartments were below one, but sprinklers were economically efficient for nursing homes for the elderly (2.0),

children (4.5) and people with reduced mobility (1.1). Williams et al. also calculated the effectiveness of sprinklers in homes and concluded that they reduced the risk of fatality by 55 -85%, injuries by 15-45%, and property damage by 35-65%.

Gros, Spackman and Carter (2010) performed a cost-benefit analysis of sprinklers in a specially planned construction area outside the UK. They summarized studies from the United States, New Zealand and Britain, and found efficiency figures of a 70% risk reduction for risk of fatality, a 30% reduction of the risk of injury, and a 50% reduction of fire-damaged areas of dwellings. They showed that sprinklers in different homes were not economically efficient with benefit- cost ratios from 0.4 to 0.8. The closest to economic efficiency were sprinklers in so-called "social housing".

Jaldell (2011) analyzed data from emergency incident reports for 2005 to 2008 that took into account both response time and the effects of other fire protection such as sprinklers, fire extinguishers, automatic alarms, etc. There are very few homes in Sweden that have sprinklers installed (only 0.4% of the homes have automatic fire extinguishing systems), making it difficult to find a statistical association. However, it is notable that, during these years, no one died in house fires when the houses had automatic extinguishing systems. In a study of all types of buildings, he noted that sprinklers only had an effect on the fire for restaurants , night clubs and metal industries and on the spread of the fire after the arrival of emergency services for schools and metal industries.

4. Data, assumptions, calculations and results.

All analyses in this section are based on an assumption of a typical elderly home building of 2000 m² with 40 apartments of 50 m² each. This assumption may seem limiting when it comes to general conclusions, and a sensitivity analysis is therefore performed in section 5 to compare the results here with a smaller and a larger building.

Costs

A reasonable technical life of a sprinkler is 25 years according to fire experts. The following costs apply in newly constructed elderly homes per apartment, according to the Swedish sprinkler promotion society of residential sprinklers:¹⁰

Installation costs	8000 SEK
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¹⁰ All monetary figures are in 2010 prices.

Delivery inspection	100 SEK
Maintenance cost	100 SEK
Service agreements (per year)	80 SEK

The costs are assumed to be 37.5 % higher, which means 11 000 SEK for installing residential sprinklers in existing buildings (called renovation here). The other costs are assumed to be the same. Table 1 shows the yearly cost (in consumer prices). The cost is calculated using consumer prices with a value-added-tax (VAT) of 25 % included. The reason for correcting to consumer prices is that the monetary value of the benefits of the reduced risk of dying are given in consumer prices (since they are from stated or revealed preference studies of consumer statements or behaviour). Following the latest Swedish official recommendations, no account is taken of the social marginal cost of public funds (SIKA 2009).

The costs should be seen as approximations and best guesses of the mean values. In an actual bidding process for a real installation of sprinklers, the firms' bids will of course differ and the suggested figures above, even if they are accurate estimates, will not be true in all places all over Sweden. To take this into account, a sensitivity analysis, using Monte Carlo simulations where the costs fluctuate, will be performed in section 5.

In the analyses different data sources with slightly different definitions have been used. Cost data for residential sprinklers has been obtained from the Swedish sprinkler promotion society. Intervention statistics and fire death statistics are based on the classification made by the Swedish fire and rescue services when putting out fires in "elderly homes". The total number of residents in elderly homes comes from the classification of The Swedish National Board of Health and Welfare "special housing".

Table 1 in here

Benefits – “full” life

In order to compare costs, which of course are expressed in monetary units, we also calculate the benefit in monetary terms. The benefit consists of the effect on risk times the monetary value. The effect is calculated in terms of risk reduction in the form of fewer fatalities, fewer serious injuries, fewer minor injuries and less property damage.

Section 3 describes different studies that show divergent results on the efficiency of sprinklers. For simplicity, we have chosen to use the same effect figures of 70 % for both personal and property damage. A sensitivity analysis of this assumption is performed in section 5.

To calculate the property damage, we have not made a new investigation. Instead, we use the value of 648 SEK from Juås (1994), and add an additional 6% to take indirect costs of insurance administration and reimbursement apartments into account. The average value of the property damage is therefore 960 SEK in 2010 prices.

The calculation of the marginal effect of reduced injury has been done by first calculating the risk of harm that would have existed if no one had had sprinklers. This risk is then reduced by the effect of sprinklers and multiplied by the respective monetary value of injury.

The Swedish Civil Contingencies Agency's fire death statistics (2000-2008) have been used and the source for severe and light injuries is the same agency's response data from fire and rescue services for the years 1999-2008. The mean number for these years has been used. The fire death statistics show that the number of fatalities is approximately 2.7 times higher than the fatalities reported in the response statistics. This means that some data are missing and therefore the same correction has also been made for severe and slight injuries.

In 2010, 95,600 people lived in so called 'special housing' for the elderly (National Board of Health and Welfare 2010a). In this study it is assumed that only one patient lives in each apartment. The death and injury risk in special housing for the elderly is much higher than for residents in ordinary Swedish homes. The risk of death in elderly homes is six times greater and the risk of other injuries is ten times greater. When the marginal effect of sprinklers is calculated, the fact that about 10 % of the elderly homes already have sprinklers installed (without this protection there would have been even more deaths and injuries today). The corrected figures in table 2 takes this aspect¹¹ into account, including the likelihood that there are probably missing values for severe and slight injuries in the data set.

Table 2 in here

¹¹ $x*(1-effect)*(share\ of\ buildings\ with\ sprinklers) + x*(share\ of\ buildings\ with\ sprinklers) = y$
 $x*(1-0.7)*0.1 + x*(1-0.1)=4.9$
 $x=5.3$

Monetary values used in the study are the official Swedish values from the transport sector. The reasons for using these are that they are most reliable, since most valuation studies for deaths and injuries have been done within the transport sector when it comes to revealed preference studies, and the transport sector is used as the scenario when it comes to stated preference studies. The monetary values used are 23.8 million SEK for deaths, 4.4 million SEK for severe injuries and 0.2 million SEK for slight injuries.¹²

We must also add savings on hospital and medical costs, ambulance care, fire service, etc. Using a Swedish cost-of-illness study of the costs of fires (MSB 2008), we have tried to calculate these costs for the age group in question in this study. For deaths we add 125000 SEK, for severe injuries 310000 SEK, and for slight injuries 36 000 SEK.

Table 3 in here

Benefits – life years and QALYs

If we were to use QALYs as a measure of reducing injuries, the total effect of sprinklers would be reduced due to three aspects. First, the life expectancy of an average death in traffic is 37 years. The average age of the elderly is much higher and thus their life expectancy is much shorter. Based on the average age and life expectancy in Sweden, the average for that age group is 6.9 years. Second, life expectancy in elderly homes is even shorter. Using the data from the National Board of Health and Welfare (NBHW 2001), in which data are available for different age groups and types, we have calculated the average life expectancy to be 3.2 years.

Third, using QALYs does not only take life expectancy into account, but also quality of life. The weight of quality of life is equal to one for a perfectly healthy human. That the residents of elderly homes do not have a quality of life weight equal to one is self-evident, but it is hard to find empirical evidence for what number to use. The main problem is that the surveys used are not well-formulated for elderly people. Here, we adopt the weight 0.6 for the quality of life in elderly homes and use the information from the studies surveyed in section 2.

The effect of sprinklers measured as life years and QALYs can be divided into an effect on fatality, an effect on serious injuries and an effect on slightly injured. The effect on fatality is obtained by

¹² Values from 2006 adjusted for inflation to 2010.

multiplying the present value of 3.2 years loss of life by the effect of sprinklers on deaths. The effect on severely damaged is calculated by multiplying 2 / 12 with the effect of sprinklers on the severely injured, and the effect on slightly injured is calculated by multiplying 2 / 52 with the effect of sprinklers on minor injuries. All information about the chosen values is given in Table 4.

Table 4 in here

Table 5 in here

Table 5 contains the calculations of monetary values for life years and QALYs. Using life years gives, as expected, a higher monetary value of the effect of sprinklers than using QALYs. One problem with the monetary values of life years is that the values for other injuries, except deaths, become relatively high, since people in elderly homes are only expected to live for another 3.2 years. This will have the effect that deaths and slight injuries have about the same value, which does not seem plausible. Therefore a corrected value is also calculated where the monetary values for severe and slight injuries have been reduced by the same per cent as for deaths. This is probably too much, but the value can then be seen as a minimum value for life year calculation. However, this corrected value is still higher than the total monetary value using QALYs. One additional setback is that the property values share of the total value increases from 32 % to between 50 % and 79 %. Using QALYs as a measure of welfare therefore indicates that personal values are worth much less than material values.

The benefit-cost differences and ratios for the eight cases are shown in table 6. Sprinkler installations in newly built homes for the elderly seem to be cost efficient for society regardless of the quantitative measure used. However, when it comes to installing sprinklers in existing elderly homes, this is only cost efficient when using “full” life values or uncorrected expected life years.

Table 6 in here.

5. Sensitivity and robustness analyses

The values calculated in table 6 have been checked by using several sensitivity and robustness analyses. First, the results have been checked for a change in the interest rate from 4 % to 3 %. Second, the cost efficient results have been checked for the lowest effect values for sprinklers that can be used and still obtain cost efficient results. Third, Monte Carlo simulations have been run for the cost figures assuming different costs with triangle and uniform distributions, as well as for the effect of sprinklers assuming different effects and therefore leading to different benefit values. Fourth, a Monte Carlo simulation has been run for the weights of quality of life assumptions in the QALY calculations. Fifth, to only rely on results from a typical size of an elderly home may seem limited. Therefore two additional assumptions about the size of the elderly home have been considered; one smaller and one larger. Finally, on the 17 November 2011 only Reduced Ignition Propensity (RIP) cigarettes were allowed in Sweden (and in the EU). An analysis of what effect this may have on the benefit – cost ratio has also been performed.

Changing the interest rate

Using a lower interest rate (3 % instead of 4 %) leads to lower annuity costs. The lower interest rate also decreases the benefit values using life years and QALYs (but not full lives). However the two effects are not enough to make the below one B-C ratios turn to over one. The lowest B-C ratios are now 0.92 and 0.88.

Figure 1 in here.

Changing costs and effects

Figure 2 in here.

Figure 2 shows the efficiency percentages needed to still be cost efficient. Using ‘full life’ values, the benefit-cost ratio will still be above 1 even down to sprinkler efficiency of 28 % and 36 % for new and renovation installations, respectively, which means that the results are robust when it comes to the efficiency assumption. Using QALYs the results are not robust; for new installations almost 70 % efficiency is needed, while for renovations 86 % efficiency is needed.

That all sprinkler installations would cost the same irrespective of the firm doing the work, where in Sweden the installation takes place, the local competition among the firms and the design of the

building is not realistic. To take this fact into account, Monte Carlo simulations (10000 repetitions) have been done where the costs vary in certain intervals, assuming a uniform distribution.¹³

Table 7 in here.

It is also reasonable not to consider the benefit side as fixed, but as consisting of random variables. Therefore Monte Carlo simulations (n=10000) have been also performed using different assumptions about the benefit side variables. Looking at data for personal injuries for the years 2000-2008, the yearly injuries vary quite a lot for all three categories, and it is not unreasonable to see them as uniformly distributed. For the injury variables a uniform distribution has been chosen with the range between upper and lower values being the same. The number of dead, for example, varies between 1 and 10 yearly in 2000-2008. For property loss we have no data to estimate a distribution from. Instead we assume a triangular distribution where the value varies +/- 25 %. The effect from sprinklers is also assumed to vary according to a triangular distribution +/- 10 %-units, and the current sprinkler frequency is varied according to a triangular distribution of +/- 5 %-units.¹⁴ Tables A1 and A2 in the appendix contain the descriptive statistics of the Monte Carlo simulation assumptions and results for the benefits and costs.

We could compare the Monte Carlo –simulation results from both the benefit and cost calculations. The different benefits and costs are shown in figures 3-6. It can be seen that the benefits using ‘full lives’ monetary and benefit values are in almost all cases above costs no matter if new installation, renovation, triangular or uniform distribution are assumed. For ‘life years’ the benefits are greater than the costs in almost all cases of new installations and in about 85-90 % of renovations. For ‘corrected life years’ and ‘QALYs’ the distribution for new installation about three fourths and two thirds, respectively, are above the benefit-cost ratio equal to one line. Using costs for renovation installations, only 15 % and 10 %, respectively, of the results have a benefit-cost ratio above 1.

Figur 3 in here.

¹³ A triangular distribution has also been tested. The variation is smaller using a triangular distribution, but the figures 3-6 look quite similar.

¹⁴ It seems reasonable to vary expected life year in elderly homes and the different QALY-weights in a Monte Carlo-simulation. This was also tested, but the results were very similar to those in table 12 and are therefore not discussed in the paper.

Figure 4 in here.

Figure 5 in here.

Figure 6 in here.

Changing the size of the building

Costs have also been calculated for one smaller and one larger elderly home. The smaller home has 13 patients in an area of 520 m² and the larger home has 100 patients in an area of 4000 m². Since there are fixed costs per home the annuity cost increases to 892 SEK for the smaller home and decreases to 604 SEK for the larger home. In figure 7 the benefit-cost ratios for the 'original' size and the two comparisons are shown for all eight cases. For 'larger' homes the B-C ratio is above 1 no matter which benefit measure is used, i.e. sprinkler installations in larger homes are cost efficient for society. For 'smaller' homes, however, the benefit-cost ratios are only above 1 for benefits measured using 'full life' and 'life years'.

Figure 7 in here.

Assuming less risky cigarettes

The last robustness test we consider is the introduction of Reduced Ignition Propensity (RIP) cigarettes. This is the only cigarette type allowed to be sold in the European Union after 17 November 2011. Of course there will be 'old' cigarettes still in circulation, private imports of other cigarettes will still exist and it is also possible that there will be some illegal import of other cigarettes which will be sold in the EU including Sweden. However, for people living in nursing homes, it is reasonable to assume that they will not engage in private import and that they will almost only buy legally sold cigarettes. Given this assumption, how much will the injuries and damages from fires decrease with the new legislation? Here, we use 40 %. The figure comes from Finland where the RIP cigarettes were introduced in April 2010 and the number of fires are said to have been reduced by 43 % (European Commission 2011). From table 2 we know the risk of injury and damage in elderly homes. Looking at the fire statistics we note that most fire deaths are due to smoking, but smoking is not the main cause of the other fire related personal injuries.

Table 7 in here.

The marginal effect from assuming a 40 % reduction of smoking-related injuries and damages is presented in table 7. The total marginal effect is 24 % lower, which affect all comparisons of benefits to costs. The benefic-cost-ratios for all eight cases of different benefits and costs are presented in table 8. The results indicate that sprinklers are cost efficient for society valuing benefits with 'full life', and that sprinklers are cost efficient valuing benefits with 'life years' when building new elderly homes. But for the rest of the cases sprinklers are not cost efficient.

6. Conclusions

The main conclusion of this study is that the result of the cost-benefit analysis of sprinkler installations in nursing homes for elderly depends on what value you put on the elderly. Treating them as having the same value as an average person makes the benefits being greater than the costs, considering sprinkler installation in existing buildings. However, when using remaining life years, VSLYs, avoiding fire deaths brings the benefits closer to the costs. If quality adjusted life years, QALYs, are used instead, as is standard in health economics, the benefits are lower than the costs. In other words, it is the value we put on the elderly that decides the outcome of the cost-benefit analysis and therefore affects the decision on whether to install sprinklers or not. This conclusion seems to be robust when it comes to variations in the installation cost levels and efficiency levels for sprinklers in reducing fires. When performing a study like this, one would ideally want to have the "correct" ethical value for the elderly in nursing homes. One would also like to know how people's preferences about using VSLs, VSLYs, and QALYs vary. More research on these topics is wished for.

Another conclusion that can be drawn is that there are many uncertainties about variables and parameters used in the cost-benefit analysis. There are uncertainties about how to convert a monetary value of statistical lives to a monetary value of statistical years and, even more difficult, to a monetary value of QALYs. There are uncertainties in finding quality of life weights to be used for the QALY. Not much research has been done on finding a value for elderly people, and especially for elderly people in nursing homes. Even if the standard methods (e.g. time-trade-off and standard gamble) used today to find quality weights seem to result in different weights depending on the method used, the problem of finding appropriate ways to value the lives of elderly people in nursing homes is greater. There are also uncertainties about changes in QALYs from fires, when it comes to directly lost QALYs and won QALYs from burn treatment. More research in this area seems appropriate. However, the sensitivity analyses using Monte Carlo simulations in this study show that perhaps the chosen QALYs does not affect the outcome of the cost-benefit analysis too much.

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Appendix

Cost item	SEK, base case	Assumption	Mean	Stddev
		Uniform distribution		
Installation costs new installation	8000	± 1/4	7998.4	226.5
Installation costs renovation	11000	± 1/4	10996.5	313.4
Delivery Inspection per apartment	100	± 1/3	100.03	3.78
Maintenance per hospital per apartment	100	± 1/7	99.98	1.61
Service agreements	80	± 1/8	79.99	1.11
Annuity new installation	804		805.20	92.22
Annuity renovation	1044		1045.40	126.76

Table A1 Descriptive statistics costs Monte Carlo Simulation (n=10000).

Benefit item	Base case	Assumption range	Assumption distribution	Mean	Stddev
Dead	4.9	± 92 %	Uniform distribution	4.91	2.12
Severe injuries	4.1	± 85 %	Uniform distribution	4.09	1.96
Slight injuries	29.8	± 77 %	Uniform distribution	29.80	1.78
Property loss	960 SEK	± 1/4	Triangular distribution	961.7	97.26
Effect from sprinkler	70 %	± 1/7	Triangular distribution	70.00	4.11
Current sprinkler frequency	10 %	± 1/2	Triangular distribution	9.95	2.04
Benefit 'Full life'	2171			2174.2	475.1
Benefit 'Life years'	1389			1390.5	235.5
Benefit corrected 'life years'	903			904.4	111.6
Benefit 'QALYs'	849			850.3	99.9

Table A2 Descriptive statistics benefits Monte Carlo Simulation (10000 iterations).

Tables

	Installation costs (excl VAT)	Present value of all costs (excl VAT)	Annuity of cost (incl VAT)
New constructions	8000	10053	804
Renovation constructions	11000	13052	1044

Table 1 Costs for residential sprinklers in elderly homes per apartment.

	Number per year (actual)	Number per year (corrected)	Risk per person Elderly homes (corrected)	Risk per person All other homes (corrected)
- Deaths	4.9	5.3	0.0000512	0.00000849
- Severe injuries	4.1	12.0	0.0001167	0.00001062
- Slight injuries	29.8	87.2	0.0008486	0.00007924
Property value per apartment	960 SEK	960 SEK		

Table 2 Risk of personal injury and property damage

	Risk reduction effect (70 % effect)	Risk reduction effect per apartment (70 % effect)	Marginal effect in monetary values
- Deaths	-3.7	-0.0000551	924 SEK
- Severe injuries	-8.4	-0.0000878	416 SEK
- Slight injuries	-61.1	-0.0006387	159 SEK
Property value per apartment	-672 SEK		672 SEK
<i>Total</i>			<i>2171 SEK</i>

Table 3 Effect with full life calculations using sprinklers.

	Assumptions:	Source:
QALY full health (one year)	1	
QALY death (one year)	0	
QALY severe injury (one year)	0.5	Own estimate from section 2
QALY slight injury (one year)	0.9	Own estimate from section 2
QALY elderly home (one year)	0.6	Own estimate from section 2
QALY average Sweden (one year)	0.8	Burström et al. (2001)
Lost life years road traffic deaths	37 years	Own calculations using data from Statistics Sweden
Expected life years in Sweden with same average age as in elderly homes	6.9 years	Own calculations using data from Statistics Sweden and National Board of Health and Welfare
Expected life years in elderly homes	3.2 years	Own calculations using data from National Board of Health and Welfare
Expected illness length severe injury	2 months	Own estimate
Expected illness length slight injury	2 weeks	Own estimate
Hospital costs etc deaths	125000 SEK	Own calculation using MSB (2005)
Hospital costs etc severe injuries	310000 SEK	Own calculation using MSB (2005)
Hospital costs etc slight injuries	36 000 SEK	Own calculation using MSB (2005)
Monetary value life year	1 244 000 SEK	Estimated using value of statistical life from transport sector and 37 lost life years. (4 % interest rate)
Monetary value QALY	1 556 000 SEK	Monetary value life year + 1/average quality of life weight in Sweden ((4 % interest rate)

Table 4 Assumptions and values for life years and QALYs.

	Monetary values 'life' years per apartment	Monetary values using corrected 'life' years per apartment	QALY per apartment	Monetary values with QALYs per apartment
- Deaths	142 SEK	142 SEK	0.0000683	106 SEK
- Severe injuries	416 SEK	63 SEK	0.0000073	11 SEK
- Slight injuries	159 SEK	24 SEK	0.0000025	4 SEK
Total injuries	717 SEK	229 SEK	0.000078	121 SEK
Hospital costs etc.	(incl. above)	(incl. above)		55 SEK
Property value per apartment	672 SEK	672 SEK		672 SEK
<i>Sum</i>	<i>1389 SEK</i>	<i>903 SEK</i>		<i>849 SEK</i>

Table 5 Effect on life years and QALYs with sprinklers.

	Monetary values 'full life' per apartment	Monetary values 'life' years per apartment	Monetary values using corrected 'life' years per apartment	Monetary values with QALYs per apartment
Benefits	2171 SEK	1389 SEK	903 SEK	849 SEK
Costs new	804 SEK	804 SEK	804 SEK	804 SEK
B-C difference	1367 SEK	585 SEK	99 SEK	44 SEK
<i>B-C ratio</i>	<i>2.70</i>	<i>1.73</i>	<i>1.12</i>	<i>1.06</i>
<hr/>				
Benefits	2171 SEK	1389 SEK	903 SEK	849 SEK
Costs renovation	1044 SEK	1044 SEK	1044 SEK	1044 SEK
B-C difference	1127 SEK	345 SEK	-141 SEK	-196 SEK
<i>B-C ratio</i>	<i>2.08</i>	<i>1.33</i>	<i>0.86</i>	<i>0.81</i>

Table 6 Benefit-costs relations.

	Number per year (actual)	Number per year (corrected figures)	Number due to smoking per year (actual)	Number per year assuming 40 % reduction of smoking related injuries (corrected figures) ¹⁵	Marginal effect in monetary values 70 % effect
- Deaths	4.9	5.3	3.8	3.6	638 SEK
- Severe injuries	4.1	12.0	1.3	10.5	364 SEK
- Slight injuries	29.8	87.2	2.4	84.4	154 SEK
Property value per apartment	960 SEK	960 SEK	?	720 SEK	504 SEK
					<i>1659 SEK</i>

Table 7 Risk and marginal effect of personal injury and property damage assuming use of Reduced Ignition Propensity (RIP) cigarettes.

¹⁵ For property value a 25 % reduction is assumed, which can be compared to the 31 % reduction in number of deaths, 13 % in the number of severe injuries and 3 % in the number of slight injuries. The corrected figures include the effect of probable missing data for severe and slight injuries and the aspect that 10 % of the elderly homes already have sprinklers.

	Monetary values 'full life' per apartment	Monetary values 'life' years per apartment	Monetary values using corrected 'life' years per apartment	Monetary values with QALYs per apartment
Benefits	1659 SEK	1119 SEK	735 SEK	640 SEK
Costs new	804 SEK	804 SEK	804 SEK	804 SEK
B-C difference	854 SEK	315 SEK	- 69 SEK	-164 SEK
<i>B-C ratio</i>	<i>2.06</i>	<i>1.39</i>	<i>0.91</i>	<i>0.80</i>
Benefits	1659 SEK	1119 SEK	735 SEK	640 SEK
Costs renovation	1044 SEK	1044 SEK	1044 SEK	1044 SEK
B-C difference	614 SEK	75 SEK	-309 SEK	- 404 SEK
<i>B-C ratio</i>	<i>1.59</i>	<i>1.07</i>	<i>0.70</i>	<i>0.61</i>

Table 8 Benefit-costs relations assuming use of Reduced Ignition Propensity (RIP) cigarettes.

Figures

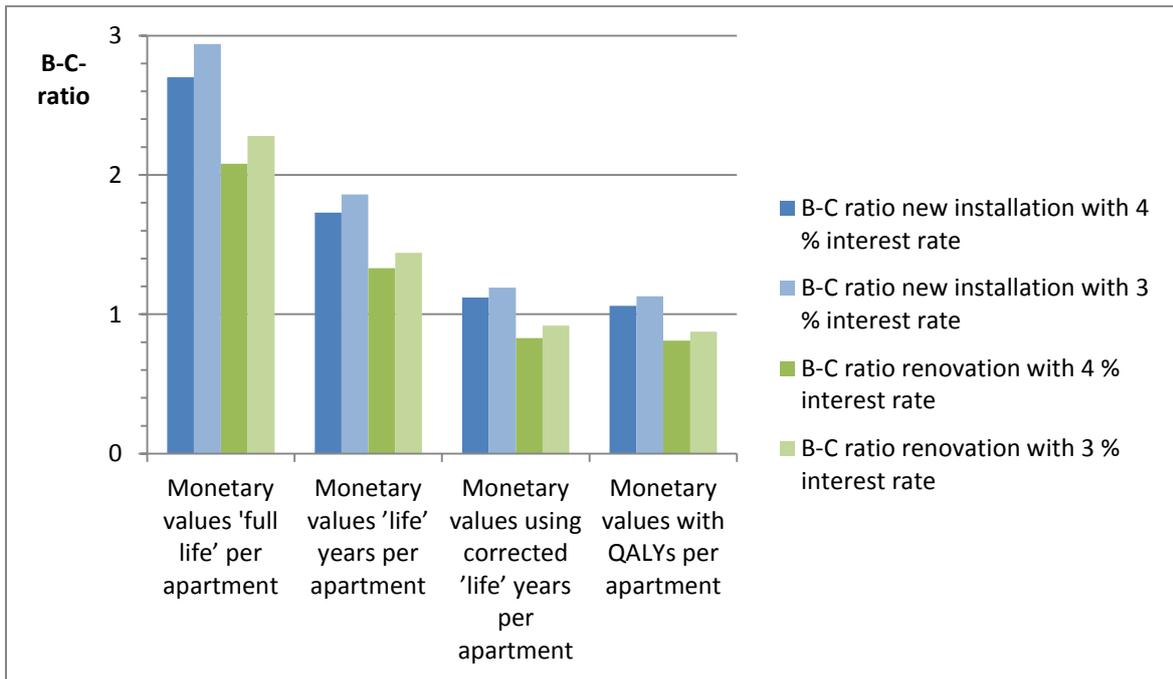


Figure 1 B-C-ratios using 4 % and 3 % interest rates.

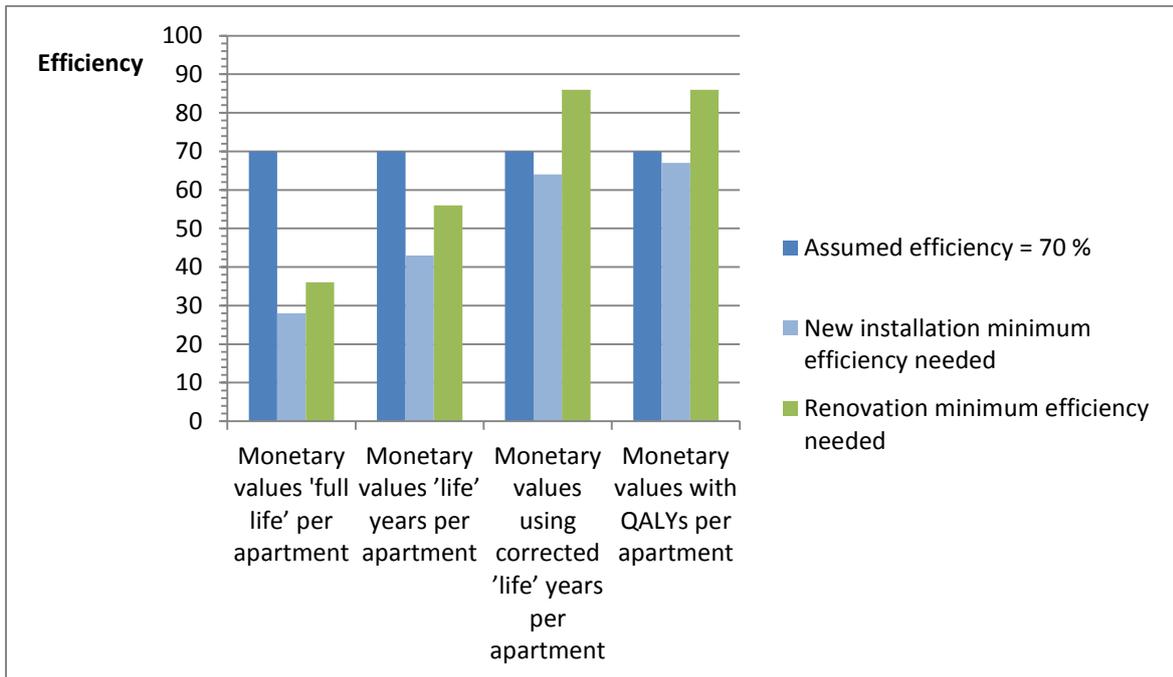


Figure2 Efficiency of sprinklers needed to still be cost efficient for society.

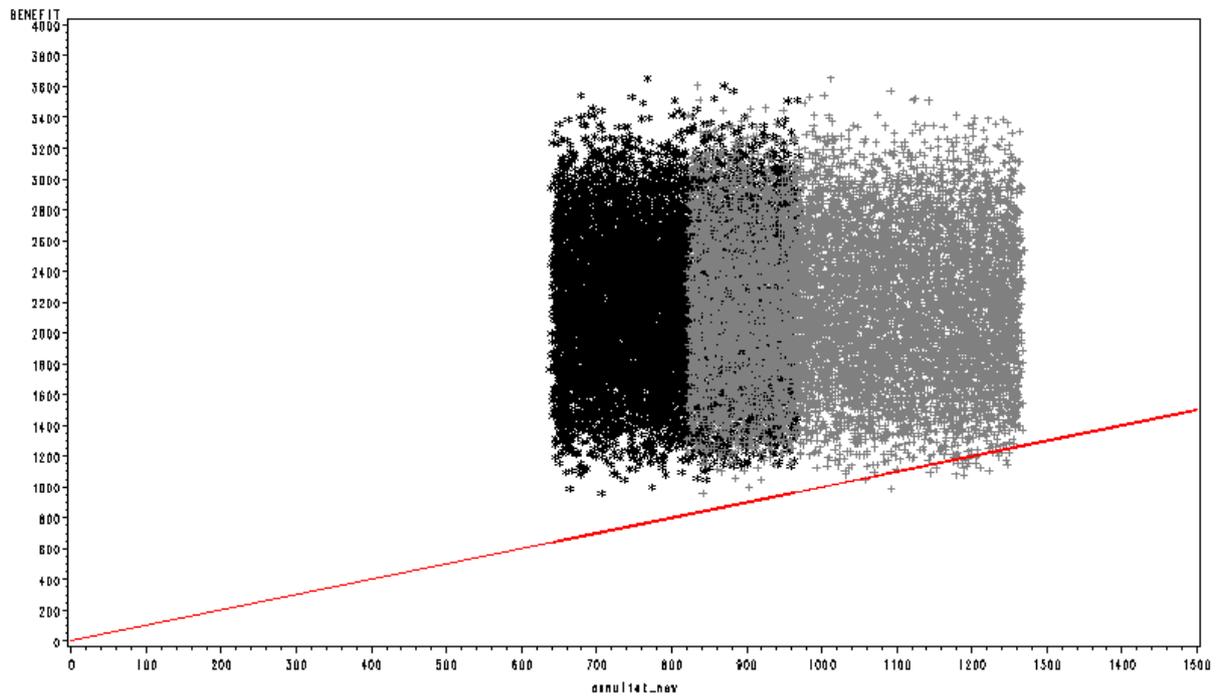


Figure 3 Benefit-costs comparisons with Monte Carlo-simulations (n=10000) for benefits='Full life' and costs (black=new, grey=renovation). The red line is where the benefit-cost ratio is 1.

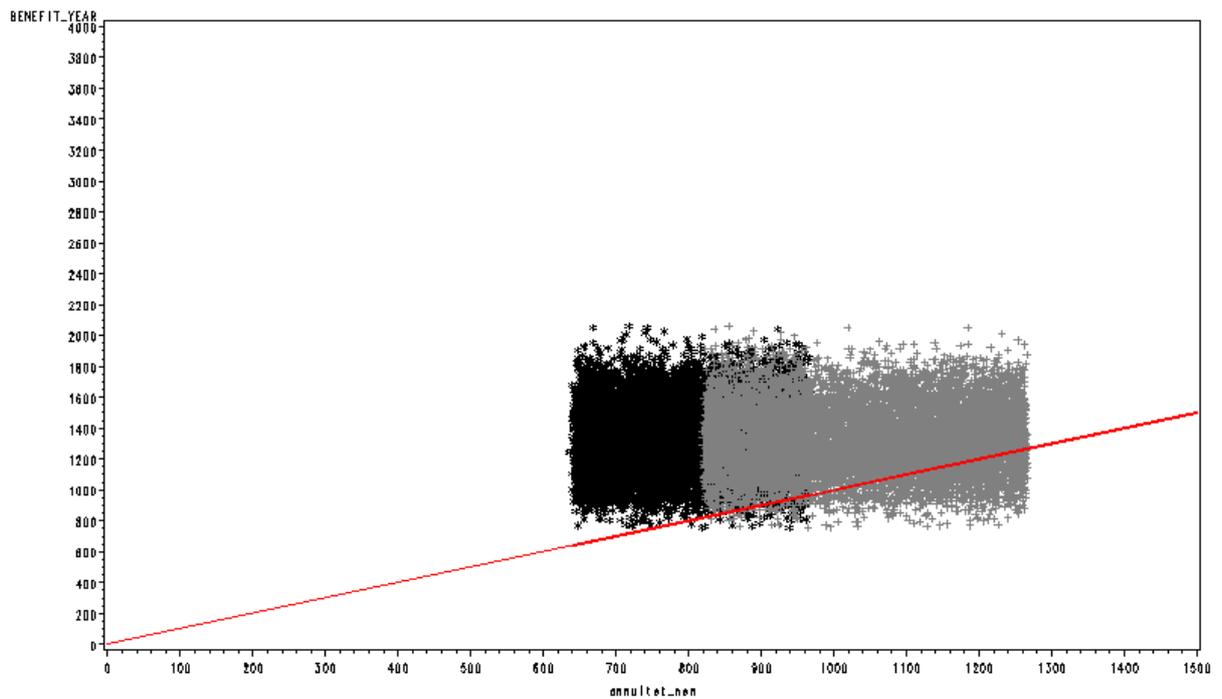


Figure 4 Benefit-costs comparisons with Monte Carlo-simulations (n=10000) for benefits='Life years' and costs (black=new, grey=renovation). The red line is where the benefit-cost ratio is 1.

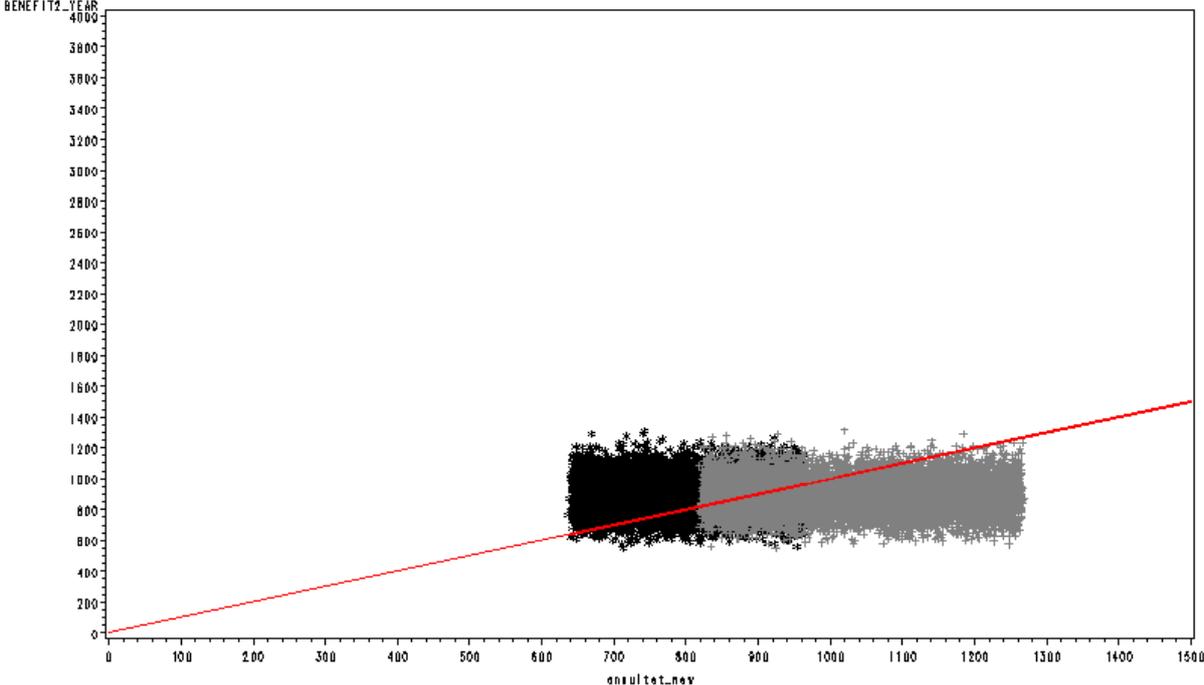


Figure 5 Benefit-costs comparisons with Monte Carlo-simulations (n=10000) for benefits='corrected Life years' and costs (black=new, grey=renovation). The red line is where the benefit-cost ratio is 1.

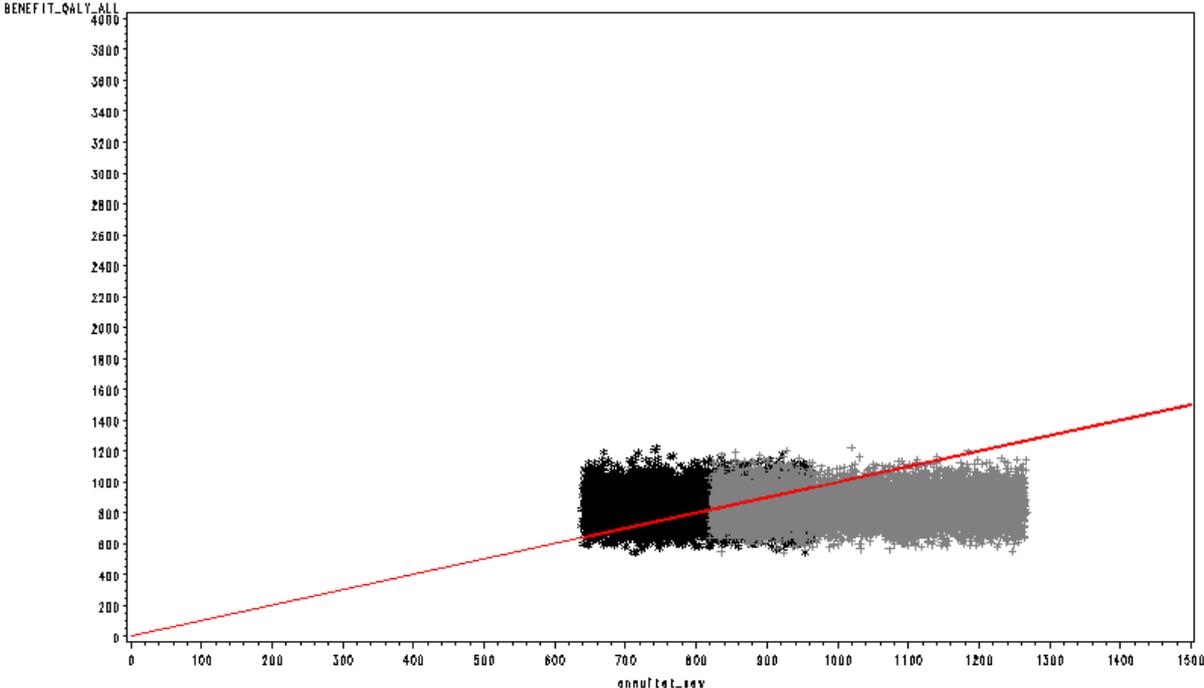


Figure 6 Benefit-costs comparisons with Monte Carlo-simulations (n=10000) for benefits='QALY' and costs (black=new, grey=renovation). The red line is where the benefit-cost ratio is 1.

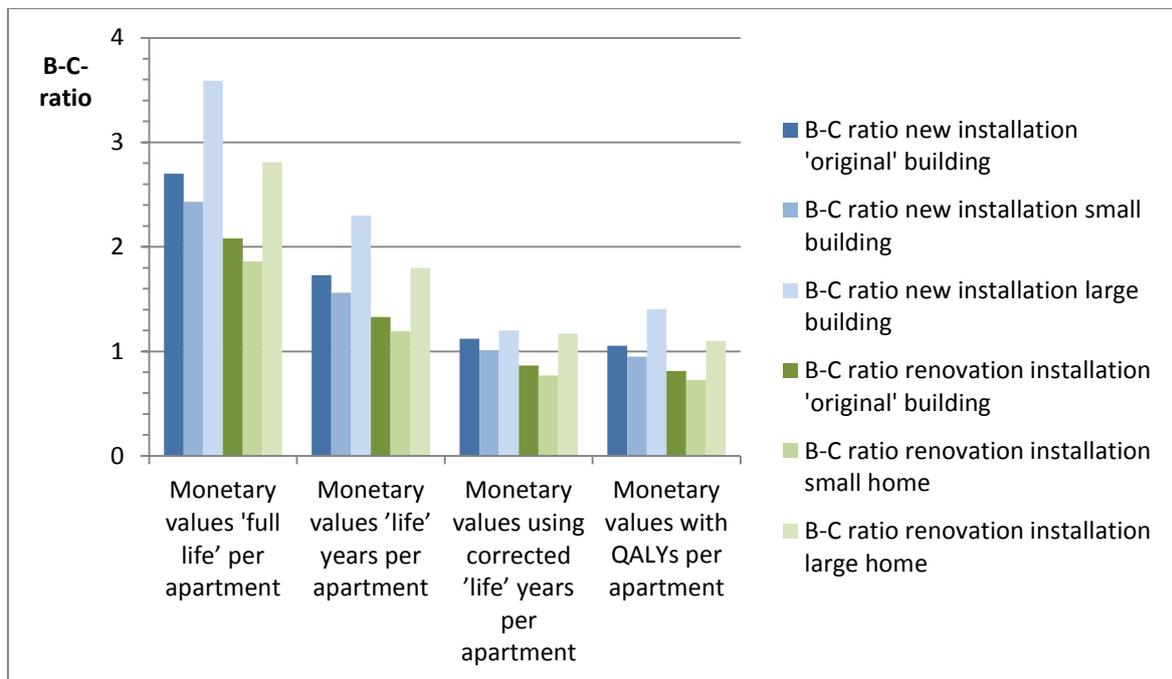


Figure 7 B-C-ratios for different sizes of homes for elderly.