C o n t e n t s p a g e

EXECUTIVE SUMMARY

SUMMARY

The Department of Trade and Industry introduced the Furniture and Furnishings (Fire) (Safety) Regulations in 1988. This was as a result of a rising number of house fires and deaths resulting from polyurethane foam filled furniture. At that time, furniture caused 7.5% of all house fires but resulted in 35% of all deaths in fire. These Regulations specify that the fillings and coverings of all furniture should pass stringent flammability tests. These tests are stricter than any used in continental Europe.

With the benefit of almost ten years of fire statistics since the introduction of these Regulations the Department commissioned the University of Surrey to evaluate if the number of lives lost due to furniture fires had indeed reduced and also to see if the overall benefits of the Regulations outweigh the costs to industry. The result of this evaluation is given in this report.

The findings are extremely good news. Looking just at simple statistics for fires started in upholstered furniture in the home, it can be seen that in 1992, 4 years after the introduction of the Regulations, there were at least 65 fewer deaths than in 1988. In 1997 there were 138 fewer deaths than in 1988 and by 1997, as a conservative estimate, the Regulations had saved at least 710 lives following their introduction.

These 710 lives have probably been saved because upholstered furniture complying with the Regulations did not catch fire. In addition where a fire started in another item but involved upholstered furniture in the house, furniture complying with the Regulations will not catch fire as quickly as non-compliant furniture, thus allowing occupants more time to escape from a fire. This is particularly relevant where smoke alarms detect the fire early. These additional benefits could mean that the actual number of lives saved could be as high as 1860 in the period from 1988 to 1997.

The Furniture Regulations have also resulted in a decrease in the growing number of injuries in fires that have occurred over the last 30 years. There were 526 fewer recorded injuries from fires started in upholstered furniture in 1992 compared to the trend that existed in 1988 and there were 1,126 fewer in 1997. This means that at least 5,770 fewer people were injured in fires as a result of the Regulations.

This report also looks at experiences in the USA which does not have stringent Furniture Regulations as in the UK. The USA has seen a small and progressive reduction in the number of residential fire deaths since 1978. However, the USA has not seen a significant drop in fatalities from fires started in upholstered furniture despite the fact that smoke alarms detected at least 50% of all residential fires. Smoke alarms have played a role in reducing deaths in the UK and when alarms are operating correctly the risk of death in a fire detected by a smoke alarm can be as low as 4 per 1000 fires compared to 9 per 1000 fires where an alarm is not present. This report concludes that further gains can be made by better use of smoke detectors. The conclusion to be drawn from this is that gains from the Furniture Regulations could be even larger if smoke alarms are present and effectively operating during a fire.

This report considers the cost of these regulations to industry and those who buy furniture. The cost is between £15 and £20 per item of furniture which is a total cost of £22 million to £30 million a year. Based on insurance industry loss-adjusted estimates of the cost of serious fires in 1997, the annual cost saving arising from upholstered furniture meeting the Regulations was estimated to be £53 million. However, using previous DTI commissioned work on the value of a statistical life of £3 million, the actual economic benefit in 1997 is about £1.1 billion (excluding injury and indirect costs of fire) and this gives a benefit to cost ratio close to 40:1.

Since 1988 it has not been possible to buy new upholstered furniture in the UK which does not comply with the stringent flammability tests required by the Furniture Regulations. However, some households still have furniture that they obtained before the introduction of the Regulations. The possible full benefits of these Regulations have not been realised to date. Manufacturers estimate that their upholstered furniture lasts between 8 and 15 years and future potential savings based on this lifetime range are given in the report.

The benefits of the Regulations are likely to be realised most by those people who experience the highest incidence of fires such as the financially challenged who would tend to buy cheaper lower quality furniture and young children between 1 and 4 years of age and the elderly, both of whom may be more involved in starting fires and who are also the most vulnerable when escaping from fire.

1 BACKGROUND AND SCOPE

In 1988 the UK Government introduced regulations to improve the fire performance of furniture and furnishings and related products (the Furniture and Furnishing Fire Regulations, (HMG, 1988, 1989)). This followed a series of major home fires involving furniture that led to a statistically disproportionate loss of life for these consumer products in the period before the introduction of the regulations.

The Polymer Research Centre was commissioned by the Department of Trade and Industry to carry out a study to assess the current and future potential benefits arising from the introduction of the Furniture and Furnishing Fire Regulations (FFRs). This followed earlier PRC work, which critically reviewed the risks and benefits of flame retardant use in consumer products (Stevens and Mann, 1999).

The objectives for the study were to:

1. Examine pre- and post-regulation trends in UK Fire Statistics and the British Crime Survey to construct a retrospective analysis of pre-regulation trends and a prospective analysis of post-regulation, current and future trends.
2. Account for the potential contribution to the statistics arising from the installation of smoke detectors and alarms in UK dwellings using British Crime Survey information.
3. Construct a model to account for the consumer-use lifetime of pre- and post-regulation furniture and bedding in the UK economy using data obtained from the furniture and bedding manufacturers, their retailers and trade bodies.
4. Account for contributions arising from UK demographic trends in the size of the population, the number of households and other factors that could influence the volume of pre- and post-regulation furniture and bedding stored within dwellings in the economy.
5. Draw direct comparisons with trends in another country where such regulations have not existed and where the quality of fire statistics would support a reasonable retrospective and prospective analysis. It was decided that the United States would be a good candidate.

In carrying out this study the authors would like to acknowledge the assistance of several organisations. These are listed in Appendix 1.

2 THE REGULATIONS IN PERSPECTIVE

In their original form the regulations sought to address the fire resistance of upholstered furniture. This was extended to include indoor and outdoor furniture and coverings and upholstery on bedding (HMG 1988, 1989). Further information on the regulations can be found in a DTI guide (DTI, 1996).

Whilst the regulations were introduced in November 1988, they came into force progressively. From 1 November 1988 all fabric and polyurethane (PU) foams used in the construction of furniture were required to be of a fire resistant type. Requirements on the fire resistance of other filling materials applied from the 1 March 1989. Finally, second hand furniture for retail sale was required to meet the regulations on 1 March 1993. Recent work for DTI suggests that very little second hand furniture is being sold that does not meet the regulations.

In the case of mattresses, including cot mattresses, the controls are slightly different. In this case the filling materials were required to meet the regulations for PU foams (NB: now known as combustion modified types). However, the regulations did not specify fire resistant requirements for the cover fabric of mattresses; these are governed by voluntary standards and come under General Product Safety regulations.

Discussions with organisations representing the furniture and furniture fabric industries (see Appendix 1) suggest that designers and manufacturers were able to respond well to the rapid introduction of the UK regulations. This occurred as a result of development and standardisation/testing work taking place in the decade or more leading up to the introduction of the regulations and the willingness of the industry collectively to seek improvements in fire resistance.

In all cases the regulations do not stipulate the means by which the fire resistance standards are to be met; they are therefore performance centred and manufacturers can elect to meet them in whatever ways are appropriate.

In summary, the regulations affect the following consumer products:

(i) all indoor and outdoor upholstered furniture, foam and loose fillings, permanent and other covering fabrics

(ii) mattress foam fillings

(iii) all second hand upholstered furniture for retail sale

These are expected to meet fire resistant ignitability tests according to various British Standards including BS 5852, part 1, (1979), BS 5852: Part 2 (1982) or BS7177 which in turn makes reference to BS6807 which requires cigarette and match ignition resistance. These are specified in a DTI guide to the Furniture Regulations. In the main these requirements appear to be met by the use of chemical flame retardant systems included in combustion modified foams and in back-coating for covering fabrics.

3 SOURCES OF INFORMATION

3.1 UK Fire and Demographic Statistics

UK fire statistics were taken from the Home Office, Fire Statistics Reports; individual reports back to 1966 were consulted. UK population statistics were taken from the 1961, 1971, 1981 and 1991 decennial census reports. Inter-census estimates of population were provided by the Office for National Statistics. Data on the number and occupancy of households, including forecasts to 2016, were provided by the Department of the Environment, Regions and Transport (DETR) HDS Division.

The UK demographic data and raw fire statistics data are discussed in Appendix 2.

3.2 UK Furniture and Bedding Production

Production and sales data were provided by Business and Research Associates in their reports on The UK Market for Upholstered Furniture (September 1997) and The UK Market for Beds and Bedding (July 1997). Older data is also available in a FIRA report (FIRA, 1993).

3.3 UK Economic Impacts

Economic impacts were assessed using a variety of sources. Data on costs associated with insurance industry calculated loss-adjusted fire claims was provided by the Fire Protection Association. More general data on direct fire costs in the home environment was obtained from the 1995 British Crime Survey results (Home Office, 1997). Account was also taken of the costs associated with loss of a statistical life; this was set using recent work for the DTI on this subject (Ball et al, 1998).

We have been unable to find any accepted method for calculating the cost of fatal and non-fatal injuries and indirect costs and externalities associated with fires in dwellings. We have therefore attempted to assess this using the available loss-adjusted data combined with UK fire statistics and the DTI Consumer Safety Unit's adopted value of a statistical life to obtain an estimate of the likely range of possible cost savings associated with the impact of the regulations.

3.4 US Fire and Demographic Statistics

US fire statistics were provided by the Directorate for Economic Analysis, US Consumer Product Safety Commission in Washington D.C. US population and household statistics were obtained from US Government Census Office web pages and updated using the same web addresses. These sources are summarised in Appendix 3. Information on US smoke detector experience was obtained from the US National Fire Protection Association (NFPA, 1997).

4 STATISTICAL TRENDS IN UK HOUSEHOLD FIRES

Detailed UK dwelling fire statistical trend data are given in Appendices 2 and 4. Here we discuss some of the more important key findings. In all cases the fire statistics data are corrected for demographic changes by expressing the number of fatalities and injuries in terms of per million of the population to remove variations in total population. This data is also corrected for the number of smoke alarms in dwellings; in this case the parameter of interest is multiplied by $(1 + f_s)$ where f_s = fractional proportion of fires detected by smoke detectors; so, if 25% were detected the data would be multiplied by 1.25. In the case of UK data these corrections are small while for US data they are more significant.

4.1 Fatal Injuries

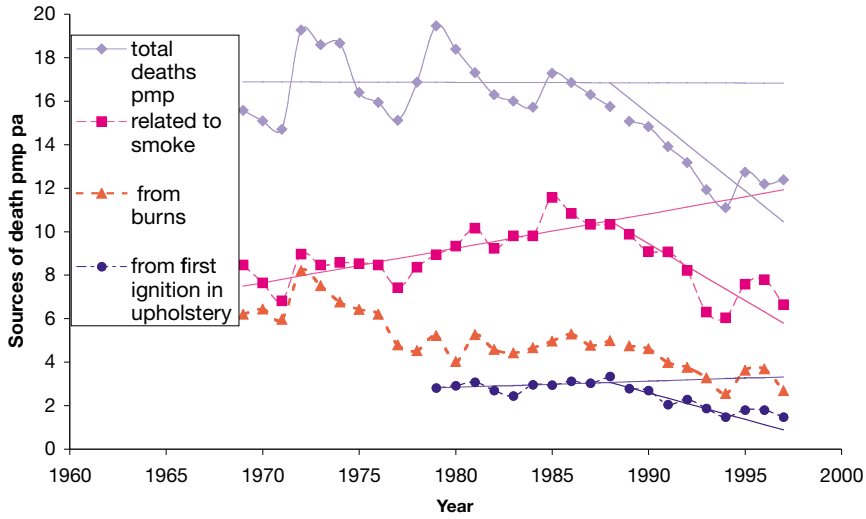
Using the demographic data in Appendix 2 and correcting for the effects of smoke alarms, some of the more important trends in fatal injuries in UK dwelling fires are shown in figure 1.

Against a background where the total number of UK dwelling fires and injuries have continued to increase, the total number of deaths per million of the population (pmp) before 1988 appear to be generally constant within the large statistical fluctuations of the data. After 1988 there is a very clear and significant downward trend. In contrast, the number of fatal injuries pmp related to smoke inhalation increase prior to 1988, a trend which is opposite to that for the number of fatal injuries caused by burns which show a steady decrease. Indeed, these last two trends appear to account for the level trend in the total number of fatalities pmp.

Significantly, the number of fatal injuries caused by smoke inhalation show a clear downward trend after 1988 whereas the pre-1988 downward trend in the number of fatal injuries caused by burns appears to be unaffected by the introduction of the regulations.

If we focus on the number of fatal injuries pmp associated with upholstered furniture being the first item ignited, we see a trend change similar to that of the total number of fatal injuries. This trend is not repeated for bedding as discussed in Appendix 4. This suggests that the post-1988 trends in the total number of deaths and injuries related to smoke is largely influenced by upholstered furniture either acting as first item ignited or as a fuel source following some other cause of the fire.

Figure 1 Pre- and post 1988 UK trends in fatal fire injuries.



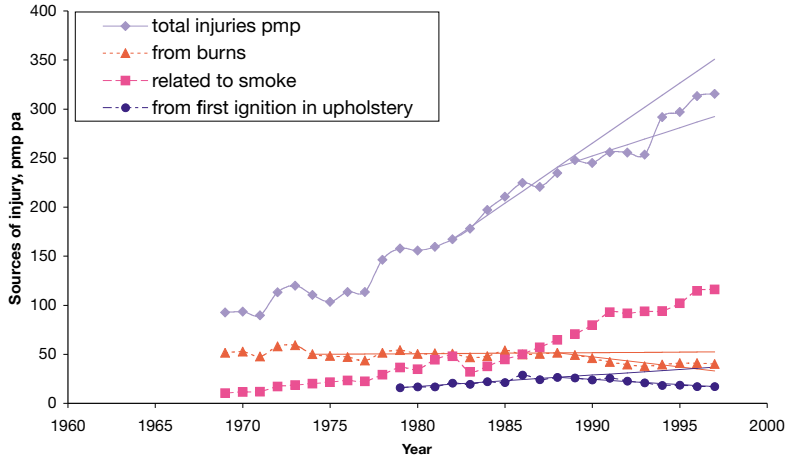
It is also clear that the absence of a change in the trend for fatal injuries caused by burns indicates that most of the post 1988 reduction in fatalities is related to smoke and toxic gas inhalation.

The linear fits to the data are produced using least square fitting and the post-1988 fit is pinned to an intercept of zero with the pre-1988 trend. This approach is clearly acceptable for the data for smoke-related deaths and those arising from upholstery as the first item ignited. It appears to be less acceptable for the data on total number of dwelling deaths however we have sustained this to maintain consistency recognising that fluctuations in the statistics could accommodate the differences that exist.

4.2 Non-Fatal Injuries

Demographic and smoke alarm corrected trends in the number of non-fatal injuries across the introduction of the regulations are shown in Figure 2.

Figure 2 Pre- and post 1988 UK trends in the number of non-fatal fire injuries.



Against a background of a constantly increasing total number of non-fatal injuries pmp, Figure 2 shows clear reductions in the rate of growth post-1988 with similar trends shown by the number of non-fatal injuries related to burns and due to upholstery being the first item ignited.

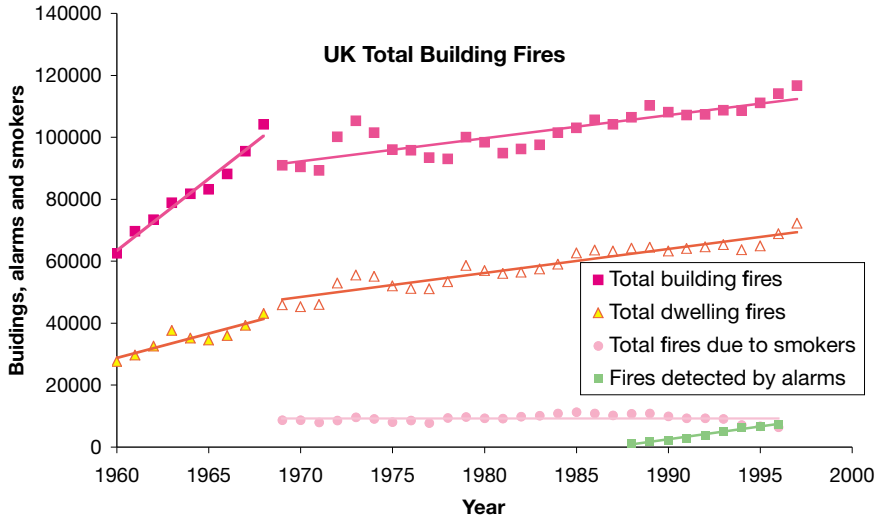
Interestingly no such change is seen in the case of non-fatal injuries arising from smoke inhalation in dwelling fires; this shows an uninterrupted progressive increase. We believe this reflects the precautionary trend in the UK for the fire authorities to refer people who are exposed to fire atmospheres to hospital for check ups and that most of these casualties will be considered to be suffering from the affects of smoke inhalation. This is to be contrasted with the change in trend for fatal injuries (figure 1) where death is a much more definitive indicator of effect.

4.3 The Influence of Smoke Detectors and Alarms

The effects of smoke detectors and alarms on fire statistics were first reported in 1988. The post-1988 increase in the number of dwelling fires detected by smoke alarms is shown in figure 3 in the context of other statistical trends. It is clear that in the UK the impact of smoke alarms has been small and the number of fires detected by alarms is currently only around 1 – 2% of the total (Stevens and Mann, 1999) and about 10% -12% of the number of dwelling fires in 1997.

Figure 3 shows the number of fires detected by alarms increasing from 1,100 in 1988 to 6,600 in 1995. Other information indicates that detection times of less than 5 minutes currently apply to only around 68% of dwelling fires (Home Office 1997a). However this is very small in comparison with the estimated 750,000 fire incidents and the more than 65,000 serious dwelling fires reported in 1995.

Figure 3 UK dwelling fires discovered by fire alarms from 1988 to 1995 (Home Office, 1997a) compared to the total numbers of fires



Further analysis of the statistics indicates that alarms have a beneficial effect on reducing fire fatalities with a death rate of 4 per 1000 fires when fires are detected by alarms in comparison with 9 per 1000 fires when fires are not discovered by alarms. This should be compared with the 1995 UK average of 8.7 deaths per 1000 fires.

However in 1995 only 11% of dwelling fires were detected by smoke alarms despite a MORI poll survey of the general UK public in January 1997 showing that 79% of households owned an alarm and 73 % of households had them installed. This compared with ownership levels of 70% in 1996 and 45% in 1994. This disparity in detection versus ownership of smoke alarms is explained by the high number of alarms that were fitted but unable to detect the fire due to poor or inappropriate positioning or because they simply were not working. UK statistics indicate that 66% of fitted alarms did not respond to fires for these reasons (1997 Fire Statistics Bulletin).

Hence the clear potential benefit of smoke detectors and alarms as a fire-risk reduction measure is currently not being fully realised because of the low numbers of fully functioning alarm installations in dwellings. We would expect a similar finding for other European countries.

4.4 Statistical Trends With Age

The effect of age on the frequency of fatalities and non-fatal injuries is shown in figures 4 and 5 respectively. In the case of fatalities the 5 yearly trend data shows that the greatest impact is on the older adults (60+ years old) and young children (from 1 to 4 years of age). In the case of fatalities both age groups have experienced a reduction in the number of fatalities per annum whilst other age groups have remained largely unchanged with time. This clearly shows that

the most vulnerable groups in domestic fires are the elderly and young children. This is probably a consequence of these age groups being responsible for causing more fires and for being less able to escape from fires without assistance.

Figure 4 Trend in the number of fatalities in household fires in the UK including the effect of age.

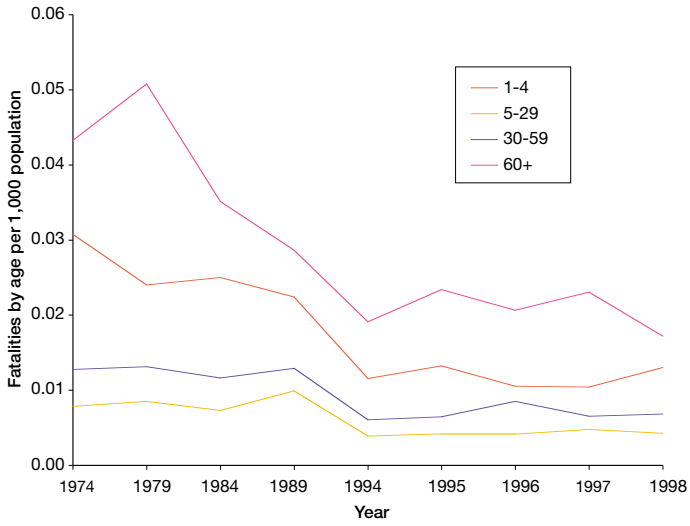
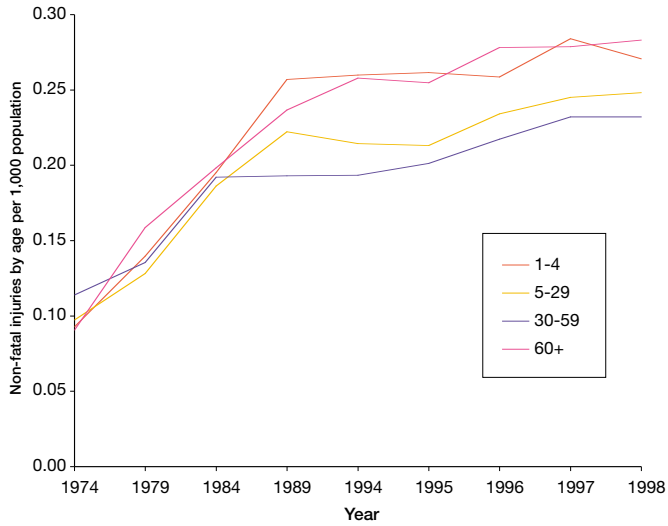


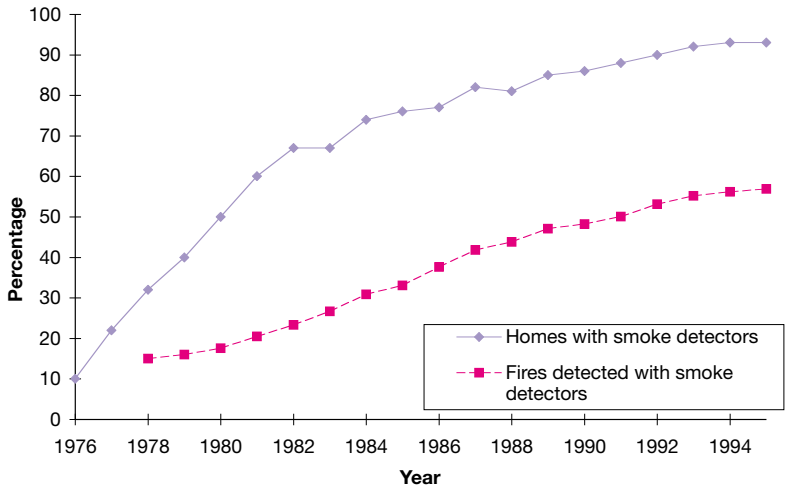
Figure 5 Trend in the number of injuries in household fires in the UK including the effect of age.



5 STATISTICAL TRENDS IN US RESIDENTIAL FIRES

US fire statistics trends in the last two decades appear to be dominated by the influence of smoke alarms, in contrast to the position in the UK. As shown in figure 6, in the period from 1976 the number of homes containing fire alarms has increased to over 90% of the total (although not all may be working effectively) and over 50% of domestic fires are now first detected by a smoke alarm. This has progressively contributed to reducing the total number of serious fires, deaths and injuries.

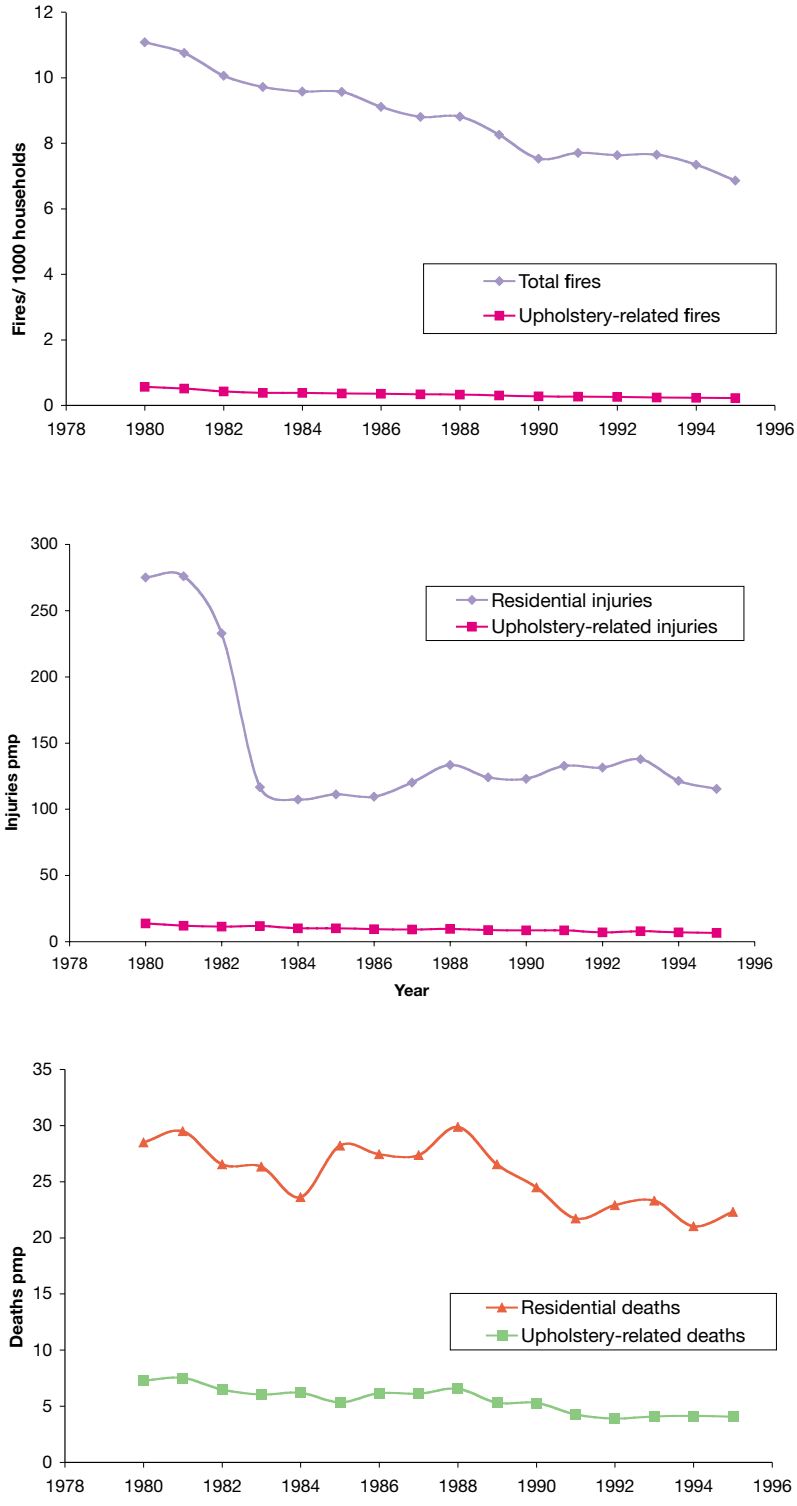
Figure 6 US smoke alarm household penetration and fire detection rate



In order to make comparisons with UK fire statistics, the US data has been corrected for demographic changes and for the effect of smoke alarms. Some of the key results are shown in figure 7 in terms of the number of fires, deaths and injuries per household or pmp. With the exception of an anomalous step reduction in the number of injuries between 1980 and 1983, the trends are continuous and show level or small reductions in each of the statistical measures considered. The cause of the step change in residential fires injuries between 1980 and 1983 is unknown but we assume it is due to a change in the data collection or the reporting method.

There is no evidence for a change in statistical trends similar to that observed for the pre- and post-1988 UK dwelling fire statistics and all key indicators show a slow but progressive reduction in time.

Figure 7 US fire statistics corrected for demographic changes and the influence of smoke alarms.

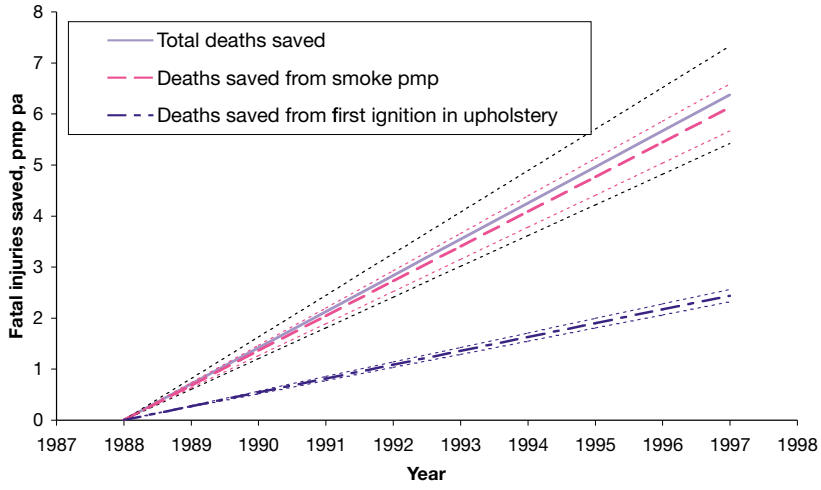


6 POST 1988 LIFE, INJURY AND ECONOMIC SAVINGS

6.1 Life Saving Benefits

The life saving benefits can be determined by comparing the pre- and post-1988 projections. Pre- and post-1988 trends have been projected forward to 1997 using a simple linear least squares fitting model. This analysis and the errors associated with the projections are discussed in Appendix 5. By subtracting the pre- and post-1988 projections in figure 1 where the intercept is set to give a zero difference in 1988 it is possible to estimate the number of fires, deaths and injuries saved, as shown in figure 8.

Figure 8 UK non-fatal injury savings pmp per annum from 1988 (dotted lines correspond to the 95% confidence limits)

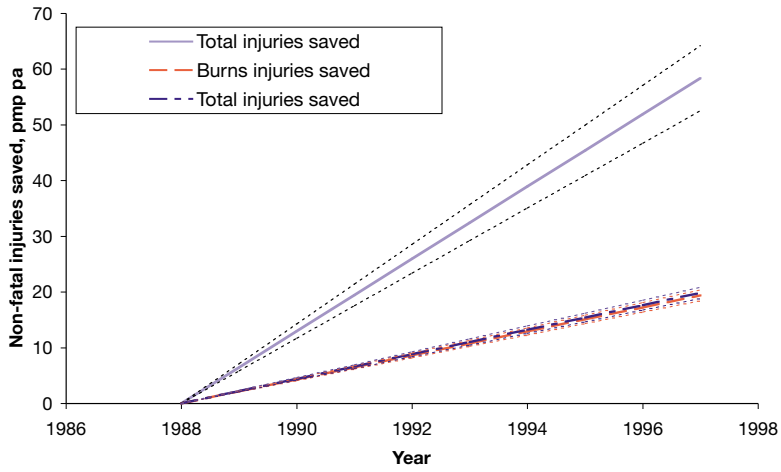


This indicates that in 1997 an overall annual life-saving benefit of 6.0 pmp per annum was achieved against a historic trend of around 17 pmp per annum; this is close to 362 lives saved in 1997. In the case of fatal injuries saved that can be directly attributed to upholstered furniture as the first item ignited, the corresponding benefits are 2.4 lives pmp per annum or around 138 lives saved in 1997. Since the introduction of the regulations the cumulative saving amounts to around 12 lives pmp (around 710 since 1988).

6.2 Injury Saving Benefits

The number of total non-fatal injury savings pmp and that for burns and upholstery are shown in figure 9.

Figure 9 UK non-fatal injury savings pmp per annum from 1988 (dotted lines correspond to the 95% confidence limits)



In 1997 the estimated gross annual injury savings amount to 56.2 pmp per annum (close to 3,315 injuries saved in total). For injuries saved in relation to upholstered furniture as the first item ignited, the actual saving amounted to 19.1 pmp per annum (or around 1,126 injuries in total).

6.3 Economic Losses and Benefits

The insurance industry data on loss-adjusted fire claims was provided by the Fire Protection Association and Appendix 6 discusses their conditional criteria and the data we have used to assess the cost savings estimated from this claims data. We have also taken the DTI Consumer Safety Unit's assumed cost associated with the loss of a standard statistical life as £3m.

The average insurance loss-adjusted cost per fire claim was approximately £60,400 in 1997 (it has been around this value for the last 13 years – see Appendix 6) based on a total claim figure of £5.9m. Since 1988 the number of claims involving fatalities has been in the range 15-30% of the annual number of reported dwelling fire fatalities from the UK fire statistics. Similarly, the number of large claims (according to the criteria given in Appendix 6) is only around 0.24% of the annual number of UK dwelling fires and this percentage has been progressively decreasing over the last decade.

This suggests that the FPA loss-adjusted fire claims annual costs are not representative of the actual losses experienced across the UK as a whole. If taken at face value they would be expected to significantly understate the true losses. However, we have elected to use the average annual loss-adjusted cost per fire claim to estimate what the true costs might be. In this case we assume that around 10% of reported dwelling fires would result in losses comparable with those of loss-adjusted fires. This appears to be a reasonable starting point because the number of dwelling fire fatalities is around 10-12% of the total number of reported fires and as little as 15% of dwelling fatalities appear in loss-adjusted claims (all of which contain fatalities).

For 1997 this would account for a loss of £415m on the basis of the loss-adjusted average for this year, in contrast to the £5.9m actually reported. In 1995 the loss would be £351m according to this approach. This 1995 figure is almost identical to that given in the British Crime Survey for 1995 (HMG, 1997b) which estimated £355m for all home fires and just over £300m for those fires that were reported i.e. fires to which the fire brigade was called. This should be contrasted with costs based solely on the value attached to a statistical life; in 1995 the total loss by this measure was about £1.7bn. In turn this can be compared with the 1995 loss-adjusted claim total of £7.7m.

Using the same unit costs we can calculate the effective cost saving benefits resulting from the regulations. In 1997 the loss-adjusted savings would be £53m and the life-saving benefit would be about £1.08bn; in 1995 the corresponding savings would be £36m and £868m respectively. Further annual and cumulative economic benefits are given in the next section.

It is also possible to calculate the cost of dwelling fires per fatal casualty in the US and for the UK. These are remarkably close with the US being £810k per fatal injury and the UK £650k per fatal injury using the 1995 estimates.

6.4 Annual and Cumulative Benefits and Costs

In order to gauge the progressive growth in lives saved, injuries reduced and economic benefits arising from the introduction of the regulations, we summarise in Table 1 the 1992 and 1997 annual benefits and the cumulative benefits from 1988 to 1997.

Table 1 Change in annual savings benefits and cumulative benefits of the regulations up to 1997

Benefit Measure	1992 Annual Benefit	1997 Annual Benefit	1988-1997 Cumulative Benefit
Number of dwelling fires	3,715	8,769	42,754
Total lives saved	169	362	1,856
Lives saved for upholstery as item first ignited	65	138	710
Total non-fatal injuries saved	1,548	3,315	17,000
Injuries saved for upholstery as the first item ignited	526	1,126	5,774
Loss-adjusted cost saving, £m p.a.	23	53	249
Fatality cost saving, £m p.a.	507	1,085	5,567
Total cost saving, £m p.a.	**530**	**1,138**	**5,615**

Critically we could ask " *how many of these benefits could be solely ascribed to the introduction of the regulations?* ". We suggest the minimum position is that of lives and injuries saved for upholstered furniture as the first item ignited; this gives cumulative figures of 710 lives and 5,774 injuries. The corresponding minimum cost savings would be a pro-rata of the first-item ignited life saving, i.e. £2,150m. We believe the actual savings are closer to the "total lives saved" row in Table 1.

In this analysis we have not attempted to critically assess the corresponding costs of achieving these benefits. However, discussions with the furniture and coverings industry indicate that the additional cost of treatment is between £15 to £20 per unit of furniture. For the expected 1997 annual production of around 1.5m furniture units (see section 7.1) this would amount to approximately £22.5m to £30m per annum (£225m to £300m cumulative since 1988) or around 2.3% to 3.1% of total sales revenue. This would produce a benefit:cost ratio of around 2 based on insurance industry cited loss-adjusted savings for 1997 and a benefit:cost ratio of 38 for the more realistic total cost savings we estimate for 1997 – a large economic benefit in relation to the costs. This assessment also places no value on the social impacts of fire or on the externality costs of fires.

Interestingly, these estimates compare with UK furniture retailers and manufacturers allocating £214m and £28.5m respectively to direct advertising in 1996 of which about 14% is spent on upholstered furniture advertising, i.e. ~£34m p.a. This compares with total sales of £980m on upholstered furniture and around £3b for the total sales of domestic furniture in 1996 (Business and Research Associates, 1997a).

7 FUTURE UK PROSPECTIVE TRENDS AND BENEFITS

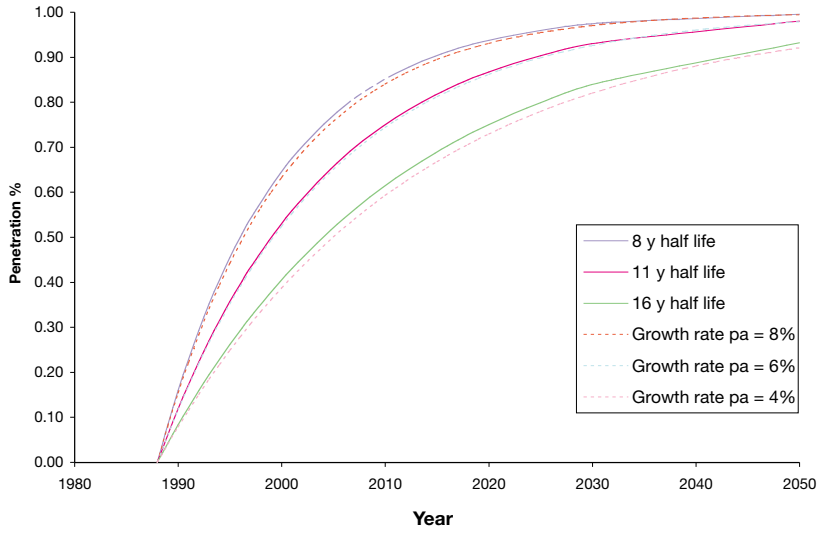
7.1 Furniture and Bedding Production and Replacement Trends in the UK

The furniture production index remained approximately constant over the period 1985 to 1996, with a small peak in 1988 (Business and Research Associates, 1997a). Production estimates for the first half of 1997 are quoted as 0.77m units of furniture; so in round terms we assume that the actual number of units produced is close to 1.5m per annum.

Table 3 Estimate of annual number of units of bedding sold

	1994	1995	1996
Interior spring mattresses	3.1m	3.0m	3.1m
Upholstered bases	2.3m	2.4m	2.5m
Divan beds			1.9m

Figure 10 Penetration of furniture, based on scenarios of half-lives of 8, 11 or 16 years, solid lines (equivalent to penetration rates of 8, 6 and 4% pa respectively, dashed lines)



The corresponding most recent bedding production figures are given in Table 3 (Business and Research Associates, 1997b). Again, to a first approximation the number of units sold each year is constant.

Using the above figures it is estimated that the number of households buying a unit of upholstered furniture per year is approximately 6% of the total and the number buying a unit of bedding is approximately 12%. A unit of furniture could, for instance, be a 3-piece suite or a single chair. It is assumed that a unit of bedding is sufficient for one bed, with an average of 2.5 to 3 units of bedding (bedrooms) per household.

The percentage penetration (PN) of the market by new upholstered furniture since 1988 has been estimated using these figures and an exponential penetration growth model has been used of the form:

$$P_n = (1 - e^{-kt}).100\% \qquad [1]$$

Where k is the annual rate of penetration, shown as the dash lines in graph of figure 10.

The solid lines of figure 10 show that these annual replacement figures equate to half-lives of 8, 11 and 16 years (i.e. 50% of households change their furniture every 8 to 16 years). The equivalent penetration curves based on annual percentage change have been calculated at 8%, 6% and 4% of the old furniture population, which was taken to be 100% in 1988. Thus the fraction of new furniture in the population is calculated using the formula:

Current year's % population of new furniture = $\{1 - P_n.$(previous-year % population of old furniture)$/100\}.100\%$

i.e. $N_{n,i} = \{1 - P_n \,.\, N_{o,i-1}/100\}.100\%$ [2]

In both calculations, it is assumed that the overall rate of production and UK sales of furniture remains constant, as known for the period 1985 to 1996.

7.2 Estimating Prospective Benefits

Post-1998 forward projections of the savings in the number of fires, deaths and injuries are dependent on making assumptions about a) the rate of penetration of the market by new furniture (P_n), b) the effectiveness (E_I) of the regulations (and the measures that satisfy the regulations) in reducing the incidence of fire and c) its consequences (e.g. deaths, injuries etc.). In general, we can say that the number of savings (S) is a function (F) of the product $P_n.E_{n,i}$ where P_n is also a function of time. Mathematically:

$$S = F\,[\,P_{n(t)}.\,E_I\,] \qquad [3]$$

It is impossible to separate the 2 variables at this point in time from the data available. The best we can do is make assumptions about $P_{n(t)}$ and use the existing data to infer the effects of E_I.

Note that $P_{n(t)}$ and E_I must change in opposing senses if the savings product is to fit the existing data, i.e. the more rapid the assumed penetration, the less effective the regulations must be to give the same result. The corollary therefore is also true, that the scenario with the highest assumed rate of penetration of new furniture will give the lowest predicted savings when $P_{n(t)}$ approaches 100%. The question to answer is "*when will the savings plateau out and at what level?*".

Plotting S against $P_{n(t)}$, as estimated as above, gives a clue to the value of E. The relationship turns out to be a simple power law function of the form (as shown in Annexe 5):

$$S = A.P_{n(t)}^{B} \qquad [4]$$

Where A and B are constants which vary according to the penetration function chosen; between them the constants set the maximum value of S as P(t) approaches 100%. We can use the penetration scenarios of figure 10 as the best upper, lower and middle case options currently available. The values of A and B for each case are given in Table 4.

Table 4 Power law function constants for fire saving expression.

Scenario	A	B
Lower: 4% of households buying new per annum	718	1.169
Middle: 6% of households buying new per annum	909	1.121
Upper: 8% of households buying new per annum	1223	1.082

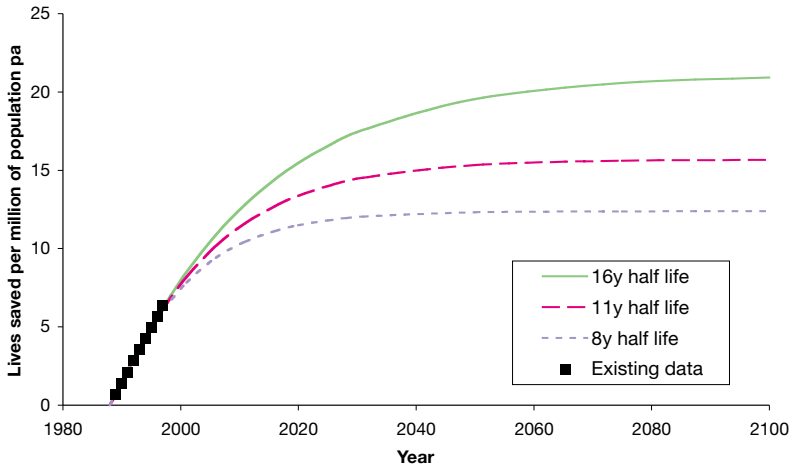
Projecting these figures forward, we can predict a middle-case scenario saving of 836 fires per million households per annum by the year 2031, with lower and upper case figures of 702 and 1012 and average savings of 882 and 902 by 2050 and 2100 respectively. Using the same techniques for deaths and injuries, we calculate average number of lives saved of 19.5 and 20.9 per million of population per annum by 2050 and 2100 respectively and corresponding injuries saved of 179 and 192 pmp per annum by 2050 and 2100.

7.3 Prospective Long Term Benefits

We follow the same approach as that used to assess post-1988 benefits to estimate the prospective post-1998 long-term benefits of the regulations. In this case we consider the prospective number of lives saved, injuries reduced and economic benefits arising. These are considered fully in Annexe 5.

By way of illustration the projected number of lives saved for the 3 furniture replacement scenarios is shown in Figure 11. It is clear that the upper case scenario (4% pa replacement condition with a replacement half-life of 16 years) has the longest time to plateau of the 3 cases but it produces the largest long term saving. This case also sets the time scales for full achievement of the benefits. We have taken this to be 2100 for the 16-year half-life case and 2030 for the 8-year half-life case.

Figure 11 Projected number of lives saved for different furniture penetration scenarios



In Table 5 we compare the prospective annual and cumulative savings in the years 2010 and 2031 for the lower case scenario in which the annual replacement rate is 4% - this is the most conservative case to consider.

Table 5 Prospective annual and cumulative benefits of the regulations up to 2031

Benefit Measure	2011		2031	
	Annual	Σ	Annual	Σ
Fires saved, x1000	16.1	94	21.3	142
Lives saved	644	3,833	791	5081
Injuries saved, x1000	5.9	35.1	7.25	46.5
Cost saving, £M	93	1268	112	1,406
Cost savings on fatalities at £3M per fatality, £M	1,933	26,695	2,373	36,000

This lower case scenario demonstrates that the medium to longer-term prospective annual and cumulative benefits are substantial in relation to pre-1988 trends.

8 DISCUSSION

Examination of the fire statistics data demonstrates very obvious changes in trends after the introduction of the regulations. This is particularly true for fatal and non-fatal injuries despite a strong upward trend in the case of non-fatal injuries. It is also true for data on upholstered furniture as the item first ignited but it is less clear for beds. This is perhaps not too surprising as upholstered furniture fires are more common and potentially more serious than bedding fires. As a consequence of this we made no attempt to assess the benefits arising from any change in bedding performance. Indeed we assume that these savings will be integrated into the total number of dwelling fire fatal and non-fatal injuries which are used to assess gross benefits.

UK and US fire statistics that have been corrected for demographic changes and the influence of smoke alarms provide a very effective comparison to underscore the change in trends seen in the UK post-1988. No corresponding change is seen at all in the US data but what is observed is a progressive reduction in fatal and non-fatal injuries arising from the steady and now significant penetration of smoke detectors and alarms in US residences over the last 20 to 25 years. Smoke detectors in the UK have not achieved the same success as in the US. Despite this it is clear that further US reductions are possible and this could be achieved via additional passive and active fire safety measures.

Our calculation of benefits relies on the linear fits we have obtained to the pre- and post-1988 fire statistics data which have been corrected for demographic changes and the influence of smoke alarms. Whilst the statistical fluctuations can be large the fit of pre-1988 data over 20 years or so and of post-1988 data is reasonable and provides a good estimate of the actual benefits achieved by the regulations to date. We estimate that the uncertainty in our projections is typically ± 10%.

In contrast, the fit of our post-1988 market penetration model for new furniture and the separation of the penetration curve from the effectiveness parameter is a matter for further discussion and refinement if the uncertainties are to be reduced. Despite the uncertainties, the range of effectiveness for the 8 to 16 year half-life cases suggests that if we have a long replacement cycle for furniture the remaining long term benefits will be very large in comparison with the benefits that have been realised to date.

Care is required in the interpretation of the data we present because it is likely that those households with lower incomes and/or greater monetary problems may be more inclined to purchase furniture having a shorter replacement cycle. If this is combined with the observation that such households carry much higher risk factors (up to 3 times greater than the best performing households – Stevens and Mann 1999) then most of the benefits may actually accrue to the shorter replacement-cycle furniture. If this is true the 8-year half-life case is the most relevant.

The 8-year half-life case produces the lowest effectiveness of the three scenarios we have considered. Indeed in this case most of the benefits of the 1988 regulations will be realised by the year 2030 (see Figure 11 and Figure A5.8) and the plateau saving level will be around 12

lives saved pmp in contrast with a pre-1988 loss of 17 lives pmp. This amounts to an effectiveness of 70% which is probably the most conservative case. This compares with an achieved effectiveness in 1997 of 35% corresponding to an overall life saving benefit of 6 pmp per annum. So at the time of writing we have probably experienced just over half the maximum potential benefit of the Regulations.

In contrast the 11-year half-life case will produce an effectiveness close to 88% while the 16-year case exceeds 100% at plateau (see Figure A5.8), a result which is meaningless unless the pre-1988 background trend is increasing. We are therefore inclined to believe that reality sits somewhere between 70% and perhaps 90% effectiveness in relation to the 1997 level of 35%.

This range of 35%-achieved to 90%-prospective future benefit is precisely the range of potential effectiveness assessed for flame retardants used in high risk consumer products such as upholstered furniture and televisions. This was based on several lines of evidence including laboratory and fire test results expressed in terms of risk reduction (Stevens and Mann 1999).

These benefits are realised most by those in society who experience the highest incidence of fires. These are the financially challenged who would also tend to buy cheaper lower quality furniture having shorter lifetimes. The other groups include young children between 1 and 4 years of age and the elderly, both of whom may be more involved in starting fires and are also the most vulnerable when escaping from fire.

9 CONCLUSIONS

1. Significant life saving and injury reduction benefits have resulted from the introduction of the Furniture and Furnishings (Fire)(Safety) Regulations in 1988 (the Regulations) in the UK. Corresponding benefits relate to reductions in the number of serious dwelling fires and in cost savings arising from reduced property loss and from lives saved.

2. In 1997 an annual life-saving benefit of 6.0 per million of the population (pmp) per annum was achieved as a result of the introduction of the Regulations. This compares with a pre-1988 dwelling fatality trend of 17 pmp per annum. This is equivalent to 362 lives saved in 1997. The corresponding benefit for fires first ignited in upholstered furniture is 2.4 lives pmp per annum, equivalent to 138 lives saved in 1997. Since the introduction of the regulations the cumulative saving amounts to around 12 lives pmp which is equivalent to 710 lives saved since 1988. In 1997 the estimated gross annual injury savings amounted to 56.2 pmp per annum (close to 3,315 injuries saved in total). For injuries saved in relation to upholstered furniture as the first item ignited, the actual saving amounted to 19.1 pmp per annum (or around 1,126 injuries in total).

3. We calculate the effective cost saving benefits resulting from the regulations to be £53m on a total estimated cost of £415m in 1997 (in comparison to the £5.9m reported by the insurance industry) using insurance loss-adjusted cost data. There is a further £1.08bn for the life-saving benefit based on a figure of £3m for the value of a standard statistical life. The estimated minimum cumulative cost saving between 1988 and 1997 is £2.15bn based upon lives and injuries saved in upholstery related fires.

4. In relation to the costs of meeting the regulations, we estimate the benefit: cost ratio to be around 2 based on the grossly underestimated but reported insurance loss-adjusted savings. In contrast a benefit: cost ratio of 38 is achieved using more realistic cost savings estimates.

5. Against a background where the total number of UK dwelling fires and injuries have continued to increase, the total number of demographically corrected deaths before 1988 appear to be generally constant at around 17 pmp per annum. After 1988 there is a very clear and significant downward trend.

6. In contrast, the number of demographically corrected non-fatal injuries related to smoke inhalation increases with time both before and after 1988. Significantly however, there is a clear reduction on the rising number of injuries after 1988. Interestingly the pre-1988 downward trend in the number of fatal injuries caused by burns appears to be unaffected by the introduction of the regulations.

7. Post-1988 trends in the total number of deaths and injuries related to smoke is largely influenced by upholstered furniture either acting as first item ignited or as a fuel source following some other cause of the fire.

8. Against a background of a constantly increasing number of non-fatal injuries over the last 30 years there is a clear reduction in the rate of growth after 1988. Similar trends exist for the number of non-fatal injuries related to burns where upholstery is the first item ignited.
9. We estimate prospective future life savings of 790 fires per million households per annum by the year 2030. For deaths and injuries, we calculate that the average number of lives saved will be at least 12 pmp per annum and injuries saved 110 pmp per annum by 2030. These translate to total annual fire and fatality cost savings of £2.4bn by 2030.
10. Smoke detector penetration into UK domestic dwellings is modest and appears to have had little affect on post-1988 trends. This is in contrast to US trends where a progressive reduction in fatal and non-fatal injuries per capita, recorded since 1976, has resulted from a significant penetration of smoke detectors into residential buildings. This penetration has been matched by a significant number of residential fires being detected by smoke detectors in comparison with very small numbers being detected in the UK. Poor positioning and maintenance of smoke detectors in UK dwellings is the prime cause.
11. There is no evidence for a decrease in the rate of change in US residential fire statistical trends compared to that which occurs in the UK following the introduction of the 1988 furniture fire regulations.
12. We estimate the eventual long-term life-saving effectiveness of the introduction of the 1988 regulations to be 70% in the most conservative case, related to short furniture lifetimes (i.e. 8 year half-life), and potentially up to 90% or more for longer lifetimes. This compares closely with the levels of risk reduction previously estimated for the use of flame retardants in high risk consumer products.
13. These benefits are realised most by those in society who experience the highest incidence of fires. These are the financially challenged who would tend to buy lower quality furniture having shorter lifetimes. The groups include young children between 1 and 4 years of age and the elderly both of whom may be more involved in starting fires and are also the most vulnerable when escaping from fire.

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