Mortality Projections in the United Kingdom

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Abstract

In common with other developed countries, the United Kingdom has experienced a dramatic fall in mortality rates over the course of the 20th century. This paper discusses the key forces likely to influence U.K. mortality in the 21st century, and describes the methodology and assumptions used in the latest projections of U.K. mortality. The paper also describes recent tables of mortality rates published by the Continuous Mortality Investigation, based on the experience of people taking out insurance contracts and the approaches taken to projecting these.

1. Introduction

The population of the United Kingdom is projected to increase over the coming decades; at the same time, the proportion that are elderly is also projected to increase, mainly as a result of increasing longevity and the ageing of the baby boomers born in the 1950s and 1960s. As a result, the proportion of the population aged 65 and over is projected to increase by 63 percent, and those aged 75 and over by 76 percent over the next 25 years.

This paper discusses past mortality trends in the United Kingdom and some of the factors likely to influence future trends. It outlines the methodology used for projecting mortality rates as part of the official national population projections for the United Kingdom and describes the assumptions used in the latest 2006-based national population projections for the United Kingdom. These projections are used by U.K. government departments to provide a common framework for planning and policy decisions. They are also used for costing benefits and assessing contributions to the U.K. National Insurance Fund.

The paper also describes recent tables of mortality rates published by the Continuous Mortality Investigation, based on the experience of people taking out insurance contracts and the approaches taken to projecting these.

2. Mortality Trends in the United Kingdom

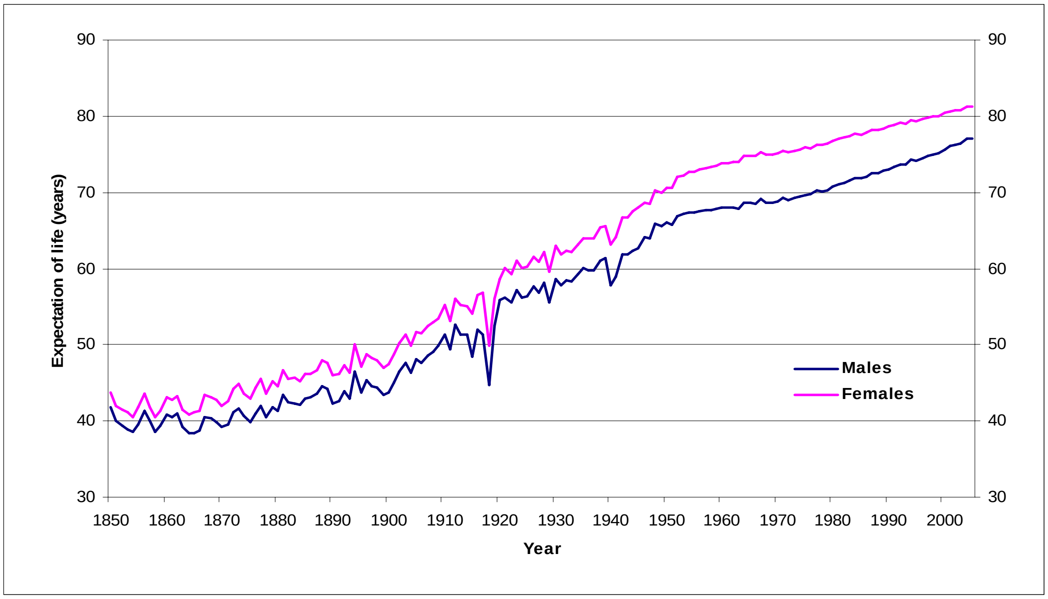
In common with other developed countries, during the course of the 20th century the United Kingdom saw a continuation of the pattern of falling death rates that began during the 19th century. Over these two centuries, there has been a change from a regime of high infant and child mortality, with a preponderance of acute and infectious diseases, to a new regime in which adult mortality predominates and chronic and degenerative diseases are the most common causes of death.

Period life expectancy at birth at the beginning of the 20th century was around 45 years for males and 50 years for females. Life expectancy at birth then rose dramatically until the mid-1950s; since then there has been a continuing increase but at a less rapid rate (see Figure 1).

Much of the increase in the first half of the 20th century arose through the reduction of infant and child mortality to very low levels by the mid-1950s due to increasing control of infectious diseases through improved sanitation, better public health measures and the development of vaccines and antibiotics. These rates are now so low that further reductions can have little effect on the expectation of life at birth. Compared to the improvements at younger ages, there was rather less reduction in mortality rates at the older ages. In the second half of the century, the increase in life expectancy at older ages has been much more marked and accounts for an increasingly higher proportion of the overall increase in life expectancy at birth.

FIGURE 1

Period Expectation of Life at Birth, England and Wales, 1850-2005

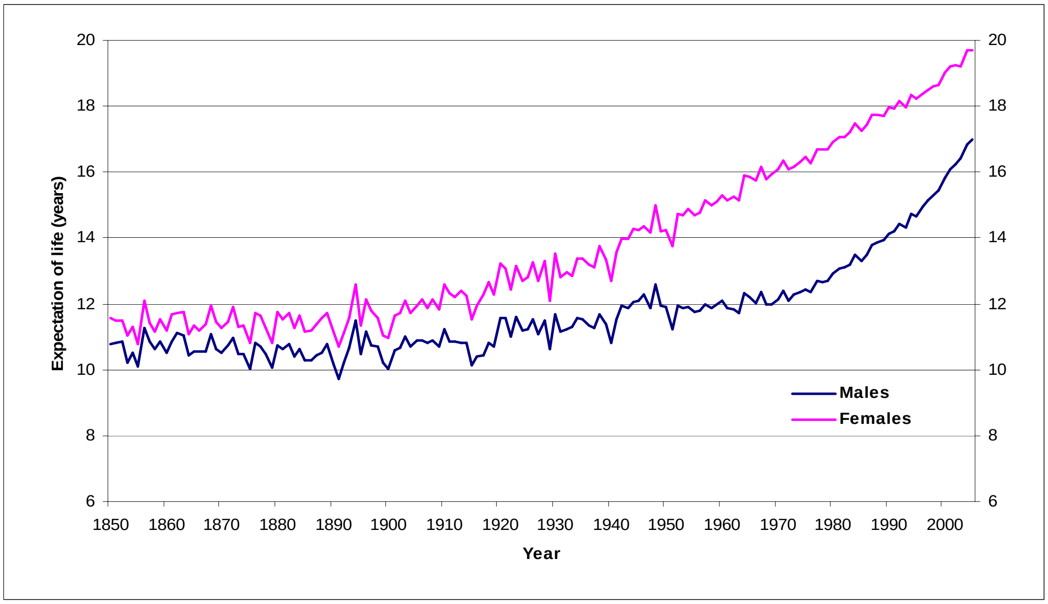


Source: UK Office for National Statistics

The pattern for period life expectancy at age 65 is somewhat different. Figure 2 shows that period life expectancy at age 65 was fairly stable at around 10.5 years for males and 11.5 years for females during the latter half of the 19th century. These figures began to rise during the 20th century, initially more rapidly for women than for men. However, the greatest decline in death rates for advanced ages has occurred since the 1970s; this is particularly so for males, whose mortality at older ages began to improve more rapidly than female mortality.

FIGURE 2

Period Expectation of Life at age 65, England and Wales, 1850-2005



Source: UK Office for National Statistics

A partial explanation for this may be the different historical patterns in cigarette smoking between men and women, with a higher proportion of males than females smoking in the past and the peak consumption for males occurring earlier (1940-1960) than for females (1960). This might suggest that the rate of increase in female expectation of life at 65 may experience a further slowing down relative to that for males over the next few years.

The Office for National Statistics (and previously the Government Actuary's Department) publishes national life tables based on population data. Decennial Life Tables based on graduated mortality data in the three years around a census year are produced for England and Wales (although confusingly entitled English Life Tables) and for Scotland. More recently, life tables covering three consecutive calendar years have been produced annually for the United Kingdom and constituent countries (these are termed Interim Life Tables). These life tables show that whilst period life expectancy at birth for males and females in England and Wales rose roughly in parallel during the first half of the 20th century, the increase in male life expectancy fell behind that for females during the 1950s and 1960s, with the age difference between males and females rising to a high of 6.3 years in 1970 (see Table 1). Since 1970, male life expectancy has been increasing faster than female, and the age differential has fallen to around 4.2 years by 2005. The gap between male and female period life expectancy at age 65 has also narrowed from highs of around 4.0 years during the 1970s and early 1980s to around 2.8 years in 2005.

TABLE 1

Period Life Expectancy at Birth and at Age 65—England and Wales *years*

Year	Life expectancy at birth			Life expectancy at age 65		
	Males	Females	Difference	Males	Females	Difference
1901-10	48.5	52.4	3.9	10.8	12.0	1.2
1910-12	51.5	55.4	3.9	11.0	12.4	1.4
1920-22	55.6	59.6	4.0	11.4	12.9	1.5
1930-32	58.7	62.9	4.2	11.3	13.1	1.8
1950-52	66.4	71.5	5.1	11.7	14.3	2.6
1960-62	68.1	74.0	5.9	12.0	15.3	3.3
1970-72	69.0	75.3	6.3	12.2	16.1	3.9
1980-82	71.0	77.0	6.0	13.0	17.0	4.0
1990-92	73.4	79.0	5.6	14.3	18.1	3.8
2004-06	77.2	81.4	4.2	17.0	19.8	2.8

Source: English Life Tables and Interim life tables 2004-06, U.K. Office for National Statistics

Table 2 shows the average annual rates of improvement in age standardised mortality rates for 5-year age groups between successive England and Wales life tables. The average rate of improvement for ages 0 to 99 over the 93-year period 1910-12 to 2003-05 was around 1.1 percent per annum for both males and females. The average rate of improvement over successive decades since 1930-32 remained relatively constant for females; for males, the table shows a relatively constant rate of improvement over the period 1930-32 to 1970-72, lower than that experienced by females, followed by a period of increasing mortality improvement. Over the 43-year period 1960-62 to 2003-05, the rates of improvement were around 1.5 percent per annum for males and 1.3 percent per annum for females.

Table 2 also indicates the wide variations in mortality improvement for differing age groups over differing periods. It also shows the "ageing of mortality improvement" in the United Kingdom. In the first half of the 20th century, the highest rates of improvement were seen at the younger ages. However, from 1960-2 onwards, excluding children and teenagers, the ages at which the highest rates were seen has gradually been getting older (at ages 40 to 49 over the period 1970-2 to 1980-2, ages 50 to 59 over the period 1980-2 to 1990-2 and ages 60 to 69 over 1990-2 to 2003-5, for both males and females).

TABLE 2

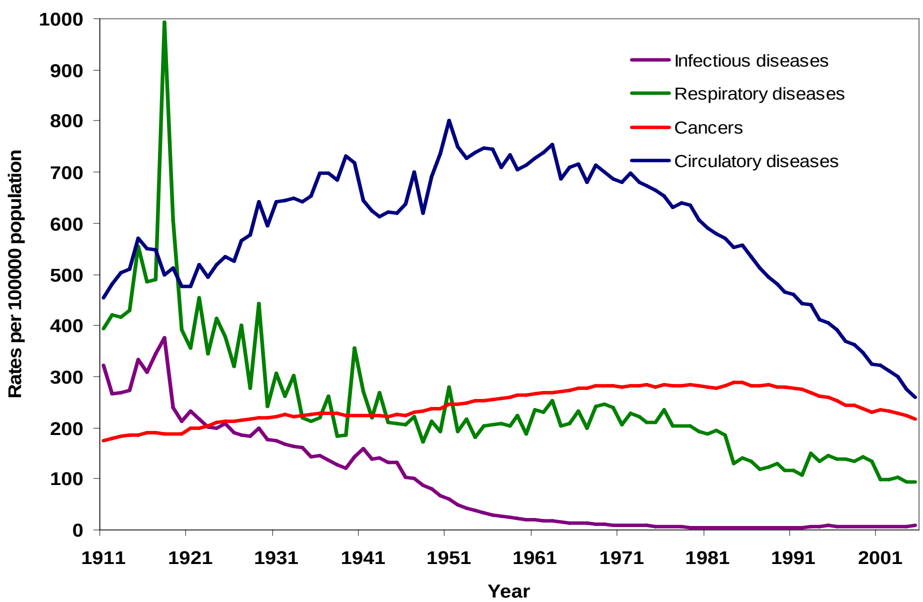
Percentage Annual Rate of Mortality Improvement in Age-Standardised Aggregate Mortality Rates (Using m_x values from successive English Life Tables and Interim Life Table for England and Wales for 2003-05)

	1911-1921	1921 - 1931	1931–1951	1951 - 1961	1961 - 1971	1971 - 1981	1981 - 1991	1991 - 2004	1911 - 2004
Males									
0-4	3.1%	2.9%	4.9%	3.0%	2.1%	4.3%	4.2%	3.0%	3.6%
5-9	1.4%	2.2%	6.1%	3.1%	1.5%	4.0%	3.4%	4.7%	3.7%
10-14	0.5%	2.0%	4.9%	3.0%	1.3%	2.6%	2.3%	3.2%	2.8%
15-19	0.1%	0.9%	4.8%	0.2%	0.3%	1.0%	1.9%	3.3%	2.0%
20-24	0.1%	1.3%	4.3%	1.8%	1.3%	1.4%	-0.2%	1.8%	1.8%
25-29	0.5%	2.0%	4.0%	3.5%	1.4%	0.6%	-0.4%	1.0%	1.8%
30-34	1.0%	2.7%	3.7%	2.7%	1.6%	1.4%	-0.2%	0.1%	1.8%
35-39	1.4%	2.4%	3.6%	2.2%	1.1%	1.8%	-0.1%	0.7%	1.8%
40-44	1.8%	1.6%	2.9%	2.0%	0.0%	2.2%	1.4%	0.8%	1.7%
45-49	2.3%	0.5%	2.0%	1.8%	-0.4%	2.1%	2.5%	1.2%	1.6%
50-54	2.0%	0.7%	1.0%	1.2%	0.2%	1.6%	3.0%	1.9%	1.4%
55-59	1.9%	0.7%	0.3%	0.6%	0.8%	1.2%	3.1%	2.7%	1.3%
60-64	1.4%	0.6%	0.1%	0.2%	0.8%	1.4%	2.4%	3.0%	1.2%
65-69	0.9%	0.2%	0.2%	0.1%	0.3%	1.7%	1.8%	3.5%	1.1%
70-74	0.6%	-0.1%	0.4%	0.2%	0.1%	1.5%	1.8%	3.1%	1.0%
75-79	0.3%	-0.3%	0.4%	0.5%	0.4%	0.9%	1.8%	2.5%	0.8%
80-84	0.1%	-0.4%	0.2%	0.9%	0.7%	0.5%	1.7%	2.0%	0.7%
85-89	0.1%	-0.7%	0.0%	1.3%	0.8%	0.5%	1.4%	1.4%	0.6%
90-94	0.0%	-0.8%	-0.1%	1.6%	0.6%	0.8%	0.8%	0.9%	0.4%
95-99	-1.7%	-0.8%	0.1%	1.8%	-0.1%	1.2%	-0.2%	0.6%	0.1%
0-99	0.9%	0.3%	0.7%	0.8%	0.5%	1.2%	1.8%	2.3%	1.1%
Females									
0-4	3.4%	3.2%	5.0%	3.0%	2.1%	4.3%	4.2%	2.7%	3.6%
5-9	1.5%	3.3%	7.2%	3.4%	1.5%	3.6%	3.1%	3.9%	3.8%
10-14	0.3%	2.7%	6.5%	4.1%	1.1%	1.7%	2.4%	2.8%	3.1%
15-19	0.2%	1.2%	6.2%	5.4%	-0.4%	1.8%	1.1%	2.2%	2.7%
20-24	-0.4%	1.4%	5.5%	6.4%	0.6%	2.0%	1.1%	1.4%	2.6%
25-29	0.0%	1.8%	4.8%	6.1%	2.0%	1.4%	1.7%	0.3%	2.5%
30-34	0.9%	2.1%	4.3%	4.4%	2.1%	1.6%	1.5%	0.8%	2.4%
35-39	1.8%	2.0%	3.7%	2.9%	1.7%	2.0%	1.3%	1.3%	2.2%
40-44	2.3%	1.7%	3.0%	2.1%	0.7%	2.4%	2.0%	1.0%	2.0%
45-49	2.4%	1.2%	2.5%	1.8%	-0.1%	2.2%	2.3%	1.2%	1.7%
50-54	2.0%	1.2%	2.0%	1.7%	-0.1%	1.3%	2.6%	1.6%	1.6%
55-59	2.1%	0.9%	1.8%	1.6%	0.3%	0.6%	2.3%	2.3%	1.5%
60-64	1.5%	0.8%	1.6%	1.5%	0.8%	0.5%	1.4%	2.9%	1.4%
65-69	1.2%	0.6%	1.3%	1.3%	1.0%	1.0%	0.9%	2.9%	1.3%
70-74	1.0%	0.4%	1.1%	1.3%	1.1%	1.4%	1.1%	2.5%	1.2%
75-79	0.6%	0.1%	0.8%	1.4%	1.2%	1.5%	1.5%	1.7%	1.1%
80-84	0.3%	-0.1%	0.5%	1.4%	1.4%	1.2%	1.9%	1.3%	0.9%
85-89	-0.1%	-0.5%	0.3%	1.2%	1.3%	0.8%	2.1%	0.6%	0.7%
90-94	-0.1%	-0.6%	0.2%	0.8%	1.1%	1.0%	1.5%	0.1%	0.5%
95-99	-0.4%	-0.6%	0.6%	0.2%	0.2%	2.1%	0.3%	-0.3%	0.3%
0-99	0.8%	0.3%	1.1%	1.4%	1.1%	1.2%	1.6%	1.2%	1.1%

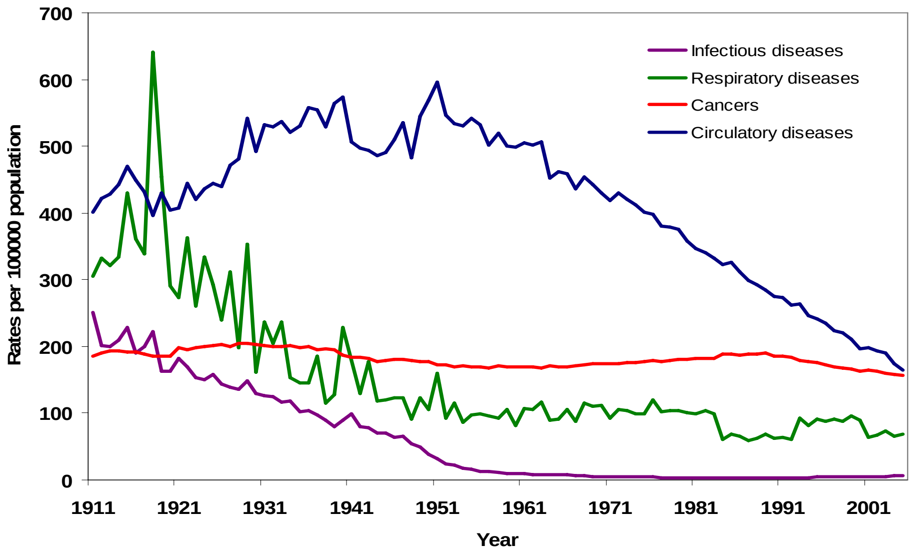
Source: U.K. Office for National Statistics

Figure 3 shows age standardised mortality rates by selected major causes of death for England and Wales over the period 1911 to 2005. As can be seen, the rapid improvements in mortality over the last 40 years or so have been largely driven by falls in mortality rates due to circulatory diseases, of around 60 percent for both males and females. Mortality from cancer rose gradually over the period for males to a peak in the early 1980s followed by a decline during the 1990s. The pattern for female mortality from cancer is broadly similar over recent years. The trends in mortality from respiratory disease are more difficult to discern because of changes in the ICD coding relating to deaths involving certain respiratory disease such as pneumonia during the 1980s and 1990s. Allowing for these changes, mortality rates from respiratory diseases have been declining slowly for males and relatively stable for females over the past 20 years or so.

FIGURE 3
Mortality by Major Cause—England and Wales, 1911-2005
(a) Males



(b) Females



Source: UK Office for National Statistics

In general, cancers and circulatory disease are the major causes of death for males aged 45-64. Deaths from circulatory diseases become more dominant at older ages. For those aged 85 and over, deaths from respiratory disease also become a major factor so that the distribution of deaths by cause for males in their 80s is rather different to that for males in their 60s. At these older ages, cancer and heart disease are less significant than strokes and respiratory disorders. Broadly similar patterns exist for females, although circulatory disease is a less important cause than for males at ages 45-64, as is cancer at older ages.

It is debatable whether the dramatic decline in mortality from circulatory diseases can continue at its current rate (which, if extrapolated, would mean the eradication of such deaths in the next 25 years or so) or whether it will slow down in the future (as appears to be the case for deaths from respiratory diseases). Even if the decline were to continue, as the proportion of deaths from circulatory disease reduces it would be the results of changes in mortality rates from other causes which would have a greater effect on the rate of future mortality improvement.

3. Key Drivers of Future Mortality in the United Kingdom

Key forces thought likely to drive mortality change in the United Kingdom in the 21st century include the following:

- Reduced levels of deprivation, better housing
- Government support for increasing wealth and health
- Medical advances
- Public support for spending on medical research
- The prevalence of smoking
- The prevalence of obesity
- Other lifestyle patterns
- Emergence of new infectious diseases
- Re-emergence of old diseases
- Increasing uncertainty at younger ages
- Differentials by social class
- “Cohort effects”
- The ageing of mortality improvements.

3.1 The Cohort Effect

Analyses of historical U.K. mortality rates suggest patterns in past rates of mortality improvement by year of birth. Figures A1 and A2 in Annex A show the annual percentage rates of improvement in smoothed mortality rates by age and year for males and females found by comparing the mortality rate for a given age and year with that for the same age in the preceding year. The percentage levels of improvement are denoted by the various colours, with dark red indicating annual rates of mortality improvement of 3.0 percent and over, whilst blue areas denote ages at which mortality rates have increased over successive years.

The figures exhibit several features. For males, those born in the late 1920s and in the 1930s have consistently exhibited, over a very long period, higher rates of mortality improvement than those born in the years on either side. These patterns have been termed “cohort effects.” There is evidence that there may be cohort effects arising for those born in later years of birth, with those born around 1945 exhibiting a similar pattern of higher rates of mortality improvement than those born on either side; whilst those born in the early 1950s and early 1960s are experiencing continuing lower rates of mortality improvement, or even worsening, relative to those born in between. As is discussed later, official projections of U.K. population mortality have been strongly linked to trends by year of birth for older ages. The female data exhibit similar patterns for similar years of birth, although the differentials in mortality are not currently as high as for males. It is possible that these effects may be partly due to period effects rather than factors specific to years of birth. Cohort effects have also been found for the subgroup of the U.K. population who buy life insurance or are in pension schemes run by insurance companies.

It is not known for certain what has caused these patterns. Various explanations for these cohort effects have been put forward, including:

- Differences in smoking patterns between generations
- Better diet during and after the World War II
- Differing birth rates with those born in periods of low birth rate facing less competition for resources as they age
- Benefits from the introduction in the late 1940s of state education and the National Health Service
- These generations have been the beneficiaries of medical research and advances which have moved on from causes of death affecting children and young adults to those affecting older people, as these generations have aged.

An analysis of mortality by cause of death for circulatory disorders, cancer and respiratory diseases also displays cohort effects for those born in the 1930s (Willets et al., 2004). Willets (2003) suggests that trends in smoking prevalence may be a major driver for the relatively high improvements for those born in the 1930s, whilst the cohort effect for those born in the early 1940s appears to be driven more by improvements in mortality from heart disease, perhaps caused by the early life experience of those born in or around World War II.

Inevitably, the smoothing process chosen has some effect on the resulting patterns of mortality improvement. However, similar patterns have been observed in

U.K. data by other observers and also in other countries such as Denmark and Japan, and, for males in particular, in France, Italy and Switzerland. The cohorts most affected are not always centred on the same years of birth; for example, in Japan it is those born around 1910 who have been exhibiting the highest rates of improvement (Andreev and Vaupel, 2005; Richards et al., 2007; Willets, 2003).

3.2 The Ageing of Mortality Improvement

Table 2 and Figures A1 and A2 of Annex A show that for the U.K. population the ages at which the highest rates of improvement have occurred have been increasing over time. To some extent, this effect is tied up with the cohort effects, but it encompasses a wider range of ages and years of birth; it is not necessary that rates of improvement follow a cohort effect for an ageing of mortality improvement to be exhibited.

3.3 Medical Advances

A large element of the current improvements in mortality has been driven by medical advances. There appears to be ongoing public and political support and availability of funding for continuing medical research, which would suggest that medical advances will continue to lead to further mortality decline. For example, the availability of statins has been described as a potentially major influence on modern medicine.

3.4 Smoking Trends

The prevalence of smoking in the United Kingdom fell from 51 percent for males aged 16 and over in 1974 to 28 percent in 1994; since then the decline has slowed down with 25 percent of males smoking in 2005. There has been a similar pattern for females with smoking prevalence declining from 41 percent in 1974 to 26 percent in 1994 and 23 percent in 2005. Various studies have suggested that changes in smoking behaviour in the United Kingdom have contributed significantly to the decrease in mortality (e.g., the National Heart Forum (1999) has suggested that the change in cigarette consumption has been responsible for a decrease of between one-quarter and one-third of the reduction in heart disease mortality). Studies by Doll et al. (2004) suggest that smoking doubled the age specific mortality rates in middle and old age for British men born in 1900-09 and tripled them for those born around 1920 and that longevity has been increasing rapidly for non-smokers but not for men who continued to smoke. However, if a smoker gave up before age 30, his life expectancy was similar to that of non-smokers. The effects of smoking are dependent not just on overall prevalence but on the duration of smoking and also tend to be correlated with age. For instance, lung cancer rates for men in the United Kingdom have peaked and are falling, with the peak being later for each successive age, and in general, each time relating to the cohort of men born in the 1900s; for women the peak has been later for each successive age group, each time relating to women born in 1925-30, so that lung cancer mortality rates are still rising for women aged 75 and over (Willets et al., 2004).

The recent slowdown in the decline of smoking prevalence may lead to lower gains in mortality improvement from the effects of smoking behaviour in future years. Smoking take-up rates were much higher for older cohorts than for those born most recently, but many had given up by age 30 or 40. However, for manual workers, although fewer younger cohorts take up smoking, the vast majority have remained smokers compared to earlier cohorts. If they remain resistant to giving up smoking, then rates of smoking among older people will be higher compared to previous generations (Davy, 2007).

3.5 Obesity

There has been much discussion about the increase in obesity levels and the possible consequential effects on future mortality. Olshansky (2005) has suggested that the current levels of obesity in children and young adults in the United States could lead to reductions in future life expectancy over the next 40 years. A recent U.K. government report (Butland et al., 2007) projects that, by 2050, 60 percent of adult males and 50 percent of adult females in the United Kingdom could be obese.

Whilst increased obesity levels are likely to lead to increases in future morbidity, it is less clear how future mortality will be affected. For example, obesity may lead to increases in deaths from causes which are currently experiencing large reductions. If levels of these diseases increase significantly, medical research is likely to be focussed on treating these diseases or the causes of death arising from them, which may mitigate the effects on mortality. There is considerable debate about the likely effects of increasing obesity on mortality with some suggesting that obesity has less impact on mortality than previously thought (Flegal et al., 2004).

3.6 Medical Advances vs. Lifestyle

There are several studies which have aimed to assess the contributions of medical advances to the increase in life expectancy (e.g., Mackenbach, 1996; Bunker, 2001; Nolte and McKee, 2004). Some of these look at different causes of mortality, which are termed amenable mortality (i.e., are considered to be amenable to medical treatment, such as breast cancer, leukaemia, hypertensive diseases) and preventable mortality (i.e., are considered preventable through individual behaviour or public health resources limiting exposure to harmful substances/conditions). Other causes may be considered to be neither amenable nor preventable (such as cancers of the pancreas, ovary and prostate). Usually only deaths below a certain age are considered (age 75, say). Data for the United Kingdom suggests that mortality under age 75 from amenable causes has decreased substantially since 1993 for both males and females. Mortality from preventable causes has decreased by a larger amount for males than for females but in both cases by a lesser amount than amenable mortality. There has been a relatively modest decrease in mortality from unavoidable causes (Wheller et al., 2007).

Coronary heart disease (CHD) mortality has declined by over 50 percent in England and Wales between 1981 and 2000 for men and women aged 25 to 84. A recent study (Capewell et al., 2004) suggests that approximately 40 percent of this decrease was attributable to the combined effects of modern cardiological medical and surgical treatments and almost 60 percent to reduction in major risk factors, particularly smoking, followed by cholesterol and lower blood pressure levels. Factors acting to increase mortality were increases in obesity, diabetes and physical inactivity.

3.7 Infectious diseases

Whilst recent medical advances and other factors have continued to lead to a regime of increasing life expectancy, factors which could work in the opposite direction, such as the threat from infectious diseases, should not be forgotten.

As well as new infectious diseases, old ones such as tuberculosis have re-emerged, which may prove resistant to existing antibacterial agents. Increased and rapid travel provides the means for infectious diseases to spread quickly around the globe (e.g., severe acute respiratory syndrome—SARS). Human behaviour has also helped spread certain diseases, for example hepatitis C and HIV.

So far, HIV is the only new example which has had a dramatic impact on mortality globally. In general, medical advances, rapid detection and global cooperation have managed to limit the effects of other newly arrived infectious diseases.

As deaths from heart disease and cancers reduce in the future, resistance to antibacterials could mean that deaths from infectious diseases become more common at older ages   Estimating the effects of an epidemic of an infectious disease is particularly difficult; whilst there would be a short-term increase in mortality, the longer-term effects on mortality are less predictable. The effect may be simply a relatively short-term shock, for example, if those affected are mainly the elderly, causing mainly an advance of a few years of the deaths of those who would most likely have died in the immediate following years. On the other hand, the effects could be longer term if those of working age are particularly affected, leading to possible decreases in economic output in future years.

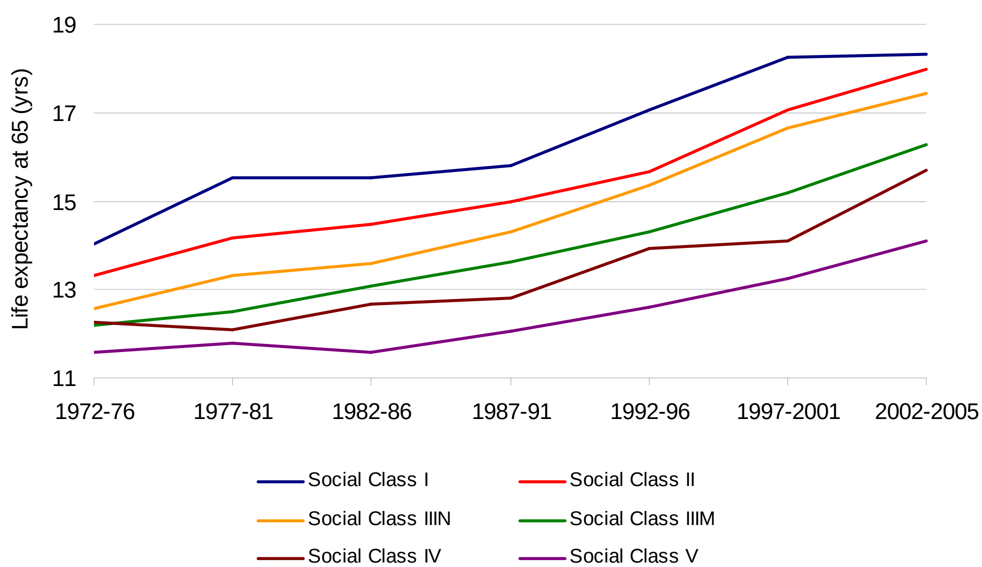
3.8 Uncertainty at Young Ages

Mortality rates in the 1980s and 1990s increased for young ages as deaths related to AIDS, drug and alcohol abuse and violence more than offset improvements in health-related causes of death. This trend appears to have been reversed in more recent years, but indicates that the future course of mortality rates at young ages is considerably uncertain.

3.9 Mortality by Social Class

Period life expectancy by social class exhibits a gradient both at birth and at older ages, with those in Social Class I living longest and those in Social Class V least, as can be seen from Figure 4. This gradient persisted over time, although the latest data suggests that it may be narrowing, at least for males (however, it should be noted that both Social Class I and Social Class V cover only around 5 percent of the population each, and hence the results are more variable than for the other classes).

FIGURE 4
Trends in Male Period Life Expectancy at Age 65 by Social Class, 1972–2005, England and Wales



Source: U.K. Office for National Statistics

The definitions of the broad social classes are as follows:

Social class I:	Professional, e.g., doctors, accountants
Social class II:	Managerial and technical, e.g., managers, journalists, teachers
Social class IIIN:	Skilled non-manual, e.g., clerks, retail staff
Social class IIIM:	Skilled manual, e.g., plumbers, electricians
Social class IV:	Partly skilled, e.g., security guards, waiters, care assistants
Social class V:	Unskilled, e.g., labourers, cleaners, messengers

A partial explanation for the existence of a mortality gradient by social class is that cigarette smoking is more prevalent in the lower social classes, as discussed earlier. Other reasons suggested include selection effects, nutrition, environmental conditions and cultural/lifestyle differences (Townsend and Davidson, 1982) and differentials in work-related stress (Marmot et al., 1997). Valkonen (2001) has concluded that explanations for social differentials are likely to differ for different causes of death and by country and time period.

3.10 Future changes

There is currently considerable debate as to the potential for future human longevity and whether the impact of future technical, medical and environmental changes will have a greater or lesser effect on improvements in mortality in the future than they have had over the 20th century and hence, whether the current high rates of mortality improvement experienced at some ages will continue in the future.

A reduction over time in the rates of mortality improvement is a common assumption made in official national projections for many countries. This is often based partly on the arguments that the high rates of improvement seen over the 20th century were a result of medical and environmental change which are unlikely to be repeated in the future to such an extent and that it is also likely to be more difficult to sustain these levels of improvement in mortality indefinitely. Ageing and death are not genetically programmed, but are predictable by-products of stable reproductive biologies. Whilst advances in biomedical technology and lifestyle will permit life expectancy to continue to increase over the short term, a repetition of the gains experienced over the 20th century would require an ability to slow the rate of ageing—a capability which does not currently exist and which would need implementation on a large scale to have a measurable impact.

Potential biological limits, the increase in obesity, the emergence of new diseases and reemergence of drug-resistant older ones and the possibility difficulties in making medical advances which would have as great an effect on mortality as past advances may also all lead to reductions in the rate of future mortality improvements (Carnes et al., 2003). In the United Kingdom, whilst there has been considerable improvement in mortality at ages in the 60s and 70s over the last 20 years there has been little improvement in mortality rates for males in their 30s and early 40s over the same period.

However, other demographers argue that current rates of mortality improvement might continue into the future indefinitely or at least over a much longer period than often assumed, based on the experience of the recent past (Oeppen and Vaupel, 2002) and an assumption of continued medical advances, for example in stem cell research. Analysis of large cohorts of data suggests that mortality rates reach a plateau at advanced ages and may even decline (Thatcher et al., 1998), which appears to contradict the supposition of increasing mortality after the end of the reproduction period. It is also pointed out that maximum limits proposed on biological grounds in the past for the expectation of life have always been exceeded.

4. Projection Methodologies

Most mortality projection methodologies involve some form of extrapolation of historical trends. Such methods involve some element of subjective judgement, for example in the choice of period or age range over which past data are used. Simple extrapolative methods are only reliable to the extent that the conditions which led to changing mortality rates in the past will continue to have a similar impact in the future. Advances in medicine or the emergence of new diseases could invalidate the results of an extrapolative projection.

One problem with projecting historical trends in age-specific mortality rates into the future using these methods is that the relationship between the rates at different ages is often ignored. If mortality rates at different ages are projected forward independently, it is possible that the results will not seem plausible; for example, mortality rates at older ages may eventually become lower than those at younger ages.

Another method involves fitting a parameterised curve to data for previous years and then projecting the parameters forward. However, the shapes of the resulting curve may not continue to describe mortality satisfactorily in the future.

Targeting methods involve assuming a target or set of targets, which are assumed to hold at a certain future date and to which the population being projected is assumed to approach over time. Targets could involve, for example, a set of age-specific mortality rates, specified rates of mortality improvement or expectations of life for some future year. Assumptions will be required as to the speed of convergence to the targets. Targeting can overcome some of the drawbacks of a purely extrapolative approach, since the targets chosen can take into account any evidence of the possible effects of advances in medical practice, changes in the incidence of disease or the recent emergence of new diseases which may not have appeared yet in past trends.

The methods used can either be applied deterministically or stochastically; most official national population projections are currently carried out deterministically.

Explanatory-based methods are an alternative approach. These employ a causal forecasting approach, for instance using econometric techniques based on variables such as economic or environmental factors. However, data allowing deaths to be categorised by the risk factors used may not be readily available on death certificates and may need to be obtained from other sources such as medical or longitudinal studies. If the explanatory variables themselves are as difficult to predict as the dependent variables (or indeed more so), then the projection's reliability will not be improved by including them in the model. These methods appear to be rarely used in official projections because the explanatory links are not generally sufficiently understood, although this approach has been used to model Dutch mortality (Tabeau et al., 2001).

Although an explanatory approach may not be possible, examining past effects of key explanatory variables may provide insight into past trends and the possible future course of mortality.

Another approach to projecting mortality are process-based methods which concentrate on the factors that determine deaths and attempt to model mortality rates from a bio-medical perspective. For example, an assumption that death is caused by the accumulation of defects leads to a mathematical description of mortality. Such methods are only effective to the extent that the processes causing death are understood and can be mathematically modelled. They are not generally used by official bodies to make projections.

Many of the available methodologies can be applied either to aggregate mortality data or data by cause of death. Projecting mortality by cause of death appears to provide a number of benefits such as providing insights into the ways in which mortality is changing. However, there are problems associated with this approach; in particular:

- deaths from specific causes are not always independent,
- the actual cause of death may be difficult to determine or may be misclassified and
- changes in the diagnosis and classification of causes of deaths can make analysis of trend patterns difficult.

These difficulties are especially relevant at older ages, where most deaths occur.

5. Mortality Projections for the U.K. Population

The U.K. Government Actuary's Department (GAD) has prepared the official national population projections for the United Kingdom and its constituent countries since 1954. Following a review of the U.K. actuarial profession and of the role and work of the Government Actuary's Department, responsibility for producing the official national population projections and the official national life tables was transferred from GAD to the Office for National Statistics Centre for Demography (ONSCD) in January 2006.

The projections are prepared at the request of the Registrars General of England & Wales, Scotland and Northern Ireland. A new set of projections is normally made every second year, based on a full-scale review of the trends affecting the underlying assumptions about fertility, mortality and migration

The latest published U.K. population projections are the 2006-based projections.

The methodology adopted for producing projections of future mortality rates by age and gender for each year of the projection period follows that recommended by a full review of the methodology to be used for projecting mortality rates in the national projections which was carried out as part of a programme of quality assurance of U.K. National Statistics (2001).

The current process for setting the mortality assumptions is as follows:

Proposed assumptions are prepared after a meeting with an advisory panel of U.K. demographic experts to discuss possible future trends in mortality (and fertility and migration). The proposals are then discussed with the main users of the projections. The final assumptions are then agreed in consultation with the statistical offices of the four constituent countries and the Registrars General taking into account input from both the demographic experts and the users.

For the 2006-based projections, a questionnaire was piloted with the expert advisory panel. This set out a series of suggested drivers for changes in mortality (and fertility and migration) and asked respondents to assess whether the arguments were valid and, if so, the likely effect on future life expectancy and their relative importance. A time series of data for the United Kingdom was also provided, and respondents were asked for their best estimates of life expectancy at birth in 2010 and 2030 and to give a suggested plausible range which they felt would cover roughly 67 percent of the possible trends.

6. Current Methodology for Projecting Mortality in U.K. National Projections

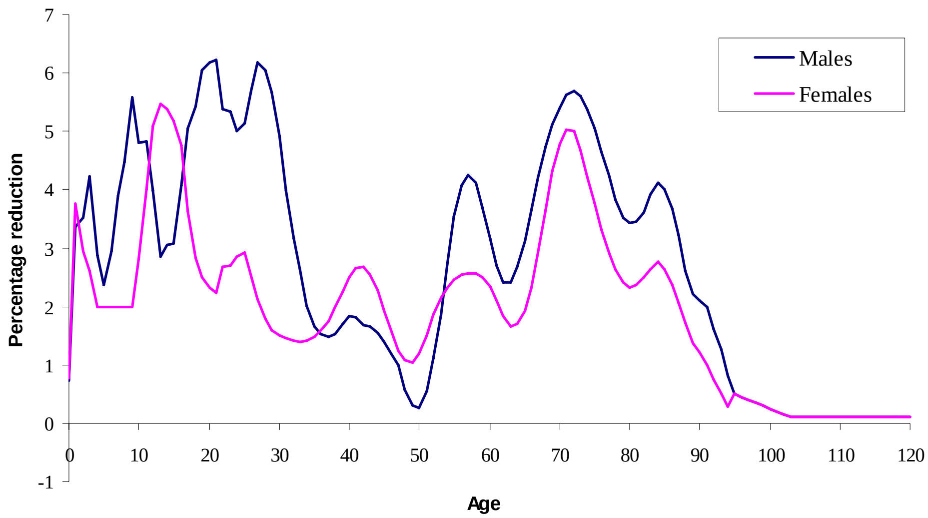
The current methodology used for projecting mortality in the national population projections can be broken down into various elements as follows:

Mortality rates and rates of improvement in mortality by age and gender for the first year of the projection are estimated from an analysis and extrapolation of the trends in recent historic data for the United Kingdom. Figure 5 shows the assumed initial rates of mortality improvement for 2006 used in the 2006-based projections**.** These rates vary from those shown in Table 2 since they are based on extrapolations of smoothed historical mortality rates and are partly dependent on the methods of smoothing and extrapolation chosen. They also take into account the size and direction of recent improvements by age. In particular, the high rates for ages in the mid-60s to mid-70s reflect recent high rates of mortality improvement at these ages. The mortality rates for the first year of the projection, mid-2006 to mid-2007, were later obtained by adjusting the trend mortality rates so as to obtain the best estimates that could be made in the autumn of 2007 of the numbers of deaths at each age in 2006-07.

Consideration is then given as to how trends might change in the future. Rates of mortality improvement are set for a future 'target year' in the projection period (taken to be the 25th year of the projection) based on an analysis of past trends and expert opinion.

FIGURE 5

Assumed Initial Smoothed Percentage Reductions in Death Rates by age 2005-06—United Kingdom



Source: U.K. Office for National Statistics, 2006-based U.K. population projections

The age standardised rates of improvement for the age group 0 to 99 using the assumed rates of improvement by age for 2005-06 shown in Figure 5 are around 3.6 percent per annum for males and around 2.3 percent per annum for females and even higher for the age group 50 to 89 at around 3.9 percent per annum for males and around 2.7 percent per annum for females. Whether the recent average levels of improvement shown in Table 2 will remain at similar levels in the future or increase or decrease is particularly difficult to determine at present. As described earlier, there is considerable debate amongst demographers as to whether life expectancy will continue to increase at around its current rate indefinitely, or even accelerate, or whether other factors will cause the rate of increase to diminish or even turn negative.

The average annualised rate of mortality improvement for the United Kingdom over the period 1965 to 2005 was around 1.6 percent a year for males and 1.2 percent a year for females. The rate of improvement over the latter half of this period was higher than over the first half, particularly for males. Table 3 shows the average rates of improvement in the smoothed mortality rates for the United Kingdom used as the basis for analysing and projecting trends for various periods between 1965 and 2005.

TABLE 3

Annual Rates of Improvement in Standardised U.K. Mortality Rates

Period	Decrease in standardised UK mortality rate			
	Ages 0-99		Ages 50-99	
	Males	Females	Males	Females
1965-2005	1.59%	1.22%	1.65%	1.33%
1965-1985	0.85%	0.91%	0.80%	0.93%
1985-2005	2.32%	1.55%	2.50%	1.74%
1980-2005	2.10%	1.42%	2.25%	1.60%

The average annual rate of improvement over the whole of the 20th century was around 1.0 percent for both males and females although the improvement rates vary by age. Taking these various factors into consideration, the target rate of improvement for 2031 (the 25th year of the 2006-based projections) was assumed to be 1.0 percent for most ages (i.e., equivalent to the average annual rate of improvement over the whole of the 20th century).

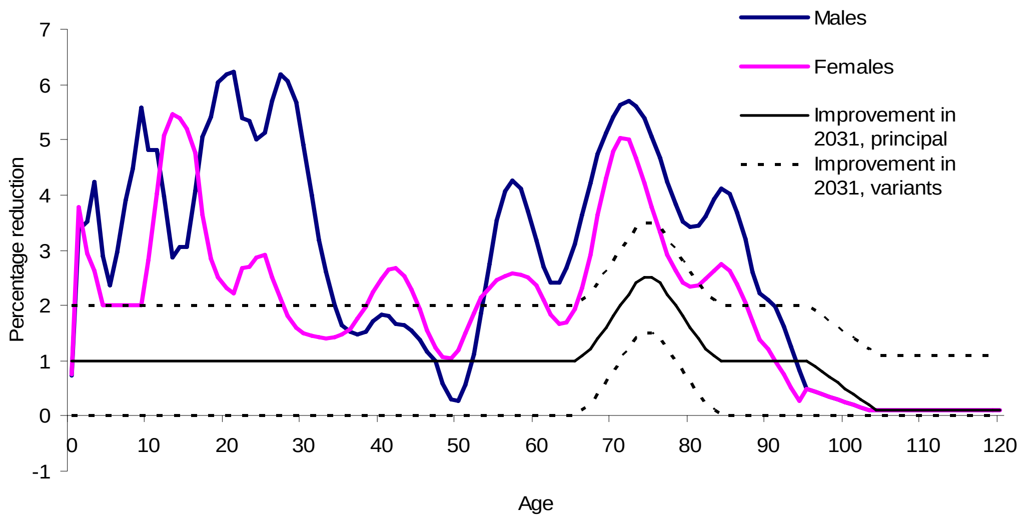
However, those born during the period 1923-1940 (and centred around 1931) have exhibited greater rates of improvement over the last 25 years than those born on either side. There is currently no evidence that these differentials are declining. Similar cohort effects seen in other countries suggest that these differentials may persist well into the oldest ages. As a result, it is now assumed that these cohorts will continue to experience higher rates of improvement after 2031 with the assumed rate of improvement in 2031 and beyond rising from 1.0 percent a year for those born before 1923 to a peak of 2.5 percent a year for those born in 1931 and then declining back to 1.0 percent a year for those born in 1941 and later. In the 2004-based projections, it was assumed that these cohort differentials would disappear over time with a common rate of improvement of 1.0 percent assumed at all ages by 2029. On the other hand, there is little evidence of mortality improvements at the oldest ages in the United Kingdom. As a result, and in order to avoid implausible numbers surviving to age 120, the notional target rates for those born in 1911 and earlier are assumed to reduce from 1.0 percent for those born in 1911 to 0.1 percent for those born in 1902 and earlier.

The transition from current rates of mortality improvement by age and gender, derived from recent trends, to the assumed rates in 2031, is not assumed to take place linearly, but more rapidly at first for males and less rapidly for females. This partly reflects the fact that males are currently experiencing rather higher rates of mortality improvement than females. There is now also growing evidence of generational effects after the 1945 cohort. Thus, in these projections, convergence to the assumed rate of improvement in 2031 has been done by cohort for all those born before 1960. For those born in 1960 and later, for whom there is little evidence of generational effects, the changes in the rates of improvement to the target rate are projected by calendar year. There is a resulting triangle of rates of improvement by age and year which are not covered by either of these processes; the rates of improvement here for a given age in a given year are obtained by interpolation between the rates for ages at either end of the gap for that year.

Figure 6 shows the assumed initial rates of improvement in 2005-06 (as shown in Figure 5) together with the assumed rates of improvement in 2031 for the principal projection (solid black line) and the assumptions for the two variant projections described later (dotted black lines). These are plotted by age attained in 2006 so that the assumed rate of improvement for a male or female aged x in 2006 is shown vertically above that age on the x-axis. For those aged 46 or under in 2006, convergence is assumed to take place by age; for those aged 47 or over, convergence takes place along a year of birth. Thus, for example, the estimated rate of improvement in mortality in 2006 for a male aged 30 is estimated to be 4.9 percent. Future rates of improvement at age 30 are assumed to fall from 4.9 percent in 2006 to 1.0 percent by 2031. The estimated rate of improvement in 2006 for a male aged 75 (i.e., born in 1931) is estimated to be 5.1 percent. Future rates of improvement are then assumed to fall from 5.1 percent in 2006 to 2.5 percent by 2031 as that person ages over time.

The rates of improvement after 2031 are assumed to remain constant (by cohort or by age, as described above) at the rate assumed in 2031 for each year thereafter.

FIGURE 6
Assumed Initial Rates of Improvement in Death Rates 2005-06 and Projected Rates of Improvement in 2031, United Kingdom



Source: U.K. Office for National Statistics, 2006-based U.K. population projections

The same future improvements have been assumed for all countries of the United Kingdom except for some differences (generally, slightly smaller improvements) in the period to 2031 at some ages for males in Scotland. Table 4 shows the rates of mortality improvement assumed for males (except for Scotland) and females for specimen years and ages.

TABLE 4
Assumed Percentage Reduction in Death Rates, m_x, between Calendar Years, Males (England, Wales and Northern Ireland); Females (all countries)

Age last birthday	2006 to 07		2011 to 12		2021 to 2022		2030 to 2031		*Reduction over 25 years*	
	Males	Females	Males	Females	Males	Females	Males	Females	*Males*	*Females*
	%	%	%	%	%	%	%	%	%	%
0	0.74	0.77	0.82	0.80	0.94	0.88	1.00	1.00	*20.2*	*19.5*
2	3.36	2.88	2.67	2.60	1.54	1.95	1.00	1.00	*39.0*	*41.2*
12	3.80	4.97	2.98	4.37	1.64	3.00	1.00	1.00	*41.7*	*57.1*
22	5.12	2.62	3.90	2.38	1.95	1.82	1.00	1.00	*49.2*	*38.9*
32	3.04	1.41	2.44	1.35	1.47	1.21	1.00	1.00	*36.9*	*26.8*
42	1.64	2.62	1.45	2.38	1.15	1.82	1.00	1.00	*27.1*	*38.8*
52	0.58	1.48	1.00	1.20	1.00	1.12	1.00	1.00	*20.7*	*24.8*
62	2.61	2.07	3.03	2.27	1.00	1.12	1.00	1.00	*33.1*	*31.6*
72	5.40	4.95	2.79	2.11	1.66	1.75	1.00	1.00	*41.7*	*39.9*
82	3.32	2.34	3.90	3.16	1.65	1.70	1.00	1.00	*46.9*	*45.4*
92	1.93	0.99	2.78	2.14	2.89	2.85	1.20	1.20	*44.8*	*42.7*

Source: UK Office for National Statistics, 2006-based UK population projections

The resulting rates of improvement are then applied sequentially to the assumed trend mortality rates estimated for the base year of the projections to obtain projected mortality rates for each future year in the projection period by age and gender.

Taking account of the generally higher rates of improvement assumed prior to 2031, the assumptions produce averaged annualised rates of improvement in age standardised mortality of nearly 1.4 percent pa for both males and females over the whole 75-year projection period, around 0.1 percent to 0.2 percent a year higher than that experienced over the past 75 years. As Table 5 shows, the new projections generally assume slightly higher average rates of improvement for the future than experienced over corresponding periods in the past.

TABLE 5
Actual and Assumed Overall Average Annual Rates of Mortality Improvement

	Males		Females	
	Past (actual)	Future (assumed)	Past (actual)	Future (assumed)
Last/next 23 years	2.1%	2.2%	1.4%	2.2%
Last/next 43 years	1.5%	1.6%	1.3%	1.7%
Last/next 73 years	1.2%	1.4%	1.2%	1.4%

Note: Analysis relates to England & Wales. Historic estimates are based on comparison of 2003-05 interim life tables with English Life Tables for 1930-32, 1960-62 and 1980-82.

Figures A3 and A4 in Annex A show the actual and projected annual rates of mortality improvement using the same colour patterns as for Figures A1 and A2. The figures show the prolongation of the rates of improvement by cohort for those born before 1960 (and in particular continuing higher rates of improvement for those born around 1931) and by age for those born later.

7. Projection Results

Tables 6 and 7 show life expectancies for the United Kingdom with and without mortality improvements after the specific years shown. As a comparison, Switzerland currently has one of the highest period life expectancies at birth in Europe for both males and females. Under the U.K. 2006-based projections, period life expectancy at birth would not reach those experienced in 2005 in Switzerland (of 78.7 years for males and 83.9 years for females) until 2010 for males and 2017 for females.

The nature of the projected pattern of future mortality improvements results in increasing expectations of life at all ages but at a declining rate until after 2031, on both a period and cohort basis. A period expectation of life is calculated using the mortality rates at all ages for the period in question with no allowance for known or projected future changes thereafter; a cohort expectation of life allows for known or projected future changes in mortality.

TABLE 6

Life Expectancies, without Improvements after Year Shown, United Kingdom 2006-Based Projections *years*

Age	Males				Females			
	2006	2031	2056	2081	2006	2031	2056	2081
0	77.2	82.7	85.5	88.3	81.5	86.2	88.7	91.2
10	67.7	73.1	75.9	78.6	72.0	76.6	79.0	81.4
20	57.9	63.2	66.0	68.7	62.1	66.6	69.1	71.5
30	48.3	53.4	56.1	58.8	52.3	56.8	59.2	61.6
40	38.9	43.8	46.5	49.0	42.6	47.0	49.4	51.7
50	29.7	34.5	37.0	39.5	33.1	37.4	39.7	42.0
60	21.1	25.8	28.1	30.4	24.2	28.3	30.4	32.6
65	17.2	21.7	23.9	26.1	20.0	23.9	26.0	28.0
70	13.6	17.8	19.8	21.9	16.0	19.8	21.7	23.6
75	10.4	14.2	16.0	17.9	12.4	15.8	17.5	19.3
80	7.7	11.0	12.6	14.3	9.2	12.1	13.7	15.4
85	5.7	8.2	9.6	11.0	6.6	8.9	10.3	11.7

Source: UK Government Actuary's Department

TABLE 7

Life Expectancies, with Improvements after Year Shown, United Kingdom 2006-Based Projections *years*

Age	Males				Females			
	2006	2031	2056	2081	2006	2031	2056	2081
0	88.1	91.3	94.4	97.4	91.5	94.2	97.0	99.7
10	77.4	80.5	83.6	86.5	80.9	83.6	86.3	88.9
20	66.3	69.4	72.4	75.4	69.9	72.6	75.2	77.9
30	55.4	58.5	61.4	64.4	59.0	61.6	64.3	66.9
40	44.8	47.7	50.6	53.5	48.2	50.8	53.4	56.0
50	34.6	37.3	40.1	42.9	37.8	40.3	42.8	45.3
60	24.9	27.7	30.2	32.8	27.8	30.3	32.6	35.0
65	20.6	23.2	25.5	28.0	23.1	25.5	27.7	30.0
70	16.2	18.9	21.1	23.4	18.3	21.0	23.0	25.2
75	11.9	15.0	17.0	19.0	13.5	16.6	18.5	20.5
80	8.5	11.5	13.2	15.1	9.7	12.7	14.4	16.2
85	5.9	8.5	10.0	11.6	6.7	9.3	10.7	12.3

Source: U.K. Government Actuary's Department

7.1 Projections for Constituent Countries of the United Kingdom

The initial analysis of past trends is carried out at the U.K. level. A comparison of the mortality experience since 1961 of each country to that for the United Kingdom as a whole is then carried out to ascertain whether there should be any changes to the U,K, assumptions when applied to the constituent countries. In practice, the same rates of mortality improvement have been used for each country as projected for the United Kingdom as a whole, except for Scottish males, where different, usually lower, rates of improvement are assumed for certain ages over the first 25 years of the projections. The base mortality rates assumed for each country are derived by comparing recent mortality experience for that country with the United Kingdom as a whole.

The projections are carried out at a country-specific level. Projected mortality rates for combinations of countries such as England and Wales, Great Britain and United Kingdom are obtained by back calculation from the appropriate projected aggregated deaths and midyear population estimates.

7.2 Variant Projections

Because of the inherent uncertainty of demographic behaviour, any set of projections is likely to be proved wrong. To help users take into account the consequences of future experience differing from the assumptions made and to give some idea of the sensitivity of the results to changes in the assumptions, variant projections are also carried out based on alternative assumptions of mortality (and also fertility and migration). Two standard variant mortality assumptions (labelled high life expectancy and low life expectancy variants) are provided for each set of projections. These are intended to be plausible alternatives to the principal assumptions and not to represent upper and lower limits to future demographic behaviour. At present it is not possible to provide probabilistic interpretations for these variants. However, work on the possible ways of attaching probability levels to mortality variants is being taken forward by ONSCD.

For the 2006-based projections, the high life expectancy variant assumes target rates of improvement in 2031 and thereafter equal to those assumed in the principal projection plus 1.0 percent (i.e., 2.0 percent a year for most ages) and the low life expectancy variant assumes target rates in 2031 and thereafter equal to those assumed in the principal projection minus 1.0 percent (i.e., 0.0 percent a year for most ages). A "no mortality improvement" special scenario variant was also produced, where it was assumed that future mortality rates will remain constant at the values assumed for the first year of the projections.

Table 8 shows the resulting period expectations of life at birth in 2050 under the principal projection and each of these variants projections. Figure 7 shows actual and projected period life expectancy at age 65 for the United Kingdom under the principal projection and the high and low life expectancy variants.

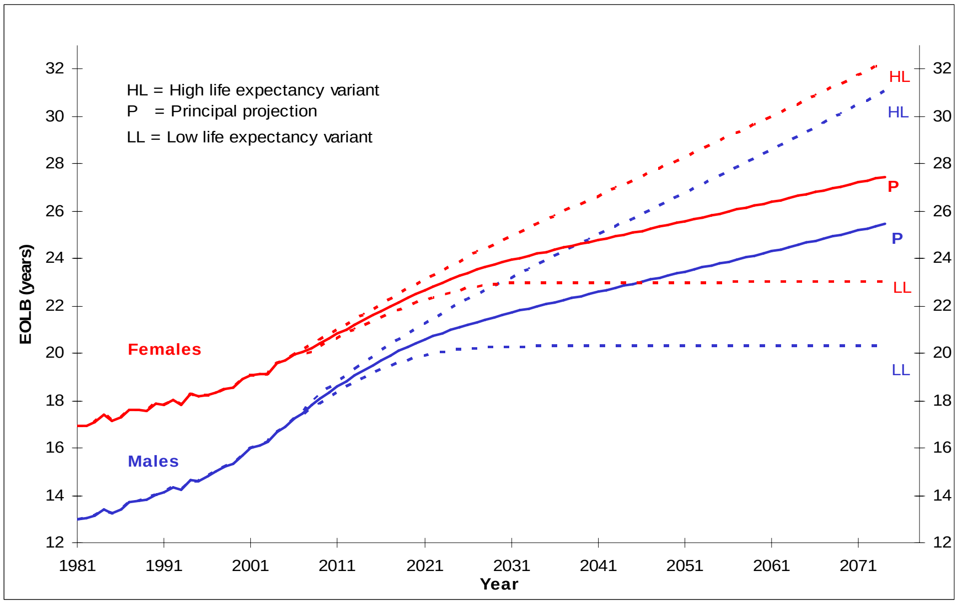
TABLE 8

Principal and Variant 2006-Based Population Projections: Assumed Period Expectations of Life at Birth and at Age 65 in 2050—United Kingdom *years*

	Standard variants			Special case scenario
	High variant	Principal projection	Low variant	No improvement
Males				
At birth	88.9	84.9	80.8	77.6
At age 65	26.6	23.4	20.3	17.4
Females				
At birth	91.3	88.1	85.0	81.9
At age 65	28.1	25.5	23.0	20.2

Source: U.K. Office for National Statistics, 2006-based U.K. population projections

FIGURE 7
Actual and Projected Period Life Expectancy at Age 65—United Kingdom 1981-2076



Source: U.K. Office for National Statistics, historical data and 2006-based U.K. population projections

The effects of the variant mortality projections are seen mainly in the differences in the numbers of people aged 75 and over, with less than 10 percent of the increase, or decrease, attributable to ages under 60 in 2050.

The "elderly" support ratio (defined as the ratio of all persons aged 16 to 64 to those aged 65 and over) for the United Kingdom was around 4.0 in 2001. Under the principal projection, this falls to just over 2.4 in 2050. Under the high life expectancy variant, the support ratio would fall to 2.2 and under the low life expectancy to 2.7. However, it is worth noting that, in the United Kingdom at least, the future fall in the support ratio is a continuation of a past trend: for example, it fell from 6.0 in 1951 to 4.0 in 2001.

8. Continuous Mortality Investigation

The Continuous Mortality Investigation (CMI) is a body funded by the U.K. life insurance industry, and run by the Faculty of Actuaries and Institute of Actuaries, which collects deaths and in force data by age and gender from participating U.K. life offices for various population subgroups who have taken out insurance contracts, including annuities.

Data are collected of numbers of claims (or annuities ceasing payment by death) by calendar year, and the numbers of policies in force at the end of each calendar year. For pensions and annuity business, total amounts of annuity are collected as well. Thus, the investigation is of claims, rather than deaths, and various crude adjustments are needed to allow for persons with duplicate policies.

The CMI produces standard mortality tables for use by actuaries in life insurance companies. New standard tables have been produced every 10 years or so, based on mortality experienced over a quadrennium. The latest tables, the “00” Series based on the mortality experience of 1999-2002, were published in September 2006.

The methodology used for graduating the base tables has for some time been based on maximum likelihood fitting of a Gompertz-Makeham family of functions of the general form “polynomial + exp(polynomial)” to the force of mortality. It is described in detail in Forfar, McCutcheon and Wilkie (1988).

Data for assured lives are collected on a smoker/non-smoker basis and mortality tables are provided for both categories. These illustrate the large differentials in mortality between smokers and non-smokers with mortality rates for assured lives in the “00” tables for smokers being over twice those for non-smokers for those aged 50 to 70.

Tables for pensioners and annuitants are produced in two stages. First, base tables are prepared, which are straightforward graduations of the data from the quadrennium. Second, the base tables are projected forward to allow for future improvements in longevity. Currently, the projection methodology is attracting much interest, because improving longevity is recognised as a significant factor in capitalising annuity business. Allowance for improvements has been made in past tables; latterly explicit projection formulae were used, which, in the form of reduction factors applied to the base table, resulted in a two-dimensional table indexed by age and calendar year. The “92” Series reduction factors assumed rates of mortality declining exponentially to asymptotic values, the latter chosen to produce greater improvements at younger ages than at older ages, as follows:

Let $q_{x,0}$ be the probability of someone aged x in the base year dying before reaching age $x+1$,and

$q_{x,t}$ be the probability of someone aged x in year t dying before reaching age $x+1$.

(i) The long term mortality rate at age x is taken to be $\alpha(x).q_{x,0}$.

(ii) The mortality rate declines exponentially to its long term value.

(iii) For some period integer (n = 20, for example) a proportion $f(x)$ of the total long-term reduction in mortality at age x has occurred by time n

that is $[q_{x,0} - q_{x,n}] = f(x). [q_{x,0} - q_{x,\infty}]$.

These assumptions imply that

$$q_{x,t} = q_{x,0} . \{\alpha(x) + [1-\alpha(x)].[1-f(x)]^{t/20}\}.$$

Thus, having chosen n, the improvement is modelled by the two functions $\alpha(x)$ and $f(x)$, which are taken to be linear over the age range 60 to 110. The values of $\alpha(x)$ at age 60 and of $f(x)$ at ages 60 and 110 are chosen to obtain a best fit to the observed mortality improvements over a recent 20-year period. The “92 series” projections assume that $\alpha(60)$ = 0.13, $\alpha(110)$ = 1.0, $f(60)$ = 0.55 and $f(110)$ = 0.29 with linear interpolation for intermediate ages. These rates of improvement were applied to base mortality rates derived from analysing the mortality experience for 1991-94 to obtain projected mortality rates by age and gender for future years.

The method has certain similarities in approach to that of the GAD projection methodology in the use of targets together with a form of exponential interpolation from current levels to the target level. However, the parameters are derived from observed trends in a subset of the total population, namely those receiving insured occupational pensions. In general, these people tend to be in the higher socioeconomic classes, which have exhibited lower mortality than the population as a whole.

Mortality tables are produced both for lives and amounts of pension. Lives tables provide mortality rates based on deaths of persons (after adjusting to allow for those with more than one pension). These would typically be applied to numbers of pensioners alive by age to estimate numbers of deaths of pensioners during a year.

Amounts tables provide mortality rates per unit of pension; these are applied to amounts of pension by age to estimate amounts of pension ceasing to be paid during a year. In general, mortality rates per unit of pension are lower than those calculated on a lives basis, reflecting the fact that mortality appears to be lower for those with larger amounts of pension. This suggests a correlation between wealth (using higher pension as a proxy for wealth) and higher life expectancy and is one of the factors in the mortality gradient by social class.

The experience of the 1990s suggested that even the most recent projections underestimated actual improvements in mortality. To some extent, this may reflect changes in the population covered by insured pension annuities, as well as the improving mortality in the population at large, with the development of an active market in the United Kingdom in impaired lives annuities resulting in the ordinary market becoming more and more select. Further investigation of the assured lives data for males also found cohort effects similar to those in the general population, but based around an earlier year of birth of 1926.

New interim projections were issued in 2002 (CMI Working Paper No.1) in which the existing reduction factors, based on exponential decline, were adjusted in an ad hoc manner to allow for the main cohort effect. Three possible scenarios were put forward, called short, medium and long cohorts, depending on the period during which the excess rates of improvement enjoyed by the main cohort were supposed to wear off. Previous CMI projections had presented a single scenario.

The Financial Services Authority (the U.K. insurance regulator) is introducing new rules for capital adequacy based on stochastic evaluations of risk. A working party of the CMI has evaluated recent advances in projection methodologies, with a view to proposing methods suitable for use with the “00” Series tables, and adequate to meet the needs of life insurers under the new regulatory regime being introduced in the United Kingdom. Thus, the working party has examined projection methodologies capable of producing quantitative measures of risk as well as sample or central projections. CMI Working Paper No. 3 discusses, inter alia, contrasting methodologies such as time-series approaches (typified by the Lee-Carter model in much of the literature) and extrapolation of smoothed regression models; model, parameter and stochastic risk, and the problems of quantifying them; and the extent to which measures of uncertainty based on large populations could be applied to different, smaller populations such as an insurer's annuitant portfolio.

The CMI has evaluated two methodologies for mortality projections—the P-spline model and the Lee-Carter model (CMI Working Paper Numbers 15, 20 and 25)—and aims to explain the benefits and shortcomings of each. The CMI has not sought approval for either methodology nor does it rule out alternative approaches to projecting mortality. It is for individual actuaries to understand the implications of the different methodologies and the appropriateness of each in any given situation. Non-commercial grade software has been made available to illustrate the methodologies and to allow users to experiment with the methodologies.

In both cases it is recommended that the historical dataset used should go back at least 20 years and should contain a large amount of data for each year for the age ranges fitted. The two U.K. datasets which fit these criteria are the CMI assured lives dataset, which goes back to 1947, or population data

The P-spline model fits a surface of mortality rates to historical data and in the region of the projections provides estimates of the standard deviation of the log mean values of the rate of mortality. The degree of smoothing of the past data can be specified as can the method for projecting forward. Projections can be done on an age-period or age-cohort basis (the latter provides more emphasis on projecting forward past cohort effects). The method provides a range of surfaces of projected mortality improvements; these can then be applied successively to the assumed base mortality rates. Different surfaces can be regarded as percentiles, so it is possible to pick the 50th percentile sheet as the main projection and look at variations by considering the 97.5th and 2.5th percentiles, for instance.

The Lee-Carter model produces sample paths of future mortality improvement based on historical data. Several thousand of these are generated and then the resulting projected improvement for a given age and year can be ordered and confidence intervals obtained by comparing the requisite percentiles of the ordered data. One of the difficulties in adapting Lee-Carter methods to U.K. data is the existence of cohort effects in historical U.K. data. These are not readily picked up by the original Lee-Carter methods, either in fitting past data or in projecting these effects forward. Adapting the Lee-Carter model to deal adequately with cohort effects has so far proved problematic.

8.1 Occupational Pension Scheme Mortality—Self-Administered Pension Schemes Investigation

The CMI has recently started to collect and analyse mortality data from a sample of occupational pension schemes. These data suggest that for ages 60 and over, both male and female mortality in the sample occupational schemes was higher than the corresponding "00" graduations for 2000 for both lives and amounts (CMI Working Paper 29). The data also show a clear correlation with pension size with lower mortality being experienced for those with larger pensions, the effect diminishing with increasing age. Schemes in industries with high proportions of manual workers usually exhibited higher mortality than those in industries with more non-manual workers. Draft graduated tables of mortality rates for these data were published in January 2008 (CMI Working Paper Numbers 31 and 32).

8.2 Comparisons of Mortality

The CMI "00" mortality tables for pensioners in insured pension schemes provide mortality rates for pensioners taking normal or late retirement, for early retirements (for whom mortality rates are in general higher than for normal retirements, since this group includes retirements on ill-health grounds) and for all pensioners combined. These are based on the mortality experienced in 1999 to 2002 and hence are most directly comparable to population life tables for the years 1999-2001 and 2000-2002.

Tables 9 to 12 show the values of expectations of life on various mortality tables both with and without the projected improvements associated with each tables as follows:

- The column headed ILT99/01 gives period life expectancy values from the interim life tables for the United Kingdom based on population mortality experienced in the United Kingdom in three years 1999-2001.

- The figures shown in the columns headed PCML00 and PCFL00 are calculated using lives mortality from the “00 series” mortality tables for the combined group for males and females respectively.
- The columns headed PCMA00 and PCFA00 figures are calculated on an amounts basis from the “00 series” mortality tables for the combined group for males and females respectively (here pension amounts rather than lives are used as the units of exposure and a “death” is the cessation of payment of pension).
- The figures in the two columns headed Population mortality 2007 show period and cohort life expectancy for the United Kingdom for age attained in 2007 calculated using the 2006-based U.K. population projections.

TABLE 9

Expectations of Life—Males *years*

Age	ILT 99/01	PCML00	PCMA00	Population mortality 2007	
	Period life expectancy	Period life expectancy	Period life expectancy	Period life expectancy	Cohort life expectancy
60	19.47	21.17	22.52	21.35	25.10
65	15.66	17.18	18.40	17.46	20.70
70	12.25	13.47	14.50	13.79	16.44
75	9.35	10.27	11.02	10.50	12.16
80	6.97	7.71	8.12	7.78	8.66

Source: U.K. Office for National Statistics, Continuous Mortality Investigation, U.K. Government Actuary’s Department

TABLE 10

Ratios of Expectations of Life in Table 9 to Those from Interim Life Table 1999-2001 for Same Age—Males, UK

Age	ILT 99/01	PCML00	PCMA00	Population mortality 2007	
				Period	Cohort
60	1.00	1.09	1.16	1.10	1.29
65	1.00	1.10	1.17	1.11	1.32
70	1.00	1.10	1.18	1.13	1.34
75	1.00	1.10	1.18	1.12	1.30
80	1.00	1.11	1.17	1.12	1.24

TABLE 11

Expectations of Life—Females *years*

Age	ILT 99/01	PCFL00	PCFA00	Population mortality 2007	
	Period life expectancy	Period life expectancy	Period life expectancy	Period life expectancy	Cohort life expectancy
60	22.96	24.41	25.26	24.30	27.88
65	18.83	20.06	20.85	20.08	23.17
70	14.98	15.98	16.68	16.05	18.58
75	11.55	12.33	12.91	12.32	13.77
80	8.57	9.23	9.67	9.13	9.84

Source: UK Office for National Statistics, Continuous Mortality Investigation, UK Government Actuary's Department

TABLE 12

Ratios of Expectations of Life in Table 11 to Those from Interim Life Table 1999-2001 for Same Age—Females, UK

Age	ILT 99/01	PCFL00	PCFA00	Population mortality 2007	
				Period life expectancy	Cohort life expectancy
60	1.00	1.06	1.10	1.06	1.21
65	1.00	1.07	1.11	1.07	1.23
70	1.00	1.07	1.11	1.07	1.24
75	1.00	1.07	1.12	1.07	1.19
80	1.00	1.08	1.13	1.07	1.15

The tables show a projected increase of around 12 percent in period expectations of life between 2000 and 2007 for older males in the United Kingdom (and 7 percent for older females). If future mortality improvements at these ages occur as projected, the cohort expectations of life will be around 18 to 19 percent higher for males aged 60 to 70 in 2007 than would be expected if mortality rates remained in the future at the same level as currently projected for 2007. The tables also show that period expectations of life of people in insured occupational pension schemes in 2000 were higher than for the population as a whole in 2000 by around 10 percent for males and 7 percent for females on a lives basis for ages 60 to 80 (and even higher if measured in terms of pension amounts rather than lives).

9. Pensions Commission

A Pensions Commission was appointed in December 2002 with a remit to review the adequacy of private pension saving in the United Kingdom and to advise on appropriate policy changes. Whilst acknowledging the difficulties in projecting future mortality rates, the Commission believed that the 2002-based projections assumed too little future mortality improvement. The changes made in the GAD/ONS assumptions used in the 2004-based and 2006-based projections have produced projected cohort life expectancies for males aged 65 which were rather closer to the middle of the Commission's assessed range of uncertainty for this measure.

The Commission made a number of recommendations regarding mortality including:

(i) that official publications as far as possible use the cohort approach when describing current and future trends in longevity;

(ii) that official publications which set out estimates of projected life expectancy should ideally provide not only the best estimate but also the range of possible results which could arise from alternative reasonable assumptions and

(iii) that pensions systems should be resilient in the face not only of rising life expectancy, but also of the large uncertainty of how rapid this rise will be.

Following consultation on the Commissions report and recommendations, the U.K. government has introduced legislation to raise the state pension age to 68 for males and females by 2046.

10. Discussion

Mortality rates in the United Kingdom declined significantly in the 20th century at all ages and for both males and females. There are many ways in which future mortality rates might be modelled. The official national U.K. population projections use a combination of extrapolation and targeting using informed judgment. It is assumed that the current high rates of mortality improvement seen at most ages for both males and females will reduce to 1 percent pa (the average rate of improvement over the 20th century) over the first 25 years of the projection. For those born before 1960, cohort effects are allowed for by projecting changes from the current rates of improvement to those assumed in 2031 by year of birth rather than by year of age. In addition, those born between 1923 and 1940 have experienced higher rates of improvement than those born on either side, and there appears to have been no reduction in this differential over recent years. As a result, the rates of improvement assumed in 2031 and beyond for these cohorts are higher than those for other cohorts.

The existence of these cohort effects means that some extrapolation methods such as Lee-Carter appear to work less well on U.K. data, unless they can be modified to allow for these effects. This suggests that it is important to look at the patterns in improvements in historical mortality rates and assess whether these should be projected forward and in what way, when choosing a suitable projection methodology.

The U.K. national population projections are currently deterministic only, with high and low life expectancy variables also produced to give some idea of the sensitivity to plausible changes in the assumptions. There is a demand from users of the projections for variant projections; for example, the effects of the variant mortality (and fertility and migration) projections on projected contribution rates are considered and published as part of the reviews of the U.K.'s National Insurance Fund, carried out by the U.K. Government Actuary. However, no probabilistic statements can be attached to these. There is a growing movement towards producing stochastic projections among national statistical institutes and the production of stochastic projections is currently under consideration for the national U.K. projections.

For mortality projections from mortality tables produced on behalf of the U.K. actuarial profession, the current emphasis is on providing measures of the uncertainties involved and methodologies have been proposed to enable these to be provided. Of course, there still remain uncertainties related to the suitability of the actual projection model chosen and this uncertainty would be very difficult, if not impossible, to measure.

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Annex A

FIGURE A1
Annual Percentage Improvements in Smoothed Mortality Rates
Males, 1962-2005, UK

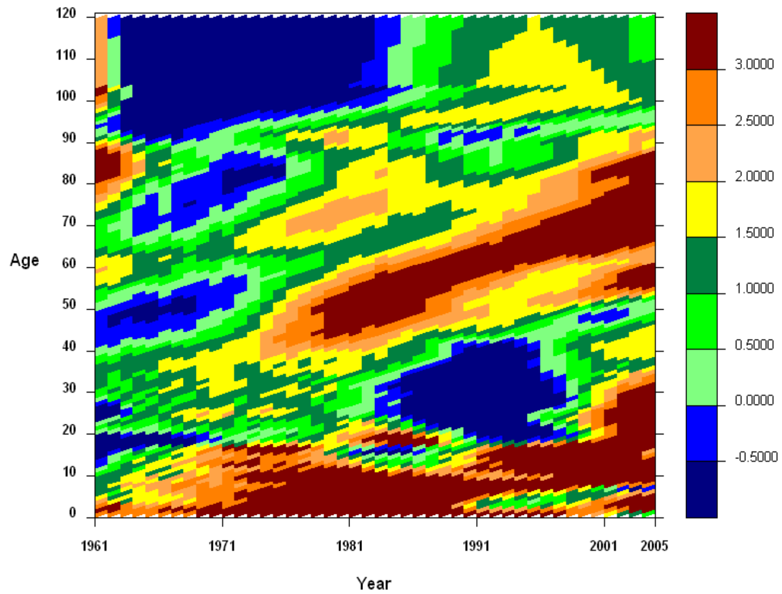

FIGURE A2
Annual Percentage Improvements in Smoothed Mortality Rates
Females, 1962-2005, UK

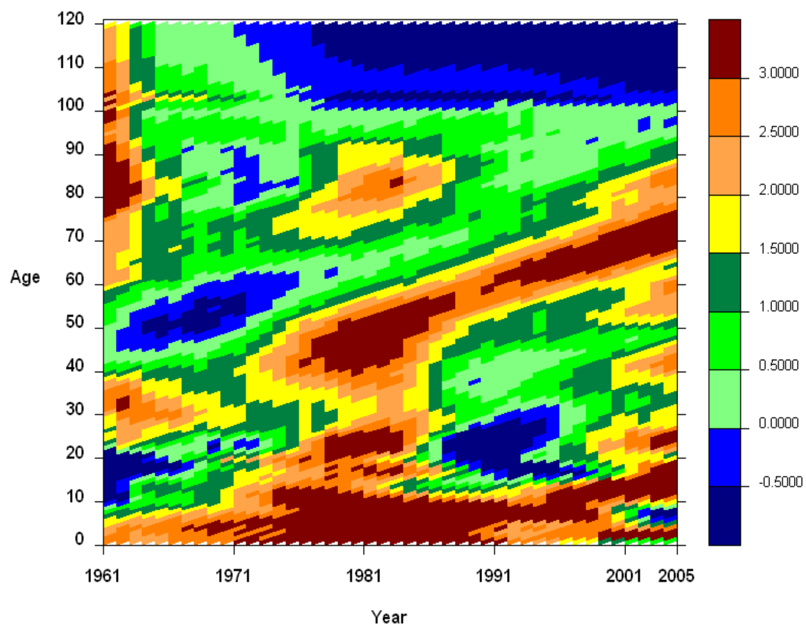

FIGURE A3

Actual and Projected Annual Percentage Improvements in Smoothed Mortality Rates—Males, 1962-2031, UK

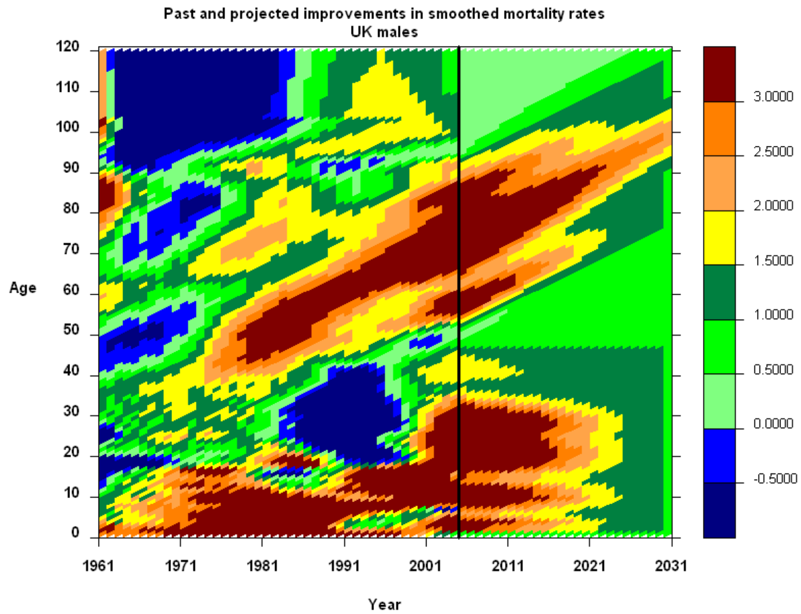

FIGURE A4

Actual and Projected Annual Percentage Improvements in Smoothed Mortality Rates—Females, 1962, 2031 UK