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Expectations Aplenty

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Abstract:

This paper provides a summary of the history of mortality improvement rates for the population in Australia.

A basis of projection of mortality rates is briefly discussed utilising various improvement rates derived directly from past experience and comparing these to the rates used for official projections. We provide a set of expectations of life by current age to allow for improvement.

Finally, we explore what can be considered to be meant by 'old age' in the context of life table statistics and the eligibility age for the social security age pension.

Note that a more complete set of the results of the paper can be obtained from the author. The paper will be subject to revision as further interviews are to be conducted with retired officials involved in the production of earlier life tables.

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Opening Remarks

Accurate projection of future mortality rates is desirable for those considering the aging of the population, the future of our health and aged care systems, and the retirement incomes strategies for the nation. It is also of great interest to individuals – despite the fact that the published figures represent the effect of averages over large numbers.

In this paper we provide a discussion of mortality projection in Australia with several sets of results presented to indicate the potential for a range of expectations into the near term. In this context, we consider both the life table based rates which summarise the overall mortality experience at a point in time as well as the implications for cohorts by current age.

In addition, we explore what can be considered to be meant by ‘old age’ in the context of life table statistics, the determination of traditional dependency ratios and the eligibility age for the social security age pension.

Preliminary Comments on Life Tables and their Graduation

Mortality rates themselves can be considered in a number of forms. For example, the usual life table measures of mortality include

- The initial rate of mortality - q_x
- The central rate of mortality - m_x
- The force of mortality - μ_x
- The expectation of life e_x , particularly the expectation of life at birth e_0 .

Often, the life table expectation of life at birth is treated as a “headline” rate. As a result, the figure is used to compare mortality over time or to highlight the differences in mortality between groups, for example between men and women or between the indigenous and non indigenous populations. The high public status of these numbers suggests to the lay public that they may well be the beneficiaries or sufferers of the relative positions perhaps more so than those of us with a greater experience would accord to the figures. Sometimes strongly indicative results are helpful but, all too often, impressions can be given that a particular trend is somehow likely to be reflected in the life expectancy of a particular group.

An example would be the fact that a reduction in life expectancy can follow from a reduction in infant mortality but the resulting publicity can suggest that most of us are benefiting from this improvement.

Australian mortality rates have been the subject of a long history of analysis since the nation's official federation in 1901. A popular expression of this study has been through the examination of life tables. These tables are not pure expressions of the crude mortality rates observed at the time. Instead, they are subjected to graduation, and in some cases considerable reinterpretation, of the crude rates.

Figure 1: Males and Females. Crude central mortality rate $m_x^{ALT1995-97}$

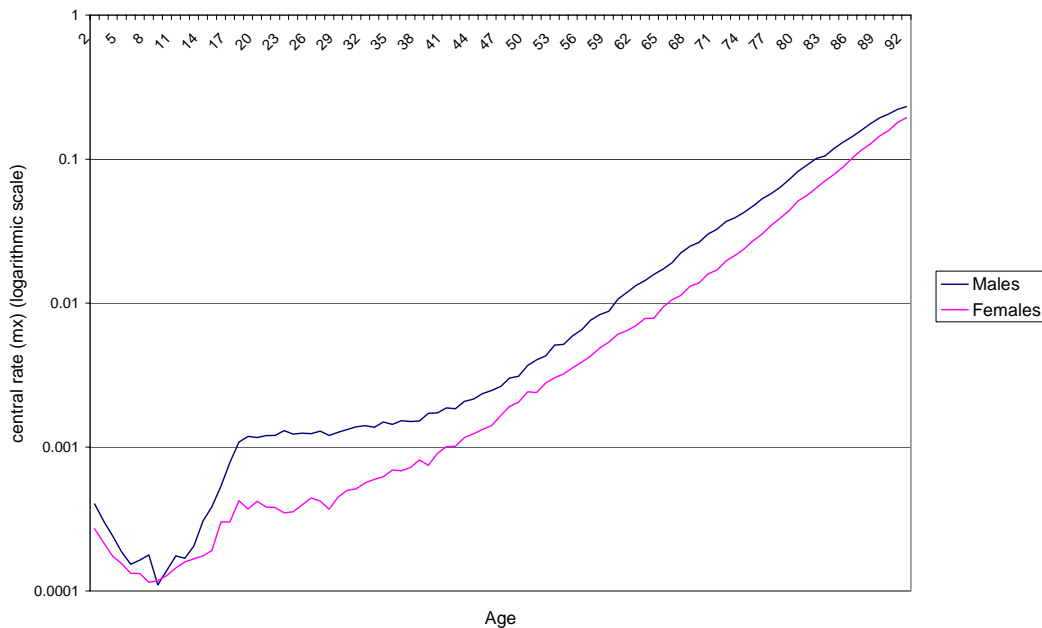


Figure 1 shows the crude rates derived for the ALT1995-97 tables by way of example. The absence of smoothness is clear by inspection. A life table is, therefore, a model of the mortality assuming that there are certain criteria to be met and that the underlying observed rates are, themselves, subject to statistical fluctuation.

That is, the graduation process seeks to find a suitable set of q_x values that:

- Represent the underlying observed mortality;

That is, present a reasonable fit to the underlying observed data. There is a battery of tests based on a statistical perspective that have been developed to assess the quality of a graduation. Importantly, however, not all published graduations would be

expected to pass all tests.

- Comply with expectations of mortality curves;

There is a view that mortality tends to increase from age to age, with the usual exception of infant mortality and a possible accident “hump”, and that this progression should be a smooth one; and

- Are suitable for the use to which they are likely to be applied;

Depending on the use, the degree of smoothness may play a greater part or there may be a desire not to overstate or understate mortality overall or over particular age ranges¹. Population tables tend to be structured so as to neither overstate or understate the actual experience observed when averaged over the whole of the age range but could do so for particular age ranges within the table.

Or, alternatively, expressed algebraically

$${}^o q_x = \hat{q}_x + \varepsilon_x$$

where

${}^o q_x$ is the underlying rate of mortality of the population under examination;

\hat{q}_x is the rate of mortality observed; and

ε_x is an error term that, in an unbiased table would be expected to have a normal distribution with mean zero. The ε_x should be independent of each other over the age range.

If this premise with respect to the ε_x terms holds then the calculated life expectancy at a given age will be the same whether it is based on graduated or crude (not graduated) mortality rates.

¹ Introducing bias (ie avoiding overstatement or understatement) or a greater priority on smoothness is a common feature of tables produced for insurance applications. For this reason, it is not completely fair to compare the experience of, for example, life insurance company annuitants with the general population tables without understanding the methodology underlying both tables and the influence this may have on the comparison.

Population Mortality Rates in Australia

This section provides a summary of the history of Australian mortality studies at the national official level.

A little about the Tables Published by the Australian Government Actuary

The Commonwealth Statistician produced a series of tables covering the periods 1881-90, 1891-1900 and 1901-10 using periods of data based on various census records (two census dates for each table) and deaths recorded over a 10 year period. Tables for 1920-22 and 1932-34 were also prepared by the Commonwealth Statistician² – taking into account the three years of death observations around the single census year. The publication of these tables included specific acknowledgement of the actuary who had assisted with their preparation.

After this, the series was prepared and published by the Australian Government Actuary. The latest in the series, covering deaths 1995-97 and utilising the census data from 1996, was released in August 1999.

These tables will continue to be produced every five years based around the census. Aside from the usefulness as a representation of population mortality levels, the tables are also used for various legislative purposes including, for example, the determination of taxation obligations and social security entitlements for those in receipt of an annuity in retirement. They are also used for various state stamp duty applications and by property valuers in determining approximate values for certain types of property.

The tables are produced by a method which can be described as follows:

- ❑ Crude (central) rates of mortality are calculated by taking the number of deaths and dividing by the number exposed to the risk of death for each year of age - Deaths in each of the three years around the census, and three years of exposed-to-risk were used in the calculations;
- ❑ Exposed to risk is determined making allowance for the need for consistent treatment between deaths and those alive – there is equal potential to contribute to the count of exposure and deaths. The availability of data makes allowance for the late reporting of deaths and exposures.
- ❑ Treatment of cases outside Australia has incurred particular attention. In these cases, the philosophical merits of inclusion is measured against the potential to provide

² The Australian Government Actuary's publication of the tables attributes the production of the tables up to the 1932-34 table to the Australian Statistician but, for example, the ABS in standard footnotes to tables 8 of the early editions of Cat no 3302.0 indicates that "annual life tables calculated by the Australian Statistician" were introduced in 1973.

accurate and timely data.

- The table is then graduated – for some time, the methods used have been reasonably consistent and efforts have been taken to make them more so over the last five years although this is at the margin. As a result, methodology has not been a source of great inconsistency between tables in Australia. We do, however, use the cubic spline methods which includes some judgement. Only recently has this judgement been mechanised by developing some decision rules. There is scope for some analyses of results from table to table to show cycles through the age ranges which are, in fact, the result of consistent application of the methodology and principles. Equally, it needs to be recognised, if comparing Australian tables with those of other nations, that the method may be a source of some inconsistency as would the comparison of these tables with those generated by the Australian Government Actuary for each state and, to a greater extent, with the experimental indigenous table produced some time ago by the ABS.
- Deaths and Exposures for ages 0 and 1 are given special treatment to make allowance for the sharply uneven rates of death over the year of age. As a result, care needs to be taken in forming any views about rates at these ages.
- Rates for those of very advanced ages have been problematic for some time. Observers will have noted that, more recently, male rates have been reported as falling below female rates. This has, interestingly, been a permanent feature of the data for the last 20 years at least as far as I can determine by speaking to those involved in the development of tables at that time and is also observed in other countries. For some time, the observation was put down to paucity of data and “graduated out” by the Actuary. More recently, it has been retained although the first case where this was done was less obvious to all as it occurred after age 100 where the published values of the table were truncated.

About the Tables Published by the Australian Bureau of Statistics

At the same time, the Australian Bureau of Statistics (ABS) publishes a life table in the *Deaths, Australia* bulletin.

This publication was first produced in 1967. The early editions have a life table death rate shown for “an abridged life table” from 1963 although these tables did not appear in the publication. The life table death rate is the reciprocal of e_0 so determination of the rate requires a life table to be constructed although it does not require it to be graduated.

The e_0 value was provided from the 1971 edition (table 16 p 31) which showed values for each of the tables 1946-48, 1953-55, and 1960-62 as the “Official Life Tables, compiled by the Commonwealth Actuary” and a value for 1965-67 which was described

as “calculated by the Commonwealth Statistician. Subject to revision when Official Life Tables become available.” (footnote to table 16 of 1971 edition). Of note, the life table “true death rates” were not included in 1971.

The 1972 edition was expanded and included (at table 7) expectations of life at birth and true death rates for Australia from 1921 to 1972. (p 11). This format continued for sometime although it is interesting to note that the “Official Life Tables” remained attributed to the AGA and that the annual life tables were qualified with a note:

“Because of the method of calculation, these figures are subject to annual fluctuations which may not be indicative of a longer term trend.”

footnote in Deaths, Australia Table 7.

It is also of passing interest to note that the table in the 1974 edition dispensed with reporting the annual time series back to 1963 and reverted to a shorter series only covering the intervening period since the latest “Official Life Table” produced by the Actuary.

It was not uncommon for adjustments to be made to the series as far back as three or four observations for each publication suggesting that there remained some revision even that late in the process.

The 1978 edition broke new ground by including life expectancies at a wider range of ages including back trends from the ABS tables to 1973 and the full life table as an appendix. A similar table was produced in 1979. The 1980 edition saw the table with a more substantial note as follows.

“Note: These tables are prepared by the Australian Bureau of Statistics. Their purpose is to summarise the mortality relating to the number of deaths registered in 1980 by providing a set of summary indicators in terms of life table values. These tables are not constructed according to strict actuarial principles and consequently it is *recommended* that they be not used for actuarial purposes. Those wishing to use life tables for actuarial purposes are recommended to use the Official Life Tables prepared by The Australian Government Actuary, the latest of which were published in October 1980, see paragraph 11 of the Explanatory notes.”

I note that this edition of 3302.0 was published on 3 March 1982 (R J Cameron was the Statistician at the time). Note 11 indicates that the ALT 1975-77 was released in October 1980 with a contact name for details – Mr J DeRavin.

We have interviewed Mr De Ravin, now a senior actuary but at the time a junior officer at the Office of the Australian Government Actuary. He indicated that the recollection of the situation was that the tables of the ABS were subject to (the expected) demarcation questions about what would be appropriate as the “official tables”. He recalled that

differences existed between the statistician and the actuary as there was a desire to generate consistent tables in a timely fashion.

Mr De Ravin reported to the author that the critical difference involved timeliness, which was important to the ABS whereas the AGA wanted to hold out until it had counted deaths and exposures allowing for timing delays.

Additionally, at the time, the ABS were looking to use a single year of data each year and the AGA were concentrating on three year figures. The concern of the AGA was the impact that a single year where there had been a poor winter and the impact of a 'flu effect arose would distort the figures where this was statistical variation rather than a real trend. As a result, the AGA were committed to a 3 year data set whereas the ABS were looking for a 1 year set – this also effects timeliness.

This description remained largely unchanged until 1995 – continuing to be published by the ABS with the extensive qualifier although the reference to “Official Life Tables” was replaced with a reference to tables “constructed by the Australian Government Actuary” during this period.

In 1995, the tables were altered to become a “new series produced jointly by the ABS and the Office of the Australian Government Actuary. The tables differ from those published previously in this bulletin in a number of important respects. Firstly, they are based on three years of population and deaths data. This is designed to reduce the impact of year-to-year statistical variations, particularly at younger ages where there is a small number of deaths and at very old ages where the population at risk is small. Secondly, the population and deaths data are based on Australian residents who are physically present in Australia over the three year period i.e. Australian residents temporarily overseas are excluded. Thirdly they have been actuarially graduated based on the same principles as are used for the quinquennial Australian life tables prepared by the Australian Government Actuary.”

The note went on to indicate that “Life tables for states and territories are produced on the same principles as these tables and are available on request.” (refer p 70 of Cat no 3302.0 1995 edition). The actual methodology for the production of the state tables differs from the national table in that the method of graduation is different. Where the national table is graduated using the same spline methodology as is the case with those published by the Actuary, the state tables are graduated using a method that depends on the national table, graduating the state data with reference to the “standard” national table and an algebraic transformation.

Notation

For convenience, we will refer to the Australian Life Table series as ALT, for example the most recent table will be referred to here as ALT1995-97, and the annual series

published by the Australian Bureau of Statistics in their *Deaths, Australia Bulletin* as “A” making the most recent one at the time of preparing this paper (September 2000) A1996-98. In each case, we will place an identifier in advance of the symbol to indicate the sex (M or F) where applicable. We will use a similar approach to identifying life table values such as q_x or e_x .

As such, then ${}^M q_x^{ALT1995-97}$ could be taken to represent the rate of mortality at age x for a male life as observed in the *ALT1995-97* tables.

Some observations on Mortality Improvement when the ALT1995-97 Tables were produced.

Very recent changes in mortality can be illustrated from the changes in rates between the last two tables, particularly as their methodology and approach provided no effects.

Figure 2: Percentage change between $m_x^{ALT1990-92}$ and $m_x^{ALT1995-97}$ ($x=18$ to 92).

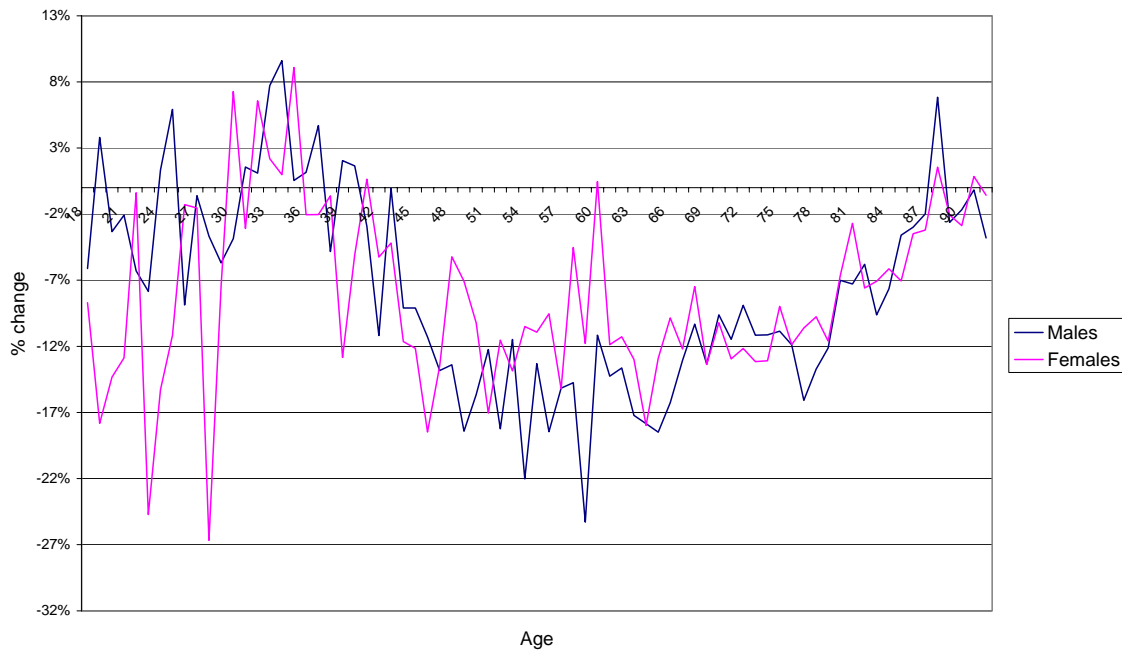


Figure 2 conveys the extent of mortality change between the two most recent ALT tables by presenting the percentage change in central mortality rates over the five year period for ages 18 to 92. The relatively low number of deaths prior to the late teens is the cause of the high volatility in the percentage change from one age to the next, particularly among females.

Of note is the increase in mortality (deterioration) for males and females aged from the early to mid-thirties. The increasing mortality for this group is consistent with that observed during the construction of ALT1990-92. In these tables it was noted that there was little improvement in female mortality rates around age 30 between 1985-87 and 1990-92, and an increase in mortality rates for males in this age group. Inspection of the state tables suggests that this trend may not be nationally uniform although this has not been thoroughly investigated at this point.

Other changes of note since 1990-92 were that:

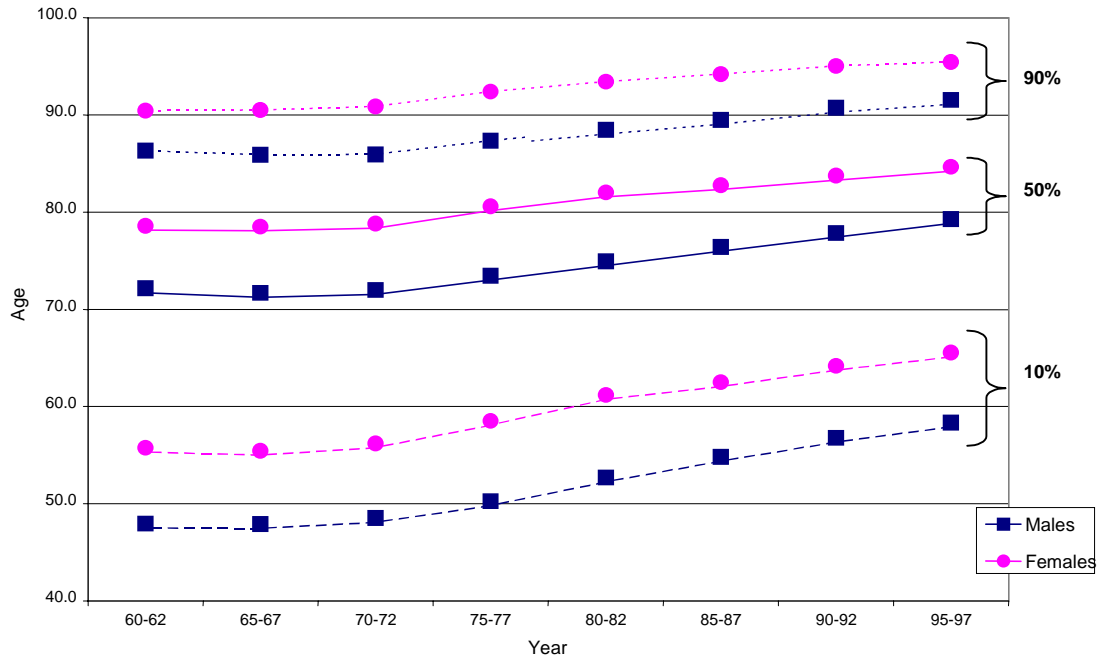
- mortality rates had improved substantially for both males and females between ages 40 and the late 80s, with male mortality rates improving relatively more than females between ages 50 and 70;
- there are visibly lower female rates from ages 18 to 25 than in the 1990-92 Life Tables (with the exception of age 22). The improvement in mortality is most apparent between ages 21 and 25;
- female rates are consistently lower than the male rates. As indicated above, male and female rates cross-over at an advanced age. In ALT1990-92 the cross-over occurred at age 103. For ALT1995-97 the cross-over occurs at age 98; and
- relatively high mortality at ages 18 and 20 for females, and lower mortality between 21 and 25 results in the appearance of a "hump" in the female q_x curve around age 20. This phenomenon was present in ALT1985-87 and ALT1990-92, though the "hump" has recently become more pronounced.

As a means of visualising the effect of past mortality improvement on current Australian mortality, probability of death was compared for various Australian Life Tables.

Figure 3 shows the age by which 10%, 50% and 90% of the population would have died according to graduated rates extracted from the last eight Australian Life Tables. The age gaps between male and female values in Figure 3 have narrowed since 1980-82 and have continued to narrow over the last five years.

The greatest increase has occurred in the age at which 10% of the population has died (about 10 years). The 90th percentile age has also increased significantly (5 years). With improving health outcomes we would expect the compression to continue.

Figure 3: Age by which 10%, 50% and 90% of population has died.



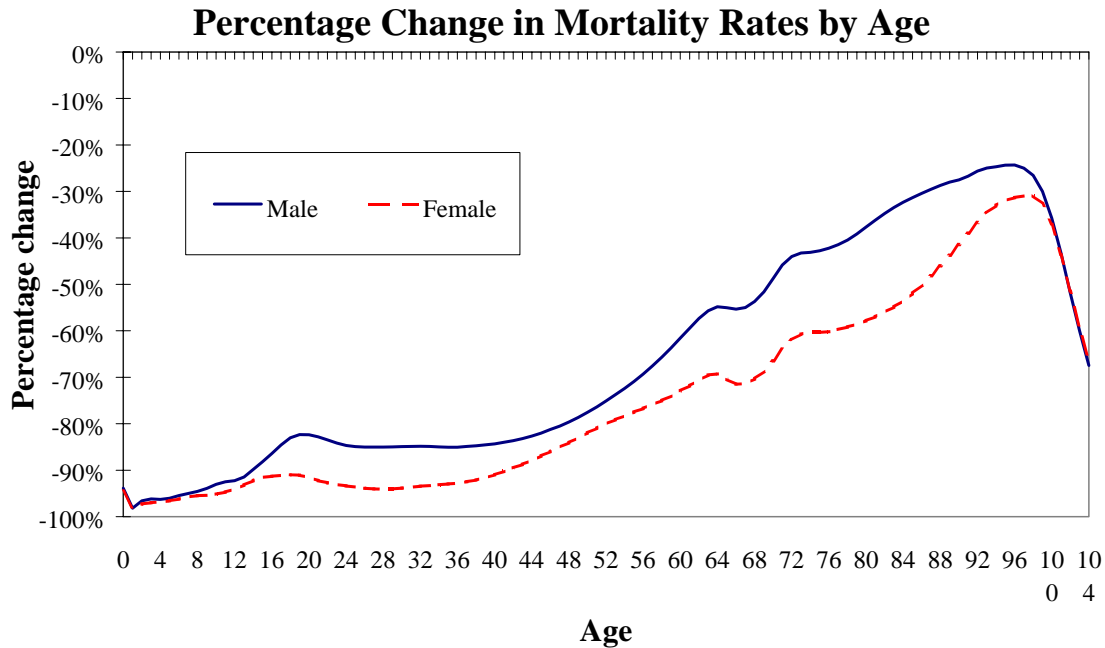
Mortality Improvement

It is reasonable to consider that future mortality improvement is more predictable than future changes in fertility and migration³. Never the less, accurate “prediction” of mortality in the term required for long projection periods remains problematic. Primarily, this is due to the fact that the possibility of stepped change in the future is unclear and ever present.

As figure 3 shows above, there has been substantial improvement in mortality over time. In fact, comparison of the first and most recent tables in the ALT series highlights the magnitude of change over the longer period.

³ For a discussion of this point see Thorburn (1999).

Figure 4: Change in the values of q_x over the full range of the periods covered by the ALT series.



In fact, infant mortality is now just 5% of the levels originally measured.

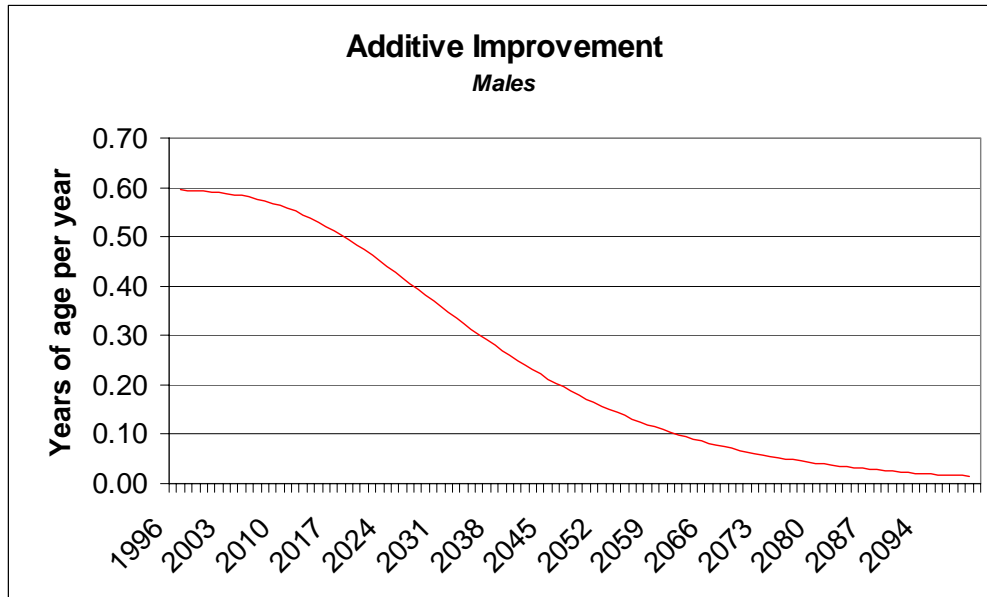
There are a number of ways to consider potential future improvement. For example: a constant level of change or a constant rate of change in

- Life expectancy at birth e_0 ;
- Mortality rates q_x ; or
- The force of mortality μ_x .

For the purposes of this paper, we consider mortality improvement in terms of geometric rates of change in q_x . This approach has the advantage of smoothly moving to reducing effects of increase in the expectation of life and therefore, contrasts with a method that targets life expectancy.

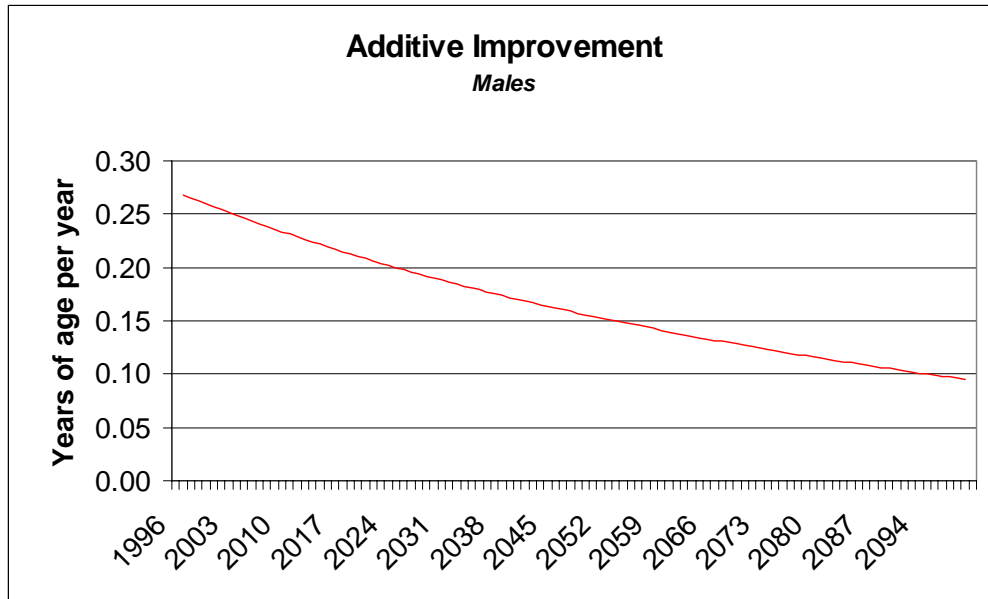
To illustrate this effect, we have projected the effect of a constant 5% rate of improvement at all ages. The change in life expectancy each year would be as follows (Note that there is a more complete set of results in the appendices):

Figure 5 : Improvement in life expectancy at birth that would result from a multiplicative constant future change of 5% in mortality rates. (Males)



This curve is a function of the pattern of improvement relative to mortality levels over the age range of the table. For example, a different pattern emerges if we apply the rates of improvement observed over the last 25 years (see Figure 6). In fact, aside from the level of the chart in figure 6, the pattern of more concave downward trends is consistent across all age based scales in contrast to the constant rate curves of Figure 5.

Figure 6 : Improvement in life expectancy at birth that would result from a multiplicative future change following the age pattern and level of the last 25 years observed experience. (Males)



The Appendices are presented with copies of these charts for each assumption set used, and for both male and female tables.

Actual experience has been calculated using the ABS tables and is shown in Figure 7 and 8. Note that the move to three year average tables can be expected to reduce the volatility seen in the earlier years on these charts.

Figure 7 : Observed Improvement in life expectancy at birth. (Males)

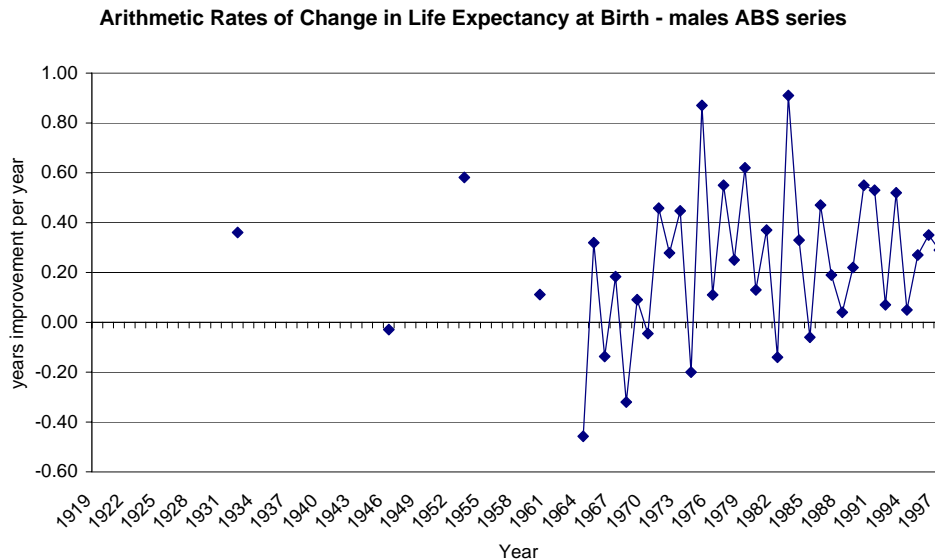
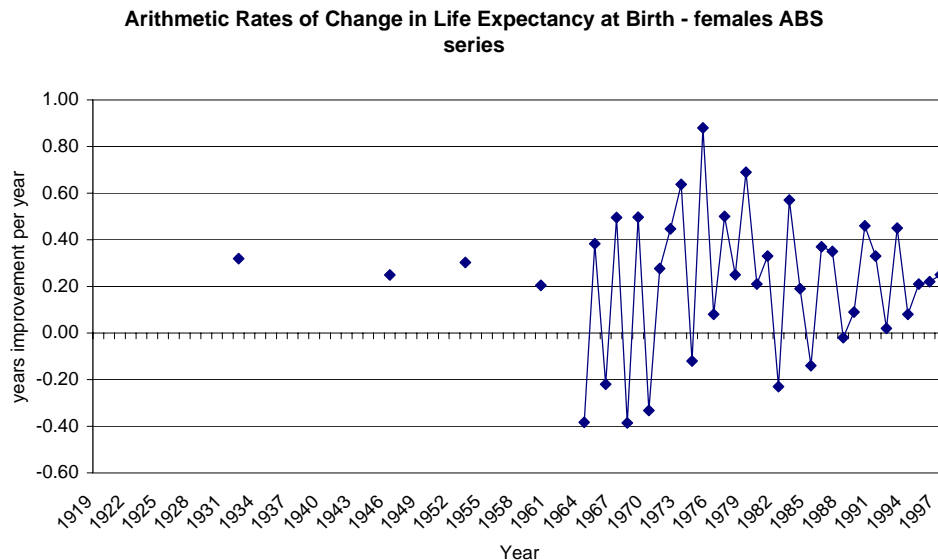


Figure 8 : Observed Improvement in life expectancy at birth. (Females)



The most recent publication of projections for the Australian population were issued by the ABS in August this year. Following earlier work, the ABS provided results on a single set of mortality assumptions:

“All series assume that life expectancy at birth will rise and attain levels of 83.3 years for males and 86.6 years for females in 2051. After this it will remain constant until 2101.”

ABS Cat 3222.0 page 4

The ABS publication did also include a section considering the sensitivity of results to the assumptions. To provide for this analysis and conclusion, a second assumption (the “optimistic” scenario) was introduced that the “rate of improvement of life expectancy at birth experienced between 1986 and 1996 will continue unabated for the next 50 years”. The ABS go on to explain that “If this occurred, life expectancy at birth would increase to 92.1 years for males and 93.4 years for females in 2051 (high assumption).” (ABS Cat 3222.0 page 38).

These comments suggest that the assumption is made in terms of the life expectancy rather than the q_x values. Of course, the other alternative is that the assumption is “re-expressed” in terms of e_0 . Advice to the author from the ABS is that they have, in fact, determined the expectation values and then worked to the q_x values from there. It is not made clear in the publication just which rates of change or adjustment to q_x values have been applied. This is a change in methodology compared to earlier years.

Examination of the data suggests that experience can be divided between the observations over the last century and the observations over the last 25 years (or less). It is well known that the improvement experience over the last quarter century has well exceeded that of the earlier period.

Figure 9 - Rates of change in ${}^M q_x$

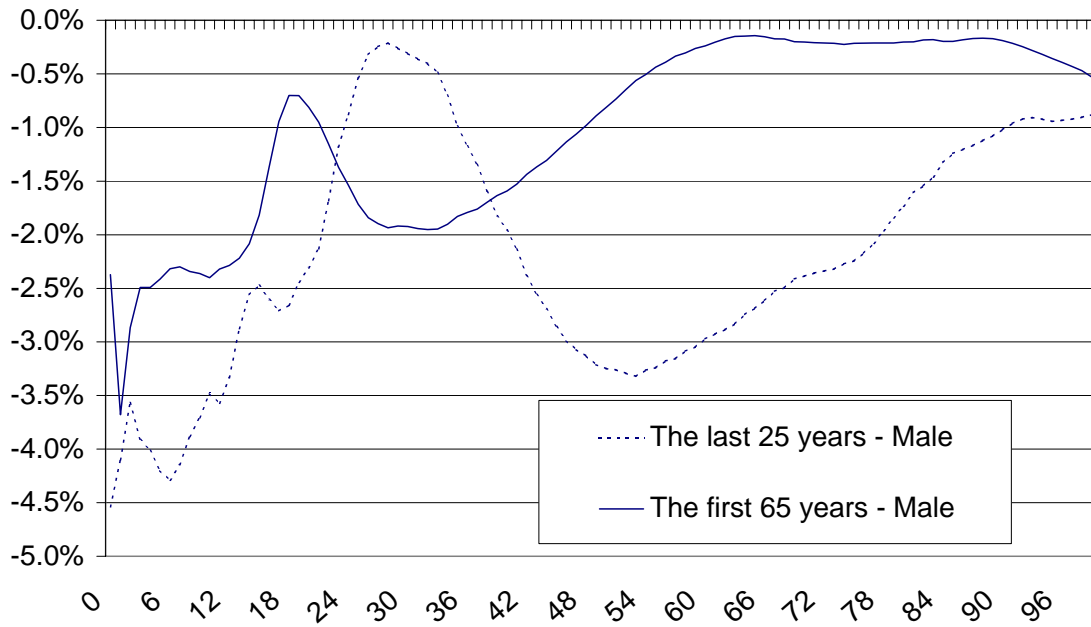
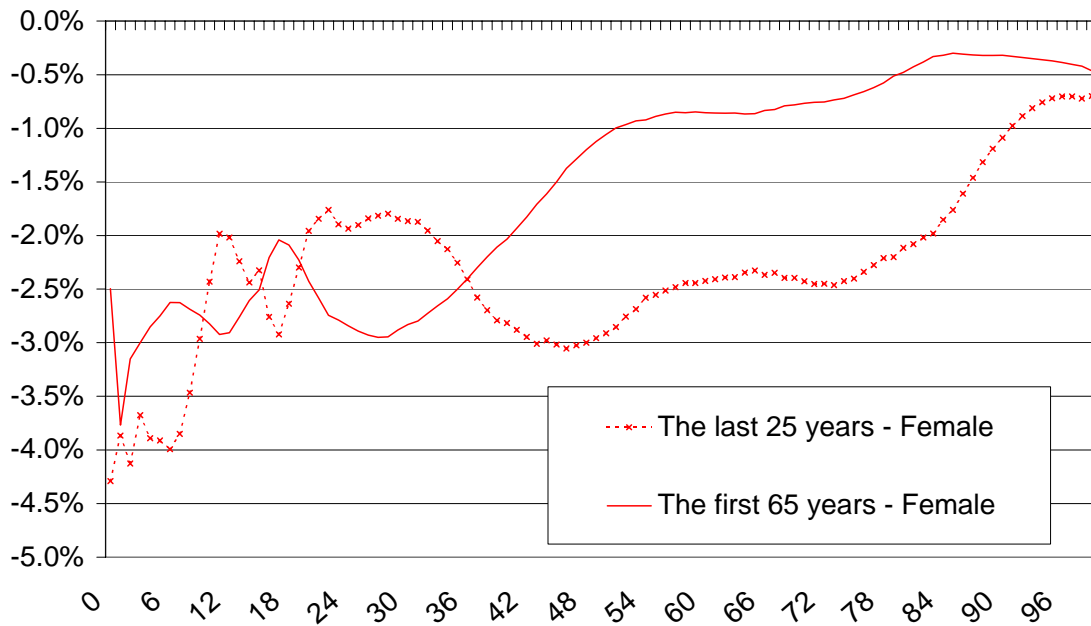


Figure 10 - Rates of change in ${}^F q_x$



Again, the different patterns of improvement by age will lead to different effects in the rate of change in the values of the life expectancies projected depending on the patterns used.

As a result, there are several readily available alternatives for a data based assumption if we are looking to explore the impact of a continuation of the “status quo”. We consider here ...

- Mortality improvement based on the rates observed for the last century;
- Mortality improvement based on the rates observed for the last 25 years;
- Mortality improvement based on the rates observed for the last 20 years;
- Mortality improvement based on the rates observed for the last 10 years;
- Mortality improvement based on the best result for each age of the above four bases;
and
- Mortality improvement based on the worst result for each age of the above four bases.

We have also explored the effect on life expectancy of improvement in a single year of age separately and examined the effects of a constant rate of change over all age ranges uniformly (as noted above).

Results are presented by examining the rates that would be determined by calculating a life table rates at a designated future time and by considering the cohort based life table for a range of current ages.

For example, we have investigated the effect of improvement at a constant rate of 5% per annum on the life expectancy of a child born today.

The improvement peaks coincident with the life expectancy – this result would be intuitively valid – at a 0.38% improvement for males if the targeted rate of improvement is focused on age 75 or 76 and 0.34% for females targeting age 81.

Figure 11:

Percentage improvement in Life Expectancy at Birth if mortality improves at 5% per annum for the stated age only

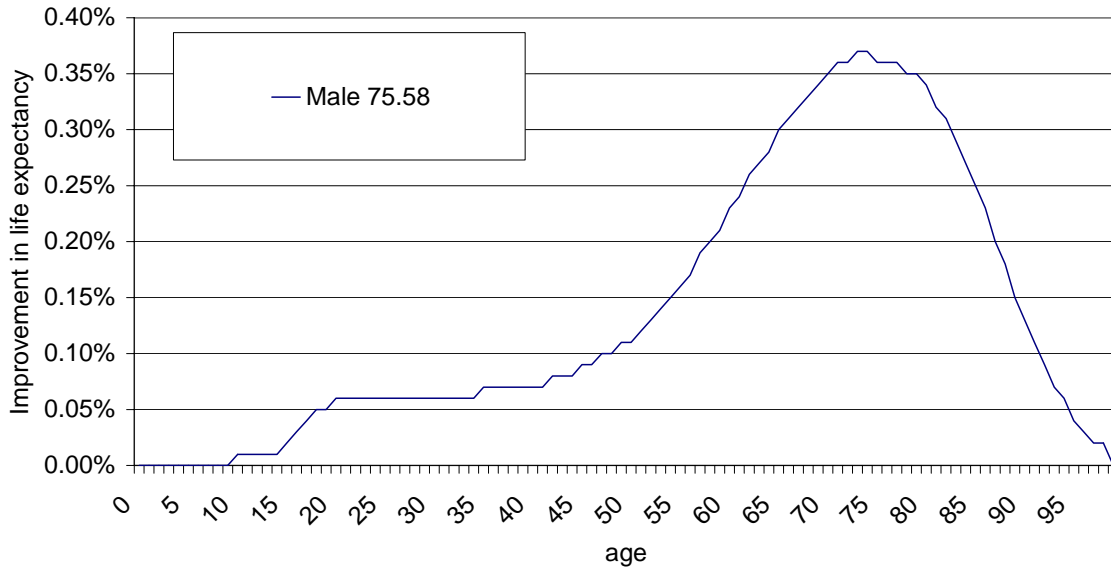
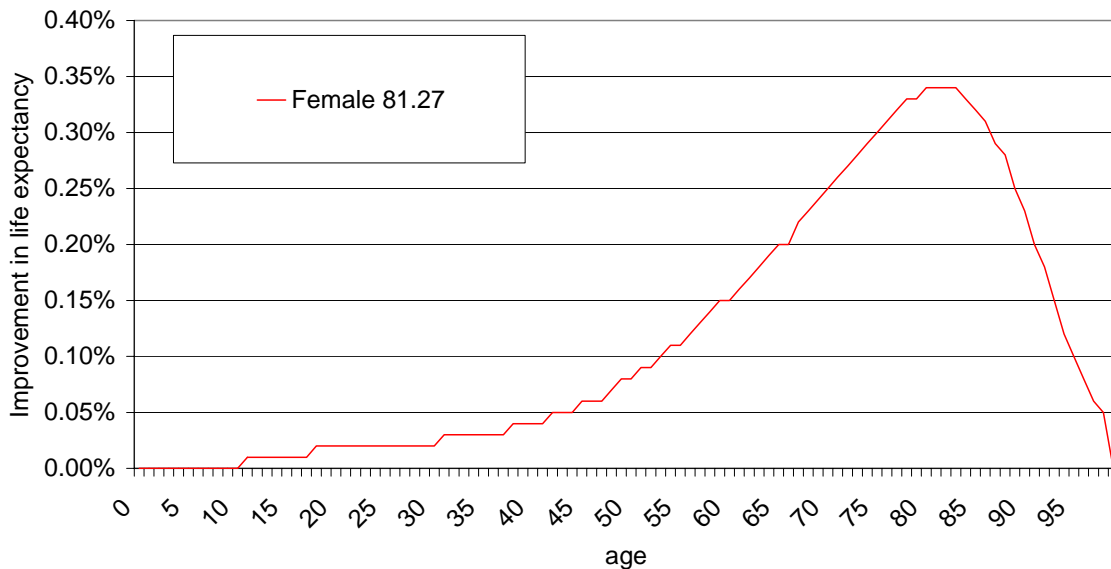


Figure 12:

Percentage improvement in Life Expectancy at Birth if mortality improves at 5% per annum for the stated age only

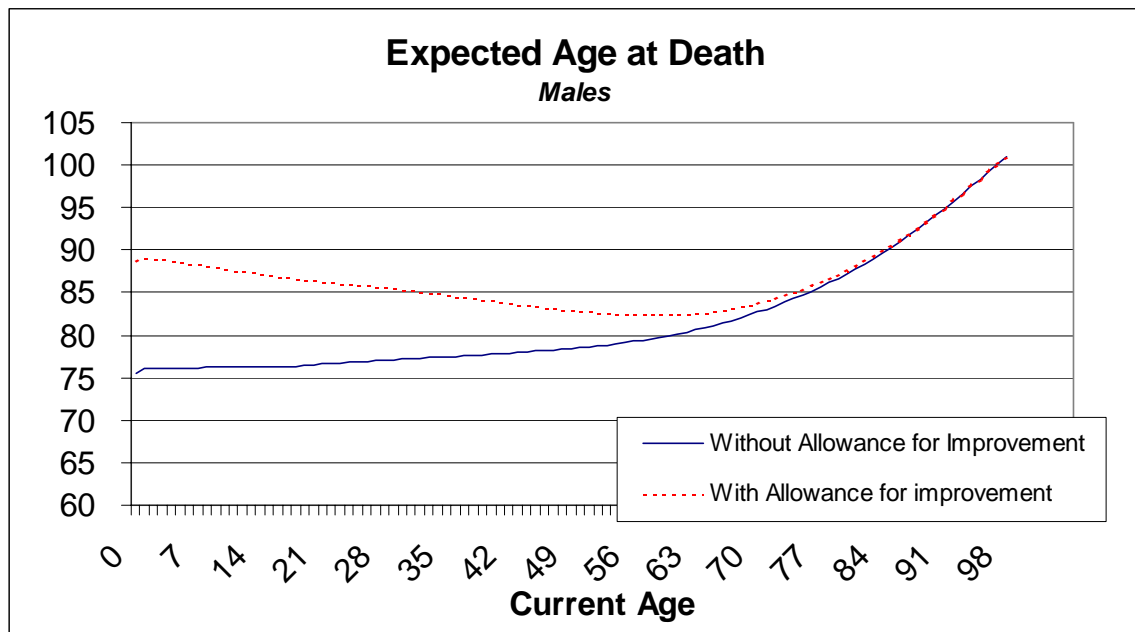


Life tables at a designated future time represent a summary of the estimated mortality levels at that time. Life table based rates by current age, in effect cohort based rates, have been calculated as part of the illustration of the effects of future improvement in the reasonable expectations of those alive today.

The key factors driving cohort results will be the rate of future improvement and the current age – which is a proxy for the amount of years that improvement can bear on the results before the eventual pressure of increased mortality rates proves overpowering.

It can be seen from the next figure that the principle determinant of potential age at death moves from that impacted by the future improvements at younger ages then to a value that is far more a function of current age attained.

Again, full sets of these values are in the attachment.



Whilst the full results are at appendix A, we observe that:

Table 1: Life Expectancy – Various Scenarios
(Sorted in order of Males result)

	Life Expectancy at 2050		Expectancy for those current age 0	
	Male e_x^o	Female e_x^o	Male e_x^o	Female e_x^o
Constant 0% - no improvement	75.6	81.3	75.6	81.3
“Worst” improvement at every age	80.2	86.6	80.5	87.5
Observed rates – century	81.1	86.9	81.1	87.7
Constant 1% improvement	81.8	86.7	83.2	88.4
ABS Standard Assumption	83.3	86.6		
Last 10 years observed	86.2	89.3	88.1	90.9
Last 20 years observed	86.3	89.9	88.1	91.6
Last 25 years observed	86.7	90.7	88.7	92.6
“Best” improvement at every age	87.5	90.1	89.3	92.7
Constant 2%	87.6	91.5	90.4	94.1
ABS “Optimistic” Scenario	92.1	93.4		
Constant 3%	92.5	95.2	95.3	97.6
Constant 4%	96.0	97.8	98.0	99.4
Constant 5%	98.4	99.5	99.4	100.3

We observe :-

- The ABS scenario represents a worse outcome than the recent history and, therefore is dependant on the longer term historic trend as a justification;
- The “Optimistic” scenario is well above recent experience;
- There would be a serious up-tick required to get to the 100 year figure for today’s girls at this stage.

How old is old?

It would be a reasonable assumption to state that the advent of a later death has considerable benefits in terms of potential to participate fully in life particularly where it is provided alongside a similar deferral of deteriorating health. For a considerable time, Australia, like other countries, has had expected age qualifications for such things as “retirement” which have been institutionalised in the social security system and reinforced in the taxation arrangements for superannuation.

For example, men have qualified for the age pension at the age of 65 since this was the eligibility age for the Social Security Age Pension in 1908. What if we were to ask “what is a corresponding appropriate age today based on life table criteria?”. Similarly, for women the age of qualification was 60 in 1908. The age of qualification for women is progressively moving toward 65 at the moment (increasing by half a year each year) although the increased life expectancy since 1908 is not the motivator for this change.

Equally, when analysing the dependency ratios it is common to consider projected trends in the ratios including those over age 65 as representing dependants. Clearly, changing mortality as well as changing workforce participation (in its various forms) can be considered to impact the validity of this assumption.

Taxation rules for retirement benefits through superannuation include a recognition that the preservation age of 55 is the age that represents “early” retirement. Superannuation rules also embody a late retirement age of 75 which is also included in the terms and conditions of several statutory offices.

So, how can we compare what is meant by “65” over time using life table criteria?

A paper recently published in Canada titled ‘How Old is Old ? Revising the Definition Based on Life Table Criteria’, examined methods of comparing statistics between life tables with respect to a definition of “old”. In particular, they posed the question, ‘If 65 was considered appropriate (as the point of entry into “old-age”) four decades ago, what is the corresponding age today ?’ (Denton and Spencer, 1996).

We have utilised the methodology developed by Denton and Spencer to pose a similar question for Australia, namely: ‘Given that 65 was the eligibility age for the Social Security Age Pension in 1908, what is a corresponding appropriate age today based on life table criteria?’. We ask a similar question for age 60 for females. In addition, the methodology enables us to consider perhaps a more interesting question: ‘Given that 65 is the current male eligibility age for the age pension in 1995-97, what would the corresponding female age be based on life table criteria ?’.

Australian Life Tables 1901-1910 and the preliminary 1995-97 Australian Life Tables were used in the analysis. Readers will note that it may be preferable to use cohort based tables but this, of itself, immediately implies that the current tables need to be established utilising a projection of mortality rates into the future which is, as we saw previously, open to speculation as to the degree of optimism that can be considered either likely, conservative or optimistic.

Denton and Spencer conduct 19 tests based on criteria ranging from common statistics such as mean, median and mode, to modern mathematical tests involving ‘fuzzy’ definitions. They found that, despite the differences in the tests conducted, the results achieved were quite similar.

They proposed tests were based on:

- Mean years of life remaining;
- Mean as a proportion of years already lived;
- Median years of life remaining;
- Modal years of life remaining;
- Total years remaining as a proportion of the total remaining at some earlier age;
- k-year survival rate conditional on living at least c years⁴;
- Slope of mortality rate curve over next period of years;
- Old years as a proportion of total years remaining at some earlier age;
- Along with a further series of fuzzy definitions noting that “Old” is essentially a vague concept where they draw on the theory of fuzzy sets.

Denton and Spencer also noted two unacceptable criteria which illustrate that there is a need to consider the implications of any measure.

The first is the oldest k percent of the population, which has the effect of defining the dependency ratio for the older age group as a constant. Quite apart from the lack of instruction that such a measure produces, it is noted that the criterion is based on the characteristics of the population as a whole. The definition of old would be derived by the direct consequence of past fertility and migration, as well as mortality.

The second unacceptable criterion is the age of retirement which would be a direct function of changing labour force participation and would be a particularly poor criterion for women for example.

For the Australian cases, we have conducted 6 tests: mean years of life remaining; mean as a proportion of years already lived; median years of life remaining; and k-year survival rate comparisons for k=5, 10 and 20.

The results of the analysis for the two main cases considered are presented below in Tables 2 and 3:

⁴ The population at any age includes people who are in poor health and people who are in good health. This definition considers equalising the probability of a certain period of healthy life for the proportion that are healthy at the initial age.

Table 2

	Male equivalent age at 1995-97 given age 65 at 1901-1910
mean years of life remaining	72.40
mean as a proportion of years already lived	70.76
median years of life remaining	72.66
5 year survival rate	72.94
10 year survival rate	72.70
20 year survival rate	71.76
average	72.21

Table 3

	Female equivalent age at 1995-97 given age 60 at 1901-1910
mean years of life remaining	69.58
mean as a proportion of years already lived	68.47
median years of life remaining	69.80
5 year survival rate	71.13
10 year survival rate	70.54
20 year survival rate	69.38
average	69.81

In addition, it was found that given that females were eligible for an age pension at age 60 in 1908, a corresponding age in 1995-97 would be 69.6.

If social security eligibility ages were to change based solely on a desire to reflect life expectancy increases, then an equivalent age based on the criteria above is approximately 72 for males. Alternatively, if 65 is to remain the eligibility age for males, then an equivalent age for females in 1995-97 is 70.

Of course, this section provides technical comparisons. Many other issues would be considered in establishing rates of eligibility for such benefits as the age pension. Equally, consideration of length of life ignores considerations of any change in the quality of life. Never the less, the results provide an interesting summary of the effects of mortality change over the century.

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Attachment A : Summary Output for each Scenario

Summary of Projections

Model Number 100

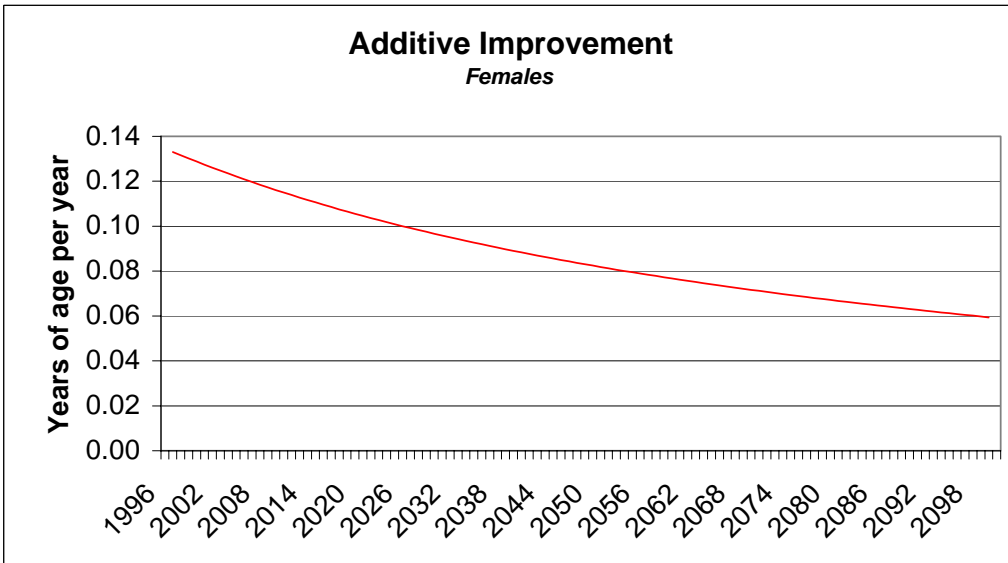
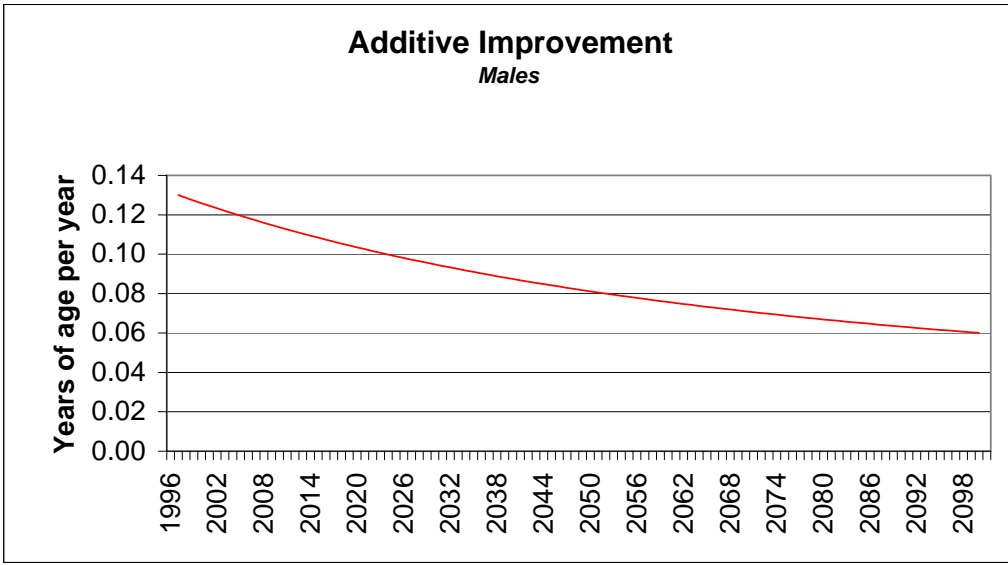
Model Name Last century observed
 Single Age Adjustment at : 0 by 0.00%
 Uniform Age Adjustment by: 0.00%
 Improvement ceases after: 2101

Progress in Life Table Life Expectancy at Birth

Year	Male		Female	
	Life Expectancy	Annual Average Improvement in years of life per annum	Life Expectancy	Annual Average Improvement in years of life per annum
1996	75.58		81.27	
2000	76.09	0.1279	81.80	0.1309
2010	77.28	0.1190	83.01	0.1216
2020	78.36	0.1079	84.12	0.1102
2030	79.34	0.0986	85.12	0.1005
2040	80.25	0.0907	86.04	0.0924
2050	81.09	0.0839	86.90	0.0853
2060	81.87	0.0781	87.69	0.0792
2070	82.60	0.0731	88.43	0.0739
2080	83.29	0.0687	89.12	0.0691
2090	83.94	0.0649	89.77	0.0649
2100	84.55	0.0615	90.38	0.0610

Current Life Expectancies allowing for Improvement

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
0	75.58	81.11	7.33%	81.27	87.69	7.90%
10	76.20	80.87	7.05%	81.82	87.41	7.78%
20	76.50	80.25	6.63%	81.98	86.66	7.55%
30	77.15	80.03	6.11%	82.20	85.96	7.20%
40	77.77	79.83	5.47%	82.51	85.35	6.69%
50	78.53	79.86	4.64%	83.02	84.99	5.97%
60	79.93	80.66	3.64%	84.04	85.24	5.01%
70	82.69	83.02	2.55%	85.85	86.44	3.78%
80	87.21	87.32	1.53%	89.04	89.25	2.34%
90	94.03	94.06	0.87%	94.59	94.63	0.96%



Summary of Projections

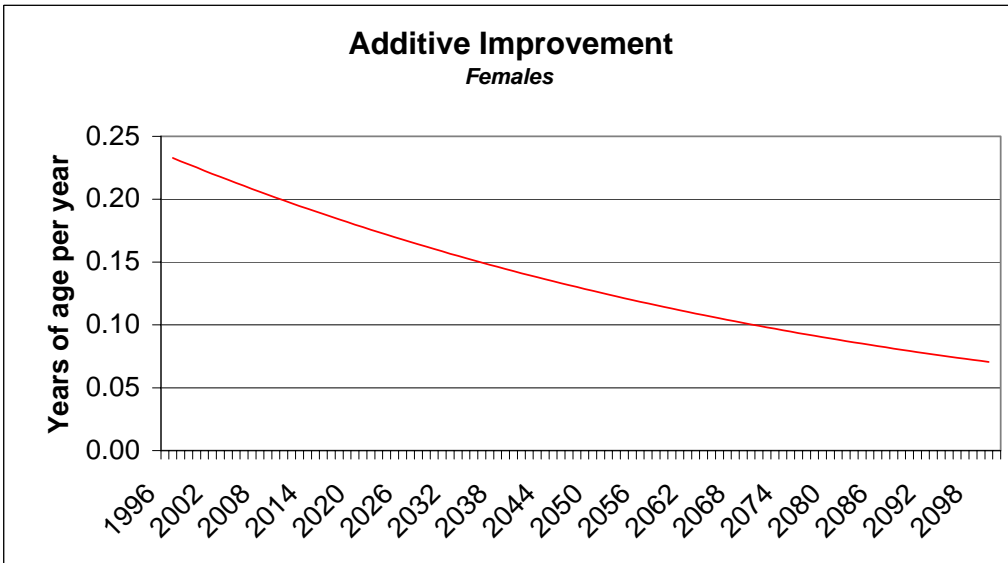
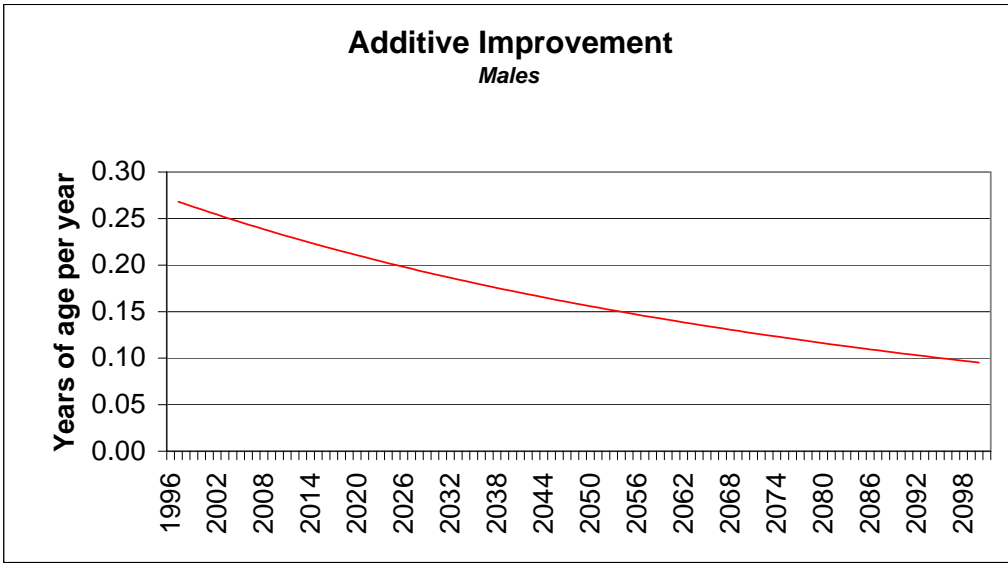
Model Number 101
 Model Name Last 25 years observed
 Single Age Adjustment at : 0 by 0.00%
 Uniform Age Adjustment by: 0.00%
 Improvement ceases after: 2101

Progress in Life Table Life Expectancy at Birth

Year	Male		Female	
	Life Expectancy	Annual Average Improvement in years of life per annum	Life Expectancy	Annual Average Improvement in years of life per annum
1996	75.58		81.27	
2000	76.63	0.2639	82.19	0.2291
2010	79.08	0.2450	84.31	0.2119
2020	81.29	0.2207	86.20	0.1893
2030	83.28	0.1991	87.89	0.1690
2040	85.08	0.1800	89.40	0.1506
2050	86.71	0.1630	90.74	0.1341
2060	88.19	0.1477	91.93	0.1192
2070	89.53	0.1339	92.99	0.1060
2080	90.74	0.1214	93.93	0.0942
2090	91.84	0.1100	94.77	0.0837
2100	92.84	0.0996	95.51	0.0744

Current Life Expectancies allowing for Improvement

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
0	75.58	88.67	17.32%	81.27	92.61	13.95%
10	76.20	87.81	17.53%	81.82	92.03	14.22%
20	76.50	86.42	17.56%	81.98	90.88	14.36%
30	77.15	85.35	17.39%	82.20	89.66	14.29%
40	77.77	84.04	16.61%	82.51	88.39	13.83%
50	78.53	82.79	14.92%	83.02	87.26	12.84%
60	79.93	82.36	12.18%	84.04	86.72	11.18%
70	82.69	83.79	8.63%	85.85	87.21	8.64%
80	87.21	87.57	5.05%	89.04	89.51	5.21%
90	94.03	94.13	2.54%	94.59	94.68	2.06%



Summary of Projections

Model Number 111

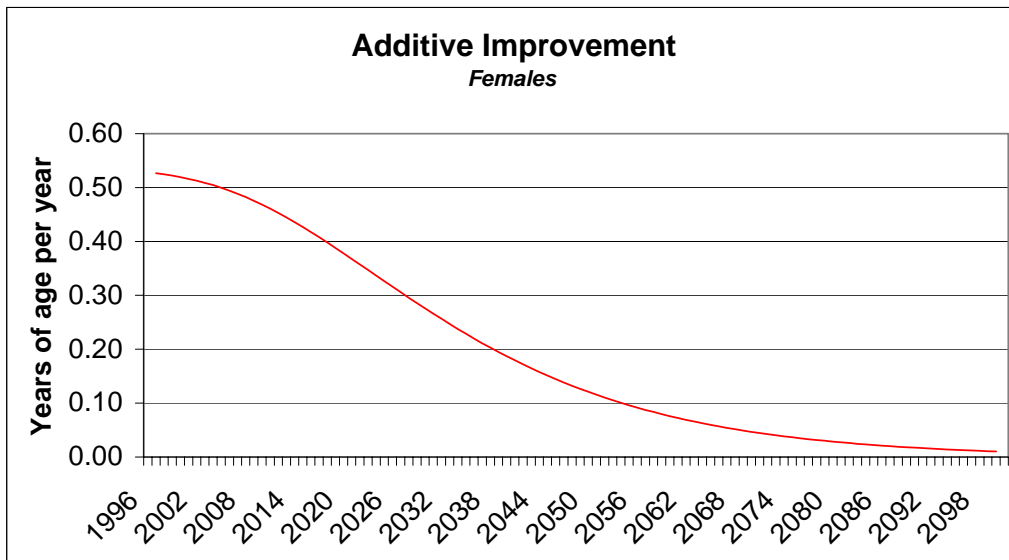
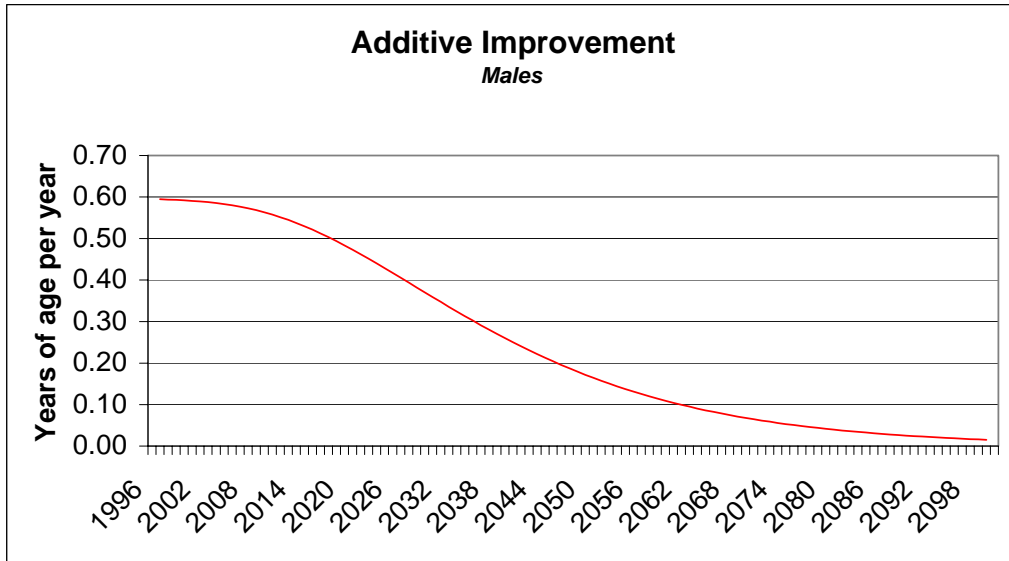
Model Name Flat improvement independent of age
 Single Age Adjustment at : 0 by 0.00%
 Uniform Age Adjustment by: 5.00%
 Improvement ceases after: 2101

Progress in Life Table Life Expectancy at Birth

Year	Male		Female	
	Life Expectancy	Annual Average Improvement in years of life per annum	Life Expectancy	Annual Average Improvement in years of life per annum
1996	75.58		81.27	
2000	77.95	0.5933	83.37	0.5232
2010	83.75	0.5797	88.32	0.4950
2020	88.98	0.5236	92.53	0.4209
2030	93.21	0.4225	95.74	0.3213
2040	96.29	0.3084	97.99	0.2251
2050	98.39	0.2093	99.48	0.1487
2060	99.74	0.1354	100.42	0.0945
2070	100.59	0.0850	101.01	0.0587
2080	101.11	0.0524	101.37	0.0359
2090	101.43	0.0319	101.59	0.0218
2100	101.62	0.0193	101.72	0.0132

Current Life Expectancies allowing for Improvement

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
0	75.58	99.35	31.46%	81.27	100.29	23.40%
10	76.20	98.99	34.42%	81.82	100.29	25.72%
20	76.50	97.61	37.36%	81.98	99.49	28.26%
30	77.15	96.13	40.26%	82.20	98.34	30.91%
40	77.77	93.86	42.62%	82.51	96.66	33.29%
50	78.53	90.87	43.25%	83.02	94.48	34.69%
60	79.93	88.02	40.56%	84.04	92.23	34.07%
70	82.69	86.97	33.72%	85.85	90.65	30.32%
80	87.21	88.92	23.81%	89.04	91.09	22.75%
90	94.03	94.51	12.01%	94.59	95.12	11.68%



Attachment B: Detailed Life Expectancy based on Current Age

Summary of Projections

Model Number 100
 Model Name Last century observed
 Single Age Adjustment at : 0 by 0.00%
 Uniform Age Adjustment by: 0.00%
 Improvement ceases after: 2101

Current Life Expectancies allowing for Improvement

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
0	75.58	81.11	7.33%	81.27	87.69	7.90%
1	76.04	81.52	7.30%	81.68	88.05	7.89%
2	76.08	81.47	7.28%	81.72	88.00	7.88%
3	76.11	81.41	7.25%	81.74	87.94	7.87%
4	76.13	81.34	7.23%	81.76	87.87	7.86%
5	76.15	81.27	7.20%	81.77	87.80	7.85%
6	76.16	81.19	7.18%	81.78	87.72	7.84%
7	76.17	81.11	7.15%	81.79	87.64	7.82%
8	76.18	81.03	7.12%	81.80	87.57	7.81%
9	76.19	80.95	7.09%	81.81	87.49	7.79%
10	76.20	80.87	7.05%	81.82	87.41	7.78%
11	76.21	80.79	7.02%	81.83	87.33	7.76%
12	76.22	80.71	6.98%	81.84	87.25	7.74%
13	76.23	80.62	6.94%	81.85	87.17	7.72%
14	76.25	80.54	6.90%	81.86	87.09	7.70%
15	76.26	80.47	6.86%	81.87	87.01	7.68%
16	76.29	80.40	6.82%	81.89	86.93	7.66%
17	76.32	80.34	6.77%	81.91	86.86	7.63%
18	76.37	80.30	6.73%	81.93	86.79	7.61%
19	76.43	80.27	6.68%	81.95	86.72	7.58%
20	76.50	80.25	6.63%	81.98	86.66	7.55%
21	76.57	80.23	6.58%	82.00	86.59	7.52%
22	76.63	80.20	6.53%	82.02	86.52	7.49%
23	76.70	80.18	6.48%	82.05	86.45	7.46%
24	76.77	80.16	6.43%	82.07	86.38	7.43%
25	76.83	80.14	6.38%	82.09	86.31	7.40%
26	76.90	80.12	6.33%	82.11	86.24	7.36%
27	76.96	80.10	6.27%	82.13	86.17	7.32%
28	77.02	80.07	6.22%	82.16	86.10	7.28%
29	77.09	80.05	6.16%	82.18	86.03	7.24%
30	77.15	80.03	6.11%	82.20	85.96	7.20%
31	77.21	80.01	6.05%	82.23	85.90	7.16%
32	77.27	79.99	5.99%	82.25	85.83	7.11%
33	77.33	79.96	5.93%	82.28	85.76	7.07%
34	77.40	79.94	5.87%	82.31	85.70	7.02%
35	77.46	79.92	5.81%	82.34	85.64	6.97%
36	77.52	79.90	5.74%	82.37	85.58	6.92%
37	77.58	79.88	5.68%	82.40	85.52	6.86%
38	77.64	79.87	5.61%	82.44	85.46	6.81%
39	77.70	79.85	5.54%	82.47	85.40	6.75%
40	77.77	79.83	5.47%	82.51	85.35	6.69%
41	77.83	79.82	5.39%	82.55	85.30	6.63%
42	77.90	79.81	5.32%	82.59	85.25	6.56%
43	77.97	79.80	5.24%	82.63	85.20	6.50%
44	78.04	79.79	5.16%	82.67	85.16	6.43%
45	78.11	79.79	5.08%	82.72	85.12	6.36%

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
46	78.19	79.79	5.00%	82.77	85.08	6.28%
47	78.27	79.80	4.91%	82.83	85.05	6.21%
48	78.35	79.81	4.82%	82.89	85.03	6.13%
49	78.44	79.83	4.73%	82.95	85.01	6.05%
50	78.53	79.86	4.64%	83.02	84.99	5.97%
51	78.63	79.89	4.55%	83.09	84.98	5.88%
52	78.74	79.93	4.46%	83.17	84.98	5.80%
53	78.85	79.98	4.36%	83.26	84.99	5.71%
54	78.98	80.04	4.26%	83.35	85.00	5.61%
55	79.11	80.11	4.16%	83.45	85.02	5.52%
56	79.25	80.19	4.06%	83.55	85.04	5.42%
57	79.40	80.29	3.95%	83.66	85.08	5.32%
58	79.57	80.40	3.85%	83.78	85.13	5.22%
59	79.74	80.52	3.75%	83.90	85.18	5.11%
60	79.93	80.66	3.64%	84.04	85.24	5.01%
61	80.14	80.81	3.53%	84.18	85.31	4.89%
62	80.36	80.99	3.42%	84.32	85.39	4.78%
63	80.59	81.17	3.31%	84.48	85.48	4.67%
64	80.84	81.38	3.20%	84.64	85.58	4.55%
65	81.11	81.60	3.09%	84.82	85.69	4.42%
66	81.39	81.85	2.98%	85.00	85.82	4.30%
67	81.69	82.11	2.87%	85.19	85.95	4.17%
68	82.00	82.39	2.76%	85.40	86.10	4.04%
69	82.34	82.69	2.65%	85.62	86.27	3.91%
70	82.69	83.02	2.55%	85.85	86.44	3.78%
71	83.06	83.36	2.44%	86.09	86.64	3.65%
72	83.45	83.72	2.33%	86.34	86.85	3.51%
73	83.86	84.10	2.23%	86.62	87.07	3.37%
74	84.28	84.50	2.12%	86.90	87.32	3.23%
75	84.72	84.91	2.01%	87.21	87.58	3.08%
76	85.17	85.35	1.91%	87.53	87.87	2.94%
77	85.65	85.81	1.81%	87.87	88.18	2.79%
78	86.15	86.29	1.71%	88.24	88.51	2.64%
79	86.66	86.79	1.61%	88.63	88.87	2.49%
80	87.21	87.32	1.53%	89.04	89.25	2.34%
81	87.77	87.87	1.44%	89.47	89.66	2.18%
82	88.37	88.45	1.36%	89.93	90.09	2.03%
83	88.98	89.06	1.29%	90.41	90.55	1.88%
84	89.63	89.70	1.22%	90.92	91.04	1.74%
85	90.30	90.36	1.16%	91.46	91.56	1.60%
86	90.99	91.05	1.10%	92.02	92.11	1.46%
87	91.71	91.76	1.04%	92.62	92.69	1.33%
88	92.46	92.50	0.99%	93.24	93.31	1.20%
89	93.23	93.27	0.93%	93.90	93.95	1.08%
90	94.03	94.06	0.87%	94.59	94.63	0.96%
91	94.85	94.89	0.80%	95.30	95.34	0.84%
92	95.70	95.73	0.72%	96.05	96.08	0.72%
93	96.57	96.60	0.62%	96.82	96.84	0.60%
94	97.46	97.47	0.51%	97.62	97.63	0.47%
95	98.35	98.36	0.37%	98.43	98.45	0.34%
96	99.23	99.24	0.23%	99.28	99.28	0.21%
97	100.12	100.13	0.10%	100.14	100.14	0.09%
98	101.02	101.02	0.00%	101.02	101.02	0.00%
99	101.02	101.02	0.00%	101.02	101.02	0.00%
100	101.02	101.02	0.00%	101.02	101.02	0.00%

Summary of Projections

Model Number 101
 Model Name Last 25 years observed
 Single Age Adjustment at : 0 by 0.00%
 Uniform Age Adjustment by: 0.00%
 Improvement ceases after: 2101

Current Life Expectancies allowing for Improvement

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
0	75.58	88.67	17.32%	81.27	92.61	13.95%
1	76.04	89.05	17.34%	81.68	92.96	13.98%
2	76.08	88.94	17.37%	81.72	92.89	14.01%
3	76.11	88.82	17.39%	81.74	92.79	14.04%
4	76.13	88.69	17.42%	81.76	92.70	14.07%
5	76.15	88.55	17.44%	81.77	92.59	14.09%
6	76.16	88.41	17.46%	81.78	92.48	14.12%
7	76.17	88.26	17.48%	81.79	92.37	14.15%
8	76.18	88.11	17.50%	81.80	92.26	14.17%
9	76.19	87.96	17.51%	81.81	92.15	14.20%
10	76.20	87.81	17.53%	81.82	92.03	14.22%
11	76.21	87.65	17.54%	81.83	91.92	14.24%
12	76.22	87.49	17.55%	81.84	91.80	14.26%
13	76.23	87.33	17.56%	81.85	91.68	14.28%
14	76.25	87.18	17.56%	81.86	91.56	14.30%
15	76.26	87.02	17.56%	81.87	91.44	14.31%
16	76.29	86.88	17.57%	81.89	91.33	14.32%
17	76.32	86.74	17.56%	81.91	91.21	14.34%
18	76.37	86.62	17.56%	81.93	91.10	14.35%
19	76.43	86.52	17.56%	81.95	90.99	14.35%
20	76.50	86.42	17.56%	81.98	90.88	14.36%
21	76.57	86.32	17.55%	82.00	90.76	14.37%
22	76.63	86.22	17.55%	82.02	90.65	14.37%
23	76.70	86.12	17.54%	82.05	90.53	14.37%
24	76.77	86.02	17.53%	82.07	90.41	14.37%
25	76.83	85.92	17.52%	82.09	90.29	14.36%
26	76.90	85.81	17.50%	82.11	90.16	14.35%
27	76.96	85.70	17.48%	82.13	90.04	14.34%
28	77.02	85.58	17.46%	82.16	89.91	14.33%
29	77.09	85.47	17.42%	82.18	89.79	14.31%
30	77.15	85.35	17.39%	82.20	89.66	14.29%
31	77.21	85.23	17.34%	82.23	89.53	14.26%
32	77.27	85.10	17.29%	82.25	89.41	14.23%
33	77.33	84.97	17.23%	82.28	89.28	14.20%
34	77.40	84.85	17.17%	82.31	89.15	14.16%
35	77.46	84.72	17.10%	82.34	89.02	14.12%
36	77.52	84.58	17.01%	82.37	88.90	14.07%
37	77.58	84.45	16.93%	82.40	88.77	14.02%
38	77.64	84.31	16.83%	82.44	88.64	13.96%
39	77.70	84.18	16.72%	82.47	88.51	13.90%
40	77.77	84.04	16.61%	82.51	88.39	13.83%
41	77.83	83.90	16.48%	82.55	88.26	13.76%
42	77.90	83.77	16.35%	82.59	88.14	13.68%
43	77.97	83.63	16.21%	82.63	88.02	13.60%
44	78.04	83.50	16.05%	82.67	87.90	13.51%
45	78.11	83.37	15.89%	82.72	87.78	13.41%

Age	Male			Female		
	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement	Expected Age at Death without improvement	Expected Age at Death with improvement	Improvement in Life Expectancy allowing for improvement
46	78.19	83.24	15.72%	82.77	87.67	13.31%
47	78.27	83.12	15.53%	82.83	87.56	13.20%
48	78.35	83.00	15.34%	82.89	87.45	13.09%
49	78.44	82.89	15.13%	82.95	87.35	12.97%
50	78.53	82.79	14.92%	83.02	87.26	12.84%
51	78.63	82.69	14.69%	83.09	87.17	12.71%
52	78.74	82.61	14.45%	83.17	87.09	12.57%
53	78.85	82.53	14.21%	83.26	87.02	12.42%
54	78.98	82.46	13.95%	83.35	86.95	12.26%
55	79.11	82.41	13.68%	83.45	86.89	12.10%
56	79.25	82.37	13.40%	83.55	86.84	11.93%
57	79.40	82.34	13.11%	83.66	86.80	11.76%
58	79.57	82.33	12.81%	83.78	86.76	11.57%
59	79.74	82.34	12.50%	83.90	86.74	11.38%
60	79.93	82.36	12.18%	84.04	86.72	11.18%
61	80.14	82.41	11.85%	84.18	86.72	10.97%
62	80.36	82.47	11.52%	84.32	86.72	10.75%
63	80.59	82.56	11.17%	84.48	86.74	10.52%
64	80.84	82.66	10.83%	84.64	86.77	10.29%
65	81.11	82.79	10.47%	84.82	86.81	10.04%
66	81.39	82.94	10.11%	85.00	86.86	9.78%
67	81.69	83.12	9.75%	85.19	86.93	9.51%
68	82.00	83.32	9.38%	85.40	87.01	9.23%
69	82.34	83.54	9.01%	85.62	87.10	8.94%
70	82.69	83.79	8.63%	85.85	87.21	8.64%
71	83.06	84.06	8.25%	86.09	87.34	8.32%
72	83.45	84.35	7.86%	86.34	87.49	8.00%
73	83.86	84.67	7.48%	86.62	87.66	7.67%
74	84.28	85.01	7.10%	86.90	87.85	7.33%
75	84.72	85.37	6.72%	87.21	88.06	6.99%
76	85.17	85.76	6.36%	87.53	88.30	6.64%
77	85.65	86.17	6.01%	87.87	88.56	6.29%
78	86.15	86.61	5.68%	88.24	88.85	5.93%
79	86.66	87.07	5.36%	88.63	89.16	5.57%
80	87.21	87.57	5.05%	89.04	89.51	5.21%
81	87.77	88.10	4.76%	89.47	89.88	4.85%
82	88.37	88.65	4.48%	89.93	90.28	4.49%
83	88.98	89.24	4.21%	90.41	90.72	4.13%
84	89.63	89.85	3.96%	90.92	91.18	3.78%
85	90.30	90.49	3.72%	91.46	91.68	3.45%
86	90.99	91.17	3.49%	92.02	92.21	3.13%
87	91.71	91.86	3.25%	92.62	92.78	2.84%
88	92.46	92.59	3.01%	93.24	93.38	2.57%
89	93.23	93.35	2.78%	93.90	94.01	2.31%
90	94.03	94.13	2.54%	94.59	94.68	2.06%
91	94.85	94.94	2.28%	95.30	95.38	1.82%
92	95.70	95.78	2.00%	96.05	96.11	1.57%
93	96.57	96.63	1.67%	96.82	96.87	1.31%
94	97.46	97.50	1.32%	97.62	97.65	1.04%
95	98.35	98.38	0.95%	98.43	98.46	0.75%
96	99.23	99.25	0.58%	99.28	99.29	0.46%
97	100.12	100.13	0.24%	100.14	100.14	0.19%
98	101.02	101.02	0.00%	101.02	101.02	0.00%
99	101.02	101.02	0.00%	101.02	101.02	0.00%
100	101.02	101.02	0.00%	101.02	101.02	0.00%