Mortality Projections for Social Security Programs in the United States

Alice Wade*

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* Alice Wade , Deputy Chief Actuary, Social Security Administration, Office of the Chief Actuary, United States

Abstract

Worldwide, the 20th century brought tremendous reductions in mortality at all ages for both males and females. The reductions in mortality, combined with the aging of the baby boomers and lower fertility rates, are projected to increase the proportion of the U.S. population that is above age 65 in the coming decades. This paper examines past mortality trends and discusses how these trends may change over the next 75 years, thus influencing the growth of the elderly population. In addition, this paper describes the methods and assumptions used to project future mortality rates and presents results, including assumed annual rates of mortality reduction and projected life expectancies. As well, this paper discusses stochastic time-series methods that are used to help quantify the variability in the mortality rate projections.

1. Introduction

The U.S. population is projected to age significantly over the coming decades. Increasing life expectancies, the aging of the baby boomers and lower fertility rates are the predominant factors that will contribute to the increase in the proportion of the elderly. As a result, the population at ages 65 and over is expected to increase significantly over the next 30 years. Older age groups will experience even higher rates of growth.

Prospects of longer life are viewed as a positive change for individuals and a substantial social achievement, but often lead to concern over their implications for public spending on old-age support. The projected cost of public pensions is directly linked to the expected growth in the elderly population. In turn, the growth in the elderly population depends on how current mortality is assumed to evolve over the long-term horizon. The projection of mortality thus becomes a key element of any population projection.

The purpose of this report is to present an overview of the methods and assumptions used in projecting the mortality component of the population projections. The population projections are then used to estimate the financial status of the Old Age, Survivors and Disability Insurance (OASDI) program in the United States.

In the United States, the OASDI program provides monthly benefits to qualified retired and disabled workers and their dependents and to survivors of insured workers. Eligibility and benefit amounts are determined by the worker's earnings that are covered under the program. Benefits are designed to replace a portion of earnings prior to retirement, disability or death and are paid as an earned right to workers, their families and their survivors. There is no means test to qualify for benefits.

The methods and assumptions described in this paper reflect those included in the 2007 report to Congress by the Social Security Trustees. This report, "*The 2007 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds*," presents the current and projected future financial status of the OASDI trust funds. The mortality projections cover a long-time horizon (75 years) and place more emphasis on longer-term historical trends than on short-term fluctuations.

2. General Mortality Trends Since 1900

The 20th century brought tremendous gains in life expectancies at all ages for both males and females. Relative to the entire period of the existence of man, the 20th century was a time of exceptionally rapid rates of decline in mortality. Based on mortality in 1900, roughly 60 percent of the U.S. population would have died before reaching age 65. Based on mortality today, less than 20 percent of the population would die before reaching age 65. Over the last century, life expectancy at birth increased by an estimated 29.4 years, with most of the change occurring before 1950. Life expectancy at age 65 also increased dramatically, but in contrast to life expectancy at birth, most of the change occurred after 1950.

Over the last century, dramatic advancements were made in medicine (vaccinations and other medical interventions) and in the standard of living (improved sanitation and overall quality of life). In addition, access to medical services was greatly expanded through the Medicare and Medicaid programs for the old, frail and disadvantaged, those who account for the vast majority of deaths in the population. Increases in life expectancy at birth were much greater in the first part of the 20th century due to substantial reductions in death rates at young ages.

In the United States, the gap between female and male life expectancies at birth was 3.0 years in 1900. This difference increased to 6 years in the mid-1950s. From the mid-1950s through the late 1960s, male life expectancy at birth remained level, while female life expectancy at birth increased moderately, resulting in the gap between female and male life expectancies at birth reaching a peak of 7.7 years in 1970. After 1970, the gap stabilized in the 1970s and then began narrowing after 1979, as males made greater gains in life expectancy compared to females. The gap at birth reached 5.1 years in 2003.

The gap between female and male life expectancies at age 65 experienced a similar pattern but was somewhat delayed. In 1900, the gap was less than 1 year, reached a little over 2 years in 1950, peaked at over 4 years around 1975, and then decreased to around 3 years in 2003.

TABLE 1

Period Life Expectancy at Birth and Age 65

Calendar Year	Life Expectancy at Birth			Life Expectancy at 65		
	Male	Female	Difference	Male	Female	Difference
1900	46.0	48.6	2.6	11.4	12.0	0.7
1910	49.7	53.3	3.6	11.4	12.1	0.7
1920	54.3	56.1	1.8	11.8	12.3	0.5
1930	57.8	61.2	3.4	11.8	12.9	1.1
1940	61.4	65.7	4.3	11.9	13.4	1.5
1950	65.6	71.1	5.5	12.8	15.1	2.3
1960	66.7	73.2	6.6	12.9	15.9	3.0
1970	67.2	74.9	7.7	13.1	17.1	4.0
1975	68.7	76.6	7.8	13.7	18.0	4.3
1980	69.9	77.5	7.6	14.0	18.4	4.3
1985	71.1	78.2	7.2	14.4	18.6	4.2
1990	71.8	78.9	7.1	15.1	19.1	4.0
1995	72.5	79.1	6.6	15.4	19.1	3.7
2000	74.0	79.4	5.4	15.9	19.0	3.1
2003	74.5	79.6	5.1	16.3	19.2	2.9

3. Mortality Projections

3.1 Methodology and Assumptions for General Population Mortality Projections

The methodology and assumptions presented for the United States are based on the intermediate projections of the 2007 Annual Report of the Board of Trustees.[†] These intermediate projections reflect the Trustees' best estimates of future experience.

The methodology used to project mortality rates into the future involves making assumptions about annual rates of mortality reduction by age, sex and cause of death. The initial step in making this projection is to calculate historical average annual rates of mortality reduction by age, sex, and cause of death. These historical average annual rates are used as a guide in determining the assumed ultimate annual rate of mortality reductions. Additional details about the methodology are found in Actuarial Study Number 120, located at the following Internet site: *http://www.ssa.gov/OACT/NOTES/s2000s.html*.

3.1.1 Historical Annual Rates of Mortality Reduction and Starting Values

The base year for the mortality projections is 2003. For this year and all other historical years, rates are initially calculated using deaths from the National Center for Health Statistics and resident population counts from the U.S. Bureau of Census. For years since 1968, numbers of deaths and participants from the Medicare programs are used to determine mortality rates for ages 65 and older. Instead of using the measured mortality rates for the last single year of data (calendar year 2003) as the starting point from which mortality projections are made, starting levels of mortality rates are calculated to be consistent with the trend inherent in the last 12 years of available data, 1992 through 2003. This procedure reduces the impact of sometimes-wide swings in annual data on the starting level for the mortality projection.

Annual rates of mortality reduction are derived by fitting a least squares regression line to the logarithm of central death rates. The central death rate for a calendar year is defined as the ratio of the number of deaths in the year to the corresponding population as at July 1 of that year. The annual rate of mortality reduction is then derived from the slope of the fitted regression line.[‡]

[†] The 2007 Trustees Report is located at the following Internet site: http://www.ssa.gov/OACT/TR/TR06/index.html.

[‡] The average annual rate of mortality reduction is equal to the complement of the exponential of the slope of the least squares regression line through the logarithm of the central death rates.

Average annual rates of mortality reduction for various historical time periods are presented by age group for males in Table 2 and for females in Table 3. The time periods are selected on the basis of similar annual rates of reduction throughout the period.

TABLE 2

Historical Average Annual Rates of Mortality Reduction (Males)

Age	1900-2003	1900-1936	1936-1954	1954-1968	1968-1982	1982-2003
0-14	3.2%	2.9%	4.8%	1.7%	4.3%	2.8%
15-64	1.3%	1.0%	1.9%	-0.2%	2.3%	1.5%
65+	0.6%	0.2%	1.2%	-0.4%	1.5%	0.8%
All Ages	0.9%	0.7%	1.6%	-0.2%	1.8%	1.0%

Note: All rates of reduction shown reflect age-sex adjustment to the distribution of the 2000 U.S. population.

TABLE 3

Historical Average Annual Rates of Mortality Reduction (Females)

Age	1900-2003	1900-1936	1936-1954	1954-1968	1968-1982	1982-2003
0-14	3.3%	3.1%	5.1%	1.7%	4.2%	2.6%
15-64	1.6%	1.2%	3.5%	0.6%	2.2%	0.9%
65+	0.8%	0.3%	1.8%	0.7%	2.1%	0.1%
All Ages	1.2%	0.8%	2.4%	0.7%	2.2%	0.3%

Note: All rates of reduction shown reflect age-sex adjustment to the distribution of the 2000 U.S. population.

During the period 1900-1936, annual mortality reduction averaged about 0.7 percent for males and 0.8 percent for females. During the following period, 1936-1954, there was more rapid reduction (with the help of antibiotics and other advances in medicine), averaging 1.6 percent per year for males and 2.4 percent per year for females. The period 1954-1968 saw a much slower reduction of 0.7 percent per year for females and an *increase* of 0.2 percent per year for males. From 1968 through 1982, rapid reduction in mortality surged (with the help of Medicare and Medicaid), averaging 1.8 percent for males and 2.2 percent for females, annually. From 1982 to 2003, more moderate reduction in mortality returned, averaging 1.0 percent per year for males and 0.3 percent for females.

For the period 1982-2003, the average annual rate of reduction for females was considerably less than that for males. For all other periods mentioned above, the opposite is true, i.e., the average annual rate of reduction for males is less than that for females. Even with normal year-to-year variation, it is clear that, from the beginning of the past century, reduction was

generally greater for females until about 1980. But it is also clear that female reduction was generally less than or equal to that for males beginning about 1980.

The tables above show that average annual rates of reduction over the period 1900-2003 are greater for younger ages. The average annual rate is over 3 percent for the age group 0-14 and declines for each succeeding older age group, reaching less than 1 percent for the age group 65 and older. For the age group 65 and over, the rate of reduction experienced during 1900-2003 averaged 0.6 percent for males and 0.8 for females, while the rate of reduction during 1982-2003 averaged 0.8 percent for males and only 0.1 for females. Thus, while the average rate of reduction for males in this most recent period was slightly higher than for the entire 1900-2003 period, the average rate of reduction for females in the most recent period was dramatically lower than for the entire 1900-2003 period.

Past reduction in mortality has varied greatly by cause of death. In assessing past experience and future possible reduction in mortality, we believe it is useful to understand the variations in mortality by cause of death. For the period 1979-2003, average annual reductions in central death rates by age group and sex for six major groups of causes of death are analyzed. For rates that combine all ages and both sexes, the largest reductions, at slightly over 2.1 percent per year, were in the categories of Vascular Disease and Heart Disease. Averaging about 0.9 percent reduction per year was Violence. Cancer averaged a decrease of about 0.2 percent per year. The categories of Respiratory Diseases, Diabetes Mellitus and Other Causes, averaged increases ranging from 1.1 to 2.2 percent per year.

3.1.2 Assumed Future Rates of Mortality Reduction

Ultimate annual percentage reductions in central death rates by sex, age group and seven causes of death are assumed to apply for years starting with 2031. Annual reductions by age, sex and cause from the starting year of the projections (2003) to 2006 are assumed to equal the average annual reductions observed for the period 1983-2003.[§] For years after 2006, the reductions in central death rates are assumed to change rapidly from initial levels, equal to the

[§] The current methodology bases the starting level of decline in mortality on the average rate of decline over the past 20 years. Additionally, if the average rate of reduction for a particular cause age-sex group during the period 1983-2003 is negative, then 75 percent of that average rate is assumed.

average annual reductions observed for the period 1983-2003, to the assumed ultimate rates of reduction for years 2031 and later.

The ultimate annual percentage reductions in central death rates by age and sex (all causes combined) are shown in Table 4. The ultimate annual percentage reductions are determined based on historical trends and consideration of many factors which affect mortality. Expected rates of reduction in mortality by cause of death are considered in selecting ultimate mortality reduction assumptions. While these rates by cause of death have not effectively "controlled" the outcome for assumptions reflecting all causes combined, they serve as an important basis for analysis relative to past trends and for assessment of reasonableness of future assumptions.

TABLE 4

Assumed Average Annual Rates of Mortality Reduction

	Male		Female	
Age	**2003-2031**	**2031-2081**	**2003-2031**	**2031-2081**
Under Age 15	1.89%	1.55%	1.84%	1.58%
Ages 15 - 49	0.96%	0.86%	0.71%	0.74%
Ages 50 - 64	1.11%	0.82%	0.87%	0.72%
Ages 65 - 84	0.91%	0.71%	0.68%	0.67%
Ages 85 and Older	0.49%	0.62%	0.43%	0.60%

Because reductions in mortality have differed widely by age in the past, the ultimate reductions in death rates have been selected to vary by age group. Historically, reductions have been very rapid at the youngest ages while reductions at the highest ages, ages 85 and over, have been very slow. Assumptions have reflected for many years the belief that neither of these extremes will persist indefinitely into the future. The assumptions have reflected slower reduction at the youngest ages than evidenced over the past century and faster reduction at the highest ages (85 and over) than experienced historically.

Extrapolation of the average trends experienced for the past century (or for any other period) to project future mortality presumes that there will be a constancy to these rates in the future that has not occurred in the past. We believe it is crucial to study not only the differing historical rates of decline for various periods, but also the conditions that contributed to these

variations. Only after considering how future conditions will differ from the past can we speculate about future mortality reduction.

A number of extremely important developments have contributed to the rapid general rate of mortality reduction during the past century. These developments include:

- Access to primary medical care for the general population (in particular, the access due to Medicare and Medicaid health coverage for the elderly, disabled and poor),
- Discovery of and general availability of antibiotics and immunizations,
- Clean water supply and waste removal and
- The rapid rate of growth in the general standard of living.

Each of these developments is expected to make a substantially smaller contribution to annual rates of mortality reduction in the future. The diminishing effect of these factors has already been in evidence since 1982.

Future reductions in mortality will depend upon such factors as:

- The development and application of new diagnostic, surgical, and life-sustaining techniques,
- The presence of environmental pollutants,
- Changes in amount and type of physical activity,
- Improvements in nutrition,
- The incidence of violence and suicide,
- The isolation and treatment of causes of disease,
- The emergence of new forms of disease,
- The evolution of existing forms of disease,
- Improvements in prenatal care,
- The prevalence of obesity,
- The prevalence of cigarette smoking,
- The misuse of drugs (including alcohol),
- The extent to which people assume responsibility for their own health,
- Education regarding health and
- Changes in our perception of the value of life.

In reviewing the above list, future progress for some factors seems questionable when recent statistics are considered. Recent National Center for Health Statistics (NCHS) releases have reported a substantial increase in the prevalence of obesity and diabetes, decreased environmental air quality and an increase in negative side effects from invasive surgical procedures. On the other hand, there is good basis for speculation that there will be substantial breakthroughs in advancing medical technology and treatment in the future. The extent to which such new technologies will have purely positive effects (like improved sanitation) versus mixed effects (as in the case of chemotherapy) will determine their potential for improving mortality. A final consideration, however, is the ability and willingness of our society to pay for the development of new treatments and technologies, and to provide these to the population as a whole. A comparison of the basis for past reduction in mortality with the expected basis for future reduction suggests to us that future reduction for ages under 65 is likely to continue, but at a slower rate than experienced during the extraordinary period of the last century. It seems more reasonable, however, to expect the rate of mortality reduction for the age group 65 and older for the next 75 years to be close to that experienced over the last century.

Education and income are factors that are well correlated with mortality differences in the population. More education and higher income are associated with lower mortality. It is not entirely clear whether this correlation is largely due to the benefits of higher income and education, or to the “selection” of more advantaged (and thus healthier) individuals in gaining access to the best education and job opportunities. If the former factor is important, then increasing education and income for the population as a whole may provide some further benefits, but substantially less than in the past.

Finally, we must consider that reductions in mortality and extension of longevity through the last century were relatively unconstrained by limitations of senescence and gradual deterioration of body systems. While we do not subscribe to the notion that there is a fixed limit for human longevity, it is true that average human lifespan has improved more than the maximum observed lifespan. This suggests that even with continued technological advances, the inherent limitations of the physical body and the mind to endure successfully much past 110 years will gradually result in a decelerating force of mortality reduction. This maximum observed lifespan can be expected to continue increasing, but only at a very modest pace.

3.1.3 Projection Results

This section presents the projected central death rates by age and sex. In addition, resulting life expectancies and other mortality measures are included.

The projected central death rates in Table 5 show a continuous decrease over the projection period. For example, the central death rate for males ages 65-69 is expected to decline from 21.4 deaths per 1,000 people in 2007 to 12.5 deaths per 1,000 people in 2075. Over the period 2007 to 2075, the age for which central death rates are expected to decline the most, by 70 percent, is age 0. For age groups 65-69 and 70-74, the expected decline over this period is about 42 percent for males and 37 percent for females. The age groups that are expected to have the smallest declines, (around 33 percent) over this period are the oldest age groups.

TABLE 5

Central Death Rates by Age Group, Sex and Calendar Year

(per thousand)								
Sex and Age Group	Male				Female			
	2007	**2025**	**2050**	**2075**	**2007**	**2025**	**2050**	**2075**
0	6.7	4.7	3.1	2.0	5.5	3.9	2.5	1.6
1-4	0.3	0.2	0.2	0.1	0.2	0.2	0.1	0.1
5-9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
10-14	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
15-19	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.2
20-24	1.3	1.1	0.9	0.7	0.5	0.4	0.3	0.3
25-29	1.2	1.0	0.8	0.6	0.5	0.4	0.4	0.3
30-34	1.3	1.1	0.9	0.7	0.7	0.6	0.5	0.4
35-39	1.9	1.6	1.3	1.0	1.2	1.0	0.9	0.7
40-44	2.9	2.5	1.9	1.6	1.8	1.6	1.3	1.1
45-49	4.4	3.7	2.9	2.4	2.5	2.2	1.8	1.5
50-54	6.0	4.9	3.9	3.2	3.6	3.0	2.5	2.1
55-59	8.7	7.1	5.7	4.6	5.6	4.8	3.9	3.3
60-64	13.5	11.0	8.9	7.3	9.0	7.7	6.3	5.3
65-69	21.4	17.9	14.8	12.5	14.5	12.8	10.7	9.2
70-74	34.0	28.7	23.7	20.0	23.4	20.7	17.3	14.9
75-79	53.9	45.5	37.4	31.5	37.8	33.4	27.7	23.5
80-84	88.4	75.6	61.7	51.8	64.3	56.6	46.2	38.9
85-89	151.0	135.6	114.9	99.0	113.7	104.1	88.7	77.0
90-94	249.6	228.4	192.8	165.5	197.5	182.1	154.0	132.7

Life expectancy is the average number of remaining years expected prior to death. Life expectancies in the United States are presented in two different forms—*period life expectancies* in Table 6 and *cohort life expectancies* in Table 7. Period life expectancy is calculated for a given year using the expected death rates at each age for that year. Thus, it *does not* reflect the life expectancy for actual cohorts of individuals. Instead, it *is* a useful statistic for summarizing the death rates over all ages for a given year. On the other hand, cohort life expectancy *does* reflect the life expectancy for an actual cohort of individuals. It is calculated using death rates from the series of years in which the cohort will actually reach each succeeding age.

Table 6 shows that period life expectancies at age 0 in the United States are projected to continue growing, but at a much slower rate than was experienced since 1940. Life expectancy at age 0 for males was 61.4 years in 1940, is expected to be 75.1 years in 2007, and is projected to

reach 81.5 years in 2075. For females, life expectancy at age 0 is projected to increase from 65.7 years in 1940 to 79.7 years in 2007 and to 84.8 years in 2075.

For age 60, period life expectancies in the United States are also projected to continue to grow, but at a rate slightly less than that experienced since 1940. Life expectancy at age 60 for males was 14.8 years in 1940, is expected to be 20.3 years in 2007, and is projected to reach 24.5 years in 2075. For females, life expectancy at age 60 is projected to increase from 16.8 years in 1940 to 23.1 years in 2007 and to 26.9 years in 2075.

The assumed mortality reductions have more of an impact on increasing the number of expected lifetime years at younger ages than at older ages. For instance, from 2007 to 2075, assumed mortality reductions lead to more than a 5-year increase in life expectancy at age 0 for both male and female. However, at age 60, this increase falls to about 4 years for both sexes, and by age 85, it falls to less than 2 years.

TABLE 6

Period Life Expectancies

	Male				Female			
Age	**2007**	**2025**	**2050**	**2075**	**2007**	**2025**	**2050**	**2075**
0	75.1	77.2	79.5	81.5	79.7	81.1	83.1	84.8
10	65.8	67.6	69.8	71.7	70.3	71.5	73.4	75.0
20	56.1	57.9	60.0	61.9	60.4	61.7	63.5	65.1
30	46.7	48.8	50.5	52.3	50.7	51.9	53.7	55.3
40	37.4	39.0	41.0	42.7	41.1	42.3	44.0	45.5
50	28.5	30.1	31.9	33.4	31.9	33.0	34.6	36.1
60	20.3	21.6	23.2	24.5	23.1	24.1	25.6	26.9
70	13.1	14.1	15.4	16.5	15.3	16.1	17.4	18.5
85	5.2	5.6	6.3	6.9	6.3	6.6	7.4	8.1

Table 7 shows, on a cohort basis, life expectancies at selected ages, by sex and year of birth. If life expectancy is calculated on a cohort basis, based on the annual death rates by age of individuals born in selected calendar years, then the life expectancy of newborns born in 2007 is projected to be 80.8 for males and 84.6 for females. For newborns born in 2075, life expectancies are projected to be 85.7 for males and 88.6 for females.

TABLE 7

Cohort Life Expectancies for Selected Years of Birth

	Male				Female			
Age	**2007**	**2025**	**2050**	**2075**	**2007**	**2025**	**2050**	**2075**
0	80.8	82.3	84.1	85.7	84.6	85.8	87.3	88.6
10	71.5	72.8	74.4	75.9	75.2	76.2	77.6	78.8
20	61.8	63.1	64.6	66.1	65.3	66.4	67.7	68.9
30	52.3	53.6	55.1	56.4	55.5	56.6	57.9	59.0
40	42.9	44.0	45.4	46.7	45.9	46.9	48.1	49.3
50	33.8	34.8	36.1	37.3	36.5	37.5	38.6	39.7
60	25.0	25.9	27.1	28.2	27.5	28.3	29.4	30.3
70	17.1	17.9	18.8	19.7	19.1	19.9	20.8	21.6
85	7.5	8.0	8.6	9.2	8.7	9.2	9.9	10.5

Comparisons between period and cohort life expectancies are shown in Charts 1 and 2. Historical and projected life expectancies at age 0 for males and females are displayed in Chart 1. In addition, a similar display at age 65 is provided in Chart 2. For the cohort lines in Chart 2, *year* indicated on the horizontal axis refers to the year of attaining age 65.

Cohort life expectancy at a particular age for a specific year is based on death rates for that age in the specific year and for each higher age in each succeeding year. Life expectancies on a cohort basis tend to fluctuate less from year to year than do period-based life expectancies because of sudden and temporary events, such as a flu epidemic, which may affect the entire population, for a brief period of one or two years, but affect only one or two years of mortality experience for each of the cohorts alive during the period. Therefore, cohort life expectancies are more useful in analyzing subtle and gradual generational trends in mortality.

CHART 1: Male and Female Life Expectancy at Birth

(in years)

Actual and Projected Intermediate Alternative

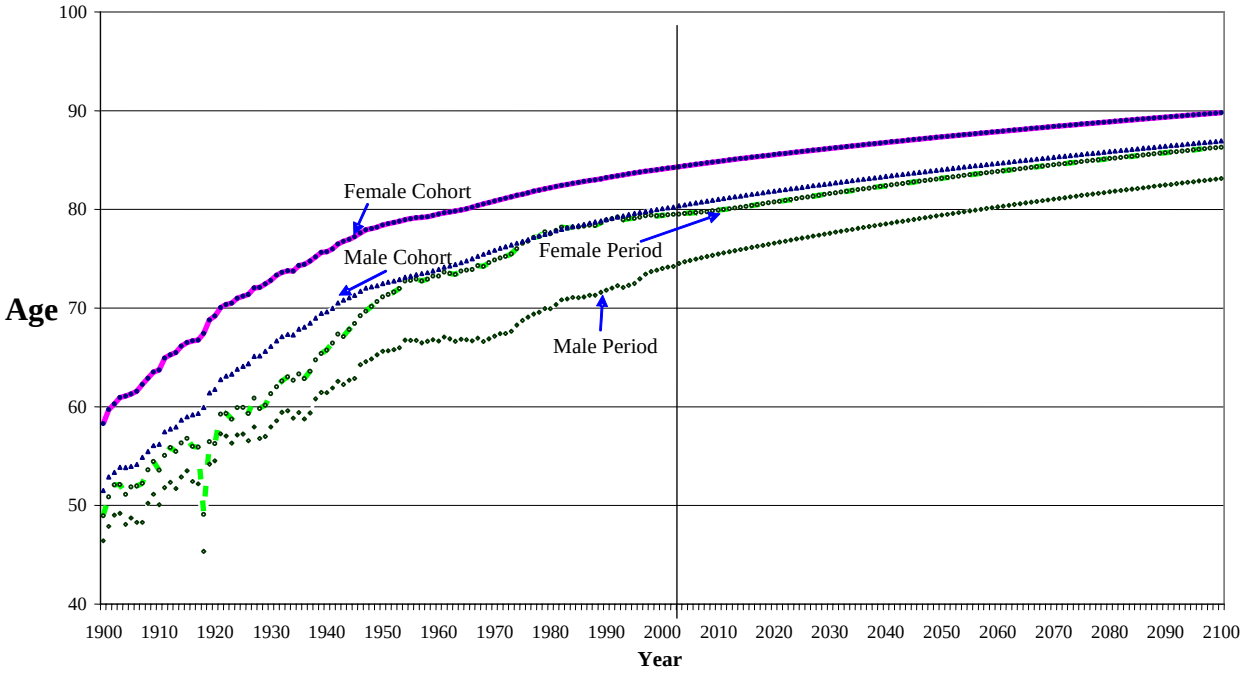
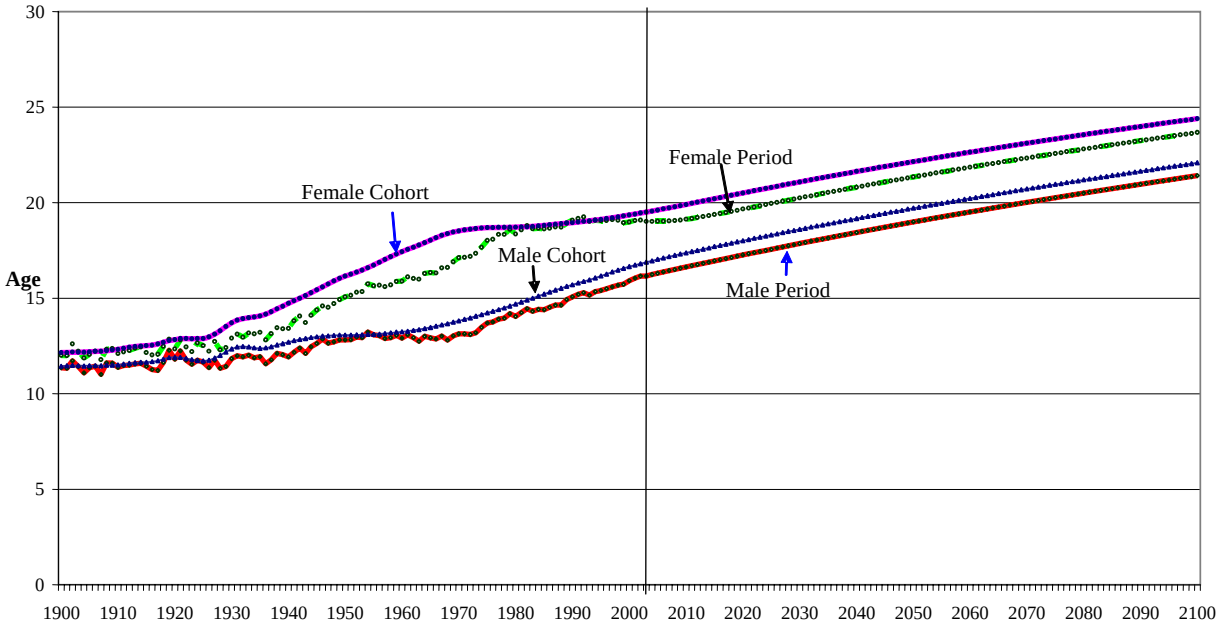


CHART 2: Male and Female Life Expectancy at Age 65

(in years)

Actual and Projected Intermediate Alternative



Year - Calendar year for period; Year attaining age 65 for cohort

Charts 3 and 4 present the population survival curves based on period life tables for selected calendar years. Great strides were made in the 20th century toward eliminating the hazards to survival which existed at the very young ages in the early 1900s. Little additional improvement to survival rates is possible at these young ages. Survival rates at the older ages are projected to continue to improve steadily.

Although the shape of the survivorship curve has become somewhat more rectangular (less diagonal) through time, it appears that little additional rectangularization will occur because survival rates are already so high at the young ages and are expected to continue increasing at older ages. The so-called "curve squaring" concept, though appealing to many, simply cannot be supported by the mathematics of mortality. The age at which the survivorship curve comes close to zero, through the compounding of single-year probabilities of survival, increased greatly during the 20th century and will continue to increase, as further strides are made against degenerative diseases. That mortality rates are found to continue to decline, at every age for which adequate data are available, demonstrates that no absolute limit to the biological life span for humans has yet been reached, and that such a limit is unlikely to exist.

As indicated in the graphs by the intersection of the vertical lines at age 65 with the survival curves, the probability of reaching age 65 increased substantially over the past century.

For the calendar year 1900, males had a 37 percent probability of reaching age 65. By 2000, this probability had increased to 78 percent, and by 2100 it is projected to reach 91 percent. For females, the probability of reaching age 65 using 1900 mortality data was 41 percent. This probability increased to 87 percent by 2000, and is projected to reach 94 percent by 2100. In general, probabilities of surviving to older ages have increased over the last century, and this trend is expected to continue at a slower pace.

CHART 3

Population Survival Curves—Male

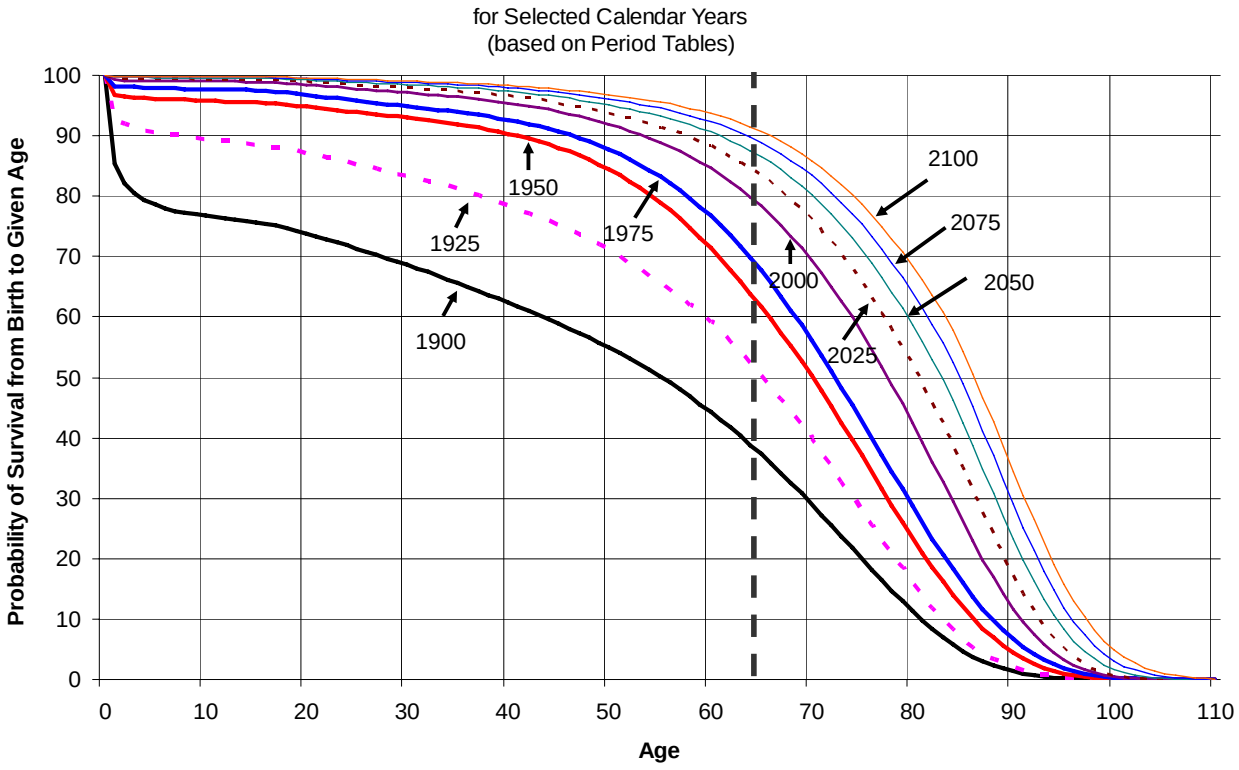


CHART 4

Population Survival Curves—Female

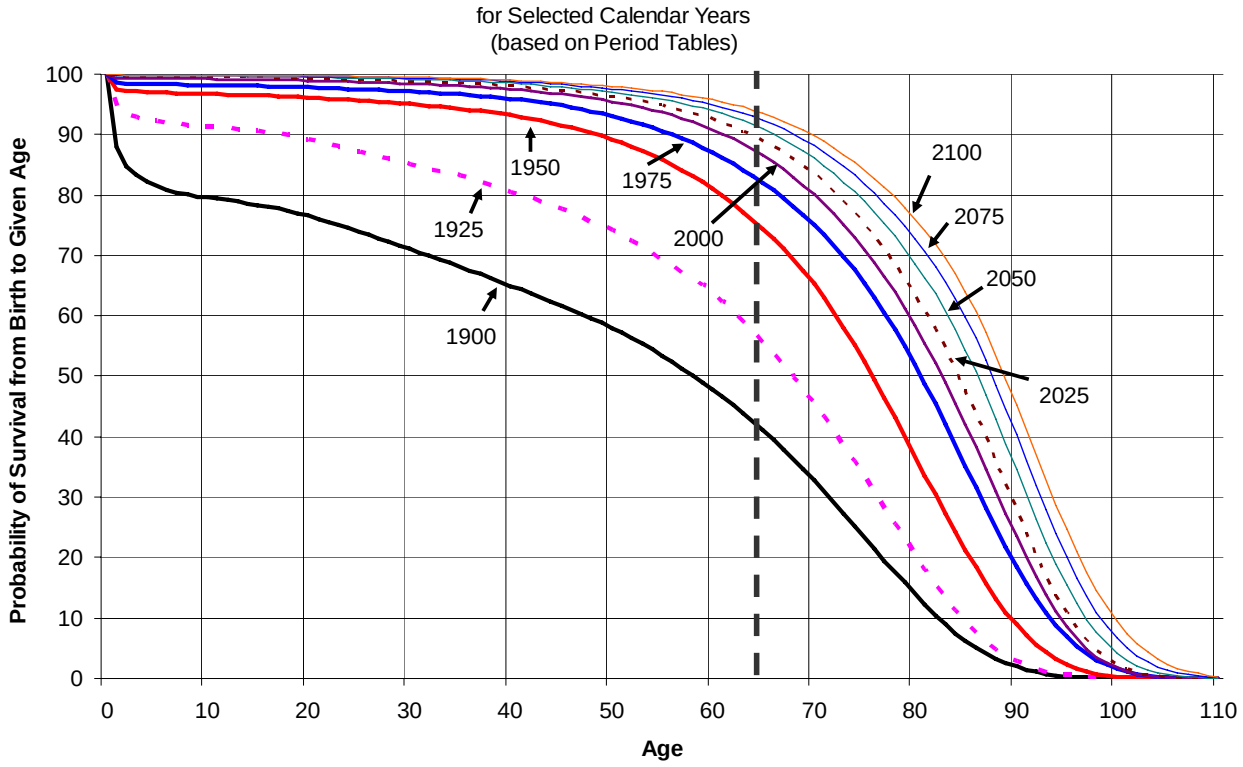


Chart 5 presents the age for three selected survival rates, by sex and calendar year on a period basis. The median age at death is indicated by the age at which the survival rate equals 0.5. The median age increased 23.4 years, from 54.7 years for males in 1900 to 78.1 in 2003. For females the increase was 25.1 years, from 57.9 years in 1900 to 83.0 years in 2003. Increases in the median age at death between 2003 and 2100 are projected to be 8.2 years for males and 5.8 years for females.

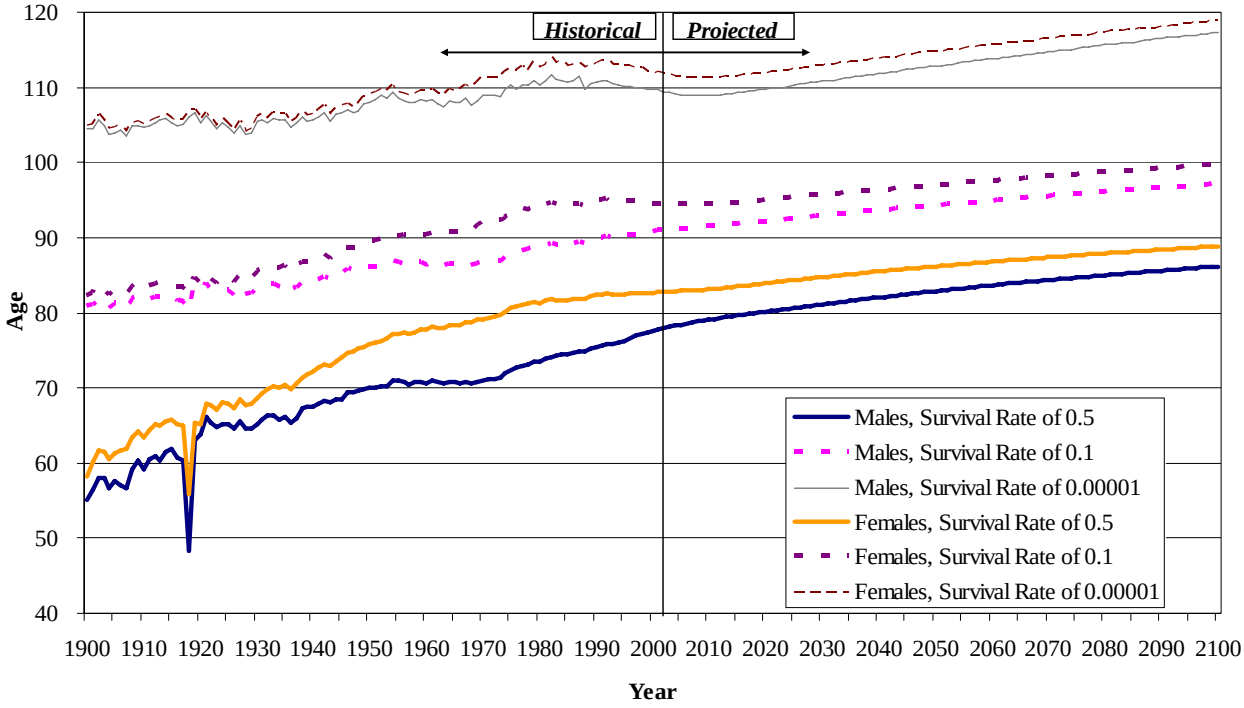
For the survival rate equal to 0.1, the corresponding age for males increased 10.4 years from 80.8 years in 1900 to 91.2 years in 2003, while for females it increased about 12.3 years from 82.3 years to 94.6 years. From 2003 to 2100, the age for males is expected to increase by 6.0 years and for females by 5.21years.

Historical data are used in calculating mortality rates up to about age 95. After that age, the probability of dying is assumed to gradually increase for each succeeding higher age. Based on this methodology, the age corresponding to a survival rate equal to 0.00001 is determined. This age for males increased from 104.4 years in 1900 to 109.6 years in 2003, while for females it increased from 104.9 years to 111.9 years. These results are in opposition to the widely held belief that the age attained by the oldest survivors in the population had increased little, if at all, during the 20th century. The extreme old age, where the survival rate equals 0.00001, increased very little from 1900 through 1930. However, this age increased rapidly between 1930 and 1954, and again between 1963 and 1982. Since 1982, this age has decreased for both males and females. For the period 2003-2100, this extreme old age is projected to increase by 7.7 years and for females by 6.9 years.

CHART 5

Age for Selected Survival Rates

by Sex and Calendar Year



3.2 Mortality by Marital Status

A complete projection of age-sex-specific death rates by marital status is not done. However, because benefits are paid to spouses and survivors of workers and because historical data indicate that the differential in mortality by marital status is significant, it is important to capture the differences in mortality by marital status. To reflect this, projected relative differences in death rates by marital status are projected to be the same as observed during calendar years 1995 and 1996. Table 8 displays the central death rates by age group, sex and marital status for these years.

TABLE 8: Central Death Rates by Age Group, Sex and Marital Status

Based on 1995-96 Data (per thousand)

Sex and Age Group	Total	Single	Married	Widowed	Divorced
Male					
15-19	1.1	1.1	1.4	9.3	4.0
20-24	1.6	1.7	1.2	8.5	2.3
25-29	1.7	2.1	1.1	5.8	2.5
30-34	2.2	3.8	1.3	5.7	4.0
35-39	2.7	5.5	1.7	8.5	4.1

40-44	3.6	7.6	2.4	9.5	5.9
45-49	4.9	9.9	3.6	10.4	8.5
50-54	7.2	14.6	5.6	14.0	12.7
55-59	11.0	19.9	9.1	19.5	19.3
60-64	17.6	30.3	15.1	27.1	29.6
65-69	26.2	42.0	23.1	34.7	42.2
70-74	40.1	58.4	36.3	49.5	59.1
75-79	59.7	90.2	54.4	71.3	84.2
80-84	95.2	142.9	84.9	117.8	124.6
Female					
15-19	0.4	0.4	0.4	2.7	0.8
20-24	0.5	0.5	0.4	1.4	0.9
25-29	0.6	0.9	0.5	3.2	0.9
30-34	0.9	1.5	0.6	2.3	1.3
35-39	1.2	2.4	0.9	3.2	1.7
40-44	1.7	3.5	1.3	4.2	2.3
45-49	2.6	4.7	2.1	4.6	3.6
50-54	4.1	7.2	3.4	6.5	5.6
55-59	6.5	9.9	5.4	9.5	8.6
60-64	10.4	14.4	8.6	14.4	13.3
65-69	15.6	21.1	12.9	19.0	20.7
70-74	24.4	31.4	20.2	27.7	32.2
75-79	38.0	48.5	31.6	40.5	49.1
80-84	63.5	84.1	49.7	66.5	80.7

3.3 Stochastic Modeling

It is important to provide policymakers with a sense of the range of variation in the financial projections that might occur if the intermediate assumptions are not realized. Traditionally, additional estimates using a low cost and a high cost set of specified assumptions are provided to reflect the presence of uncertainty. The set of assumptions chosen for the low cost estimates produces a much more *favorable financial effect* for the program. That is, mortality rates are generally higher than those assumed under the intermediate set of assumptions. Similarly, the set of assumptions chosen for the high cost produces a much more *unfavorable* financial effect. Under the high cost set of assumptions, mortality rates are generally lower than those assumed under the intermediate set of assumptions. These additional estimates provide a range of possible outcomes for the projections. However, they provide no indication of the probability that actual future experience will be inside or outside the range of these estimates. Thus, we rely on the results of a model, based on stochastic modeling techniques, to estimate a probability distribution of future mortality outcomes. It should be noted that this model is subject to further development. Future improvements and refinements are expected to be more likely to expand rather than reduce the indicated range of uncertainty.

All of the following descriptions pertaining to the stochastic process are based on the 2004 Annual Report of the Board of Trustees. Additional details concerning this process are found in Actuarial Study Number 117, located at the following Internet site: *http://www.ssa.gov/OACT/NOTES/s2000s.html*.

3.3.1 Specifics of the Stochastic Process

Central death rates were calculated for 42 age-sex groups (under 1, 1-4, 5-9, 10-14, ..., 85-89, 90-94, and 95+; male and female) for each year in the period 1900 through 2000. From these data, annual rates of decline were calculated. Using time-series analysis for the data over the entire historical period, an equation was selected for projecting annual rates of decline in the central death rate for each age-sex group. The selected equation uses the variation in the annual rates of decline observed during the historical period to estimate the future variation. The general form of the equation is:

$$MR_{k,t} = MR_{k,t}^{TR} + \varphi_k mr_{k,t-1} + \varepsilon_{k,t}$$

In this equation,

- $MR_{k,t}$ represents the annual rate of decrease in the central death rate for group k in year t;
- $MR_{k,t}^{TR}$ represents the projected annual rate of decrease from the central death rate for group k in year t that was assumed under the intermediate assumptions;
- $mr_{k,t}$ represents the *deviation* of the annual rate of decrease from that assumed under the intermediate assumptions for group k in year *t-1 (the prior year)*; and
- $\varepsilon_{k,t}$ represents the random error for group k in year t.

In order to achieve consistency amount the 42 projection annual rates of decline, a Cholesky decomposition was then performed using the residuals from the 42 fitted equations. The Cholesky matrix used was 42 x 42 with the age groups in ascending order with alternating male and female groups.

3.3.2 Results of the Stochastic Process

Tables 9 and 10 compare the resulting period life expectancies at birth from the 2004 Annual Report with those from the stochastic modeling process. The tables compare the value of the life expectancies in 2078, the increase from 2004 to 2078 in the resulting life expectancies (75-year increase) and the increase from 2029 to 2078 in the resulting life expectancies (50-year increase). The upper limit of the 90 percent confidence interval in 2078 is nearly equal to that assumed for the high cost set of assumptions (85.8 vs. 85.9 years for males, and 89.5 vs. 89.2 years for females). Additionally, the lower limit is only slightly less than that assumed for the low cost set of assumptions (77.5 vs. 78.0 years for males, and 81.6 vs. 82.1 years for females).

TABLE 9

Male Period Life Expectancies at Birth (in years)

	Intermediate Assumptions Trustees Report	Stochastic Process: Median	Low Cost Assumptions Trustees Report	High Cost Assumptions Trustees Report	Confidence Intervals Based on Stochastic Process					
					95-percent		90-percent		80-percent	
Value in 2078	81.4	81.8	78.0	85.9	76.5	86.6	77.5	85.8	78.6	84.9
75-year increase	6.9	7.4	3.6	11.3	2.9	11.3	3.7	10.6	4.7	9.8
Final 50-year increase	4.1	4.4	2.2	6.8	2.8	6.4	3.1	6.0	3.4	5.5

TABLE 10

Female Period Life Expectancies at Birth (in years)

	Intermediate Assumptions Trustees Report	Stochastic Process: Median	Low Cost Assumptions Trustees Report	High Cost Assumptions Trustees Report	Confidence Intervals Based on Stochastic Process					
					95-percent		90-percent		80-percent	
Value in 2078	85.2	85.4	82.1	89.2	80.9	90.4	81.6	89.5	82.4	88.6
75-year increase	5.6	5.9	2.6	9.6	2.1	10.2	2.7	9.5	3.4	8.7
Final 50-year increase	3.6	3.8	1.8	5.9	2.0	6.2	2.3	5.8	2.6	5.3

Charts 6 and 7 present the period life expectancies at birth for males and females throughout the entire historical and projection periods.

CHART 6: Male Period Life Expectancies at Birth, Calendar Years 1900-2078

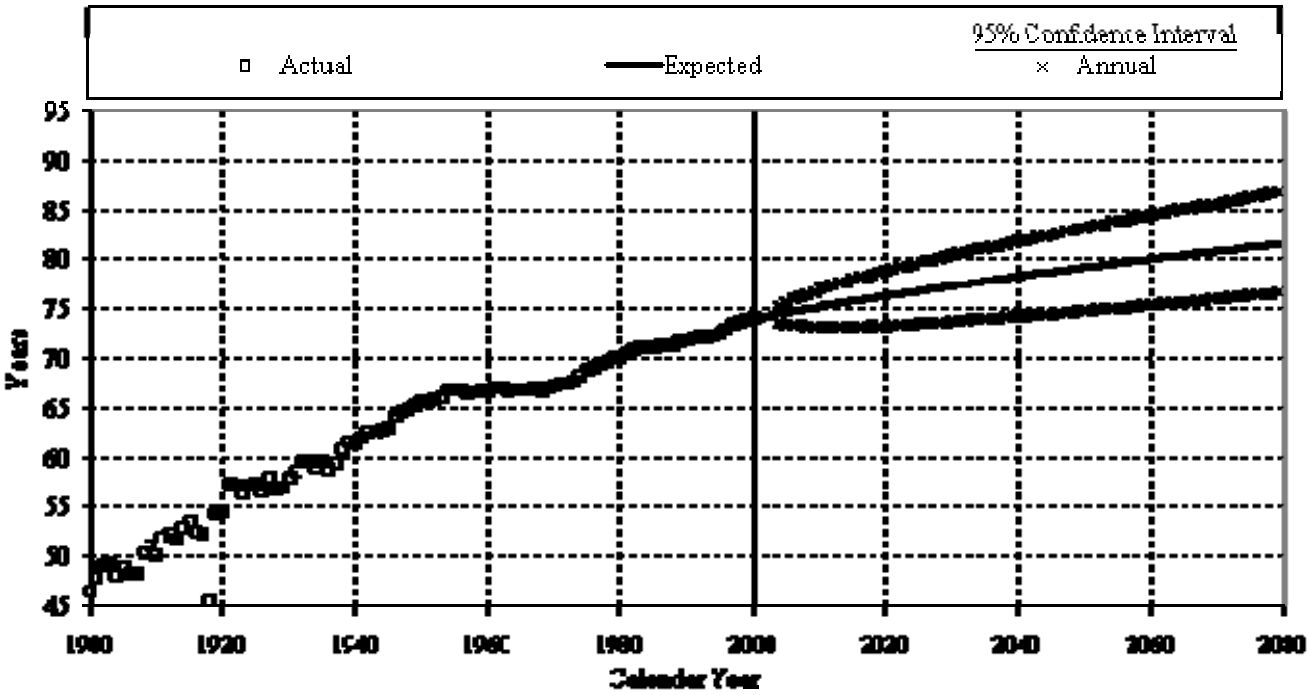
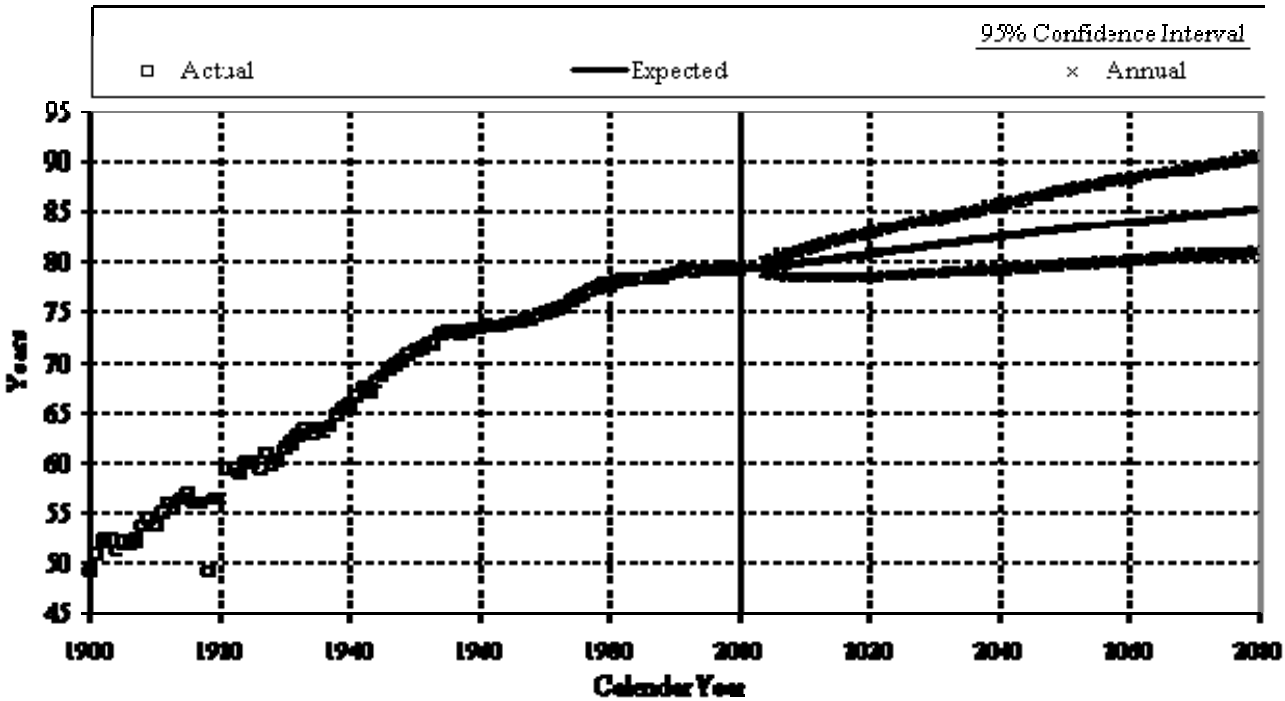


CHART 7: Female Period Life Expectancies at Birth, Calendar Years 1900-2078



Tables 11 and 12 compare the resulting period life expectancies at age 65 from the 2004 Annual Report with those from the stochastic modeling process. The values shown in these tables

are analogous to those shown for life expectancy at birth analogous. The upper limit of the 80 percent confidence interval in 2078 is close to that assumed for the high cost set of assumptions (23.2 vs. 23.6 years for males, and 26.3 vs. 26.1 years for females) while the lower limit is slightly larger than that assumed for the low cost set of assumptions (18.4 vs. 17.7 years for males, and 20.7 vs. 20.3 years for females).

TABLE 11

Male Period Life Expectancies at Age 65

	Intermediate Assumptions Trustees Report	Stochastic Process: Median	Low Cost Assumptions Trustees Report	High Cost Assumptions Trustees Report	Confidence Intervals Based on Stochastic Process					
					95-percent		90-percent		80-percent	
Value in 2078	20.3	20.6	17.7	23.6	17.2	24.8	17.7	24.0	18.4	23.2
75-year increase	4.2	4.5	1.7	7.5	1.6	8.3	2.0	7.6	2.6	6.8
Final 50-year increase	2.7	2.9	1.1	4.8	1.4	5.1	1.6	4.6	1.9	4.2

TABLE 12

Female Period Life Expectancies at Age 65

	Intermediate Assumptions Trustees Report	Stochastic Process: Median	Low Cost Assumptions Trustees Report	High Cost Assumptions Trustees Report	Confidence Intervals Based on Stochastic Process					
					95-percent		90-percent		80-percent	
Value in 2078	22.8	23.3	20.3	26.1	19.4	28.1	19.9	27.3	20.7	26.3
75-year increase	3.9	4.3	1.4	7.1	0.9	8.6	1.4	7.9	2.1	7.0
Final 50-year increase	2.6	2.9	1.1	4.6	1.2	5.3	1.4	5.0	1.8	4.4

Charts 8 and 9 present the period life expectancies at birth for males and females throughout the entire historical and projection periods.

CHART 8

Male Period Life Expectancies at Age 65, Calendar Years 1900-2078

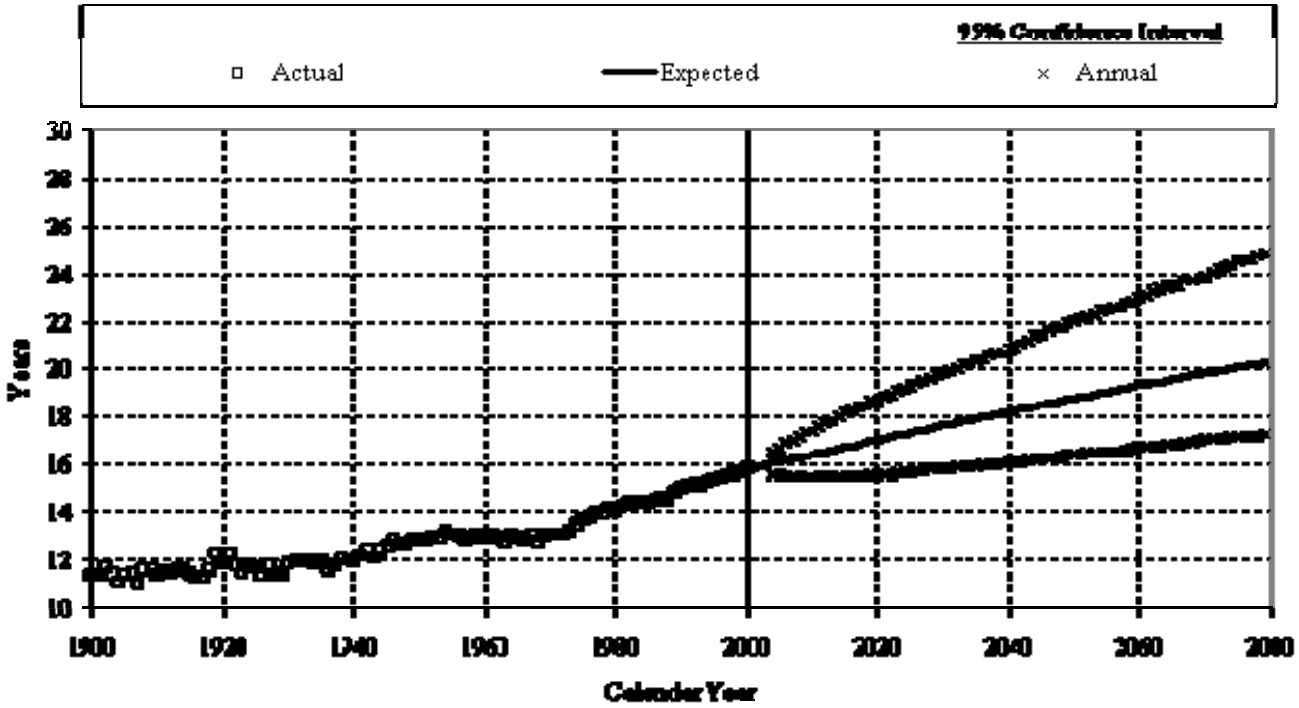
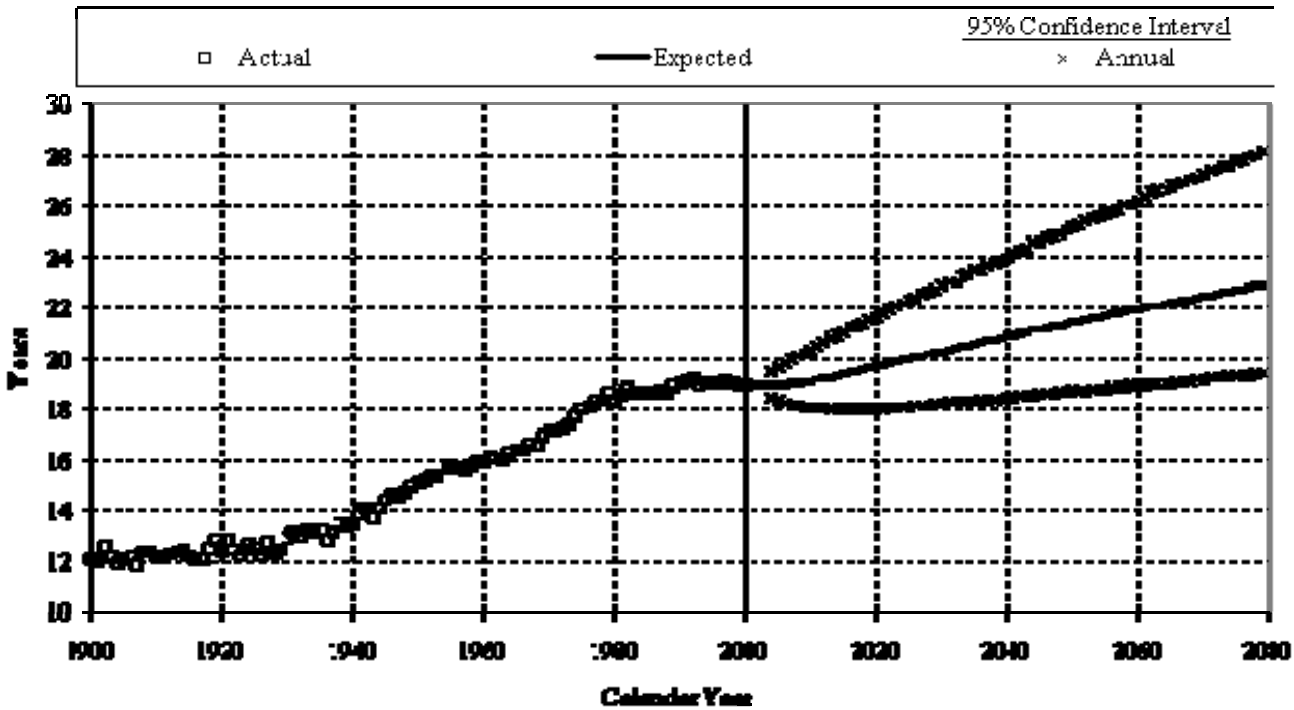


CHART 9

Female Period Life Expectancies at Age 65, Calendar Years 1900-2078



4. Conclusion

Mortality in the United States declined significantly in the 20th century at all ages and for both males and females. In fact, in the last century, life expectancy at birth increased by an estimated 27.4 years. Female life expectancies have exceeded male life expectancies; however, the gap between the two has varied over time. The gap between female and male life expectancies at birth was less than 3 years in 1900 and began to generally increase, peaking at 7.7 years in 1970. The gap has since narrowed and was 5.3 years in 2003.

Mortality is assumed to continue to decline throughout the 75-year projection period. Future mortality reduction for ages below 65 is expected to continue, but at a slower rate than was experienced during the 20th century. However, for ages 65 and above, future mortality reduction is expected to be close to that experienced over the last century.

The ultimate annual mortality reduction rates, assumed for years 2031 and later, vary by age and sex and are based on an analysis of experience since 1900 and expectations of the future changes in these rates. Annual rates of mortality reduction assumed for the first 25 years of the projection period are based on trending from rates experience over the latest 20 years to those assumed ultimately. It is also expected that the gap in life expectancies between females and males will continue to narrow over the next several years and then to continue narrowing slightly at the younger age groups and to stabilize at the older age groups.

Finally, methodologies involving stochastic time series models have been developed in order to illustrate the volatility, of mortality rates. The main advantage of a stochastic projection is that it provides a reasonable quantification of the range of uncertainty around the central (best estimate) projection. In particular, the stochastic modeling results show that the low-cost and high-cost sets of assumptions capture a reasonable range of variability.