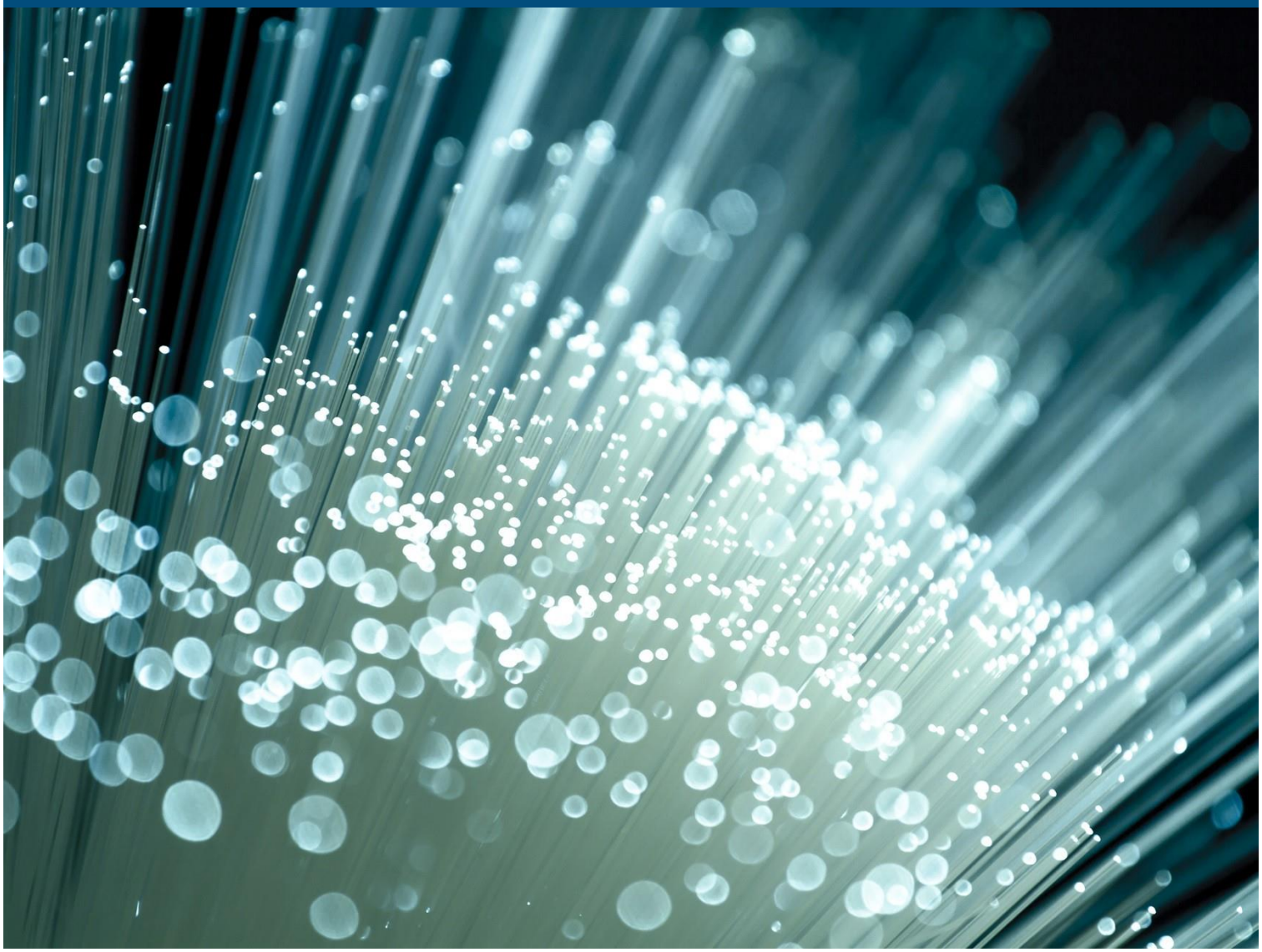
SOCIETY OF ACTUARIES

# Living to 100

## Insights on the Challenges and Opportunities of Longevity
## Literature Review 2002-2014



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## Literature Review 2002-2014


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# 1. Introduction

Living to 100 is a research initiative featuring triennial international symposia as a means to share knowledge and cultivate innovation. Sponsored by the Society of Actuaries (SOA) with many partners, the symposium brings together a diverse group of scientists and academics to share and discuss their knowledge on longevity. They discuss the latest scientific information on what makes us age and how aging has changed in the recent past; they examine recent trends in survival rates and construct projections for the future; they ponder the consequences for social, retirement, long-term care and health care systems; they examine the implications of an increasingly elderly workforce and identify private industry innovations that aim to address the challenges of an aging population. There have been five Living to 100 symposia, which were conducted in 2002, 2005, 2008, 2011 and 2014. Each has produced a lasting body of research (the "symposia material") that can educate and aid interested parties in understanding longevity and its societal implications.

The SOA commissioned Ernst & Young LLP (EY) to prepare a literature review based on the material presented at the five symposia. The review provides an overview of the technical material related to data sources, validation techniques and methodologies used by leading practitioners to develop mortality rate estimates for past, present and future periods. It also presents discussions regarding business, policy and social implications of increasing longevity.

In particular, this report aims to:

- Provide an overview of the research and discussions presented at the symposia, highlight areas of consensus or disagreement within the research presented, and identify gaps in knowledge.
- Present the techniques for modeling mortality and forecasting future mortality exposed in the symposia, followed by applying a subset of those techniques to the U.S. general population data; the report also identifies the challenges in applying such techniques and strategies to overcome them.
- Contribute commentary from interviews in which practicing actuaries discuss the lessons learned from implementing advanced-age mortality models in their work and perspectives on symposia topics.
- Provide a catalyst to the actuarial community to look beyond the modeling and forecasting aspects of old-age mortality, start conceptualizing the broader implications of increased longevity, and influence policymakers and regulators.
- Facilitate the content and relevance of symposia materials to the broad professional community and general public, and promote an interdisciplinary focus.

Several other areas within the SOA are also engaged in work related to the implications of long life, but that work is beyond the scope of this literature review. Additional work and research can be retrieved from SOA research committees like the Committee on Post-Retirement Needs and Risks Research and SOA sections such as the Long Term Care Insurance, Pension and Health sections.

In the body of the report, various techniques are presented for determining base mortality rates and forecasting older-age mortality. We hope this presentation illustrates the practical applications of these techniques, provides insight into the thought process required prior to implementing these models and facilitates the reflection process when interpreting results.

The Living to 100 symposia have produced a lasting and valuable body of knowledge on the future of longevity and its implications that will help practitioners to better understand competing perspectives on longevity and a societal lens through which to understand its impacts.

This report is divided into two parts.

**Part 1** focuses on papers that discuss data sources, validation techniques and methodologies which practitioners use to develop and project mortality rates for the past, present and future.

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**Part 2** focuses on papers that discuss the resulting implications of longevity for industry, society and government.

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Each section highlights important information from the symposia by discussing matters in which experts from industry and academia tend to agree, matters in which they tend to disagree, and any gaps in knowledge that have been identified and may present opportunities for future research.

In each section we include a list of referenced papers, along with links to their full text on the SOA website. Appendices A and B house a full listing of the symposia monographs, with links to their full text on the SOA website and a synopsis of each paper's content. Papers are referenced throughout this document by the keys [A-XXX] and [B-XXX]; these references are unique to each paper and can be used to find other references to the paper within this report, as well as to find the paper's summary in appendices A or B. Appendix C contains a heat map developed to organize the symposia academic papers by practice area—retirement, health, long-term care, life and other—and by analytical phase, and to provide an overall view of where knowledge has been abundant and lacking in prior symposia.

We note that this review is limited to material presented at the symposia. No effort has been made in this report to do independent research to fill the gaps in what has been presented at prior symposia. However, an effort has been made to identify these gaps to provide direction for future research.

## 2. Acknowledgements

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## 3. Executive Summary

Actuaries have a professional obligation as stewards of the financial safety nets that governments and individuals have created for themselves to understand and drive thought leadership on longevity—both the technical aspects of projecting longevity and on downstream societal implications.

Robert L. Brown, FSA, ACAS, FCIA, HonFIA,
Advisor, EvidenceNetwork.ca

Longevity is an important issue. The implications of increasing longevity have far-reaching effects for the world's social programs and financial security as people grow into old age. It is also a trend actuaries are well suited to analyze: Actuaries have unique skills and experience that allow for distilling large volumes of data into key elements that can nourish predictions of future events. Their partnership with other experts will shape the discussion on the implications of increasing longevity. In developing the Living to 100 symposia, the SOA is facilitating the collection of key elements of that discussion and shaping it going forward.

Papers presented at the symposia have been categorized by their scope and area of application within Appendix C. This serves as a means to easily find leading papers specific to the field of interest as well as an overall view of where knowledge has been abundant in prior symposia and what areas require additional research. As one reads the material, a few key threads appear consistently throughout the discussion.

First, the majority of people around the globe are living longer, although the rate of improvement differs across ethnicities, geographies and social status. In particular, females generally have higher life expectancies than males, placing them at a higher risk for challenges associated with longevity. However, the gap between female and male life expectancies has been narrowing in recent years, showing a relative stagnation of female mortality improvement and continuous increases in males.

Second, our understanding of what factors have a material effect on our expected lifetime is growing but is not yet complete. There are large gaps in knowledge on how the complex aging process functions as well as on the influence of genetics and its related technology. The correlation and evolution of causes of death also present challenges when forecasting longevity. Our understanding of older age mortality is also limited, in part because the data at older ages is sparse and of varying quality. There are open questions related to the rate of improvement and the ultimate age at which it is appropriate to assume a mortality table should end.

Third, in many regions there is no broad consensus on the appropriate base mortality rates and improvement factors that should be used to value life-contingent liabilities, or on the models to forecast these rates into the future. This creates challenges for practitioners who must develop their own projections; inefficiencies such as the use of different data, assumptions and models leads to different mortality forecasts; and inconsistencies across disciplines—for example, between the pension and insurance communities—as each develops its own independent view of long-term mortality. Having said this, the actuarial community has successfully dealt with issues of this magnitude in the past. As evidenced by the material presented in the body of this report, there are techniques such as stress testing, back testing, scenario testing, risk heat maps and screening systems, among others, that we can use to gain insight into pertinent assumptions for base mortality rates and improvement factors.

Last, there are broad socioeconomic implications for governments, employers, social institutions, businesses and individuals that must be addressed as our life span increases: The systems that exist to support us through our retirement and into our old age are calibrated to a certain expectation of how long we will live, and when and how we will become eligible for support. As those expectations change, our personal and social safety nets will be forced to adapt. In addition, the amount of time we allocate between work and other pursuits is changing significantly. As we grow older, we must work with our governments and employers to

identify the best terms on which we leave the workforce. There are a wide variety of views on longevity's implications and potential solutions, especially around the roles of the public and private sectors.

There are many areas where practitioners of different disciplines across the globe have come to similar conclusions. These areas include:

- Limited data points at extreme ages can lead to erratic mortality rates, proving to be a significant hurdle for research. Poor quality of data caused by external factors (e.g., overstatement of age, unreported deaths, late reporting of deaths or inaccurate diagnosis of death) is also an obstacle. Analytical and practical solutions are limited but have a range of cost/benefit profiles.
- Many sources for mortality/longevity data exist, especially from governments (social insurance, census data), but practitioners need to consider whether the underlying population is consistent with the intended application, which means that life, annuity and pension practitioners need additional sources. Retrieving non-publicly available data sources can be time consuming due to privacy, ethical and legal considerations. Nonstandard nomenclature between data sources provides a challenge in reconciling multiple data sources.
- Dependencies exist across causes of death, which provides limitations and challenges to practitioners when attributing mortality by specific diseases and projecting their interaction in the long term.
- Researchers segment mortality data in various ways to understand correlations and establish appropriate subgroupings, where gender and smoking status are standard. In addition, actuaries in government and insurance companies have typically used percent-per-year improvement scales based on tables that vary by aspects such as age and gender. Differences in subgroupings may be driven, in part, by the type of information included in a given database. Commercial and regulatory considerations also affect the type of information available for research.
- Determining predictors of mortality and morbidity proves to be challenging, mainly due to long-term lags between underlying behaviors and their mortality consequences, multiple possible interpretations of the patterns in the data, the interaction among multiple pathological and biological processes, limited knowledge of the aging process and inaccuracies in cause-of-death diagnoses.
- Practitioners agree that calibrating the extrapolation to different time periods will lead to significantly different results. Consensus also exists over how different data sources and methodologies can make it difficult to compare life tables and mortality projections between models.
- Companies should explicitly or implicitly incorporate the effects of current and recent medical advancements, but major future developments (such as a cure for cancer or increase in mental illnesses) are difficult to predict and model.
- Changes in demographics, and the resulting shift in balance between retirees and non-retirees, are increasing social insurance burdens worldwide, resulting in pay-as-you-go programs becoming increasingly difficult to maintain.
- Higher life expectancies and different life histories put women at a higher risk of financial distress in late ages than males with lower average pension benefits and higher probability of outliving assets.
- Income responsibilities post-retirement are increasingly falling onto the employees as employers reduce pension benefits and shift to defined contribution plans, increasing the demand for financial products with guaranteed income. Retirees face many risks, thus needing better education and the development of comprehensive portfolios of financial security products. However, many consumers do not have adequate resources, so the challenges go far beyond education.
- There are benefits of integrating seniors into the workforce for the employer, the elderly and the economy. Employers may be rewarded with loyalty and lower employee turnover, the government may collect more income taxes with the elderly continuing to contribute to the gross domestic product (GDP), and seniors may be able to more comfortably finance their postponed retirement.

- Rules of thumb that have often been promoted by financial advisors may be misunderstood and applied in the wrong context. Individuals should incorporate their unique needs into developing solutions, rather than depending on generalized advice.
- Those in need of long-term care should explore alternative housing models to support the funding of long-term care costs, including continuing care retirement communities, universal design communities, co-housing and reverse mortgages on their existing home equity.
- Institutional acknowledgement of longevity risk has continued to rise as evidenced by the demand for protection through use of reinsurance, capital market solutions and pension de-risking strategies.

In addition, it is also apparent there is a fundamental need to address the following gaps in knowledge:

- Are there limits to longevity? At what age should mortality tables end, if at all?
- How can the profession improve data collection for insured and annuitant populations? There is a clear, significant difference from the general population, but many companies do not participate in voluntary data submission to SOA/American Academy of Actuaries (AAA) research, resulting in tables that are not necessarily comprehensive of the industry.
- How can the profession acquire more credible mortality data by cause of death, and what are some viable strategies for resolving privacy and confidentiality concerns?
- Where should actuaries add rigor to data scrubbing/analysis processes, or to predictive modeling or any other component? In particular, at what extreme age does the quality of data show deterioration?
- What are some mechanisms for validating key data sources, technical measures and sophisticated, multivariate projections of longevity-related data?
- What impact will the current obesity epidemic have on mortality rates?
- How can we improve our understanding of the complex aging process and the role genetics plays in longevity?
- How should abnormal mortality improvement rates exhibited by outlier cohorts be treated in projections? What are the causes of these anomalous cohorts?
- What are some mechanisms for assessing the utility of finer subgroupings of the populations?
- What future medical and pharmaceutical breakthroughs will become the main drivers of longevity? Will life expectancy keep on increasing at rates similar to those experienced since the mid-19th century, or will it have a slower increment? How can companies mitigate risks associated with these major technological advances? What are some ways to model these risks?
- Can we validate a wealth/longevity effect at the oldest ages, especially for disability income and long-term care business?
- Will individual economic behavior vary as longevity patterns continue to shift, and how can that be incorporated into modeling and planning?
- What can other practice areas learn from predictive modeling practices in property and casualty (P&C), reinsurance, capital markets, life settlements, or from the Canadian space and other international bodies? Could this lead to guides or practices that can be used by regulators?
- What lessons can be learned from the challenges faced by public pension plans and long-term care products?
- How should practitioners work more closely with the academic community to learn and test the latest theories and developments?
- How will governments deal with the discredited fixed retirement age? How will society adapt to an aging workforce?

- What are the benefits and limitations of general guidelines and rules of thumb for retirement planning? How can we improve the accuracy and personalization of these generalities?
- How can the compensation and business structure for financial advisors in the U.S. be modified to better align their clients' best interests with their own?
- How can the private sector and the government solve the challenges faced by the long-term care system, during a time when confidence in insurers is low and people underestimate eligibility requirements for Medicaid while overestimating its benefits?

Following on the theme of discussion at the 2014 symposia, and with possible medical breakthroughs on the horizon, it is critical for actuaries to shift their focus from numerical technicality to social applicability. As science edges ever closer to a monumental breakthrough in longevity, the world will look to actuaries for solutions on what promises to be a major disruptor to the traditional standard of living and society itself.

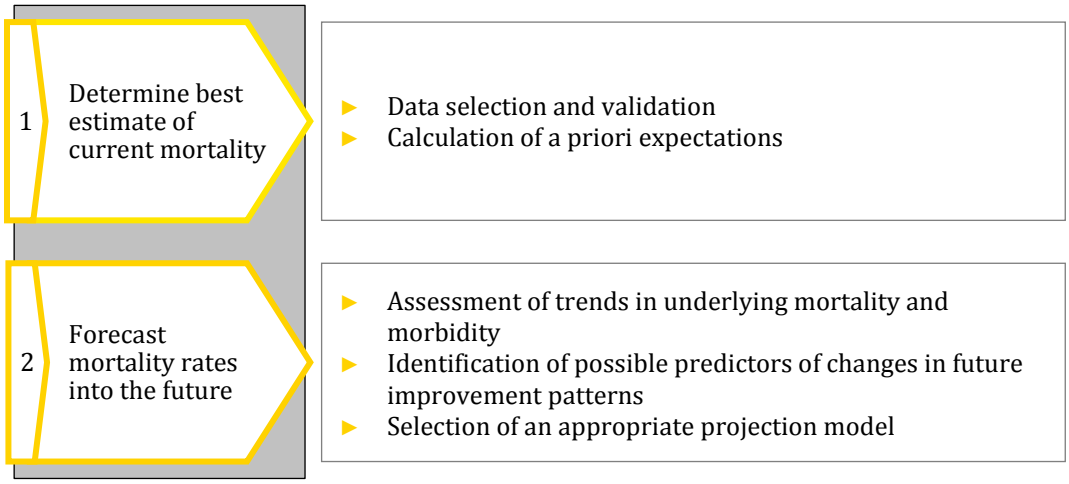
# 4. Summary of Literature Reviewed

## 4.1 Part 1: The analytical process

> The Society of Actuaries and other actuarial societies worldwide are not medical experts, but they may be the only organizations in the private and public sectors that have the technical ability to model these highly complex, multi-decade research projects. The input they could provide to public health authorities is urgently needed: reasoned advice regarding the implications of different research and funding priorities on morbidity, mortality, life expectancy and entitlement costs that will be borne by future generations.
>
> Dr. Robert Pokorski, FACP

### 4.1.1 Overview

The analytical process for developing mortality rates and projecting them forward can be broadly categorized into two main processes with five substeps.




We have used this approach to organize symposia material into five sections:

- Data selection and validation
- A priori expectations
- Assessing trends in underlying mortality and morbidity
- Identifying possible predictors of changes in future improvement patterns
- Selecting the appropriate projection model

### 4.1.2 Data selection and validation

Data selection and validation is one of the first steps in the development of mortality rates.

This section is devoted to identifying data sets available to practitioners, challenges that exist when using such data sources, and validation methods to mitigate those challenges. It focuses primarily on data for people of older ages because a number of challenges, such as limited data, hinder practitioner efforts in this area. This section attempts to present solutions to these problems; however, many of the solutions would require a significant amount of time and money, making it necessary to weigh their benefits against their required effort.

This section also explores problems that might arise from incorrect usage of data. While there are many data sources available, especially from government sources like social insurance programs and population censuses, practitioners must consider whether or not given data can be applied effectively. Health practitioners, for example, may be more concerned with factors associated with morbidity than mortality. This section highlights those problems for which there is limited consensus on methods to address. The result of applying different methods for validating and presenting data has led to different conclusions on the emerging trends and patterns. This phenomenon is discussed in this section.

The material presented in this section raises several important questions that may provide opportunities for future research:

- How can our profession improve data collection for insured, annuitant and pensioner populations? There are obviously significant differences from the general population, and many companies do not participate in the voluntary data submissions to SOA/AAA research, resulting in tables that do not necessarily provide a comprehensive view of the particular industry under study.
- How can we apply lessons learned from professional organizations like the United Kingdom's Continuous Mortality Investigation or the German Actuarial Society?
- How can the profession acquire data segmented by cause of death, and what are some viable strategies for resolving privacy and confidentiality concerns?
- What are some key articles/areas in which practitioners can learn from the academic community? Can the academic community furnish a practical and reasonable starting point for practitioners?
- Where should actuaries add more rigor to data scrubbing/analysis processes, or to predictive modeling, or any other component?
- What other validation techniques can be utilized to correct inconsistencies and errors related to issues in recording deaths and its causes?

This section is divided into three subsections. The first subsection lists data sources referenced by the symposia material. It is not meant to be an exhaustive list of all possible data sources for studying old age mortality nor an endorsement by EY, members of the POG or the SOA on the data sources that should be used in studying old age mortality. It is also noteworthy that the data sources referenced by symposia material and shown below may change over time. Thus, comments on accessibility, accuracy and/or quality presented in the papers may no longer apply. The second subsection examines the challenges practitioners face when using data. The third subsection summarizes the methods for validating such data.

#### 4.1.2.1 Key data sources

1. Medicare enrollment files[A-3]

The master records of Medicare enrollment have extensive information on the mortality of very old individuals in the United States. The data is generally of high quality—the ages in the records, for example, are

supported by documentation. However, Medicare enrollment files do contain errors related to duplicate information, incorrect ages and unreported deaths. These errors are most prevalent among older subjects.

2. The Death Master File maintained by the Social Security Administration[A–4]

The Death Master File (DMF), maintained by the Social Security Administration (SSA), is the largest collection of publicly accessible death records in the United States. As of December 2000, the public release version of the DMF (DMF-PR) contained more than 65 million death records for deaths occurring between 1900 and 2000. Furthermore, the DMF includes data for people of older ages; there are 124 records for people who allegedly lived to 125–129 years old, and there exist scattered records for even higher reported ages at death.

Some argue there is strong evidence the SSA death data is highly accurate for all but the most extreme ages. This is especially true when additional requirements, such as insured status and Medicare Part B enrollment, are imposed. Therefore, these types of carefully constructed samples from the DMF-PR hold the best prospect for valuable demographic work. In particular, the DMF-PR is an important resource for increasing our understanding of centenarianism and supercentenarianism.

Also, Natalia Gavrilova and Leonid Gavrilov note how death records are not as reliable for Puerto Rico, Hawaii and the Southern states[1] of the United States. The authors confirmed this finding as the non-Southern group demonstrated significantly less mortality understatement, suggesting more accurate age reporting in the group.[A-139]

3. International Database on Longevity[A-30]

Since the first symposium, Living to 100 and Beyond: Survival at Advanced Ages, held in 2002, there has been a collaborative effort to assemble an international database on longevity that would gather validated longevity records for people 110 years old and older. More than 15 countries, including the United States, Canada and Japan, along with European countries, have been participating in this "supercentenarian" project. Collaboration with national statistical offices and/or health departments has allowed investigators to obtain complete lists of alleged supercentenarians in most countries. By March 2004, more than 500 validated records had been gathered. This paper will later evaluate the quality of said data according to several criteria, such as the country of residence and the validation process undertaken, and will then provide an estimation of the mortality trajectory up to age 114.

4. Computerized genealogies[A–39]

Natalia Gavrilova and Leonid Gavrilov explored the availability and quality of computerized online genealogies of long-lived individuals by crosschecking them with other Internet resources, including the SSA DMF and the early U.S. censuses. Gavrilova and Gavrilov drew centenarian family histories from computerized family trees using the following selection criteria: (1) individuals should have birth and death date information and a life span of 100 years or more, (2) individuals should be born in the United States after 1875, and (3) individuals should have pedigree information for at least three generations of ancestry (both on paternal and maternal sides), as well as information on the birth date and death dates of parents.

Computerized genealogies contain important information about family and life-course events, which are otherwise difficult to collect. These life-course events include: life span of parents and other relatives, number and gender of siblings, birth order, ages of parents when person was born, age at marriage, number of spouses and life span of spouses and other nonblood relatives, number and gender of children and timing of their birth, place of birth, and information about residence during the life course.

[1] This includes Arkansas, Alabama, Georgia, Mississippi, Louisiana, Tennessee, Florida, Kentucky, South Carolina, North Carolina, Virginia, West Virginia, Arizona, New Mexico, Texas and Oklahoma.

The researchers suggest that computerized genealogies, although difficult to produce, provide the most complete information on the life span of long-lived individuals when compared to other sources.[A-129]

5. National Health Interview Survey's Health Promotion and Disease Prevention Supplement[A–87]

Data from the 1990–91 National Health Interview Survey's Health Promotion and Disease Prevention Supplement and the mortality follow-up through 2002 can be used to study socioeconomic and demographic characteristics, health status and health behaviors associated with oldest-old mortality, and survivorship among people who have survived to old age.

6. Canadian National Population Health Survey[A-93]

Longitudinal data from the Canadian National Population Health Survey was used in proportional hazards models to identify factors associated with loss of good (self-rated) health over a 14-year period and among age groups 20 to 44, 45 to 64, and 65 and older. The data shows that about 30 percent of people age 20 to 44 lost their good health over this period, compared to about 50 and 80 percent of middle- and old-age individuals, respectively.

7. Framingham Heart Study[A-103]

Researchers investigated the effects of age trajectories of physiological indices on mortality risk and longevity using longitudinal data on more than 5,000 individuals. The data was collected over a 50-year period with biannual examinations on the Framingham Heart Study (FHS) original age group.

8. Human Mortality Database[A-148]

The Human Mortality Database (HMD), a joint project by the University of California at Berkeley and the Max Planck Institute for Demographic Research, provides data on objective mortality for a large number of countries. The core data contained in the HMD is a set of period life tables for reporting age- and gender-specific death rates in a given year for a given country. The HMD also contains cohort life tables, which provide age-specific death rates for a given birth cohort.

#### 4.1.2.2 Challenges related to using publicly available data sources

1. Inconsistencies in underlying data

Publically available data is not always ready to use for analysis due to known errors related to duplicate information, incorrect ages and unreported deaths.[A–4]

Furthermore, there may be differing levels of accuracy in data collection over the years. For example, the data in the DMF is less reliable for older birth-year cohorts. While approximately 90 percent of the total deaths of U.S. residents were reported in the DMF for 1979 to 1999, records for older death-year cohorts—especially those before 1962, when death records were first automated—are far less complete. This bias affects any mortality study on extinct birth-year cohorts constructed from the DMF.[A–4]

Natalia Gavrilova and Leonid Gavrilov also noted how the quality of data within the DMF is acceptable until age 106, which they note is supported by other studies. At more advanced ages, there appears to be deterioration in the quality of data as evidenced by an observed excess of men relative to women, which is inconsistent with expectations given that female mortality is consistently lower than male mortality across all ages.[A-139]

2. Availability of good quality data at older ages

The low number of reported deaths at older ages poses serious challenges to researchers measuring mortality of the elderly. For example, for ages above 110, as observed in Japan, the inaccuracy of death reporting can be

as high as 50 percent for ages 110 and 111 due to their deaths not being tracked as accurately as deaths at more exceptional ages beyond age 111.[B-5] The growing number of people who live beyond age 100 is increasing the need for accurate measurement and modeling of mortality at advanced ages. Current limitations in the data have the following implications for the study of mortality at older ages. This list is drawn from multiple sources within the symposia materials.

- Cause of death may not be available, accurate or complete.
- The low reported number of deaths creates large fluctuations in estimated mortality rates.
- The small number of people at advanced ages may require researchers to pool data for people belonging to different birth cohorts, which results in data heterogeneity.
- A standard approach based on annual mortality estimates may not be applicable to extremely high and rapidly changing risk of death at advanced ages.
- It may be difficult to verify that the population satisfies certain mortality features such as the Gompertz law.
- The actual age at death may be lower than reported due to seniors overstating their age.
- For non-publicly available data sources, the process to retrieve death data can be elongated due to privacy, ethical and legal considerations.[B-5]
- Finally, it may be difficult to determine the appropriate age at which to terminate life tables.

There are several explanations for the poor quality of data for older people. These include: illiteracy rates and cognitive disability that prevent some centenarians from reporting their ages accurately, cultural factors that can impact an individual's knowledge of his or her true age, and an age-related sense of pride that may cause the extremely elderly to overstate their ages. Studies using highly reliable subpopulation data explore the impacts of such inaccuracies.[A-138]

In the study "Liars, Cheaters and Procrastinators: How They Upset Mortality Studies," Bob Howard quantifies the impact data contamination could have on old-age mortality analyses. In particular, Howard explores the impact of seniors overstating their age, the failure to report deaths and late reporting of deaths:[A-130]

- Overstatement of age: Individuals overstate their age due to a sense of pride. In addition, those applying for an annuity contract have a financial incentive to be thought older than they really are.

  This study offers two observations on this issue. First, seniors from older cohorts who lived to extreme ages are more likely to overstate their age than those of the same cohort who didn't live to extreme ages. Second, the impact on mortality rate increases with the length of the overstatement. For example, an overstatement of 6 percent of deaths by five years each has much less impact than 3 percent overstatement by 10 years, even though the number of life-years overstated is the same. Overstatement of age can cause mortality deceleration at very high ages.
- Unreported deaths: The study notes that if practitioners construct a mortality table where the initial number of lives is known and rely heavily on death being accurately and promptly reported (e.g., pension administration), a deceleration in the mortality curve can be caused by only a few unreported deaths.
- Late reporting of death: Howard notes there are very few instances where deaths are reported late with the intent to defraud. Most cases are from people not aware they need to report a death or how to do it. For ages under 85, late death reporting is relatively immaterial, as long as it is not ignored. At higher ages, it becomes increasingly important to make an appropriate adjustment for late reporting. Depending on the method used for handling late-reported death claims, the author notes late-reported deaths can cause a deceleration in the mortality curve at extreme old ages.

3. Lack of consistency in developing life tables

The different methodologies adopted for graduating mortality rates at the oldest ages limit the ability of practitioners to consolidate data sources and make comparisons between life tables at advanced ages.[A-36]

4. Nonstandard nomenclature

In the United States, there are different agencies that collect demographic data, such as the National Center for Health Statistics, the Census Bureau and the Social Security Administration. Since each entity has its own set of definitions and reporting approaches, this provides a challenge in reconciling the retrieved data.[B-5]

Adrian Gallop also notes how it is possible for classifications of deaths and interpretation of death certificates to be changed over time. This can make it difficult to determine mortality rates by cause of death, as it may introduce abrupt jumps due to the inconsistent taxonomy in recording deaths.[B-8]

Communication in the field of biogerontology is difficult, as commonly used terms have no universally accepted definitions. Not only does the problem result in communication failures, it also produces erroneous interpretation of research results, illogical allocation of research funds and misdirected scientific, economic, social and political policy decisions.[A-76]

#### 4.1.2.3 Validation techniques

Actuaries can use a number of data validation techniques to correct errors related to issues in recording deaths. Using validation techniques such as the ones described below, practitioners can identify consistent bias in death reports and account for them in their studies.

For instance, Bertram Kestenbaum and B. Reneé Ferguson use three techniques to deal with inconsistencies in the Medicare enrollment files:[A-3]

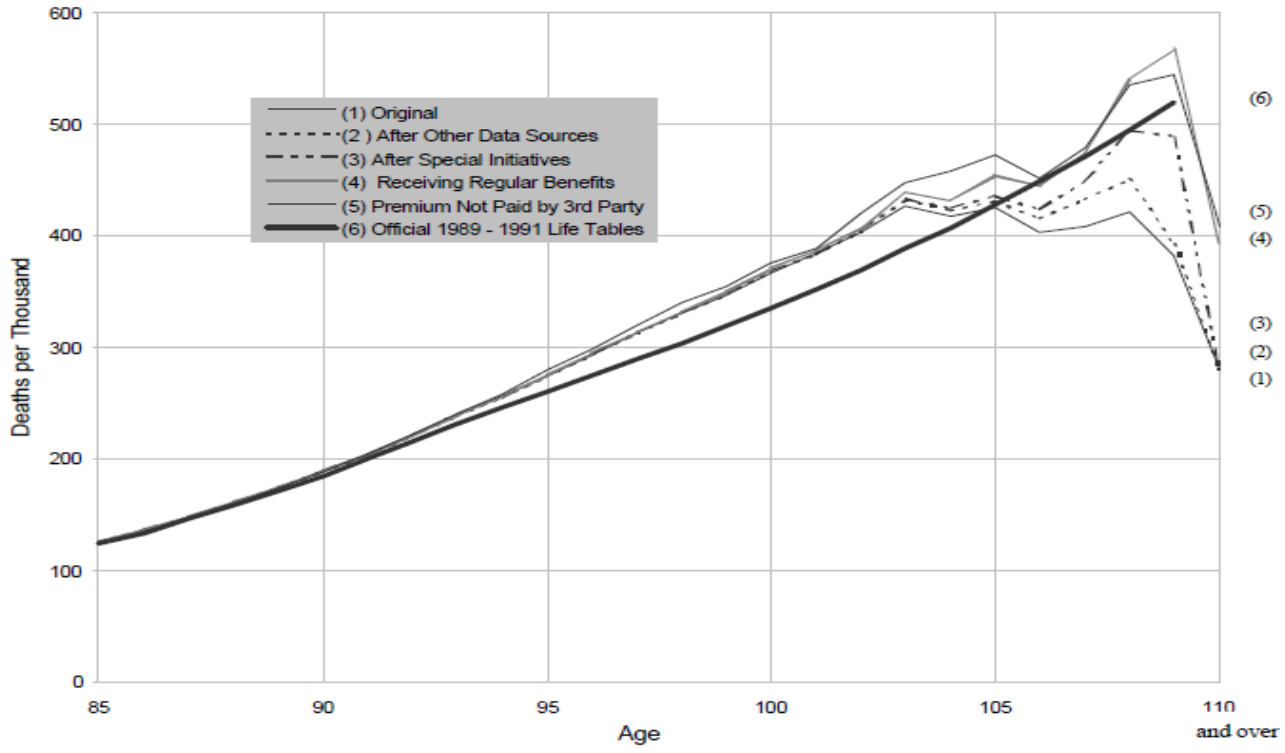
- Eliminate duplicate records: Pairs of records were identified as those with common identification numbers, or the same uncommon name, date of birth and state of last residence.
- Evaluate and react to data anomalies: Various files were compared to the SSA's Master Beneficiary Record to correct missing or invalid birth/death dates and to identify further duplicate records for alleged supercentenarians. Verification of birth dates was accomplished by checking recorded data against early U.S. census records collected when the alleged supercentenarians were children or young adults.
- Person-level records of utilization of Medicare services were linked to the Master Beneficiary Record to infer death at extreme ages from protracted non-utilization.

These are the three most common validation techniques, but there are other, less known methods as well. They include:

- Draft registration cards: To validate records in the SSA DMF of men exhibiting exceptional longevity, one study compared a random representative sample of 240 men born in 1887 who survived to age 100 to U.S. World War I draft registration cards collected in 1917, when these men were 30 years old. Natalia Gavrilova and Leonid Gavrilov were thus able to validate 171 cases of exceptional longevity and to obtain information on vital characteristics of male centenarians when they were young adults. Randomly selected, shorter-lived men with the same birth year, race and/or country of draft as the centenarians served as controls.[A-61]
- Historical data from parish registers: In Quebec, the available data on deaths of centenarians according to ethnic origin allows for the differentiation of mortality based on this characteristic. Data on French-Canadians, for example, can be found using parish registers.[A-55], [A-138]

Validation techniques like those from above have played an important role in the correction of missing or invalid data for the elderly. One set of data corrected by such methods was the 1989–91 life tables in which death dates for the elderly were originally exaggerated. Figure 01 below shows a comparison between raw mortality rates for elderly male deaths, which have been refined using techniques similar to those described above, and the 1989–91 life tables. Note that the effects of the validation techniques were most prominent between the ages of 105 and 110.[A-3]

Figure 01: Male deaths per 1,000 at the oldest ages[A-3]




#### 4.1.2.4 Related symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-3 | Mortality of the Extreme Aged in the United States in the 1990s, Based on Improved Medicare Data http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-ferguson.pdf |
| A-4 | Reported Deaths of Centenarians and Near-Centenarians in the Social Security Administration's Death Master File http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-faig.pdf |
| A-30 | IDL, the International Database on Longevity http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxiii.pdf |
| A-36 | Mortality at Advanced Ages in the United Kingdom http://www.soa.org/library.monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxi.pdf |

| | |
|---|---|
| A-39 | Search for Predictors of Exceptional Human Longevity: Using Computerized Genealogies and Internet Resources for Human Longevity Studies<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-v.pdf |
| A-55 | Data Validation and Measurement of Cohort Mortality among Centenarians in Quebec (Canada) According to Ethnic Origin<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-bourbeau.pdf |
| A-61 | Physical and Socioeconomic Characteristics at Young Age as Predictors of Survival to 100: A Study of a New Historical Data Resource (U.S. WWI Draft Cards)<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-gavrilov.pdf |
| A-76 | The Biology of Human Longevity, Aging and Age-Associated Diseases<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-03-hayflick.pdf |
| A-87 | The Role of Social and Health-Related Characteristics in Determining Survivorship Among the U.S. Oldest Old<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-alishire.pdf |
| A-93 | Age-Related Changes in Factors Associated with Loss of Good Health<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-brown.pdf |
| A-103 | Patterns of Aging-Related Changes on the Way to 100: An Approach to Studying Aging, Mortality and Longevity From Longitudinal Data<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g5-yashin.pdf |
| A-129 | Predictors of Exceptional Longevity: Effects of Early-Life Childhood Conditions, Midlife Environment and Parental Characteristics<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-gavrilov.pdf |
| A-130 | Liars, Cheaters and Procrastinators: How They Upset Mortality Studies<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-howard.pdf |
| A-138 | Measurement of Mortality Among Centenarians in Canada<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-oullette.pdf |
| A-139 | Mortality Trajectories at Extreme Old Ages: A Comparative Study of Different Data Sources on U.S. Old-Age Mortality<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-gavrilova.pdf |
| A-148 | Subjective Survival Probabilities and Life Tables: Evidence from Europe<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-peracchi.pdf |
| B-5 | Data Sources and Projection Methods for Successfully Supporting the Needs of the Senior Market (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3c-discussion.pdf |
| B-8 | Mortality Projections from a Social Security Perspective (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |

### 4.1.3 A priori expectations

This section summarizes the content from symposia papers that deal with fitting a curve to historical experience, the challenges associated with that task and the techniques for validating the result.

Since life expectancy had been relatively stagnant until the mid-19th century, and the quality of available data is poor, researchers and actuaries alike have focused their studies using data from the 20th century onward.[B-1]

In the past, actuaries have focused on developing "mortality laws" that explain data, a process that involves fitting a curve, using some intuition, to a data set. It is apparent from the symposia material that actuaries tend to fit data for the elderly with theoretical and empirical evidence studies.

The symposia papers presented several parametric models that fit a mortality curve/law to old-age data. The models were useful in several ways:

- They reveal any underlying mathematical structure.
- They show underlying trends by smoothing/removing noise from data.
- They extrapolate to older ages where the data is sparse.
- They project mortality by using underlying parameters.

A number of symposia papers focused on fitting parametric curves to population data from different countries. In the process, authors segmented data in various ways to understand correlations and establish appropriate subgroupings. Most based their subgroupings on gender and smoking status.

There was less uniformity among authors when it came to data for the elderly. For old-age data, the authors developed a variety of tables and extrapolation methodologies without any consensus on a single, standard approach. In general, there are three schools of thought about what ultimate value mortality rates by age take on, according to Roger Thatcher:[B-16]

- Value of one as age tends to infinity, which corresponds to no deceleration in the force of mortality
- Value slightly less than one as age tends to infinity, which corresponds to a deceleration in the force of mortality
- Value of one at a finite age, the traditional assumption used for closing the life table at a limiting age, omega

Furthermore, there's an ongoing debate on the existence and implications of mortality deceleration, compression and shift. There also exists a need for validation techniques, which are presently limited.

The lack of consensus has led to discussions over the following key questions:

- Are there limits to mortality rates?
- Is there a limit to life expectancy?
- Does mortality deceleration exist or is it a repercussion of poor quality of data at extreme ages?
- Where has mortality compression and shift been observed, and how can their effects be accounted for in fitting curves?

Disagreement over these questions has significant economic implications for longevity risk takers—individuals, corporations, and governments. Balancing the vested interests of all stakeholders may require a coordinated effort between policymakers, regulators and North American actuarial organizations.

#### 4.1.3.1 Selecting the methodology to fit a curve to current and past experience

1. Exponential class (e.g., Gompertz's law)

For some time, experts graduated base tables if they were able to fit mortality to the Gompertz-Makeham function.[A-36] In these models, the force of mortality increases at an exponential rate with age. Recent research has shown evidence that after mortality data has been thoroughly cleansed, mortality rates tend to resemble Gompertz curves.[B-12]

2. Logistic function

Some research has indicated that mortality deviates from the Gompertz law at old ages, showing a decrease, not an exponential increase, in mortality for the elderly. Actuaries, including Benjamin Gompertz himself, noted this phenomenon. To account for the fall-off of mortality rates at advanced ages, a logistic formula was proposed. Later, in 1939, Major Greenwood and J.O. Irwin created a detailed description of human mortality for the elderly and deduced that old-age mortality follows the law of radioactive decay with half-time approximately equal to one year.[A-39]

In Zhiwei Zhu and Zhi Li's "Logistic Regression for Insured Mortality Experience Studies," the authors listed the strengths and potential uses of logistic regression models for insured mortality experience studies, including:[A-128]

- Testing for statistical strength of mortality drivers in explaining mortality variations with effect analysis
- Generating normalized mortality metrics such as slopes and differentials with odds ratio analysis
- Extrapolating for advanced age or ultimate mortality with modeled estimation
- Bridging or smoothing between select and ultimate mortality with model link function
- Quantifying study reliability with model fit statistics
- Helping construct multidimensional experience tables by using the model as a predictive model
- Being implementable with widely available software systems

Zhu and Li studied the use of the logistic q model to analyze the U.S. insured mortality experience. They analyzed life insurance experience data from policies with relatively high face amounts since 1950. The authors found that properly designed logistic modeling processes can utilize available data to deliver solutions such as:[A-128]

- Testing the statistical significance of mortality drivers in explaining mortality variations
- Estimating normalized mortality slopes and mortality differentials, such as mortality increases by duration or variances between underwriting classes (while product and attained-age distributions are controlled)
- Addressing analytical challenges such as extrapolating for ultimate mortality, smoothing between select and ultimate estimations, and constructing multidimensional basic experience tables

Tom Edwalds noted that the above model does not produce ultimate rates and, consequently, will work better for select mortality rates (as used in life insurance).[B-12]

3. Dynamic reliability in estimating mortality at advanced ages

In this approach, aging is defined as the symptom of cumulative damage to the human system. The author of the article that describes this approach, Fanny Lin, applies a general law for hazard rates to analyze the mortality structure of Taiwan from 1926 to 1991. This is a completely different approach to the traditional

parametric models as the model does not use age-dependent relations for hazard rates. This method is not widely used.[A-13]

Actuaries have developed methods whose sole purpose is to extrapolate estimates of old-age mortality. Because these methods are focused entirely on the elderly, practitioners using them do not need to account for factors like infant sicknesses, which only apply to younger people.

Table 01 provides a summary of parametric models referenced in the symposia conference presentations. They range from older models (e.g., Gompertz from 1825) to more contemporary ones (e.g., Heligman and Pollard from 1980). This table is not intended to be a complete list of all mortality curves that may be used by practitioners but is presented as a summary of approaches discussed at Living to 100 symposia.

Table 01: Summary of parametric models referenced in symposia conference presentations

| Exponential Class | Publish Date | Model Formula | Parameters | Interpretation | Limitations | Older Age Implications | Fitting Procedure | Mortality Tables and Other Notes |
|---|---|---|---|---|---|---|---|---|
| Gompertz | 1825 | $\mu_x = \alpha e^{-\beta x}$ | $\mu_x$= force of mortality<br>α = baseline mortality, shape<br>β = aging component | Exponential increase of death rates with age. The growth is very slow at the beginning. | Questionable fit at older ages due to 'late-life mortality deceleration'. Good fit between age 30 to 90 | Continued acceleration at all ages, unbounded and tends to 1. There is an asymptote for the Gompertz function, however, in the mortality modeling case, the rate will not reach its asymptote. | Least squared errors | 1. 1941 Standard Ordinary Mortality Table 2. 1958 Standard Ordinary Mortality Table 3. K-tables for life insurance valuation. Cannot capture convexity, e.g. not used in 1958 CSO Mortality table. It holds for United States population data. |
| Makeham | 1860 | $\mu_x = \alpha e^{-\beta x} + \gamma$ | $\mu_x$= force of mortality<br>α = baseline mortality, shape<br>β = aging component<br>γ = non-aging component (e.g. accidents) | Gompertz model with an age-independent parameter for accidential death | Questionable fit at older ages due to 'late-life mortality deceleration' | Continued acceleration at all ages, unbounded and tends to 1 | Least squared errors | Used by CIA9704 mortality table for older age. 1941 CSO table. Almost any 30 year range of ages in arbitrary mortality table can be successfully regraduated using a Makeham formula |
| Heligman and Pollard (HP) | 1980 | $\frac{q_x}{1-q_x} = A^{(x+B)^C} + De^{-E(\log\frac{x}{F})^2} + GH^x$ | qx = mortality rate<br>There are three components:<br>A, B, C = mortality from birth to first year of life (A and B), then decrease in mortality rates through childhood (C)<br>D, E, F = Mortality from ages 10-40 (captures the "accident hump")<br>G, H = mortality levels and changes in the older population | The third term (older ages) can be interpreted as a version of Gompertz law of mortality. There are additional parameters to better fit childhood and younger ages (10-40) where accident years affect the mortality. For age above 50, the first two terms can be neglected. | May be difficult to fit with the large number of parameters. Parameters are highly correlated which may impede one's ability to isolate them. | Follows Gompertz's law of mortality, depending on one's view of old-age mortality this may not be appropriate | CDC: Least squared errors (non-linear weighted). Iterative procedure requires starting points which were taken from existing papers/fits. Fitting was done piece-wise on first, second and third components, smoothing methods applied to ensure smooth transition between pieces. | Used by CDC for smoothing and extrapolation for ages 66-109.<br>Supported with empirical evidence. |

| Logistic Class of Parametric Models | Publish Date | Model Formula | Parameters | Interpretation | Limitations | Older Age Implications | Fitting Procedure | Mortality Tables and Other Notes |
|---|---|---|---|---|---|---|---|---|
| Perks | 1932 | $\mu_x = \frac{\alpha e^{-\beta x} + \gamma}{\theta e^{-\beta x} + 1}$ | μx= force of mortality<br>α, θ = baseline mortality<br>β = aging component<br>γ = level component | Plus one additional parameter from Makeham, and logistic. Beard (1971) showed that logistic function can arise from hetergenous populations where each member has a Makeham distributiion. It has better adjustment to older ages in industrialized countries. Force of mortality tends to a constant as x increases | Actuaries do not use this for pricing annuities. Limitation hard to estimate parameters and variance covariance matrix. (ref. Inference for Logistic-type Models for the Force of Mortality, Louis G. Doray, PhD, ASA, January 7-9, 2008). Difficult to estimate parameters by MLE | Force of mortality reaches an asymptote as age increases to α/θ. Plateaus at a certain level, 1-e^-B/C | Least squared errors. It can be difficult to perform maximum liklihood estimation. | |
| Beard | 1971 | $\mu_x = \frac{\alpha e^{-\beta x}}{\theta e^{-\beta x} + 1}$ | $\mu_x$= force of mortality<br>α, θ = baseline mortality<br>β = aging component | Same as perks but sets gamma term to zero. Force of mortality tends to a constant as x increases. | Difficult to estimate parameters by MLE | Force of mortality reaches an asymptote as age increases to α/θ. Plateaus at a certain level | Least squared errors | |
| Kannisto | 1997 | $\mu_x = \frac{\alpha e^{-\beta x}}{\alpha e^{-\beta x} + 1}$ or $\frac{\mu_x}{1-\mu_x} = \alpha e^{-\beta x}$ | $\mu_x$= force of mortality<br>α = baseline mortality<br>β = aging component | - Similar to Beard, but down to two parameters<br>- Also similar to Gompertz, but fitted to a logistic function. Force of mortality tends to a constant as x increases | Difficult to estimate parameters by MLE | Plateaus at a certain level: 1-e^-1, or about 0.632. | Least squared errors. It can be difficult to perform maximum liklihood estimation. | Fits and approximates old-age mortality better than Gompertz, Weibull, and Heligman and Pollard |

Table 01: Summary of parametric models referenced in symposia conference presentations (*continued*)

| Weibull Models | Publish Date | Model Formula | Parameters | Interpretation | Limitations | Older Age Implications | Fitting Procedure | Mortality Tables and Other Notes |
|---|---|---|---|---|---|---|---|---|
| Weibull | 1951 | $\mu(t) = -\frac{1}{S(t)}\frac{dS(t)}{dt} = \frac{m}{t_0}\left(\frac{t-\gamma}{t_0}\right)^{m-1}$ , | μt= force of mortality<br>γ = position parameter<br>t0 = scale parameter<br>m = shape parameter | m <1: the mortality rate should be decreasing over time.m=1: constant death rate over time.m>1: death rate increases with time. This is one of the limiting forms of the distribution of the lowest observed value in a large sample. | This model considerably overestimates the ascent of mortality with advancing age, the discrepancy with observed data widening progressively. This tendency appears earlier and is stronger among the females. | | Least squared errors | Japanese Mortality Table JLT15 (1980), JLT17 (1990) and JLT19 (2000) |
| Mixed Weibull | | $S(t) = \sum_{i=1}^{k} p_i \exp\left[-\left(\frac{Max(t-\gamma_i,0)}{t_{0i}}\right)^{m_i}\right]$ where $\sum_{i=1}^{k} p_i = 1 \quad (p_i > 0) \quad mix\,ratio$ | μt= force of mortality<br>γ = position parameter<br>t0 = scale parameter<br>p = mixed ratio, m = shape parameter | A Mixed Weibull Model consists of two or more Weibull components combined in some fixed proportion. | Parameters are hard to estimate. | | Least squared errors | Japanese Mortality Table JLT15 (1980), JLT17 (1990) and JLT19 (2000) |
| **The Quadratic Model** | **Publish Date** | **Model Formula** | **Parameters** | **Interpretation** | **Limitations** | **Older Age Implications** | **Fitting Procedure** | **Mortality Tables and Other Notes** |
| The Quadratic model | | $\ln(\mu_x) = a + bx + cx^2$ | a, b, c = model coefficients | The log of force of mortality can be fitted by a quadratic function. | | Limited range of ages was used by Coale & Kisker (1990) for the purpose of interpolating the force of mortality in the range of ages from 85 to110, between data up to age 85 and an assumed value at age 110. | Least squared errors | |
| **Older Age Specific Methods** | **Publish Date** | **Model Formula** | **Parameters** | **Interpretation** | **Limitations** | **Older Age Implications** | **Fitting Procedure** | **Mortality Tables and Other Notes** |
| Coale Kisker (CK) | 1990 | $k(x) = k(x-1) - R, \quad x \geq last\ credible\ age$ where $k(x) = \ln\left(\frac{m_x}{m_{x-1}}\right)$ $R\ is\ a\ constant$ | $m_x$ = central rate of death<br>R = constant solved by assuming a maximum age | - Assumes that mortality rates increase at a varying rate (in contrast to Gompertz which increases at a constant rate) | '- Assumes a maximum age where the central rate of death (mx) is 1.0 | Assumes a maximum age where the central rate of death (mx) is 1.0<br>Possible for a crossover of male and female mortality. Some practioners may choose to cap the female mortality rates at the male rates. Coale and Kisker (1990) assumed that the terminal central rate of death for females was 0.8 rather than 1.0 to avoid a crossover. | Straightforward once a maximum age (and associated central death rate) is set, the constant R can be solved for directly and the mortality rates can be determined through an iterative procedure. | |
| Himes Preston Condran (HPC) | 1994 | Fitting of "standard": $logit(m_x^s) = \alpha + \beta x$ Relational fitting to the standard: $logit(m_x) = \delta + \gamma logit(m_x^s)$ | $m_x^s$ = central rate of death for the standard<br>$m_x$ = central rate of death for the table intended for extrapolation<br>α, β, δ, γ = regression coefficients | Essentially extrapolation of a straight line fit to the logit mortality rates. A "standard" set of mortality rates is set by calibrating to a large number of mortality rates across different countries. Logit function fitted through age 80-99. Extrapolated for ages 100 and beyond. Other life tables can then be related to the "standard" schedule through a logit regression.This model represents the typical mortality pattern at advanced ages based on the patterns observed in a variety of countries and periods | | | | Adopted by UN for table closing across nations |

In the next few pages, each model from Table 01 is graphed with U.S. population data from the U.S. Social Security Administration to give readers a visual representation of the various methodologies. In the figures below, there are two plots: one yellow and one gray. Through age 95, approximately the last age at which the SSA date is credible, both the yellow and the gray follow the model of interest. After age 95, the yellow plot continues along the model of interest, projecting post-95 mortality with the pre-95 data. The gray plot follows a different course. From ages 95 to 100, it uses a graduation formula, and past age 100, mortality rates are extended at a rate of 5 percent per year for males and 6 percent per year for females (the percentages are derived from an analysis of Social Security charter Old-Age Insurance beneficiaries.

The first three charts—figures 02, 03 and 04—show the plots for exponential parametric models. As is apparent in the graphs, the exponential parametric models output steeper mortality increases than the SSA assumptions for those older than 95.

Figure 02: Parametric models: Gompertz (fitted through age 95)

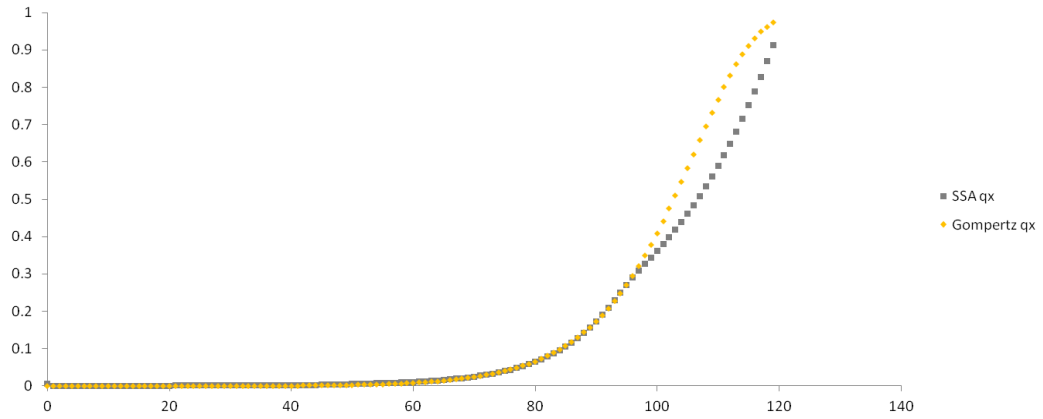



Figure 03: Parametric models: Makeham (fitted through age 95)

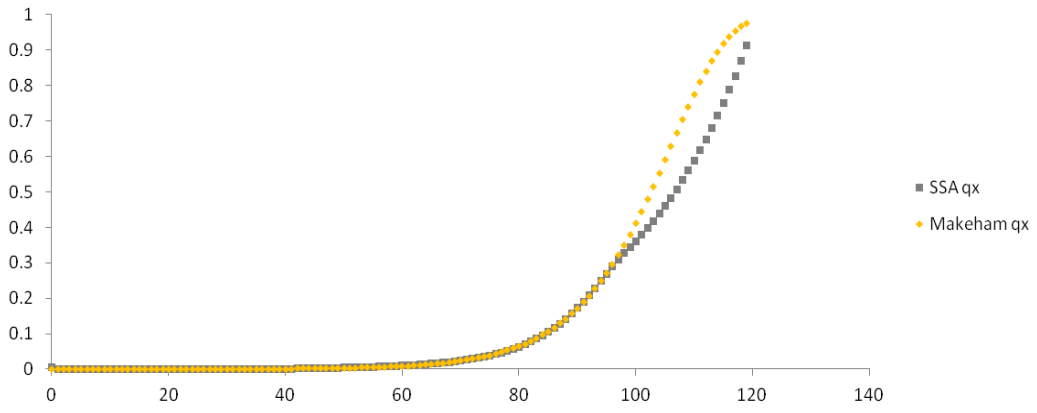
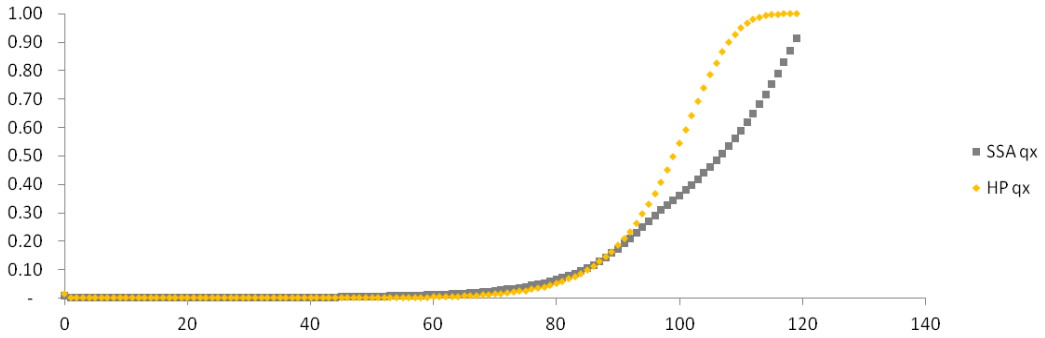


Figure 04: Parametric models: Heligman and Pollard
(piece-wise fitted through age 95)




The next series of charts—figures 05, 06, 07, 08 and 09—show the plots for logistic parametric models. Logistic parametric models follow the "mortality deceleration" trend at advanced ages, so unlike the exponential models, the logistic models level off after the age of 95. As a result, SSA assumptions record a steeper rate of mortality than logistic models after the age of 95.

Figure 05: Logistic class of parametric models: Perks (fitted through age 95)

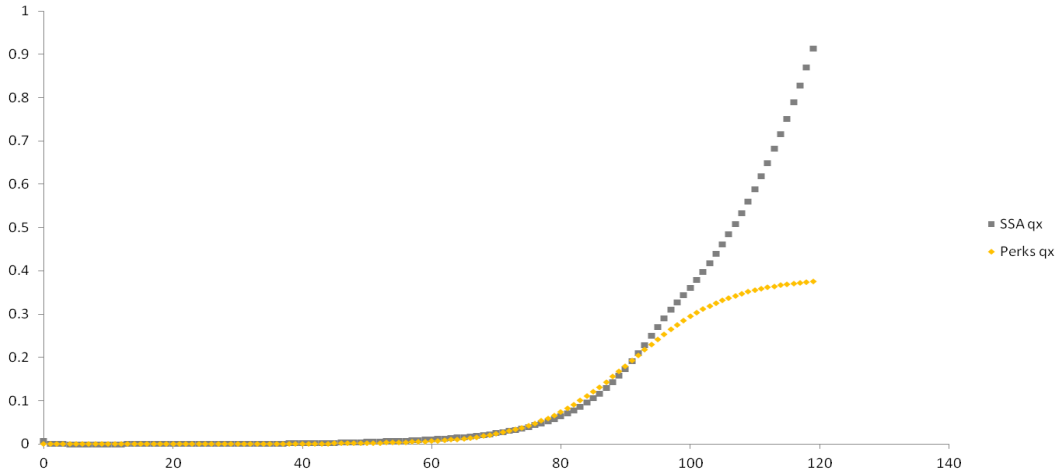


Figure 06: Logistic class of parametric models: Beard (fitted through age 95)

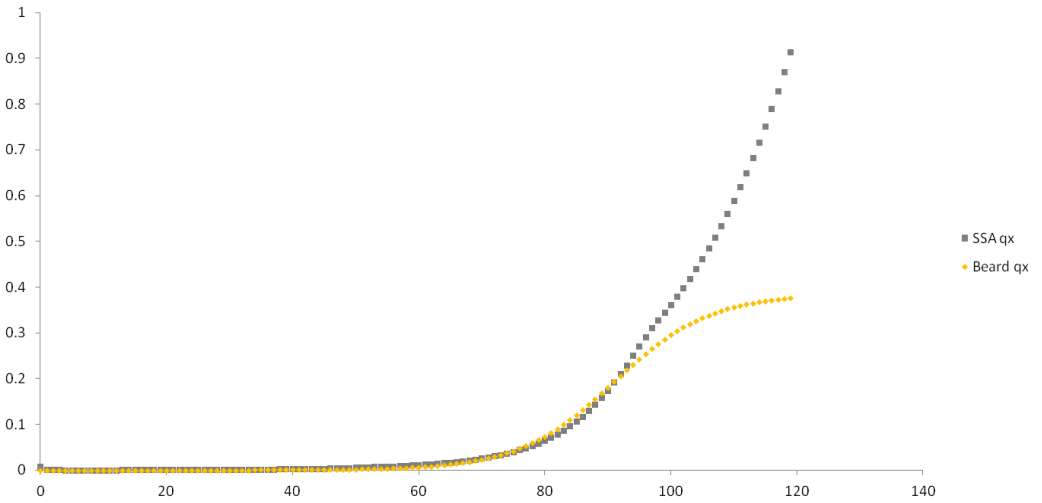



Figure 07: Logistic class of parametric models: Kannisto (fitted through age 95)

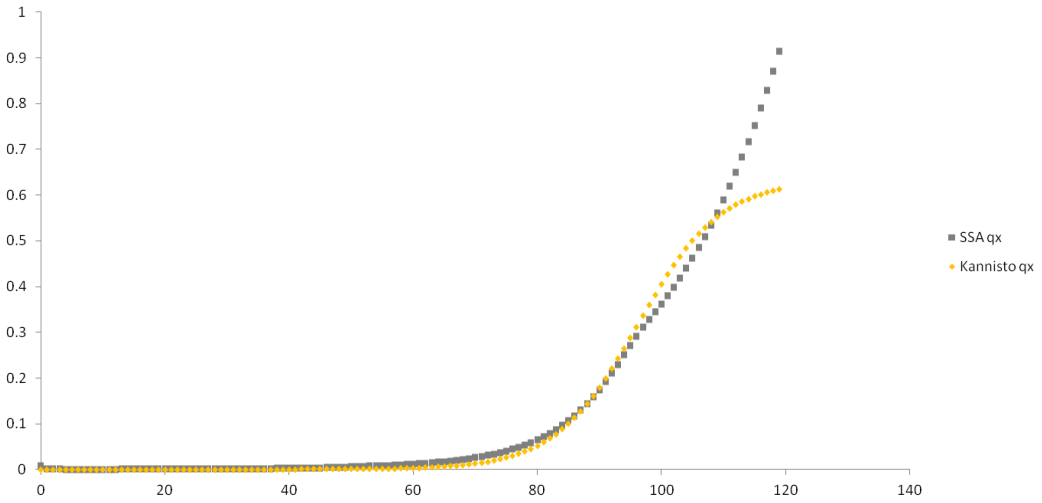


Figure 08: Weibull models: Weibull (fitted through age 95)

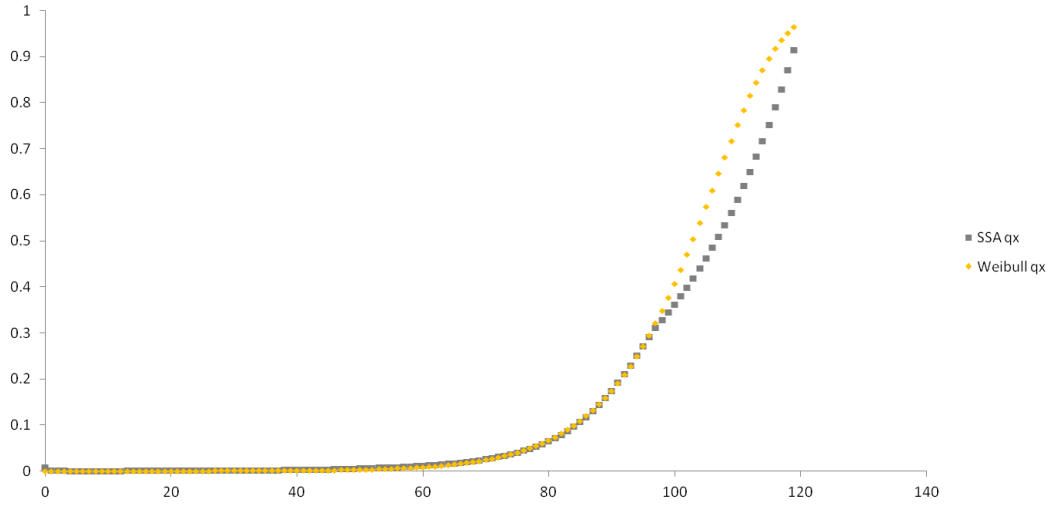
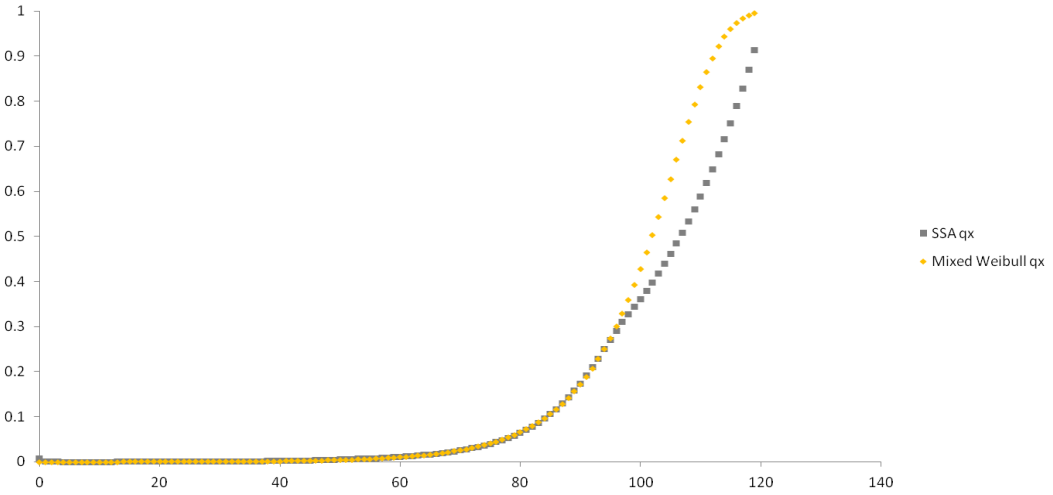



Figure 09: Weibull models: Mixed Weibull (fitted through age 95)




For future symposia, discussant Johnny Li suggested exploring extreme value theory for fitting old age data. Since extreme value theory states how the excess over a threshold must follow a generalized Pareto distribution as the threshold tends to infinity, it could have interesting applications for modeling extreme age mortality.[B-16]

### 4.1.3.2 Challenges inherent in fitting the curve

1. The debate around mortality deceleration, compression and shift

The increasing number and proportion of centenarians in developed countries has prompted researchers to conduct studies on the trajectory of mortality at the highest ages and the biological limits of human life. These studies have produced two opposing camps: The first camp maintains that industrialized countries will reach a life expectancy of 100 years by 2060; the second camp maintains that the U.S. life expectancy will not exceed 85 years by 2060.[A-40]

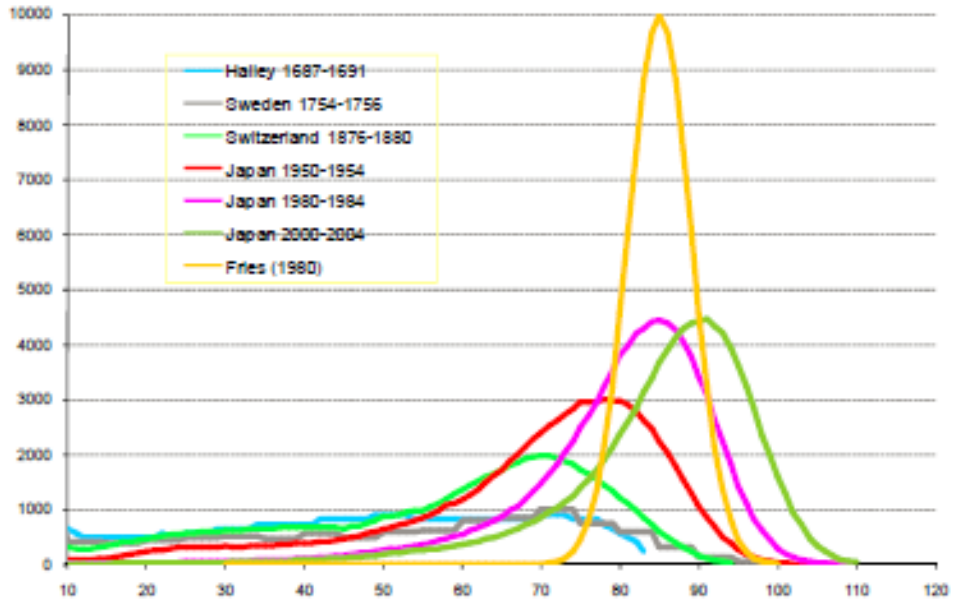
Even though both groups arrive at very different conclusions, they both assume the same cultural, technical and biological conditions (those of today) in their studies. Their large difference in opinion has serious social and economic consequences, especially for managing health services and Social Security.[A-40]

There are several forces that may cause change in human life expectancy. These forces are broadly characterized as mortality compression and shift.

*The evidence for compression and shift*

With the fall of mortality, the frequency distribution of ages at death shifts to the right, but it does not retain the same shape over time. The distribution of ages at death has become more compressed around the mode. Figure 10 shows that by comparing Swiss data from 1876 to 1880 to Japanese data from 1980 to 1984, one can see strong evidence of mortality compression in the age distribution of deaths as the modal length of life moved from 70 to 85 over the course of a century.[A-57]

Figure 10: Evidence of mortality compression[A-57]




The compression of mortality, which has occurred in almost all low-mortality countries since World War II, seems to have ceased in Japan around the late 20th century. Japan, which leads international trends in human longevity, is moving to a new trend pattern called "the shifting mortality scenario," where the modal length of life keeps increasing but the shape of death distribution curve remains unchanged. France, Switzerland and Italy seem to follow the Japanese pattern with a lag and present an intermediate situation between mortality compression and mortality shift, where a steady increase in the modal length of life is accompanied by a modest decrease in the standard deviation of the ages at death above the mode.[A-57]

Eric Stallard observed mortality compression in the SSA historical data, noting that it had run its course by the latter half of the 20th century. Future mortality improvement in the U.S. also follows the aforementioned trends of right-shifting survival.[A-145]

*The evidence against compression*

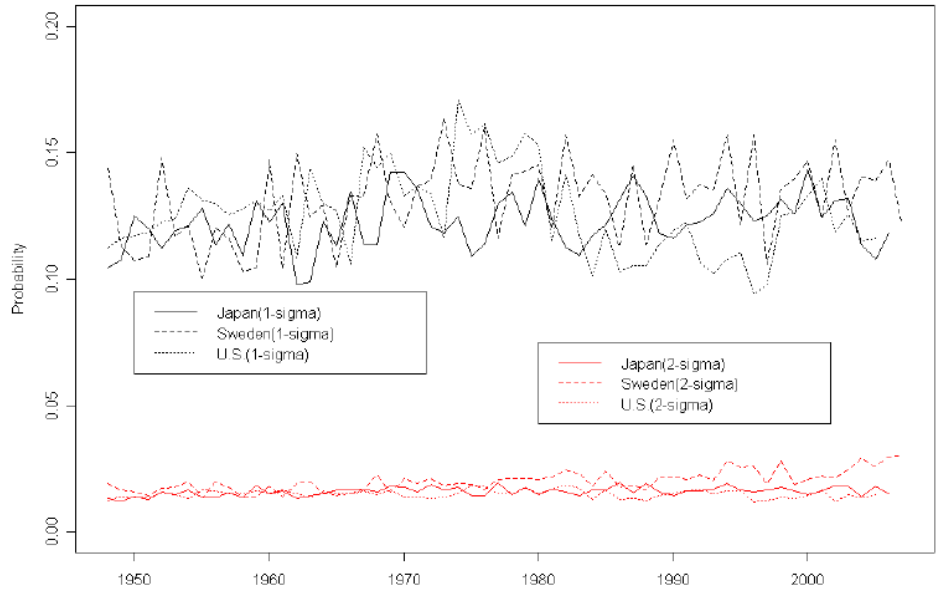
Social Security DMF data allowed the reconstruction of cohort life tables describing survival patterns after age 80 for birth cohorts that are almost extinct now (born in 1891 and earlier). Detailed information about birth

and death dates of decedents allowed the estimation of hazard rates of the oldest-old individuals with resolution of single month of their age. Study of three birth cohorts (1885, 1889 and 1891) showed that mortality grows steadily with age from 85–89 to 102–105 with almost no obvious signs of expected mortality compression. After age 105, the mortality estimates become less reliable because of significant statistical noise.[A-39]

In addition, data for extremely long-lived individuals are scarce and subjected to age exaggeration. Therefore, to obtain good-quality estimates of mortality at advanced ages, researchers are forced to pool data for several calendar periods. Therefore, one explanation for observed cases of mortality compression in other studies might be a result of data heterogeneity, as noted in section 4.1.2.2.[A-39]

Instead of fitting stochastic models for mortality rates, increasing life expectancy might be explored by examining the basic properties of survival curves. Unlike the previous results using the graduated mortality rates, the authors found no obvious signs that mortality improvements are slowing down when using this second approach.[A-82] Figure 11 shows the results of one such analysis.

Figure 11: Evidence against mortality compression:
The probability of survival beyond a high age (male)[A-82]




Furthermore, Jack C. Yue has studied alternatives to non-parametric methods for evaluating mortality compression based off data from 1950 to 2009 for 37 countries found within the Human Mortality Database. Yue concludes there is not enough evidence to conclude there is mortality compression.[A-143]

2. Mortality deceleration

Mortality deceleration is a widely debated phenomenon, characterized as the deceleration of mortality rates at extreme ages.[A-107]

There exists the common view on the exponential growth of mortality with age (Gompertz law) being followed by a period of deceleration with slower increases in mortality rates.

Using parish registers data from Quebec, Nadine Ouellette and Robert Bourbeau showed mortality deceleration to be occurring above age 110 for verified Catholic French-Canadian female centenarians.[A-138]

In contrast, Natalia Gavrilova and Leonid Gavrilov, using independent data sets and alternative statistical approaches, found mortality after age 80 to follow the Gompertz model not only for the U.S. but also for countries with smaller populations. Ouellette, Bourbeau, Gavrilova and Gavrilov agreed their discrepancy could have been attributed to Ouellette and Bourbeau working off a data set of ages above 110, while Gavrilova and Gavrilov used mortality data starting at age 80.[A-139], [B-16]

In the study "Liars, Cheaters and Procrastinators: How They Upset Mortality Studies," Bob Howard shows how mortality deceleration at extreme ages can be caused by overstatement of age, unreported deaths and late reporting of deaths. In particular, Howard goes on to show how more recent cohorts have shown less pronounced mortality deceleration at extreme ages than older cohorts. This can be explained as more recent cohorts will be required to present valid documents to prove their date of birth, making it more difficult to overstate one's age.[A-130]

Furthermore, Gavrilova and Gavrilov identified the following reasons previous studies might have concluded mortality deceleration at advanced ages:[A-139]

- Studies conducted prior to 1998 used data for older birth cohorts when age reporting was not particularly accurate.
- Most developed countries have much smaller populations compared to the U.S., and thus need to aggregate their data by combining many single-year birth cohorts, thereby increasing the heterogeneity of the sample.
- Many studies analyze age-specific probability of death, which has a theoretical upper limit equal to one. Thus when mortality is high at advanced ages, it is expected to have a tendency to decelerate.
- Mortality rates calculated for wide age intervals can produce biased estimates of hazard rates.
- Loss of individuals to follow-up in longitudinal studies may also be a factor.

Furthermore, Gavrilova and Gavrilov have identified the DMF as containing an excess of men relative to women, contrary to expectations (see section 4.1.2.2 for details). This excess suggests elderly men have overstated their ages, which in light of Howard's study where overstatement of age can cause mortality deceleration, raises the possibility of observed mortality deceleration being simply the artifact of poor quality of data at extreme ages.[A-130], [A-139]

3. The debate over when to end the life table

The decision as to when to end the life table is an area subject to debate. Within the symposia material, there are multiple studies that support a range of possible solutions; the spectrum of solutions is presented below.

Certain studies have shown it is not possible to reach life expectancies of 100 or more unless two events happen: (1) people modify their lifestyles in such a way that all causes of death currently listed on death certificates disappear; and (2) people discover an intervention that slows the current process of aging.[A-19]

Despite the findings of such studies, life expectancies appear to be increasing, causing a debate over the limits of human life.

The debate is especially interesting for developing countries because rates of improvement accelerate as these countries develop. For example, by the middle of the 20th century, life expectancy at birth was 51.4 years in Latin America and 69.0 in North America. By the end of the century, these figures turned into 69.2 and 76.9, respectively. According to current demographic tendencies and based on assumptions about the social and economic developments that affect mortality, forecasts for the middle of the 21st century suggest figures of 77.6 and 81.9.[A-33]

One reason the debate over ending the life tables exists is because unreliable data for the elderly makes it difficult to determine the level and age trajectory of mortality at advanced ages. Without uncontroversial evidence, the debate can thrive. The symposia material presents three approaches to address this problem:

- Validate a sufficient number of unbiased high-age deaths and use them to produce a level and age trajectory with the extinct or almost extinct generation method.[A-12]
- Establish a survival pattern for the elderly with convincing evidence. Actuaries could then use this information to mathematically generate mortality rates for people older than 100.[A-12]
- Identify the age at which probability of survival is so low that the life table can end there. (It is important to consider manufactured time—the result of economic, social and medical developments that prolong life—when using this method.)[A-33]

4. Technology constraints

The process for fitting a curve to base mortality involves pooling millions of records into one data system, with millions more flooding in every quarter. This presents a significant challenge to IT departments and their analysts. Transforming this amount of data into useful business information requires both data processing and data analysis. For an organization to be successful in both these tasks, it must have dedicated administrative support, strong IT operation and knowledgeable business guidance.[A-6]

5. Outlier cohorts

Adrian Gallop, from the U.K. Government Actuary's Department, noted there have been instances in the U.K. population mortality data where a particular cohort was identified to either have abnormally high or abnormally low mortality improvement rates relative to adjacent cohorts. Such instances might be considered anomalies in historical data, which should be noted when trying to fit a model.[B-8]

James Vaupel noted that life expectancy in U.S. females at age 50, as well as Danish and Dutch females, was identified by the U.S. National Academy of Science to be stagnating in the latter half of the 20th century. Smoking was found to be a primary cause as it was fairly consistent across the majority of females and is supported by how prolonged smoking effects on mortality are not observed until elderly ages. This stagnation in life expectancy was not observed in males as females generally started smoking later than males and, consequently, started quitting smoking later than males.[B-1]

#### 4.1.3.3 Validation techniques

The majority of the symposia materials did not focus specifically on validation techniques.

James Vaupel noted how validating the existence of outlier cohorts could be done through replacing these abnormal cohorts with "normal" cohort populations from other countries, when deemed appropriate. With respect to the Danish stagnation in female life expectancy in the late 20th century, Vaupel confirmed it was attributed to Danish women born between 1920 and 1940. When these two decades of women were replaced with Swedish women born in that same period, the stagnation in life expectancy virtually disappeared.[B-1]

#### 4.1.3.4 Related symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-6 | Estimating Mortality of Insured Advanced-Age Population with Cox Regression Model<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-zhu.pdf |

| | |
|---|---|
| A-12 | Dealing With Problems in Data Quality for the Measurement of Mortality at Advanced Ages in Canada<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-bourbeau.pdf |
| A-13 | Using Dynamic Reliability in Estimating Mortality at Advanced Ages<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-lin.pdf |
| A-19 | Longevity Determination and Aging<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-hayflick.pdf |
| A-33 | Shapes and Limits of Longevity in Mexico<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-ii.pdf |
| A-39 | Search for Predictors of Exceptional Human Longevity: Using Computerized Genealogies and Internet Resources for Human Longevity Studies<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-v.pdf |
| A-40 | The Great Debate on the Outlook for Human Longevity: Exposition and Evaluation of Two Divergent Views<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xv.pdf |
| A-57 | Is There a Limit to the Compression of Mortality?<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-03-cheung.pdf |
| A-82 | Mortality Compression and Longevity Risk<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1b-yue.pdf |
| A-128 | Logistic Regression for Insured Mortality Experience Studies<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-zhu.pdf |
| A-143 | A Study of Measuring the Mortality Compression<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-yue.pdf |
| A-145 | Compression of Morbidity and Mortality: New Perspectives<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-stallard.pdf |
| B-1 | The Advancing Frontier of Human Survival (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1-soa-informal-discussant.pdf |
| B-8 | Mortality Projections From a Social Security Perspective (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| B-12 | Discussant comments for session: From Population to Insured Lives, Finding Longevity Drivers<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-edwalds-discussant-comments.pdf |
| B-16 | Discussant comments for session: Mortality Age Patterns: Trends and Projections<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-lid-discussant-comments.pdf |

### 4.1.4 Assessing trends in underlying mortality and morbidity

This section is devoted to papers that support the overall trend of mortality and morbidity improvements around the globe. These papers focus on longevity patterns of developed and developing countries in North America, Europe and Asia.

This section is divided into four subsections. The first subsection summarizes papers that show support for increasing longevity in specified geographic regions. None of the papers presented supported a decreasing trend in longevity. The second subsection examines papers in which the authors identified challenges and gaps in current research and areas for future development, in particular diverging mortality rates experienced by different subgroups of the population. The third subsection presents techniques for validation of the base tables in light of observed trends, while the fourth subsection focuses on morbidity compression.

#### 4.1.4.1 Overview of trends in longevity

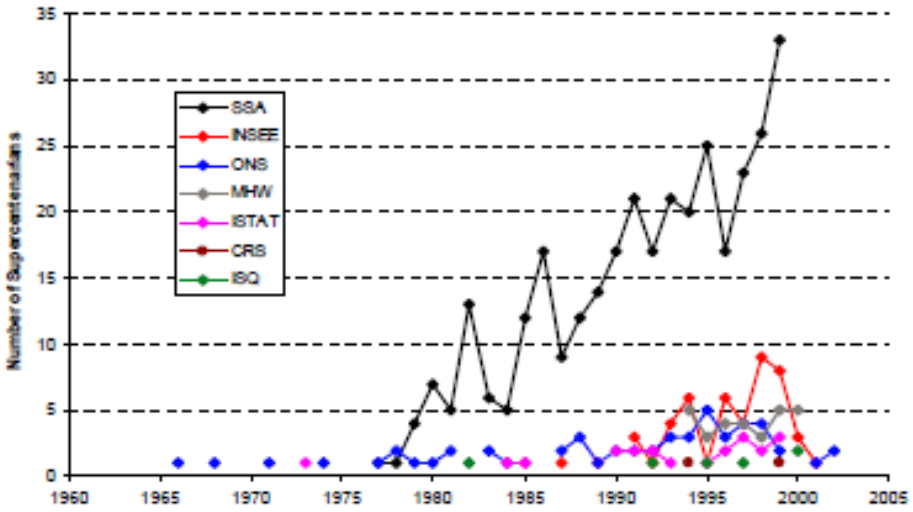
1. Global overview

Based on studies that used data from the International Database on Longevity (IDL), it has been shown that mortality rates for people between the ages of 110 and 114 have not increased over the study period (or increased very slightly). The authors of these studies believe their findings reject the exponential trajectories of Gompertz and Makeham.[A-30] However, the findings cannot distinguish between logistic and quadratic trajectories, as the latter only diverges from observations for subjects older than 115. [A-10] Regardless, the results of the IDL studies do not appear to demonstrate an obvious age limit for human longevity, meaning that no biologically controlled limits, such as clock genes or other mechanisms linked to natural selection, have yet been discovered.[A-30]

Although the exponential increase in the number of centenarians is well documented in Europe, Japan and the U.S. today[A-29], this is still not the case for older individuals of 105 years (semi-supercentenarians) and 110 years (supercentenarians) of age. However, it is still clear that the number of semi/supercentenarians has been increasing, just like that of the regular centenarians. The number of supercentenarians in low mortality IDL countries, for example, is now 10 times greater than during the mid-1970s. And as the number of regular, semi-super-, and supercentenarians has increased, so too has the maximum life span for humans, which has gone from 112 to 122 years.[A-10]

Figure 12 shows the number of individuals who have attained age 110 for countries that have submitted data to the IDL.

Figure 12: Number of individuals having reached age 110 by year[A-30]
(International Database on Longevity, March 2004, individuals deceased at age 11 and older)

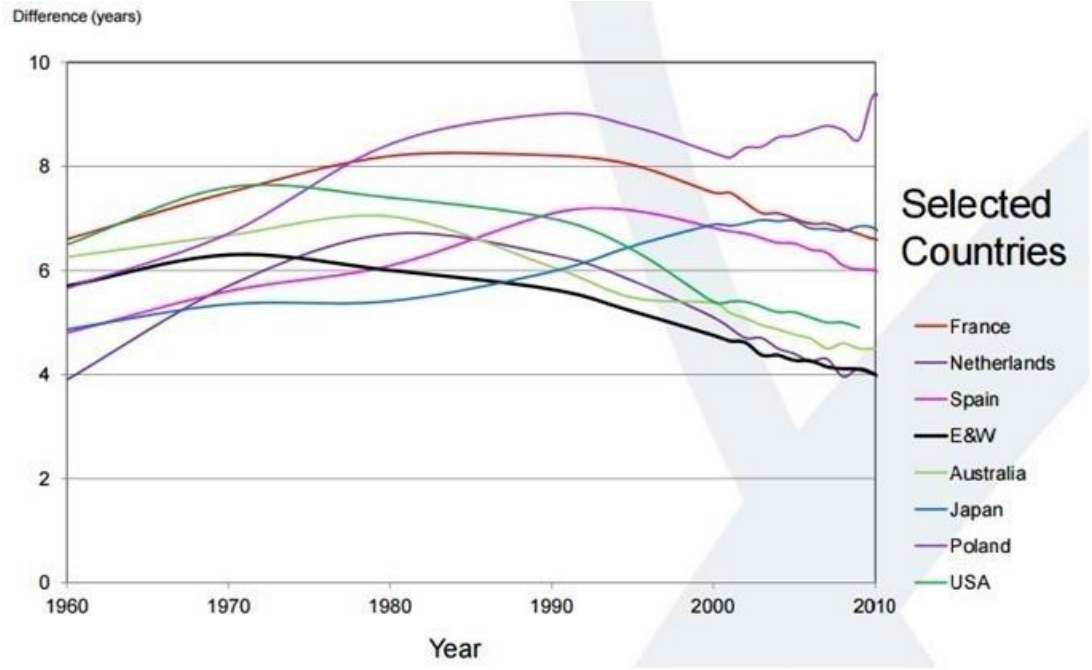



Legend

| | |
|---|---|
| SSA: | U.S. |
| INSEE: | France |
| ONS: | England & Wales |
| MHW: | Japan |
| ISTAT: | Italian |
| CRS: | Denmark |
| ISQ: | Quebec (Canada) |

Another emerging global trend is the narrowing gap between female and male life expectancies. Figure 13 below shows how the gap has changed during the last 50 years. There are countries, such as Japan, where female life expectancy has been increasing much more rapidly than male life expectancy, with the gap only starting to plateau in recent years.[B-8]

Figure 13: Gap in period life expectancy at birth (female/male) [B-8]




Sam Gutterman found that rate of mortality improvement, which in the last several decades has been greater for males, could converge to the female mortality improvement rate over the next several decades. This would

happen as the mortality effect of the earlier dramatic decreases in male smoking prevalence are followed by the effects of the smaller but still significant reduction in female smoking prevalence.[A-133]

2. United States

The state of New York examined data from 1921 onward, paying special attention to data collected after 1986. Researchers used the data to forecast future mortality rates and to calculate the effects of liabilities and the funding of the New York State Retirement System. Assuming past trends would continue into the future, the study showed that, 30 years from now, mortality rates for pensioners older than 80 would develop at approximately 67 percent of our present-day assumptions. This would translate into a four-year increase in life expectancy, from 22 to 26 years, for 62-year-old pensioners.[A-1]

Authors reviewed longevity over a similar time period (1980–98), when there were substantial improvements in the health and mortality of the elderly (age 65+), the old-old (age 75 to 85), and the oldest-old (age 85+). Interestingly, the authors found the improvements in life expectancy at age 75, which increased by 8.7 percent, differed by gender. Among males, the increase was 13.6 percent, while among females it was 6.1 percent. The improvements also differed based on cause of death and time period.[A-17]

Stephen Goss, chief actuary for the U.S. Social Security Administration, noted how the difference in mortality improvements by gender was attributed to how females started smoking later than males, and consequently, quit later. Thus, while males have surpassed the smoking-related drag on mortality improvements, females, in particular the cohort born in the early 20th century, are still experiencing its effects.[B-8]

Goss also mentioned the following factors as having been major contributors to historical mortality improvements in the U.S.:[B-8]

- 1930–50: Introduction of penicillin and antibiotics, a large increase in the standard of living and improved access to primary health care
- 1960s: Introduction of Medicare and Medicaid, creating availability of primary health care for aged, disabled and poor people who had been responsible for the majority of deaths in the population, especially at younger ages
- U.S. government health expenditure increasing from 3 percent of gross domestic product to 18 percent of GDP since 1970

However, Goss noted that mortality improvements over the last century have been shifting from occurring at younger ages to occurring at older ages. When it comes to increasing life expectancy, a minor mortality improvement at a young age is the equivalent of a major mortality improvement at an old age. Thus, Goss concluded, the implied mortality improvements required to occur at elderly ages, to maintain the historical increasing linear rate of life expectancy, is unattainable.[B-8]

On the other hand, James Vaupel argued that the current estimates of the Social Security Administration are not reasonable; they project U.S. life expectancy at birth in 2050 to be less than the 2014 values of French life expectancy (85 for females and 78 for males). While France has projected their life expectancy to be 95 years for females and 88 years for males in 2050, it is hard to believe U.S. life expectancy in 2050 will be 10 years below that of France.[B-1]

Vaupel also noted how if future trends in life expectancy were to be extrapolated from the historical increase since 1950 (of 2.5 years per decade), the projected life expectancy increase on a period basis would be three months per year. However, on a cohort-basis, it would yield an increase of four months per year. This four-month increase in life expectancy per year shows that most people born in the U.S. since 2000 would celebrate their 100th birthdays.[B-1]

3. Canada

In 2014, the Office of the Chief Actuary noted that life expectancy in Canada at age 65 has increased by two years over the previous decade, representing a growth rate of about twice of what has been observed over each of the previous decades since 1929. Life expectancy at birth in Canada has increased by approximately 33 years, with most of the change occurring before 1950. In particular, however, increases in life expectancy for the population over the last 30 years have been largely due to reduction of mortality rates after age 65, as a result of less deaths caused by heart diseases. Life expectancies at age 65 are projected to increase from 21 to 24 years for men and from 23 to 26 years for women by 2075. This means Canadians are expected to live beyond age 90 on average in the future. Moreover, if the same mortality improvement rates as the ones experienced during the last 15 years by cause of death were to be sustained over the projection period, males would be expected to outlive females from 2026 onward. Increases in life expectancy have been largely due to the decrease of deaths caused by heart diseases. It is expected that Canada will continue to have one of the highest life expectancies of the world along with Japan, France, Switzerland, Italy and Australia.[A-154]

Jean-Claude Ménard, from the Office of the Chief Actuary, noted that a life expectancy of 100 years is achievable if the maximum life span increases to 140 years for males and 132 years for females. They also comment on how the cohort effect of those born in the 1930s (who experienced higher mortality rate improvements than other cohorts) exists for Canadian males but not for Canadian females.[B-8]

Robert Bourbeau and Bertrand Desjardins performed research in the province of Quebec using parish registers to establish a computerized database with the basic demographic parameters of the French-Canadian population. The author used this data to derive a comprehensive longitudinal observation of the adult mortality of the entire population—specifically the reliable measure of the mortality of 3,697 men and 4,386 women born between 1680 and 1704, who married.[A-12]

Contrary to expectations, the data seems to show that the progression of mortality remains approximately exponential until the oldest ages where the data becomes erratic due to limited observations. The authors concluded the nature of the selections, which would slow down the rate of increase in mortality for the elderly today, were not present a few centuries ago.[A-12]

In a subsequent research on centenarian mortality using the same parish register data, Nadine Ouellette and Bourbeau noted that, while the aggregation of several birth cohorts is not responsible for the late-life mortality deceleration observed in the studied data, the studied data supports the existence of such deceleration.[A-138]

4. United Kingdom

In line with observations from other developed countries, U.K. mortality rates have fallen quite dramatically over the 20th century. Overall, mortality rates in the United Kingdom for people of age 90 fell by 22 percent from the period of 1964–68 to the period of 1999–2003. Breaking those results down by gender, those mortality rates fell for females at all ages up to 100 and for males up to 96. Death rates at higher ages are erratic as a result of the limited number of observations at higher ages.[A-36]

Other research noted that the modal age at death increased by 14.59 years for males and 11.37 years for females between 1841 and 2010.[A-144]

Adrian Gallop, from the U.K. Government Actuary's Department, noted how in 2014 life expectancy at birth was 79.0 years for males and 82.7 years for females, while life expectancy at age 65 was 18.3 years for males and 20.7 years for females. Projections to the year 2087 shows expectation of life at birth to be 90.4 years for males and 93.2 years for females, while life expectancy at age 65 will be 27.5 years for males and 29.7 years for females.[B-8]

After examining data for cohorts born before 1947, the authors of one study proved that different generations exhibit different rates of mortality improvement. For example, the mortality rates of generations born around 1931 are improving faster than those of earlier *and* later generations: the U.K.'s "golden cohort."[A-36]

Although the exact reasons for the existence of the golden cohort have not yet been determined, various hypotheses remain: the introduction of National Health Services in 1948, or calorie restriction during World War II, which has been proven to increase longevity in mice.[B-8]

5. Spain

Authors collected data on those who died between 1975 and 1995 and analyzed the number of people older than 100 with a focus on gender, cause of death, month of death, location of death, marital status and profession. The authors compared their data with that of the 10-year census (1981 and 1991) and its five-year updates (1986 and 1996). Based on the analysis, the authors showed that the number of inhabitants older than 100 increased by 43.29 percent from 1981 to 1999, which correlates to a 2.41 percent increase each year. In the same period, the total Spanish population increased by 6.68 percent, demonstrating that the percentage of people older than 100 from the total population was approximately 34.32 percent more in 1999 than it was 19 years previously.[A-11]

6. Denmark

In Denmark, it was shown that life expectancy increased by 40 years from 1835 to 2006. The initial improvement is attributed to a reduction in infant and child mortality; the improvements from 1950 are attributed to improved old-age mortality.[A-122]

7. Sweden

Sweden's modal age of death has steadily increased from 1950 until recently. Its mean deviation above the mode only started decreasing from 1970 onward, indicating a period of strong compression of mortality.[B-18]

8. Japan

Japan's modal age of death has steadily increased from 1950 until recently. However, unlike Sweden, while its mean deviation above the mode has decreased from 1950 to 1980, it has remained stagnant since 1980, suggesting Japan has transitioned from a period of strong compression of mortality to a shifting mortality scenario.[B-18]

9. France

France's modal age at death has been increasing steadily from 1950 until recently, although its mean deviation above the mode decreased only from 1970 to 1990. This indicates France experienced a short period of mortality compression from 1970 to 1990 but shifting of mortality in other years.[B-18]

10. Italy

Italy's modal age at death has been increasing steadily from 1950 until recently, although its mean deviation above the mode has increased slightly since 1950. A clear shift of mortality has occurred.[B-18]

11. India

Authors analyzed census reports, which indicated that the Indian population has approximately tripled in the last 50 years, with the elderly population having increased more than fourfold. The United Nations predicts that the Indian population will grow by another 50 percent in the next 50 years, with another fourfold increase for the elderly.[A-34]

#### 4.1.4.2 Challenges in model calibration as a result of observed trends in longevity

1. Mortality trends have different trajectories by insured group

Mortality for life settlement, life insurance and general populations is quite different at the outset because of several factors, including selection, impairments and the wealth effect. But as these populations age, their mortality rates converge, suggesting that original factors become increasingly negligible as time goes on. The convergence of different populations' mortality rates occurs much sooner than the typical 25-year select period used in life insurance populations and tables. There are current studies underway to better define the select period for these populations. Much of the primary research regarding Medicare data was performed by the Chronic Disease Research Group and will be published by the group at a later date.[A-117]

2. Varying levels of mortality improvement by cohort

Adrian Gallop, from the U.K. Government Actuary's Department, noted how the U.K. longevity outlook is more optimistic than that of Canada. One of the reasons was the different methodology used in projecting mortality improvements for their golden cohort, and how Canada only has a male golden cohort in their projections. While Canada assumes their golden cohort's higher mortality improvement rates will eventually converge to a long-term improvement factor used by other cohorts, the U.K. assumes their golden cohort's higher mortality improvement rates will be sustained through time. As a result, the U.K. model also transmits higher mortality improvement rates to later cohorts.[B-8]

#### 4.1.4.3 Validation of current base tables in light of observed trends in longevity

Because of the challenges involved in producing reliable data for older age mortality, the symposia material presents several methods for identifying the level and age trajectory of mortality at advanced ages. These methods are especially important when it comes to establishing end points for life tables.

1. The extinct generation method

It is difficult to produce accurate level and age trajectories in Canada because of problems with the reliability of data on deaths and on population counts beyond a certain point in the official statistics. Still, there are ways to determine appropriate termination of life tables. One such way is to validate a sufficient number of unbiased high ages at death, which can then be used to produce an accurate termination age with the extinct or almost extinct generation method.[A–12]

2. Develop the pattern of survival

Actuaries could establish convincing evidence in support of a survival pattern for people of old ages. With this tool, actuaries could employ mathematical techniques to generate mortality rates as extensions of those mortality rates for ages 70 to 90 or 100.[A–12]

3. Narrow the age intervals to monthly time steps

In particular, authors Natalia Gavrilova and Leonid Gavrilov use data from the DMF-PR to conduct mortality estimates for more homogeneous single-year birth cohorts with hazard rates estimated for narrow (monthly) age intervals. It was shown that mortality deceleration in humans observed at advanced ages may be caused by age exaggeration, data heterogeneity or use of improper estimates of hazard rate, which can be overcome by using data sets of higher data quality.[A-107]

#### 4.1.4.4 Morbidity compression

Morbidity compression is defined by the reduction in the total amount of time spent in a disabled state, and depends not only on incidence rates, but also on the mortality rates of the back-end such that the relationship between disabled life expectancy and disability prevalence rates dictates the direction of morbidity compression.[A-145]

The rate of mortality improvement and, consequently, the temporal improvement in life expectancy has an observable effect on mortality compression that appears to have run its course by the mid-20th century. In

contrast, the life expectancy of those age 65 displayed an increase in variability. This fact is used to bridge the relationship of mortality compression and mortality improvement to morbidity compression and morbidity improvement.[A-145]

Eric Stallard noted that for morbidity compression to occur, any decrease in disability prevalence must be larger than the increase in survival probabilities. And just as importantly, a decrease in prevalence does not necessarily result in morbidity compression.[A-145]

Observations from the National Long Term Care Survey (NLTCS) in the United States indicate that morbidity compression is apparent for the period of 1984 to 2004, which follows the reduction in prevalence rates that exceeded the survival increment. The historical observation is that there was a substantial amount of morbidity compression during a period where there was little mortality compression—so it is evident morbidity compression did not require concurrent mortality compression.[A-145]

#### 4.1.4.5 Relevant symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-1 | Pensioner Mortality in the New York State Public Retirement Systems<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-fox.pdf |
| A-10 | Emergence of Supercentenarians in Low Mortality Countries<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-robine.pdf |
| A-11 | Mortality at Advanced Ages in Spain<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-checa.pdf |
| A-12 | Dealing With Problems in Data Quality for the Measurement of Mortality at Advanced Ages in Canada<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-bourbeau.pdf |
| A-17 | Underlying and Multiple Cause Mortality at Advanced Ages: United States 1980-1998<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-stallard.pdf |
| A-21 | Some Background From Census 2000<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxxiv.pdf |
| A-29 | Number of Centenarians in the United States Jan. 1, 1990, Jan. 1, 2000, and Jan. 1, 2010 Based on Improved Medicare Data<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxvi.pdf |
| A-30 | IDL, the International Database on Longevity<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxiii.pdf |
| A-34 | Implications of an Aging Population in India: Challenges and Opportunities<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iii.pdf |

| *Appendix reference* | **Paper** |
|---|---|
| A-36 | Mortality at Advanced Ages in the United Kingdom<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxi.pdf |
| A-58 | Mortality Measurement at Advanced Ages: A Study of the Social Security Administration Death Master File<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4b-gavrilov.pdf |
| A-107 | Mortality Measurement and Modeling Beyond Age 100<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5b-gavrilova.pdf |
| A-117 | Mortality Experience of Three Senior Populations<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-granieri.pdf |
| A-122 | Social Insurance: Perspectives and Implications<br>http://www.soa.org/files/pd/2011-orlando-living-100-dengsoe-gs7.pdf |
| A-133 | Mortality of Smoking by Gender<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-gutterman.pdf |
| A-138 | Measurement of Mortality Among Centenarians in Canada<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-oullette.pdf |
| A-139 | Mortality Trajectories at Extreme Old Ages: A Comparative Study of Different Data Sources on U.S. Old-Age Mortality<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-gavrilova.pdf |
| A-144 | Modal Age at Death: Mortality Trends in England and Wales 1841–2010<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-clay.pdf |
| A-145 | Compression of Morbidity and Mortality: New Perspectives<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-stallard.pdf |
| A-154 | Mortality Projections for Social Security Programs in Canada<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs4-chief.pdf |
| B-1 | The Advancing Frontier of Human Survival (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1-soa-informal-discussant.pdf |
| B-8 | Mortality Projections from a Social Security Perspective (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| B-16 | Discussant comments for session: Mortality Age Patterns: Trends and Projections<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-lid-discussant-comments.pdf |
| B-18 | Discussant comments for session: The Changing Age Distribution of Deaths<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-robine-discussant-comments.pdf |

### 4.1.5 Identifying possible predictors of changes in future improvement patterns

This section discusses the different approaches for identifying predictors of changes in future mortality improvement.

> More and more, we are able to use our growing understanding of our genetic and nongenetic makeup to help identify the predictors of longevity. However, death can rarely be attributed to a single cause and the complexity and interrelatedness of the elements of our biological systems makes this a very intricate and very difficult exercise.
>
> Eric Stallard, ASA, FCA, MAAA, research professor, Social Science Research

To understand what drives trends in population mortality, researchers separate data into a number of subgroupings. The most common subgroupings are gender and smoker status, but several other subgroupings—including socioeconomic status, occupation, marital status, physical traits (especially obesity) and birth characteristics—are also used.

Actuaries usually begin their analyses with the same validated sources. However, the way they proceed with data from those sources differs depending on the purpose of the analysis.

> Actuaries from different disciplines need to work together on longevity issues. There is a core of longevity research—both empirical and theoretical—that would be very useful as a starting point for a number of different actuarial applications. Each SOA section would then be able to build upon that common framework to focus more explicitly on the mortality/longevity issues that are most relevant to its membership.
>
> Larry Pinzur, FSA, EA, Ph.D.

As the reader reviews the material, a number of open questions and gaps in current knowledge can be identified. In particular:

- How is the usefulness of subgroupings best assessed? There are a number of factors that could be important to consider: the logical basis for the subgrouping, the supporting data available, the intended use (for example, pricing versus valuation), the complexity of incorporating the subgrouping into projection models and, finally, the appropriateness of the subgrouping given the societal, legal, political, industry and regulatory environment.
- Do more specialized factors, such as seasonal effects (identified in A-28) or birth characteristics (identified in A-39, A-45 and A-95), provide actuaries with useful information?
- How will the current obesity epidemic in the U.S. affect future mortality rates?
- Should life, health and pension actuaries standardize their summary metrics to facilitate communication with consumers and policymakers? Which metrics would be standardized?
- As we enter the "new pharmaceutical phase of aging research," how do we incorporate pharmaceutical advancements and their effect on aging into our projections of future mortality?[A-77]
- How can dependency between causes of death be accounted for when evaluating the influence on mortality of a single cause of death?

- How will research on the role of genes in longevity and future breakthroughs affect mortality?
- What other methods can be used to validate research results and hypotheses?

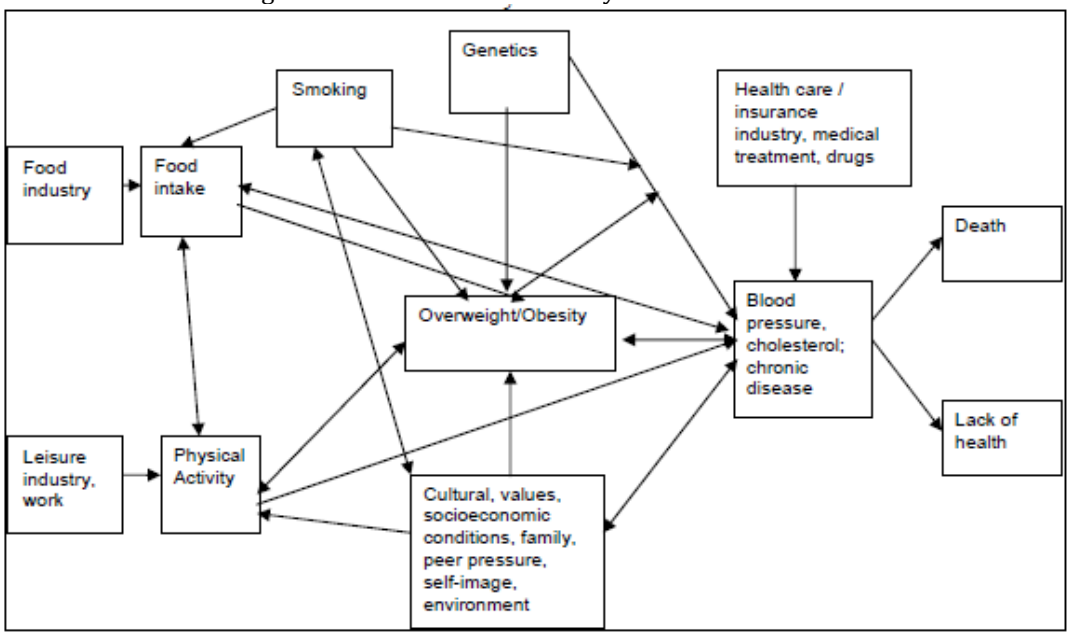
> What is the No. 1 goal of medical research? I suggest it's not to cure or prevent cancer, heart disease or dementia; these are tactical steps that support a broader strategy. Rather, the No. 1 goal is to increase healthy life expectancy. We can accomplish this goal by finding new and better ways to treat and prevent common medical problems, attacking them one by one, disease by disease. And we can try to delay aging. This is not an either/or decision; rather, it's a matter of balancing research priorities to increase the likelihood of success.
>
> Dr. Robert Pokorski, FACP

The information in the sections below summarizes the symposia information that addresses these topics.

#### 4.1.5.1 Determining the predictors of mortality and morbidity

Figure 14 is an illustration of factors that contribute to the health of an individual. These factors fit into four broad categories: (1) an individual's starting point, which is dictated by genetics; (2) the external environment—including the home, environment (e.g., medical practice and pollution) and the communities in which a person lives; (3) the cumulative effect of individual behaviors and corresponding mitigating factors—including nutrition, physical activity, smoking and medications; and (4) the current individual risk profile—including weight, blood pressure, cholesterol level and socioeconomic factors (the latter is not included in Figure 14 for simplicity's sake only).[A-48]

Figure 14: Relations between key health factors[A-48]




Human behavior has always had a significant effect on mortality and life expectancy. Many symposia papers attempt to analyze this behavior to identify statistically significant predictors of longevity. The following section summarizes that research. More detail on the assumptions and methodology associated with each result can be found in the underlying source material.[A-48]

The authors of symposia papers used three main approaches to judge the significance of predictor variables. These include:

- Cox proportional hazards model:[A-8], [A-79] This approach is the most common among symposia authors performing survival analysis. This model makes no assumption on the baseline hazard, which can take any form. The shape of the hazard function over time is defined by the baseline hazard for all cases. The covariates help to determine the overall magnitude of the function.

  The proportional hazards model was augmented in one case using a kernel estimator to obtain a semi-parametric model of mortality that describes how mortality varies by age and gender.

- Relative mortality ratio analysis:[A-79] The authors calculated actual-to-expected mortality ratios for each subgroup under study and then standardized the ratios to enable cross-group comparisons.

- Joint frequency distributions:[A-17] This approach models the complexity of diseases that led subjects to death. The authors used the technique to model changes in four types of mortality measures: underlying cause death rates, multiple cause death rates, associated (i.e., non-underlying) cause death rates, and death rates based on the joint occurrences of multiple cause conditions.

The complexity of this approach means a practitioner would likely use it sparingly. One symposia author commented that if the goal is to forecast non-underwritten total death rates, it is unnecessary to consider cause-of-death data and related risk factors and lifestyle behaviors. On the other hand, if the goal is to model the health status of the population, which is relevant to forecasts of health care costs, then the multiple cause mortality data are relevant as endpoints of the health status process.

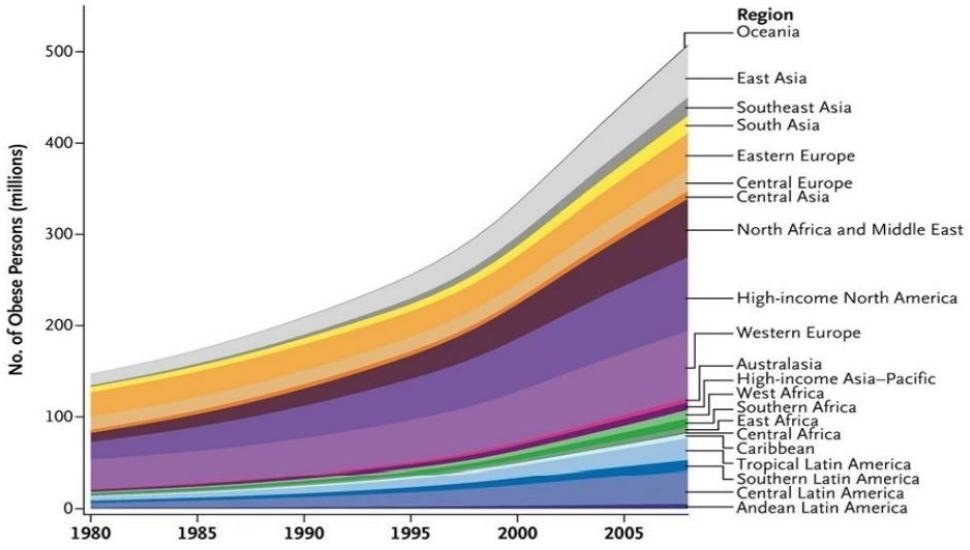
Some of the symposia papers focused on comparing the health effects caused by socioeconomic factors to those caused by behavior. In the article "Age-Related Changes in Factors Associated with Loss of Good Health," for example, the authors studied longitudinal data from the Canadian National Population Health Survey and concluded that socioeconomic factors played a much greater role than behavior in the deteriorating health among young and middle-aged people, while the opposite was true for the elderly.[A-93]

Other symposia papers focused on more specific predictor variables. The symposia studies revealed the following information on predictor variables.

1. Physical characteristics

- Stout body build: The "stout" body build (being in the heaviest 15 percent of the population) is negatively associated with survival to age 100 years.[A-61]
- Obesity: With obesity levels having dramatically increased from 1970 to the early 21st century in the United States, it has become one of the most significant factors to influence current and future mortality. Adults who suffer from obesity prior to turning 30 years old are three times less likely to reach age 100 than adults who are of the same age but who are not obese.[A-61]

Figure 15: Historical trend of global obesity levels[A-131]




A key issue discussed in a second paper is the adverse long-term health effects of adolescent obesity. The analysis shows that the effects of obesity have to date been more than offset by significant risk mitigation and other developments, particularly treatments for high blood pressure and cholesterol levels and reductions in smoking. The author notes that uncertainty associated with mortality projections includes the extent that these sets of factors and technological developments will offset each other in the future.[A-48]

Another paper discussed the effect of obesity on disability and mortality at different ages. It reports that obesity at one's current age is associated with significant increases in diabetes, insignificant increases in disability, and significant decreases in mortality among the elderly, with the latter exemplifying the obesity paradox for mortality. The paper found that obesity at age 50 has slightly different effects: significant increases in diabetes and disability, but insignificant increases in mortality among the elderly.[A-86]

A final paper by Sam Gutterman studied the "obesity-mortality paradox," where mortality experience is lower for overweight individuals, and in some cases those who are obese, than for those in the normal weight category. The study discussed 16 factors contributing to the paradox, which can be categorized into four general topics: (1) study participants have not been obese long enough for mortality deterioration to surface, (2) heterogeneity of the obese population, (3) measurement issues and (4) study design limitations. The study also pointed out that the commonly used body mass index (BMI) is not a good measure of obesity.[A-131]

The author also mentions how fundamental changes in the microbiota of the human gut may have made weight loss more difficult to incur in recent years and, consequently, contributed to the rise of the obesity epidemic. This finding is supported by other emerging evidence that identifies the presence of particular microbes in the gut prior to the introduction of certain antibiotics in the 1970s. Ultimately, current linkages between obesity and mortality are calculated using data on people who acquired their obesity in adulthood, which is not a fair representation of future cohorts exhibiting obesity-related mortality, disability and frailty who acquired their obesity during their childhood.[A-131], [B-13]

Furthermore, it appears that gender has an interaction as high BMI levels were observed to be a significant risk factor for men but not women.[A-151]

Obesity is believed to only affect mortality if the individual has been obese for a long enough period of time. Thus, excess mortality for recent cohorts will not be observed in the short term.[B-8]

2. Lifestyle characteristics

- Psychological: Recent pioneering biomedical research on the hypothalamus indicates that the brain may exert fundamental control over aging. As individuals progress beyond "young old" age (65–74), factors such as foreign languages learned, hobbies involving mental and physical exercise, club memberships, voluntary work, sense of well-being, extended family and social networks become increasingly important to understand the observed differentials in mortality.[A-152]

  Personal stress is also an indicator of health decline with it being a more significant indicator of health decline in men than in women.[A-151]

- Cognitive impairment: Using the Cox proportional hazards model and relative mortality ratio analysis, the symposia papers show that cognitively impaired individuals have a significantly higher mortality than those who are cognitively intact. In fact, holding age and gender constant, a cognitively impaired individual has a death hazard between 1.52 and 1.69 times greater than someone who is cognitively intact.[A-79]

- A longitudinal study of adult Canadians revealed that living in rural areas had a positive effect on health maintenance in men but had no notable effect on women. It seems likely to speak to the exercise received from manual outdoor labor.[A-151]

- Smoking: The decline in cigarette smoking has had a favorable impact on survival rates. Significant effort has been made in developing countries to continue this trend through public policy interventions, increased taxation and other efforts. In contrast, smoking prevalence rates continue to grow in developing countries such as China and India.[A-48]

  The global prevalence of smokers decreased from about 41.2 percent in 1980 to 31.1 percent in 2012 for males, while it decreased from 10.6 percent to 6.2 percent for females. Prevalence rates decreased at a faster pace from 1996 to 2006 (1.7 percent annually) than for the period 2006 to 2012 (0.9 percent annually). Nevertheless, due to the increase in the total population and its age structure, there was an increase of 41 percent in the number of male smokers and a 7 percent increase in female smokers, or an increase in the number of daily smokers from 721 million in 1980 to about 967 million in 2012.[A-133]

  Sam Gutterman performed a study that focused specifically on the impact of smoking on mortality, which had the following findings:[A-133]

  - Overall, males appear to have had greater sensitivity to smoking than females. This in part may be due to lower female consumption of cigarettes per day and a tendency to smoke cigarettes with lower tar content.
  - The combined effect of greater historical smoking prevalence rates by males and their corresponding earlier and larger reduction has in part been responsible for the recent improvement in mortality rates for males compared to those of females across the globe.
  - Exposure to cigarette smoke has been shown to increase mortality on a lagged basis. This lag can range from two to five decades.
  - Aggregate mortality for current smokers between ages 25 and 75 was three times the corresponding mortality of those who never smoked, which translates into a 10-year life expectancy gap between both groups.
  - The effect of smoking cessation is more rapid. Adults who quit smoking between ages 25 and 34 live 10 years longer than those who continue to smoke, nine years longer if they quit between ages 35 and 44, and six years longer if they quit between the ages of 45 and 54. In addition, it is estimated that between 10 and 19 years after cessation, lung cancer mortality rates are 42 percent and 21 percent of that of current smokers for males and females, respectively; for the period between 20 and 29 years, the corresponding percentages are 28 percent and 5 percent of

current smokers. Some studies have indicated that those who stopped smoking for more than 30 years have not experienced any appreciable extra mortality.

- Today's smokers have a much higher risk for lung cancer and chronic obstructive pulmonary disease (COPD) than did smokers in 1964, despite smoking fewer cigarettes. Gutterman found this is in part due to current smokers being likely to have been smoking for a longer period of time, as well as changes in the design and composition of cigarettes.
- In studying the combined effect of smoking and obesity, the mortality effect of smoking dominates that of obesity at ages older than 60, while the opposite holds at younger ages.

- Fitness: This factor is shown to be correlated with age; while it is demonstrated that cardiorespiratory fitness is correlated with mortality, the strength of the effect is masked by other age-related factors.[A-8]

  Symposia papers demonstrate that activity limitations and exercise play an important role in survival into old age (between 65 and 85) but have a smaller effect on survival past age 85.[A-87]

  A longitudinal study on adult Canadians showed that risk of deterioration was significantly higher among women who exercised infrequently compared to women who exercised and compared to their male counterparts.[A-151]

- Drugs: Certain drugs and substances have been associated with an extended life span:[B-7]
  - Resveratrol: This wine extract has increased life span in a variety of animals.
  - Rapamycin: Traditionally an immunomodulator given to patients after a transplant, it has been shown to elongate the life span significantly within animals.
- Nutrition: Studies have shown caloric restrictions in rodents and animals have elongated their life spans by about 40 percent.[B-7]

3. Family characteristics

Marital status: Central death rates for unmarried men at some ages are as much as three times those for their married counterparts, the resulting longevity advantage being more pronounced than that for women, perhaps by four or more years for a man age 65.[A-47]

Research on Taiwan's general population has revealed significantly lower mortality rates in married individuals relative to their single counterparts, with a higher mortality gap compared to the gap between smokers and nonsmokers for particular age groups. In particular, divorced/widowed individuals appear to have the largest gains in life expectancy, followed by marrieds, and then singles.[A-127]

A longitudinal study of adult Canadians also revealed that never-married men had an elevated risk of health deterioration than married men. It also revealed how divorced/separated/widowed women were more likely than their married counterparts to report deterioration in health.[A-151]

Jean-Claude Ménard noted how Canadian male widows' and Canadian female widows' mortality rates ultimately converge to the general population mortality at advanced ages.[B-8]

Natalia Gavrilova and Leonid Gavrilov found marital status to be less important as a predictor of future longevity relative to physical characteristics such as body build.[A-61]

In a separate paper, Gavrilov and Gavrilova performed a study of the impact of parental characteristics in longevity:[A-129]

- Chances of living to age 100 were enhanced if a parent lived to age 80 or more, with further enhancements if both parents lived beyond age 80. However, loss of parents early in life had no effect on the chances of becoming a centenarian.

- Husbands of centenarians live 2.3 years less on average than married brothers of centenarians. Although fathers of centenarians are born about 30 years earlier than brothers-in-law of centenarians, they still have longer life spans conditional on survival to age 50 than later-born non-biological relatives such as siblings-in-law and husbands of centenarians. On the other hand, mothers of centenarians survived to age 50 have the lowest life span among all relatives: 77.2 years on average.
- Males are more likely to experience improved longevity if their brother was a centenarian, while the improvement would not be as much if it was their sister who was a centenarian. In either case, being male and having a centenarian sibling still improved the male's longevity prospect more than if their wife was a centenarian.
- Overall, siblings-in-law of centenarians have the lowest life span compared to biological relatives and spouses of centenarians born in a similar time period. At the same time, life span of siblings-in-law is still higher than mean life span of the general population. This difference is particularly high for men (1.7 years).

The following have also been identified at the symposia as influential family characteristics:

- Number of children (four or more): Having a large number of children (four or more) at age 30 more than doubles the chances of exceptional longevity.[A-61]
- Growing up in a farming community increases the chances of exceptional longevity by 100 to 200 percent.[A-61] The authors refined the study by linking both childhood and midlife characteristics and concluding the actual predictor for longevity was being a farmer rather than growing up in a farming community, where the longevity effect was more prevalent for males.[A-129]
- Maternal age: Symposia papers show that young maternal age increases offspring's chance of reaching age 100 (data shows maternal ages between 20 and 24 have the largest effect). This is especially true for small families.[A-95]
- Age at first marriage: Gavrilov and Gavrilova identified females, who had their first marriage at a late age, were more likely to experience exceptional longevity.[A-129]

4. Economic characteristics

- Income equality: Symposia papers studying wealthy nations report a negative association between income inequality and life expectancy at birth. This negative association becomes insignificant after controlling for average total income. Overall, the data for wealthy nations does not support the hypothesis that higher levels of income inequality are directly related to lower levels of population health.[A-50], [A-117]
- Larson, Yaffe and Langa noted evidence supporting the theory of better education and greater economic well-being reducing the risk of late-life dementias in people who survive to old age.[B-22]
- Jean-Claude Ménard noted how Canadian social security beneficiaries with higher levels of income have higher life expectancies than the overall population. This may be explained by a possible relationship between a higher level of income and improved health and quality of life.[B-8]

5. Other characteristics

- Geography of birthplace: Geography of a birthplace (or factors associated with it) within the United States is shown to be an important determinant of human longevity. The preliminary findings presented in this paper suggest there may be a threefold difference in chances of survival to 100, depending on location of childhood residence.[A-39]

- Infectious burden: One study showed that a lower burden of infectious diseases during childhood will increase the chances of survival to 100. Geography of birthplace is one factor that influences infectious burden.[A-129]
- Seasonality: This study shows that the ages at death are more concentrated in winter where the mortality conditions are worse than in summer.[A-28]
- Birth order: Symposia papers found first-born daughters are three times more likely to survive to age 100 than daughters of higher birth orders (seven or more). Similarly, first-born sons are two times more likely to become centenarians than sons of birth orders four through six. Interestingly, last-born sons (nine or more) also had higher chances of living to age 100, something untrue for females.[A-39]
- Season of birth: Symposia papers indicate that season of birth has a significant effect on survival to age 100, with individuals born in September to November having the highest chance of becoming centenarians.[A-95], [A-129]
- Individual's own survival assessment: Subjective survival probabilities (self-assessed probability of surviving) are highly heterogeneous within a population, depending on various observable and unobservable characteristics.
    - Research in Europe has shown that subjective survival probabilities are relatively close to objective survival probabilities (probability of survival derived from life tables) based on demographic studies for males, while female subjective probabilities of survival appear to be consistently lower than their objective probabilities.[A-148]
    - On the other hand, Anna Rappaport found both men and women underestimate their survival probability. This discrepancy may be due to the fact that the SOA research Rappaport used in her paper was based on the U.S. and not Europe.[A-147]
- Access and engagement with technology and communications: One study showed that having a radio in the household in 1930 has a positive effect on longevity for women but not for men. The researchers explained this finding by the fact that women in 1930 spent most of their time at home and were much more exposed to radio (as an educational and entertainment source) compared to men. Listening to the radio improved people's feelings of happiness and energy, and an electro-encephalographic study found that listening to the radio creates high levels of positivity engagement in the brain.[A-129]

The symposia papers also discussed variables that do not have predictive power, such as body height.[A-61]

Finally, the symposia papers briefly address the principal factors that contribute to frailty, which is important to the study of morbidity. A frail person is at high risk for disability (disability insurance), failure of instrumental activities of daily living (IADLs) and activities of daily living (ADLs) (long-term care insurance), and death (life insurance and substandard annuities). The principal factors include age, gender, functional and cognitive impairment, nutritional status, co-morbid impairments, self-reported function, and difficulties with mobility, balance and aerobic capacity. Frail insurance applicants could often be identified via historical data and simple tests of cognitive and physical performance. The article referenced reviews the geriatric literature to identify risk factors that could be used by insurers to identify existing or incipient frailty.[A-7]

#### 4.1.5.2 Genetic predictors of mortality and morbidity

There is little consensus on how genes affect longevity.

One belief, as explained by Leonard Hayflick, is the determination of longevity being incidental to the main goal of the genome: to govern events in order to reach reproductive maturity. Thus, the genome only determines longevity indirectly in a non-random process through governing the levels of physiological capacity reached at the time of sexual maturation, which then starts degrading afterward due to the Second Law of Thermodynamics.[B-14]

An opposing belief of author Tom Bakos is that the main goal of the genome is not necessarily to govern events in order to reach reproductive maturity, as this is only an outcome of natural selection. The fact that organisms die at younger ages prior to sexual maturity or live a long life after sexual maturity is indicative of the Second Law of Thermodynamics being deteriorated or ameliorated by an outside influence, namely, the genetic and epigenetic control of the regenerative or self-repair processes within living cells: genetics.[B-15]

However, both Hayflick and Bakos agreed on how the loss of molecular structure within cells caused by the Second Law of Thermodynamics can be circumvented for varying time periods by the enormous capacity for biological systems to replace or repair themselves.[B-14], [B-15]

The following have been identified as genetic-related factors affecting mortality and morbidity:

- Genetic information, and its interpretation, is rapidly becoming available to individuals given it is useful in diagnosing, treating and mitigating health and life risks. This inexpensive, readily available genetic information will inevitably inform and influence decision-making processes affecting life, health and longevity, both from an individual and societal perspective.[A-134]
- Preliminary research on twins postulated that longevity may be hereditary; however, the oldest subjects in these studies were in their mid- to late-80s, and thus the results say little about the relative importance of genes and environment or behaviors in the ability to live to much more exceptional ages.[A-121]
- A possible increasing level of homogeneity in functional history and medical histories among centenarians beyond the age of 105 may lead to increased power to reveal genetic associations with the phenotype of exceptional longevity and sub-phenotypes such as the delay or escape of specific age-related diseases and syndromes like dementia.[A-121]
- The increasing relative risks of survival to very old age associated with older and older ages of studied siblings is consistent with the conjecture that the heritability of longevity is substantial only when looking at the oldest fifth and smaller percentiles of survival. The authors note that the lack of information concerning the impact of familial longevity is a glaring deficiency in the current assessment of mortality risk.[A-136]
- A study done on 600 seniors, all older than 95 and living independently, found everyone had a strong family history of longevity; the effect was tenfold if compared to the control group. They also noticed this group of centenarians had similar prevalence levels of hypertension, myocardial infarction and stroke to a group 30 years younger but without familial history.[B-7]
- Regarding longevity genotypes,[B-7]
    - certain genotypes have been linked with longevity due to their higher prevalence in centenarians as opposed to the general population. CETP and APOC3, whose genotype homozygosity is normally between 18 and 20 percent, have been identified at double the rate at age 100.
    - centenarians do not have the perfect genome; they have just as many bad snips in their genomes as the general population. It is currently hypothesized that although they have bad snips, they have certain genes ensuring their longevity. These “protector” genes are thought to guard from the effect of bad genes found in people with certain critical illnesses.

#### 4.1.5.3 Challenges associated with determining the predictors of mortality and morbidity

1. Long-term lags between the underlying behaviors and their mortality consequences

While researchers have investigated the relationship between obesity and mortality with thoroughness in recent years, they have not provided sufficient long-term follow-up information that is also important to life expectancy studies. As a result, Sam Gutterman notes there is significant uncertainty in the estimation of future mortality patterns and their relationship to obesity.[A-48]

Gutterman also noted how research on the relationship between smoking and mortality should be studied with caution given the changing dynamics of data quality, reference population issues, confounding factors, secular changes in smoking pattern and the long lag time between exposure to smoking and death.[A-133]

2. Interpretation of the patterns in the underlying data

It is not always clear what drives patterns in the underlying data. For example, when evaluating whether morbidity compression exists at older ages, recent reviews of national health trends show conflicting results. In addition, if an expansion of morbidity is shown to accompany a compression of disability, it is difficult to interpret the cause of a decline in disability. The pattern could be a result of a healthier elderly population, or a result of individuals having access to better technical devices in a more favorable environment.[A-49]

3. The interaction among multiple pathological and biological processes

When an individual dies from a disease, it is really a series of pathological processes—not one simple disease—that contributes to death. As such, when an individual dies from disease and the death is attributed to the disease, the explanation for the death is somewhat oversimplified in a deceiving manner.[A-8], [A-17]

In the articles referencing this issue, it is found first that declines in mortality rates have not been distributed evenly by disease. In particular, the success in treating the top three major killers did not translate into subsequent successes against many of the lower ranked diseases. Second, diseases can play different roles in the mortality process and it is appropriate to consider models in which certain diseases are viewed as a lethal sequel of other underlying conditions. Therefore, an understanding of the dynamics of cause-specific mortality is essential to an understanding of concurrent gains in life expectancy and to our ability to accurately forecast the rates of reduction in mortality in future years.[A-8], [A-17]

A common assumption in cause-of-death mortality studies is that causes of death are independent. However, dependencies do exist among different causes of death. Gaille and Sherris used vector error correction models (VECM) to analyze the five main causes of death across 10 major countries representing a diversity of developed economies. The five causes of death include diseases of circulatory system, cancer, diseases of the respiratory system, external causes and infectious and parasitic diseases. These are the major causes that accounted for more than 80 percent of deaths in recent years. Their analysis shows that long-run equilibrium relationships exist between the five main causes of deaths for all 10 countries. In addition, countries usually had different past experience in regards to cause-of-death mortality trends and thus applying results from one country to another may be misleading. The authors noted the study only analyzed age-standardized death rates, since applying a VECM to age and cause-specific death rates would result in a model with too many parameters.[A-132]

Dr. Robert Pokorski noted how prevention of Alzheimer's disease would markedly reduce many years of morbidity associated with the condition, but the impact on a person's aggregate mortality and life expectancy would be limited. In addition to Alzheimer's being a relatively uncommon cause of death at older ages (it accounts for 4.4. percent of deaths at ages 65 or older), people would die instead from competing causes of death. Dr. Pokorski also references a report that estimated eliminating Alzheimer's disease as a cause of death would add only 51 days to life expectancy at birth.[B-22]

Authors Anatoliy Yashin et al. note how most researchers search for genes that contribute to increased longevity and do not consider the possibility of the absence of harmful genetic factors being the driver for exceptional longevity. The authors also identify how the conventional analytic methods of data ignore externally available knowledge about the traits of interest and treat their own limited data set as the only source of information; the practice misses the opportunities presented in the research potential of the externally available data. Furthermore, it is mentioned how most genome-wide association studies do not consider the following.[A-135]

- Many genetic and non-genetic factors contribute to longevity-related traits.

- Contribution of specific genes depends on genetic background (internal milieu created by other activated genes), which, in turn, can be modulated by external conditions.
- Genetic effects are mediated by many biological variables that change their values and their influence on aging and longevity traits during the life course.

Dr. Nir Barzilai notes it is difficult to study biological factors that might influence longevity as the resulting process is highly complex. Based on his observations, he raises the following questions for practitioners.[B-7]

- How does one know if the decline in the level of one factor is causing aging and not a protective mechanism that is delaying aging? There are difficulties with approving these kinds of studies where there is a possibility of killing the participant as you alter the factor's level.
- Since centenarians have a high probability of dying in the next few years, studying their factors becomes challenging as well. How do researchers determine if their current biology reflects that of someone about to live longer or someone about to die? What if their current factor levels are at a high level because they are approaching death, but they were at low levels their entire life?
- As the body ages, it secretes more cytokines and, consequently, has different peptides circulating as opposed to those in a younger body. These different peptide compositions across different aged-bodies create a difficulty with studying the effect of one factor on the body. How will the factor interact with varying levels of peptides across young and old bodies?

4. Our limited understanding of the aging process

A lack of consensus exists on the nature of the aging process and its implications to longevity studies.

S. Jay Olshansky notes how the observed dependency across diseases exists not because they are biologically dependent on each other, but because they are all together influenced by a common risk factor: the biological aging of the body, which provides a major challenge as our understanding of the aging process is fairly limited.[B-13]

Dr. Nir Barzilai mentions how since aging is the common and major risk factor of all age-related diseases, improving health from one disease will not improve overall health much since the body will have other competing causes of death; people not dying from one age-related disease will end up dying from another age-related disease. Dr. Barzilai recommends researchers stop segregating their research by disease and focus on the primary driver of the age-related disease: aging.[B-7]

Studying the aging process poses many research challenges to overcome. For example, if the researcher gives a drug to a 50-year-old and follows up with them 30 years later, it is not clear what variable they should measure at the end of such a period. An alternative in this case would be to use a biological marker, such as the point when people become glucose intolerant.[B-7]

Leonard Hayflick notes how current knowledge supports aging being a stochastic process rooted in the intrinsic thermodynamic instability of complex biological molecules, indicating aging is a chance-driven catabolic process. He also states how the direct role genes play in the cause of biological aging has not been proven because of the failure to distinguish between aging and longevity determinants.[B-14]

However, Tom Bakos argues aging cannot be driven by the common action of an external force as different organisms and species have significant differences in rates of aging and maximum life spans. In particular, differences within species have been associated with genetic variation, indicating these are attributed at least by genetic drivers associated with the rate of aging and longevity in biological organisms.[B-15]

In addition, Dr. Robert Pokorski references a paper noting that continuing the status quo, where heart disease and cancer are addressed as separate research topics, would result in diminishing improvements in both

health and longevity over the next 50 years because of competing causes of sickness and death in aging populations. In contrast, preventive measures that slowed the aging process would have a significantly greater impact on disability and longevity.[B-22]

Advances in our knowledge of age-associated diseases have far outpaced advances in our knowledge of the fundamental aging process that underlies our vulnerability to these pathologies. Longevity determination must be distinguished from aging to take us from the common question why do we age, to a more revealing question that is rarely posed: Why do we live as long as we do?[A-18]

5. Inaccuracies in the diagnoses of causes of death

Leonard Hayflick commented on the following challenges in reliable data for cause of death.[B-14]

- Our lack of knowledge on causes of mortality in old people can partially be attributed to the decline in performance of autopsies in the United States, which has fallen from 41 percent of hospital deaths in 1961 to less than 10 percent across the United States in the mid-1990s.
- The quality of the few autopsies performed has not been too reliable either. A 2002 review by the federal Agency for Healthcare Research and Quality found that when patients were autopsied, major errors related to the diagnosis or cause of death were found in one of every four cases. Furthermore, another study showed for autopsies performed on large numbers of old people, 40 to 50 percent of the causes of death appearing on the death certificates have been inaccurate.
- Researchers who rely on cause of death found within death certificates ignore how multiple pathologies occur in older people so the true cause of death is rarely known.

6. Migration effects

While migration has not been the focus of past symposia research papers, Ward Kingkade notes how mortality for some ethnicities in a given country may seem lower than it actually is due to migration effects (i.e., the "salmon bias"). In particular, he notes that Hispanic mortality in the U.S. could be underestimated due to Hispanics immigrating to the U.S. for work and returning to their home country for retirement. Their deaths are thus not recorded in follow-up censuses within the United States.[B-5]

The Office of the Chief Actuary in Canada also noted how immigrants experience lower mortality than those born in Canada for a number of reasons: people in poor health are less likely to migrate, potential immigrants are subject to medical screening, and immigrants are partially selected on the basis of employability, which would imply a certain status of health. In this context, they are expected to be a source of bias given their healthier status relative to the nonimmigrant Canadian population.[A-154]

#### 4.1.5.4 Validation techniques

Because of the challenges involved in identifying the predictors for older age mortality, the symposia material presented limited methods to validate research results. One technique used by practitioners to validate their results was to identify proper control groups.[A-39]

For example, Leonid Gavrilov and Natalia Gavrilova found in their 2014 study that, in general, siblings-in-law of centenarians have lower life spans than biological relatives and spouses of centenarians born in a similar time period. At the same time, life spans of siblings-in-law are still higher than the mean life span of the general population. Therefore, to assess the survival of siblings of long-lived individuals (or other biological relatives), siblings-in-law is a better control group than the general population. If the general population is chosen as the control group, survival advantage of biological relatives and, hence, the genetic effect on life span may be overstated.[A-129]

Finding a control group for an extreme centenarian group is very challenging. One solution would be to consider their offspring instead, under the assumption they would most likely have the same genes that contribute to becoming a centenarian. From there, it is possible to construct a control group from the centenarians' offspring, and compare the genomes between this control group and the offspring.[B-7]

Studies of exceptional longevity using genealogical data require choosing the appropriate control group. Longevity of the population with the trait or characteristic being studied can then be compared to that of the control group to determine its predictive power.

1. Population based

For example, one might use randomly selected shorter-lived men matched with centenarian men by birth year, race and county of draft registration as controls. This approach allows the elimination of the confounding effects of birth cohort, race and place of draft registration on survival.[A-61]

2. Distant blood relatives (e.g., first cousins) or nonblood relatives (e.g., in-laws)

In this case, the authors eliminated unobserved shared factors and focused their study on specific effects such as the number of children born and the life span of parents.[A-39]

### 4.1.5.5 Relevant symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-7 | Detection and Significance of Frailty in Elderly Insurance Applicants<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-pokorski.pdf |
| A-8 | Analysis of Mortality in a Small Sample of Older Adults<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-jones.pdf |
| A-17 | Underlying and Multiple Cause Mortality at Advanced Ages: United States 1980-1998<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-stallard.pdf |
| A-18 | Plastic Omega<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-held.pdf |
| A-28 | Seasons and Longevity: Mortality Trajectories Among the Oldest Old<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxiv.pdf |
| A-39 | Search for Predictors of Exceptional Human Longevity: Using Computerized Genealogies and Internet Resources for Human Longevity Studies<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-v.pdf |
| A-45 | Ending the Mortality Table<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-ix.pdf |

| *Appendix reference* | **Paper** |
|---|---|
| A-47 | Health, Wealth and Wisdom—Living Long, Living Well: An Actuary Muses on Longevity http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-cowell.pdf |
| A-48 | Human Behavior: An Impediment to the Future Mortality Improvement: A Focus on Obesity and Related Matters http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-gutterman.pdf |
| A-49 | Is the Compression of Morbidity a Universal Phenomenon? http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-04-cheung.pdf |
| A-50 | New Findings on the International Relationship Between Income Inequality and Population Health http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2a-brown.pdf |
| A-61 | Physical and Socioeconomic Characteristics at Young Age as Predictors of Survival to 100: A Study of a New Historical Data Resource (U.S. WWI Draft Cards) http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-gavrilov.pdf |
| A-77 | Putting the Brakes on Aging: Beginning the Pharmaceutical Era http://www.soa.org/files/pd/2011-orlando-living-100-austad-gs1.pdf |
| A-79 | The Relationship Between Cognitive Impairment and Mortality Rates Among Long-Term Care Insurance Applicants http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-cohen.pdf |
| A-86 | The Impact of Obesity and Diabetes on LTC Disability and Mortality: Population Estimates From the National Long Term Care Survey http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-stallard.pdf |
| A-87 | The Role of Social and Health-Related Characteristics in Determining Survivorship Among the U.S. Oldest Old http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-alishire.pdf |
| A-93 | Age-Related Changes in Factors Associated With Loss of Good Health http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-brown.pdf |
| A-95 | Early-Life Predictors of Exceptional Longevity in the United States: Why Centenarians are Different from Their Shorter-lived Siblings http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g4-gavrilo.pdf |
| A-117 | Mortality Experience of Three Senior Populations http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-granieri.pdf |
| A-121 | Increasing Genetic Contribution to Exceptional Longevity With Increasing Age http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g4-perls.pdf |
| A-127 | Mortality, Health and Marriage: A Study Based on Taiwan's Population Data https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1b-wang.pdf |
| A-129 | Predictors of Exceptional Longevity: Effects of Early-Life Childhood Conditions, Midlife Environment and Parental Characteristics |

| *Appendix reference* | **Paper** |
|---|---|
| | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-gavrilov.pdf |
| A-131 | Obesity and Morality<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-obesity-gutterman.pdf |
| A-132 | Causes-of-Death Mortality: What Do We Know on Their Dependence?<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-arnold.pdf |
| A-133 | Mortality of Smoking by Gender<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-gutterman.pdf |
| A-134 | Genetically Informed Longevity<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-bakos.pdf |
| A-135 | How Genes Modulate Patterns of Aging-Related Changes on the Way to 100: Lessons From Biodemographic Analyses of Longitudinal Data<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-yashin.pdf |
| A-136 | Contribution of Familial Longevity to Living to 100<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-sebastiani.pdf |
| A-147 | Perspectives on SOA Post-Retirement Risk Research and What it Tells About the Implications of Long Life<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-rappaport.pdf |
| A-148 | Subjective Survival Probabilities and Life Tables: Evidence From Europe<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-peracchi.pdf |
| A-151 | Sex Differences in Predictors of Health Decline: Results From a 16-Year Longitudinal Cohort Study<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-prus.pdf |
| A-152 | Cognitive, Psychological and Social Drivers of Longevity<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-woo.pdf |
| A-153 | Is Secondary Prevention of Alzheimer's Disease Possible? A Discussion of Studies in the Alzheimer's Disease Field<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-snyder.pdf |
| A-154 | Mortality Projections for Social Security Programs in Canada<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs4-chief.pdf |
| B-5 | Data Sources and Projection Methods for Successfully Supporting the Needs of the Senior Market (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3c-discussion.pdf |
| B-7 | Could Moses Live to Be 120? (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4-soa-informal-discussant.pdf |
| B-8 | Mortality Projections From a Social Security Perspective (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| B-13 | Discussant comments for session: Behavior and Causes of Death: Impact on Mortality and Mortality Modeling<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-olshansky-discussant-comments.pdf |
| B-14 | Discussant comments for session: Learning from Genetics |

| *Appendix reference* | **Paper** |
|---|---|
| | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-hayflick.pdf |
| B-15 | Discussant comments for session: Learning from Genetics<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-bakos-reply.pdf |
| B-22 | Discussant comments for session: Longevity and Cognitive Impairment<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-pokorski.pdf |

### 4.1.6 Selecting the appropriate projection model

Increasing life expectancy may have a number of consequences, including underestimation of certain forms of premiums, pension obligations, health care costs and long-term care obligations. Traditionally, actuaries have used a fixed and deterministic mortality assumption to price and reserve for life-contingent benefits. Now, because of rapid mortality improvements, the pure premium of annuity products computed from a period mortality table can be as much as 40 percent lower than that computed from a more accurate cohort life table.[A-54]

One method used to construct a cohort mortality table that computes pure premiums for annuity products is to use stochastic mortality models or deterministic mortality projections. As a result, stochastic mortality models have become an important tool for actuarial professionals in recent years.[A-54]

It is commonly accepted by the authors of the symposia material referenced in this section that calibrating an extrapolation to different time periods will lead to significantly different results. It is also commonly accepted that the effects of current and recent medical advancements can be incorporated, but major future developments (such as a cure for cancer) are difficult to predict and model.

There is, however, modest consensus with respect to the techniques employed. In particular:

- Some practitioners calibrate experience to a published mortality scale and project future improvements for a set (or unlimited) number of years (for example, they may use 50 percent of the Scale G improvement rates and project continued improvements for 10 years).
- Some practitioners, particularly in reinsurance and capital markets, use more sophisticated techniques such as stochastic modeling.
- There are significant limitations when projecting mortality by causes of death. Disease independence is a widely used assumption for projections, but it is unrealistic since diseases are either dependent or at least related to each other.[B-13]

Practitioners in different countries use different methods and assumptions for projecting mortality. For further information on the methods adopted by:

- The United States, refer to paper A-72.
- The United Kingdom, refer to paper A-73.
- Germany, refer to paper A-35.
- Canada, refer to paper A-154.

In addition to a low level of consensus, there are a number of unanswered questions that should be the focus of additional efforts.

- Will life expectancy continue to increase at the same pace it has since the middle of the 19th century?
- How can companies mitigate risks associated with major technological advances in medicine? What are some ways to model these risks?
- What are some mechanisms for assessing the utility and validity of more sophisticated, multivariate projections?
- Will policyholder behavior vary as longevity patterns continue to shift, and how should that be incorporated in modeling and planning?
- What can life actuaries learn about predictive modeling from property and casualty, reinsurance, capital markets and life settlements? Can life actuaries learn from other industries? From other countries? Can this lead to guides or practices for principle-based reserving?

- When is it appropriate to use age cohorts for projections? What should be the size of the age groups?
- What will be key drivers of future mortality? How will these vary by age group or cohorts over time?

This section provides an overview of papers that discuss models and modeling techniques. In addition, this section illustrates the results of using those models to project U.S. male mortality based on data in the Human Mortality Database as of 2011.

#### 4.1.6.1 Selecting an appropriate model

Several classes of extrapolation models were presented at the conferences. A practitioner must first consider the merits and drawbacks of each type before choosing one.

In general, mortality projections use extrapolative approaches based on historical patterns and trends. Some projections may use only statistics to extrapolate mortality rates; others may involve expert opinion and judgments. Still others may focus on extrapolating the causes of death to form a process-based extrapolation.

In the United Kingdom, actuaries considered using the mortality curves identified in section 4.1.3.1 for projections. The U.K. actuaries applied a time series analysis and extrapolated each of the fitting parameters to make projections. Their research found this approach relatively ineffective because it lacks stability in projecting the parameters of the underlying models.[A-36]

Actuaries built another class of models that specifically project mortality rates. Instead of obtaining the best fit to current data, these models aim to capture structural changes over time. This process is simpler than the complex process of projecting best-fit curves into the future. Many researchers have found historical mortality to be remarkably stable over time, prompting them to utilize these statistical extrapolation models.

A third class of models, a process-based approach, relies on an extrapolation of the causes of death (instead of historical mortality rates). The problem with this model is its reliance on causes of death, for which data may not be reliable or readily available. Gaille and Sherris noted long-run equilibrium relationships (i.e., dependencies) exist between the five main causes of deaths across 10 studied countries. As noted in section 4.1.5.3, the common assumption of independence between mortality rates for causes of death is unrealistic, and new forecasting mortality models should take this dependency into account. They also observed that countries have differing patterns of improvement across causes of death, which led them to conclude that a future shock in some cause-specific mortality rate (e.g., a cure for cancer) will not have the same impact across countries.[A-132]

Literature discussing the selection of an appropriate statistical extrapolation model is quite involved, and currently there are not many presentations on the topic—perhaps because of the topic's heavily technical nature. The current lack of information on the subject would make it a good area of focus for symposia conferences in the future.

As interest in projection models has gained traction, a number of more subtle considerations also arise that are just as important as selection of the projection model itself. Some of these subtle considerations include the handling of outliers and the construction of prediction intervals.

#### 4.1.6.2 Important considerations for extrapolative techniques

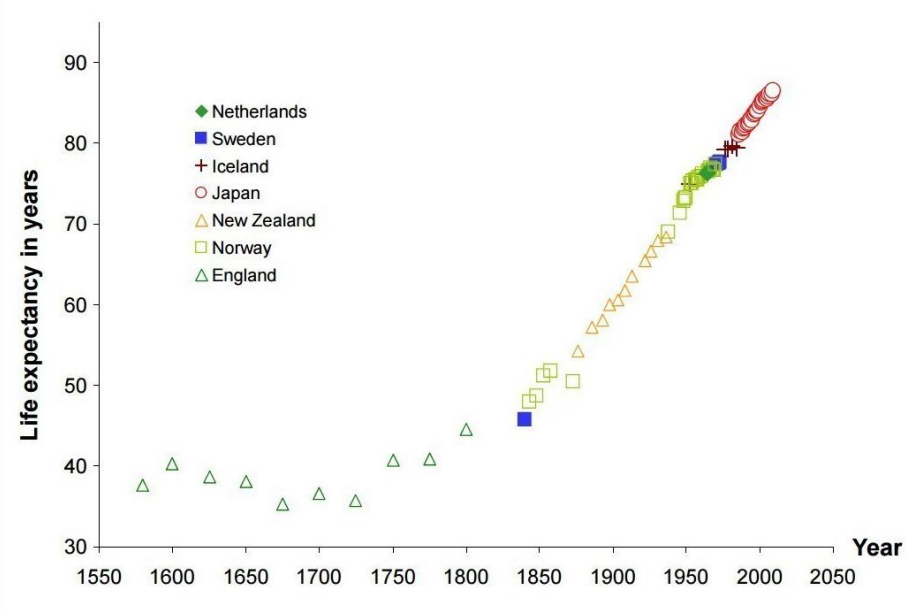
This section summarizes some of the considerations one must take into account when applying the projection techniques from above.

- Continuity of life expectancy increases: A key point of discussion in the longevity projection debate is whether life expectancy can be projected constantly and permanently into the future or will it eventually reach a plateau. James Vaupel supports the former notion: Life expectancy has increased constantly in recent history and will continue to do so. According to Vaupel, this linear extrapolation

of mortality improvement rates has been able to predict all increases in global life expectancy from the early 19th century onward. He notes how every past method used by national organizations, as depicted in Figure 16, have failed to predict historical life expectancies and even the ultimate limit to human life expectancy. However, linear extrapolation has been the only method to not fail historical forecasting. While it is generally accepted that past improvements cannot forecast future improvements, the resulting progress from past improvements has been linear and is expected to remain linear for the foreseeable future, as it is believed society will continue experiencing breakthroughs, including:[B-1]

- Progress made against cancer, dementia and developing genotype-specific therapies
- Regenerating and rejuvenating tissues
- Replacement of deleterious genes
- Nanotechnologies possibly enabling introduction of "nano-robots," capable of physically combating diseases and fixing other medical problems

Figure 16: Global historical record life expectancy[2]




On the other hand, Stephen Goss, chief actuary for the U.S. Social Security Administration, noted how researchers and clinicians who are actually developing new technologies are less optimistic about mortality improvements from future innovations. He also noted that past improvements in life expectancy have been attributed to avoidance of deaths at younger ages, and that for the later part of the 20th century, mortality improvements have been shifting from occurring at younger ages to occurring at older ages. This implies larger health breakthroughs will be needed at these older ages to sustain the improvement levels observed in the 20th century.[B-8]

- Outliers: The mortality rate time series, or the time series for other factors such as smoking prevalence, often has outliers in the data points that can heavily influence the best estimate and estimated volatility of projected mortality rates. Outlier detection and adjustment techniques can be used to lessen the influence of outliers and develop a more robust best estimate. Methods identified

[2] [B-1] presentation https://www.soa.org/Files/Pd/2014/living-to-100/2014-orlando-livingto100-gen-session-1.pdf

in the conferences include time series outlier detection and adjustment mechanisms,[A-23] as well as the use of quantile regression in place of least squares regression to lessen the influence of outliers in the estimation process.[A-89]

- Structural changes: Although the time series data for mortality rates has been fairly stable historically, some symposia presenters have detected structural changes in the time series, e.g., a permanent increase in the mortality improvement rates. Statistical methods are presented to both detect such changes as well as to handle any such effects in analysis. The detection and understanding of structural changes help inform the historical time periods that should be used for calibrating the extrapolations.[A-64], [A-89]
- Prediction intervals: As projections inherently involve uncertainty, often it is just as important to properly develop a range of projected outcomes as it is to develop the best estimate. Some papers note that prediction intervals produced by the Lee-Carter model appear to be very narrow. It has also been observed that point-wise prediction intervals can understate the uncertainty a practitioner wishes to capture. As a result, it is suggested professionals use time-simultaneous prediction intervals and Chebyshev bands instead. Further information on this consideration is provided below.[A-81], [A-92]
- Cohort effects: The existence of cohort effects is well documented and researched in U.K. literature, and some papers presented consider how cohort effects can be incorporated into extrapolative models. The existence of the cohort effect is less clear in other countries.[A-54]

  It should be considered if the abnormal mortality improvement rates experienced by the cohort will eventually converge to a long-term improvement factor used by other cohorts, as projected by the Office of the Chief Actuary in Canada, or if the abnormal mortality improvement rates will be sustained through time, as projected by the U.K. Government Actuary's Department.[B-8]
- Joint models:
  - Some have explored the use of extrapolation models that can combine different populations, thinking that the larger data set would be more credible and useful for modeling correlations between different populations.[A-90]
  - In particular, researchers have studied how joint models can aid in calibrating age-period-cohort models and provide a high degree of flexibility to combine data-driven extrapolations with expert judgment.[A-137]
  - Johnny Li also mentions how joint mortality models, by design, are very suitable for use in the quantification of population basis risk in longevity hedges.[B-16]
- Parameter uncertainty: There is inherent uncertainty in the parameter estimation process, and the inability to recognize this issue can lead to predictions that imply more certainty than may be appropriate as demonstrated by the width of the prediction interval. To counter this effect, parameter uncertainty could be reflected to create more representative prediction intervals.[A-89]
- Disease dependency: Estimates of the rise in life expectancy with the hypothetical elimination of various diseases have been a part of standard actuarial/demographic analysis for decades. However, diseases are not independent of each other and their dependency should be taken into account in an ideal projection model. In particular, S. Jay Olshansky noted that cause-elimination life tables could result in biased projections of life expectancy due to disease dependence.[B-13]
  - Overestimating life expectancy is possible since those hypothetically saved from death by one disease are being placed back into the risk pool with an altered profile as their bodies experience competing risks from other diseases due to the dependency.
  - Underestimating life expectancy can be possible as well. Since diseases are dependent, if death rates are declining due to improved risk factors for fatal diseases, then risk-factor modification would have an amplified effect by favorably influencing multiple diseases simultaneously.

Gaille and Sherris showed disease dependency does not operate in the same way across different countries; the authors concluded cause-elimination models from one country's population should not be used to extrapolate across another country's population.[A-132]

The following sections illustrate why the considerations from above are important by applying projection modeling techniques to U.S. SSA data and assessing the results with and without these adjustments.

1. Prediction intervals[A-89]

We implemented the time-simultaneous prediction interval and Chebyshev bands for both the Lee-Carter model and the Cairns-Blake-Dowd CBD model and compared the results to the original Lee-Carter model point-wise prediction interval..

Figure 17 compares the projected mortality rates using a Lee-Carter model for a person age 65 today. The 2.5th and 97.5th percentile bands are shown using the point-wise method, as well as the time-simultaneous and Chebyshev methods. The areas between the bands are set to cover 95 percent of the distribution.

Two observations are worth noting.

- The prediction intervals under the Lee-Carter model are fairly narrow and stay narrow over time, i.e., the level of uncertainty remains constant over longer projection horizons. This result—that predictions are as certain 40 years out as they are 20 years out—is counterintuitive. One technical explanation for this is that the Lee-Carter model may be too structured. The uncertainty implied by the model is given by the improvement index parameter; as this generally decreases with age, uncertainty can be understated especially for older ages.
- Although not readily apparent from the graphics, there is actually a material difference between the time-simultaneous bands and the point-wise prediction intervals. On average, the difference is more than 5 percent, with largest differences of more than 9 percent. The prediction bands are not symmetric as there was more variability at higher levels of improvement than at lower levels of improvement (i.e., the potential for higher improvement than expected is greater than the potential for lower improvement than expected). The difference is more pronounced when one considers how the uncertainty may actually be used. Consider the following example: An insurance company may set the capital levels to cover the 97.5 percent path. On average, the 97.5 percent improvement is 20 percent higher than the mean improvement rate under the point-wise prediction intervals but is 25 percent higher under the time-simultaneous prediction intervals. The 5 percent difference in liability values actually translates to a 25 percent difference in capital levels [(25% − 20%)/20%].

Figure 17: Prediction interval generated by the Lee-Carter model

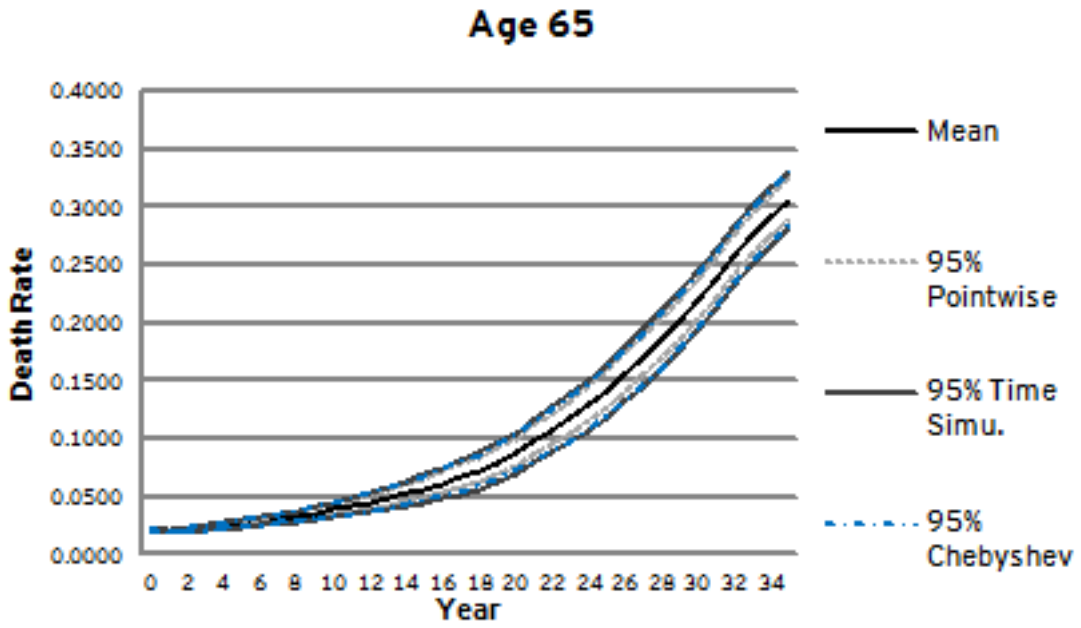
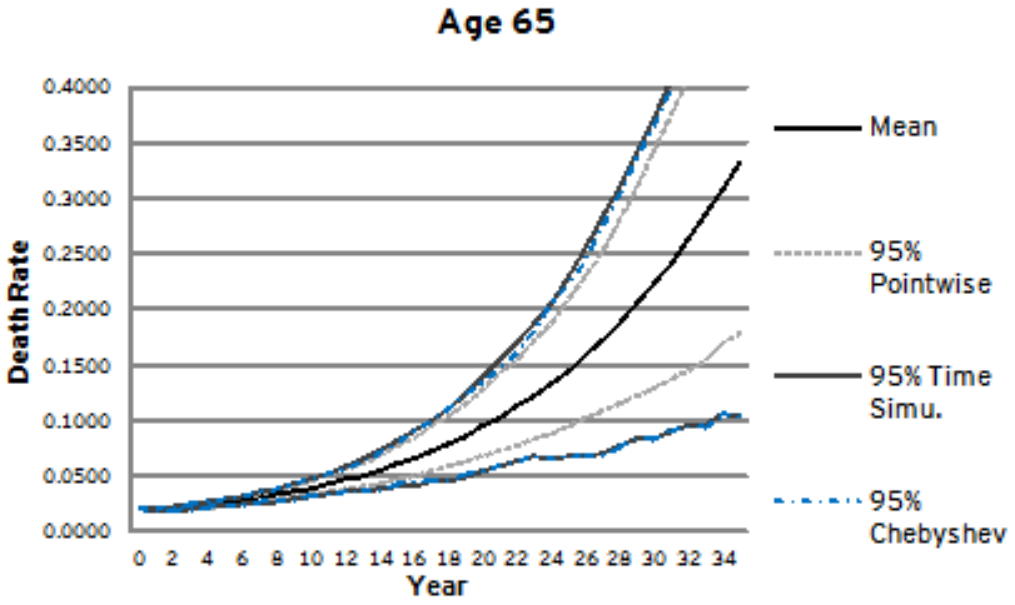



Figure 18 shows the corresponding results for the CBD model, which is similar to the Lee-Carter model but incorporates period effects in addition to age effects. The 2.5th and 97.5th percentile bands are shown using the point-wise method, as well as the time-simultaneous and Chebyshev methods.

A couple of items are worth mentioning.

- The prediction intervals under the CBD model are much broader: on average, 97.5th percentile mortality rates are 40 percent lower than the best estimate, and the difference grows over time to 70 percent.
- There is a clearer differentiation between the point-wise prediction intervals and time-simultaneous prediction intervals. The difference is more pronounced on the lower end of the mortality rates, where the time-simultaneous prediction is 20 percent lower than the point-wise prediction, and grows to more than 40 percent. Again, the difference is more pronounced when considering the implied capital levels an insurance company may hold—in this case, the average capital level would be 50 percent higher under the time-simultaneous method than under the point-wise method.
- This example helps to illustrate that both the selection of the base projection model (in this case, Lee-Carter versus CBD) as well as the prediction interval metric (point-wise versus time-simultaneous) can significantly impact the calculated results such as capital levels. In our theoretical example, the use of a CBD model leads to capital levels two to three times higher than those under a Lee-Carter prediction, while the prediction interval metric can lead to a further 25–50 percent difference. Other model differences can further compound these differences.

Figure 18: The prediction interval generated by the CBD model




2. Outliers

Another area popular with symposia presenters was the topic of trends and outliers in the mortality data. The paper "The Lee-Carter Model for Forecasting Mortality Revisited"[A-23] provides an excellent reference on outliers identified in the U.S. and Canadian data that practitioners may find helpful. The next few pages investigate a relatively simple method that aims to lessen the impact of outliers through a small change in the parameter estimation process. The paper's authors, Johnny Li and Wai-Sum Chan, propose professionals estimate parameters in extrapolation models by using quantile regression rather than the more typical least squares regression, arguing the former is a more outlier-robust method.

In the original Lee and Carter paper, the drift term for the mortality index, $k_t$, is estimated using least squares (LS). Recall the Lee-Carter formula is $\log(m_{x,t}) = \alpha_x + \beta_x k_t$. The resulting estimation is very sensitive to the first and last years of the data and not robust against outliers and extreme abnormal values.

Under the quantile regression (QR) method, estimation is matched to the specific quantiles (e.g., the median) of the response variable, unlike the LS method, which provides estimates that approximate the conditional mean of the response variable. The motivation for the QR method comes from the recognition of outlier events such as the 1918 Spanish flu epidemic and the 2003 SARS outbreak. It should be noted that the goal here is not to ignore the complexity of outlier events, but rather to develop a robust estimate that represents a more "normal course of business"—one not influenced by extreme events.

Under QR, the mortality index is fit to a random walk with the drift parameter estimated using the median (not the mean, as in LS) of the observed differences in $k_t$. The drift uncertainty is calculated using the sample standard deviation of the observed differences, as it is in LS.

We modeled the number of deaths using the Poisson model commonly employed in the mortality modeling literature, as proposed by Brouhns et al. (2002)[3]. We used data from the Social Security Administration's

[3] Brouhns, N., Denuit, M., and Vermunt, J. (2002). A Poisson log-bilinear regression approach to the construction of projected lifetables. Insurance: Mathematics & Economics, 31(3):373–393.

Historical Mortality Rates database for the period 1900 through 2007 for males. This serves to estimate initial parameters using maximum likelihood. Next, we simulated 1,000 scenarios using both LS and QR.

The drift parameters between LS and QR (the mean and median respectively) showed small differences:

| | | |
|---|---|---|
| LS | -1.58 | 3.78 |
| QR | -1.71 | 3.78 |

The difference between drifts suggests the possibility of outliers in the underlying data that may have increased mortality rates and thus the mortality index using an LS method.

In figures 19 and 20, we use the same data set to show the difference in mortality rate estimation ($q_x$) under both QR and LS approaches.

Figure 19: Difference between QR and LS by age

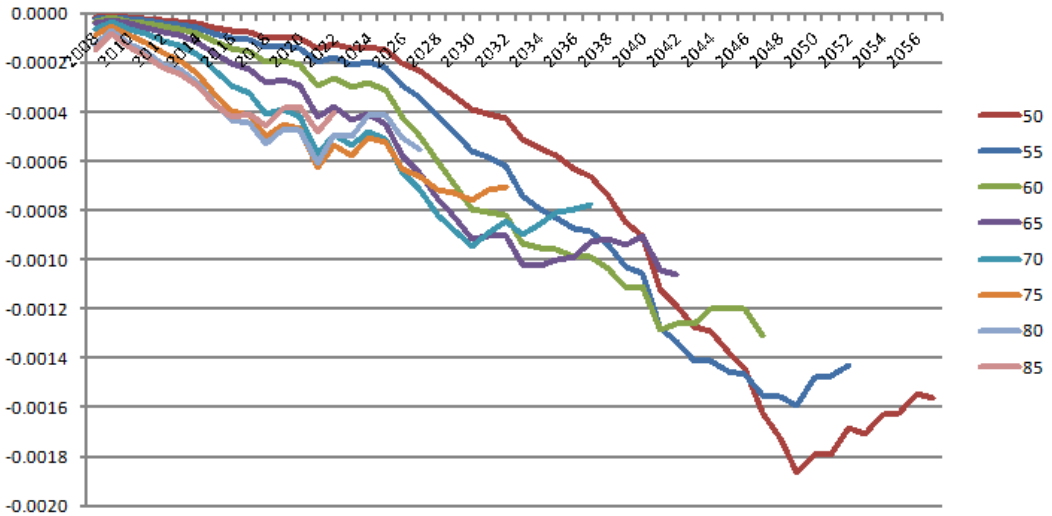
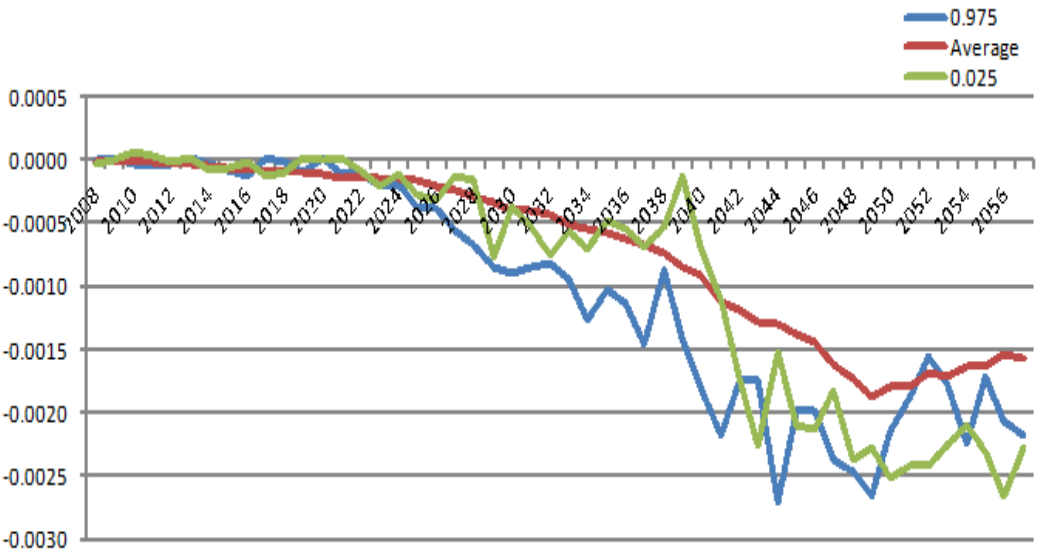


Figure 20: Difference between QR and LS at age 50




The QR average estimates of $q_x$ tend to decrease over the projection period—a consequence of the lower drift (−1.71) assumed in QR. In addition, the 97.5 and 2.5 percentiles show more volatility in the late years, which is a result of the compounding volatility in ARIMA(0,1,0). Still, both percentiles are lower for QR than for LS.

In figures 21 and 22, we show the impact of both models in life expectancy for newborns.

Figure 21: 2007 newborn life expectancy distribution

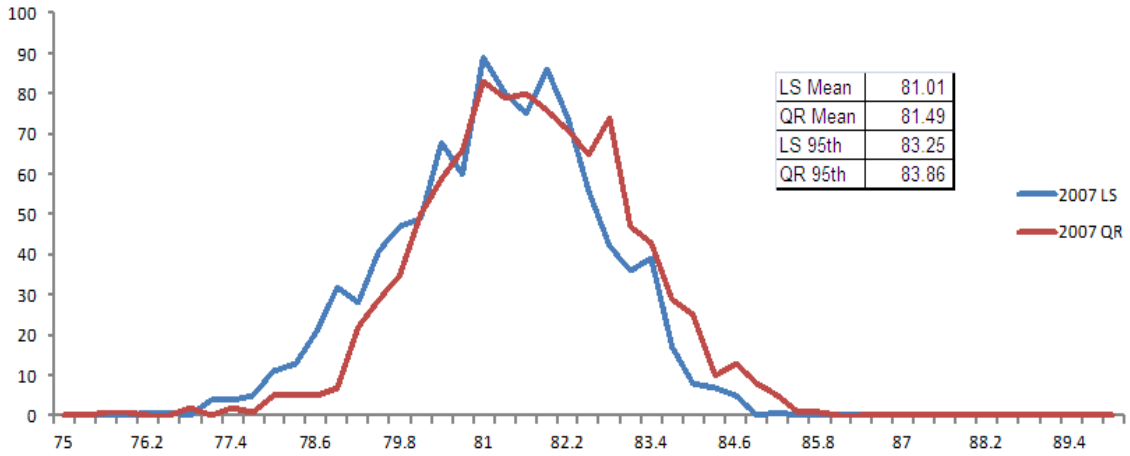
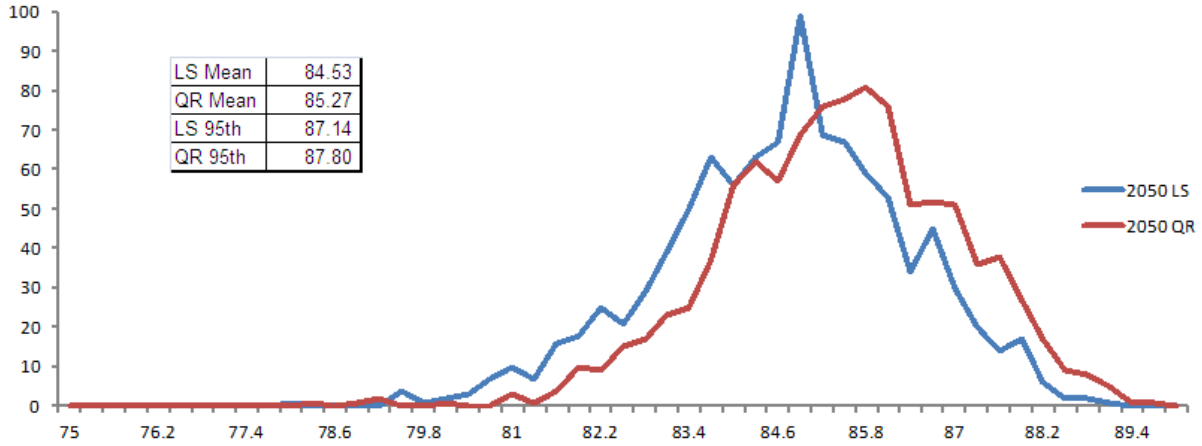


Figure 22: 2050 newborn life expectancy distribution




Here it is apparent that QR can lessen the impact of outliers by using the median of the observed Lee-Carter mortality index when projecting central death rates. The uncertainty measure ($\sigma$) is also impacted by using QR to the effect that—in the presence of outliers—its estimate is higher than under LS, resulting in more variability in the results. Both effects are desirable in actuarial considerations.

The graphs presented in this section demonstrate that the forecast performance of the Lee-Carter model can be improved with the implementation of a simple method such as quantile regression.

#### 4.1.6.3 Validation techniques

There are relatively few data sources available to validate the forecast produced by the models described above. As a result, the focus of many technical papers has been on exploring different techniques to enhance the predictive power of the resulting forecast.

James Vaupel cautions practitioners who compare improvement rates for a particular age group from different time periods. In particular, age 80 from 1950 is not the same as age 80 in 2015. A way to circumvent this issue would be by comparing ages when the force of mortality was the same in the studied periods, or compare the ages when the remaining life expectancy is—for example—10 years in the studied periods.[B-1]

Below are some highlights on how mortality improvement projections are validated for different social security programs:

- The U.S. SSA Office of the Chief Actuary, which projects mortality by cause of death in order to obtain projected aggregate mortality, considers past improvement trends within each category and ensures the projected individual mortality improvements are reasonable. Future outlook in new biomedical advancements is also consulted on by industry experts.[B-8]
- To improve understanding on the validity of projections, the Canadian Office of the Chief Actuary analyzes sensitivity of projected mortality rates through implementing different long-term mortality rate assumptions. In particular, the mortality rates are analyzed using a combination of a deterministic model based on judgment with a stochastic time series model.[A-154]

#### 4.1.6.4 Relevant symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-23 | The Lee-Carter Model for Forecasting Mortality Revisited<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xi.pdf |
| A-35 | Coping With Longevity: The New German Annuity Valuation Table DAV 2004 R<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xvi.pdf |
| A-36 | Mortality at Advanced Ages in the United Kingdom<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxi.pdf |
| A-54 | A Study of the Lee-Carter Model With Age-Shifts<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6a-huang.pdf |
| A-64 | Testing Deterministic Versus Stochastic Trends in the Lee-Carter Mortality Indexes and Its Implications for Projecting Mortality Improvements at Advanced Ages<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6a-chan.pdf |
| A-81 | Temporal Evolution of Some Mortality Indicators. Application to Spanish Data<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1b-debon.pdf |
| A-89 | Assessing and Extending the Lee-Carter Model for Long-Term Mortality Prediction<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2b-liu.pdf |
| A-90 | Coherent Mortality Modeling for a Group of Populations<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2b-yang.pdf |
| A-92 | Simultaneous Prediction Intervals: An Application to Forecasting U.S. and Canadian Mortality<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-3b-li.pdf |
| A-132 | Causes-of-Death Mortality: What Do We Know on Their Dependence?<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-arnold.pdf |
| A-137 | Coherent Projections of Age, Period and Cohort Dependent Mortality Improvements<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-borger.pdf |
| A-154 | Mortality Projections for Social Security Programs in Canada<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs4-chief.pdf |
| B-1 | The Advancing Frontier of Human Survival (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1-soa-informal-discussant.pdf |
| B-8 | Mortality Projections From a Social Security Perspective (informal discussion transcript)<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| B-13 | Discussant comments for session: Behavior and Causes of Death: Impact on Mortality and Mortality Modeling<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-olshansky-discussant-comments.pdf |
| B-16 | Discussant comments for session: Mortality Age Patterns: Trends and Projections<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-lid-discussant-comments.pdf |

## 4.2 Part 2: The social and economic implications of an aging population

Increasing longevity has been creating new challenges and opportunities for society at large and particularly

> Aging populations create opportunities and challenges for both the private and public sectors. While the basic issues are very similar in many countries, the solutions vary. Big questions today include: How does population aging change the mix of products and services needed? When and how should people be able to retire and how much retirement support should come from public programs? How will long-term care be provided and financed? What should be the role of the family? Some countries provide much more generous public benefits than others, but often these are being cut back as the population ages. Many countries need to deal with the appropriate roles of the individual, government and the private sector as solutions emerge. For individuals interested in looking at different solutions by country, the OECD [Organisation for Economic Co-operation and Development] and the Mercer Melbourne Global Pension Index are good resources to get started.
>
> Anna Rappaport, FSA, EA, FCA, MAAA, Anna Rappaport Consulting

for the retirement income industry around the globe. As a result, we have to start re-evaluating how we allocate individual, family and societal resources so we can most effectively support our growing life spans. Society also needs to think about what the labor force will look like and the products and services needed by the aging population. Symposia papers highlight a number of trends that have emerged, or are expected to result from continuing increases in longevity. These include:

- Integration of seniors into the workforce with new retirement designs and programs as pre-retirees continue to postpone their retirement
- Large increases in the number of elderly and the proportion of elderly in the population of developed countries
- The strain on private pension and retirement savings plans as engines for savings and capital accumulation
- The strain on public pension systems and other programs offering support for the elderly as they compete for public resources
- Increasing relevance of retirement planning for lower income individuals
- Increasing need for long-term care in retirement years and demand for innovative housing strategies for supporting the aging of the elderly
- Increasing shortages of both voluntary and paid caregivers
- Growth and increasing cost and utilization of health care systems, particularly due to the growing number of diseases with high old-age prevalence such as Alzheimer's
- Growth of financial solutions targeting elderly needs, including: target-date investment funds, fixed and variable annuities, long-term care insurance and, in some countries, health insurance
- Increasing demand for affordable individual insurance products with guaranteed income and ability to effectively manage longevity risk
- Rising demand from institutions desiring longevity risk protection through the use of reinsurance, capital markets solutions and pension de-risking strategies

Symposia paper "Living to 100: Socioeconomic Implications of Increased Longevity" also notes potential socioeconomic implications should longevity continue to increase. Some of the discussion points mentioned include:[A-146]

- Increased investment in higher education due to the longer time horizon the investment will pay out
- Equities having greater relevance for individuals as the investment horizon becomes longer
- Social acceptance of extended longevity, even if medically possible, if the quality of life that follows is poor
- Potential for multiple careers to become more common in the workplace, partitioned by periods of additional education

These changes will have large impacts on all of society, but they will be particularly troublesome to those age 80 and older (who are almost twice as likely to have a severe disability as their younger counterparts), not to mention the most exposed group who, in the U.S., consist of elderly females who are unmarried and more likely to be poor.[A-20]

Females will experience unique difficulties due to higher life expectancies and different life histories from males. Within the U.S., the following challenges have been identified:[A-106]

- Outliving assets is a larger concern for females than males due to their higher life expectancies and, in aggregate, lower pension benefits due to their different work histories from males.
- As women are traditionally younger than their spouses, they are more likely to experience the loss of a spouse and an ensuing decline in standard of living. Furthermore, women are more likely to need paid care since their spouses aren't alive anymore to take care of them.

As experts attempt to respond to the challenges and opportunities created by increases in longevity, conflicting viewpoints have emerged. Some of the most contested issues appear to be:

- As people need to work longer to ensure their financial security, how will jobs and the employment relationship adapt to fit more seniors in the workforce?
- Should the standard retirement age change, and at what pace? How and when will people retire and what will retirement mean?
- As retirement needs are unique for each individual, what are the benefits and limitations of rules of thumb for retirement planning?
- What is the appropriate role of government, employers and individuals in providing retirement income and support for health and long-term care?
- How can society encourage and support the aging at home of the elderly population and informal support networks within communities?
- What is more important—duration or quality of life? Is living longer a desirable goal, especially if it is accompanied by inadequate wealth and concerns regarding how to manage one's savings, or loss of mental faculties and a requirement for institutionalization?[A-67]
- Employers and insurance companies struggle to experiment with innovative solutions due to barriers arising from strict legislation and regulations. How should the government modify its mandates to encourage innovation within the private sector and provide legal safe-harbors to their experimental designs?[B-3], [B-9]
- How can society better educate the public on how to achieve financial security, including the importance of retirement planning, the risk of outliving one's assets, and the role of long-term care and health insurance in their long-term planning?
- How can the interests of financial advisors and their clients be better aligned?

The following sections summarize the implications of longevity on an aging workforce, retirement income programs, long-term care programs, health care systems and product innovations within the private industry

to the extent presented in symposia materials. We note that considerable research has been done by the SOA[4] and other groups on these topics beyond what is included here; the focus of this paper is solely on those articles presented for the Living to 100 symposia.

[4] https://www.soa.org/research/research-projects/default.aspx

### 4.2.1 Seniors in the workforce

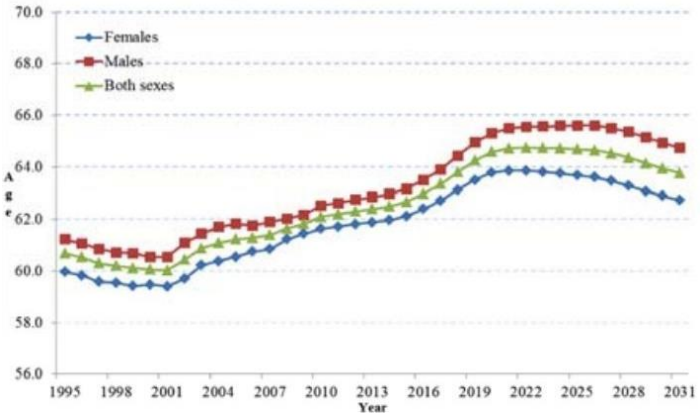
> It is in the best interest of the vast majority of individuals to work longer. It is also in the best interest of most economies and nations to have their workers working longer. If workers work longer, they will pay more taxes, contribute to GDP, rely less on entitlement programs, and ultimately become healthier and happier. It is in our best interest, individually and for our nations, to encourage people to work longer.[B-2]
>
> Sally Hass, independent consultant

One of the many implications of extended longevity is seniors retiring at later ages than in the past. This will ultimately lead to a greater proportion of seniors in the workforce relative to any historical period. With rising health costs, increasing life expectancy, volatile global financial markets and potentially unstable retirement systems, it is becoming imperative for seniors to retire past the traditional retirement age. Numerous benefits from the employment of more senior workers have been identified, including enhanced quality of the workforce and benefits to the economy as these individuals postpone their retirement and continue contributing to society.

However, as more seniors integrate in the workforce, there are several competing forces that need to be considered, such as: the need and capability of individuals to work longer, social stigmas with elderly workers, difficulty in designing and implementing new retirement programs and employers' reluctance to adapt due to uncertainties on how their operation will be affected. As societies design solutions to address these issues, it is important to recognize the interests and preferences of elderly workers themselves, as these solutions will affect them directly.

In Figure 23, Robert Brown shows the historical and projected average exit age from the Canadian labor force based on the Canada Pension Plan population. The baby boomers are already expected to retire two years later within the next decade.[B-17]

Figure 23: Average exit age from Canadian labor force[B-17]




One of the major obstacles in the U.S. society's adaption to a more senior workforce was identified by Anna Rappaport to be current age discrimination legislation, which could prove to be a two-edged sword, as it both protects people and discourages innovation. Rappaport noted how the inclusion of seniors in the workforce will be hindered by legal barriers to organizations' experimental offering of innovative programs.[B-3]

To facilitate the retention of elderly workers, people and employers alike need to start thinking differently about senior employment. It should be noted that, unless otherwise specified, the discussions below have been focused primarily on the U.S. market. Similar issues and circumstances also exist in other geographies with different legal environments.

#### 4.2.1.1 Benefits in employment of seniors

Benefits to employing seniors are not restricted to seniors themselves but also apply to their employers and the government.

Benefits for seniors include:[B-2]

- An improvement of their retirement financial resources and financial security.
- Contentment and self-satisfaction; in a survey of 200 employees at one company, Sally Hass identified the majority of respondents stated they wanted meaningful work in their last years of employment.

Benefits to employers for hiring and retaining their senior employees include:

- A high correlation between an older workforce and customer satisfaction, something especially desired by retail stores.[B-3]
- Lower turnover as older workers' tenure is three times longer than that of younger workers.[B-4]
- Lower risk of losing knowledge across generations of their workers and, consequently, increased knowledge transfer across generations.[B-3]
- Building affinity with elderly customers who will continue to make up a larger part of their customer base as baby boomers age.[B-4]
- A positive reputation among customers for being community supporters.[B-4]
- Reducing longevity risk in their pension obligations as their employees start retiring later.[B-4]
- Elongating the careers of existing talent and continuing to benefit from their experience and knowledge.[B-3]
- Promoting the firm's growth and helping prepare the next generation of technical and managerial talent.[B-3]

Benefits to the government in facilitating employment of seniors include:[B-2]

- Collecting more income tax as pre-retirees are taxed more than retirees.
- Employed seniors continuing to contribute to GDP on a nationwide scale.
- The increasing dependency of the aging population on entitlement programs slowing down as retirement is delayed.

Retained baby boomers in the workforce will help postpone the impending labor shortages from the incoming mass retirement of these generations of workers.[B-2]

#### 4.2.1.2 Challenges faced by senior employees

By remaining part of the workforce into later phases of their lives, senior employees will challenge the status quo of what has been the norm for numerous decades. This will bring many challenges that include:

- Losing technical skills over the years after having taken on managerial roles for the more recent part of their careers. If they want to return to the workforce as an individual contributor rather than a manager, they will have to be willing to improve their technical skills.[B-2]
- Having their employers maintain their defined benefit pensions despite decreasing wages for working less through flexible scheduling. Even if the defined benefit formulas are adjusted, it will take time until this information flows through the entire range of pre-retirees.[B-3]
- Having health constraints. Although the need is present for employees to retire later, not all people can be expected to work longer because of the state of their health. Some retirees are simply not mentally or physically fit for working longer. The need exists for tying health behaviors to longevity in new, innovative ways so people are healthy enough to work longer and retire later.[B-2]
- Taking a job for which they are overqualified and, if they are hired, reporting to a younger boss. This is especially important as younger bosses might believe their job security is threatened if they hire an outstanding employee to report to them.[B-4]
- Overcoming preconceptions about the elderly in the workforce and maintaining a positive mindset despite the perceived age bias.[B-4]
- Staying positive during the job search. Data from the U.S. Government Accountability Office shows it takes twice as long for an older worker to get rehired once they are out of work.[B-4]
- Altering their ideal choice of firm and opting for the more age-friendly employers.[B-4]
- Modifying their personality to embrace new technology and be accepted by younger workers.[B-4]

Anna Rappaport mentioned the following findings from SOA focus groups on resource-constrained retirees with a medium level of assets who had retired voluntarily:[B-2]

- The great majority of them had been "pushed" to retire due to difficult job environments, family issues and health problems. Only very few were retiring to meet their dreams.
- The median age at which these retirees had retired from their main long-term job was 58, which is significantly lower than the expected retirement age of 65. This finding has also been found consistent across surveys.

In today's world where employers tend to hire people older than 50 for nonmanagerial/junior roles only when there are not enough applicants in their preferred age range, it is important for elderly workers to maintain a positive outlook as they facilitate the gradual introduction of elderly people in the workforce.[B-4]

#### 4.2.1.3 Challenges faced by employers

Such a paradigm shift will also create challenges for the employers of seniors. To prepare themselves for the future, employers will need to ask themselves a number of challenging questions.[A-105]

- What challenges and opportunities do the aging society and changing workforce create for the management of talent?
- What challenges are created for the management of active employees as well as benefits of retirees?
- Does the aging of parents create special challenges for the employers of their children, who may be part of the sandwich generation?
- Are there barriers against innovation within retirement programs that discourage employers from seeking solutions?
- Is phased retirement a good idea and how should it be supported and managed by employers?

In a heavily regulated world, some legislation might restrict the flexibility employers have for exploring solutions and making an informed choice. Although regulations have been created for protecting seniors against age discrimination, they have been found as well to discourage innovation.[B-3]

- Current regulations have potential to bring on lawsuits against firms who carry out research on their own workforce. This restricts companies from learning about arguably their single biggest collective investment: human capital. In particular, a study found only 25 percent of the Fortune 500 companies had researched and analyzed the data on their workforces.
- Experimental designs and retirement programs are held back by legal barriers and concerns for mass lawsuits.
- Bona fide terminations, required to get lump sum distributions and pension payments, are abrupt and quick. There is the need for gradual phase-outs from the workforce rather than sudden termination.
- Although the Pension Protection Act authorized phased retirement plans, very few employers have adopted these new plans.
- While employers can easily educate employees about retirement, they cannot easily advise employees on retirement plans as they can get sued if they do not give their advice with caution and carefulness. Being a relatively unnecessary liability, this can discourage most employers.
- In informal settings, retired executives from major organizations admitted their firms were not hiring older workers due to the fear of frivolous age-bias lawsuits.

Talent strategies that are effective for the business vary depending on the company's business profile. Mature organizations in low growth mode usually undertake the "build strategy" for talent; they nurture talent at home and maintain low levels of employee turnover. Success of this internal labor market (ILM) structure depends on the periodic availability of a relatively high number of jobs and positions for its own employees to apply for and fill. The dynamics of this ILM are at risk of becoming stalled when employees delay their retirement. The ensuing low promotion rates and low quantity of lateral moves invites the possibility of early career employees, who are bringing new skills and perspectives required for future business success, to leave the firm in search of career growth. Delaying retirement has the potential to negatively impact these types of mature organizations in the absence of growth.[B-3]

In the end, the employers themselves might be an obstacle when it comes to implementing new retirement strategies.[B-3]

- Age of leadership: Younger leadership will not be as inclined to adopt new retirement solutions as opposed to older leadership who will be encouraged to since it will affect them sooner.
- Profitability of the company: Companies in volatile markets will not devote as much time to research these solutions further.
- Expanding too quickly: Even if the desire is there to explore solutions for an aging workforce, rapid expansions spread their resources thin, making it hard for the company to invest resources in exploring human resources solutions.
- Type of industry: Employers who require skill sets not being learned as frequently by students (e.g., welding or manufacturing) will invest more in an aging workforce than in students. Some occupations are in very short supply among new workers.
- Product life cycle: Short-cycle firms will not be interested in adapting careers to an aging population, as opposed to long-cycle firms who might be building airplanes and find it difficult to find an experienced employee who has long experience and firm-specific knowledge.

Other challenges for employers include:

- Preparing for a change that will take a multi-year timeframe to implement. Sally Hass identified that firms usually aim to finish the creation, design and implementation phases of a new retirement plan within a multi-month instead of a multi-year approach.[B-3]
- A sufficient talent pipeline and growth of economy. With new staff readily available, employers will not be willing to adjust to an aging workforce.[B-2]
- Lack of trust developed from their employees. Employers cannot keep on breaking their promises made to their employees when their pensions are not what they expect.[B-2]
- Flexible determination of work term for employees. There are pre-retirees who may want to leave their corporate job and take on a nonprofit job instead.[B-3]

#### 4.2.1.4 Proposed solutions for addressing challenges

Solutions to address the challenges stated above are few and far between as these concerns are relatively new. However, symposia discussions have noted the following possible suggestions.[B-3]

- Statistics on workforce characteristics and quality should be published in financial statements by mandate. This will help investors gauge if the company has talent and potential, as well as allow companies to carry out much needed research on their workforce.
- Legislations and regulations should be revisited and reviewed carefully and ensure they are not restricting employers when it comes to undertaking new solutions; diversity-related laws and regulations should not end up functioning as an obstacle to innovating and learning.

To accommodate more elderly workers in the workforce, society will need to consider adopting innovative solutions that align the interests of seniors with those of their employers. Since these new designs will imply pre-retirees work longer, their expectations and preferences for work should be taken into consideration as society constructs possible solutions.

- Some pre-retirees have expressed interest in being demoted or moved into different types of roles, rather than promoted, when contemplating a new position. Having spent the majority of their more recent working life in managerial positions, pre-retirees are more interested in becoming individual contributors than managers.[B-2]
- A survey conducted by Sally Hass on 200 U.S. senior workers from one company found that the respondents wanted input as to what work they would be assigned; they were mainly interested in finding meaningful work.[B-2]
- Some pre-retirees want to be able to work not just from home, but also from unconventional places such as a park or a café.[B-3]
- Several studies have shown pre-retirees' biggest concern about retirement is not monetary; about 25 percent of pre-retirees mentioned it was to remain productive and useful.[B-2]

1. Phased retirement

As the name suggests, phased retirement involves a gradual transition from being a full-time member of the workforce, to a less participative employee and, eventually, to a retiree. These types of programs are relatively new and are being tested by employers. Don Fuerst notes the following four components of a phased retirement plan:[B-3]

- Leave-of-absence program: This allows retirement-eligible employees to request an unpaid leave of absence for a full year, but with the commitment of returning to employment status before they

formally retire. This provides their employees with the opportunity to experience retirement and assess their level of satisfaction with the experience.

- Part-time employment program: Pre-retirees are able to request a reduced work schedule as long as they work a minimum of 20 hours a week. Vacation and sick leave are then prorated based on these hours worked and retirement accruals are based on actual hours worked and salary earned.
- Casual employment: The firm can rehire retirees on an as-needed basis, with the retirees retaining the flexibility to accept the return offer or not. Ideally used for surge work or special projects, this provides the firm with the benefit of rehiring ex-employees on temporary contracts who do not need to be brought up to speed or trained and can contribute immediately.
- Consulting: Retirees in very specialized and highly technical areas are hired as consultants on an as-needed basis, such as a complex project requiring knowledge from staff with decades of experience.

Companies are just beginning to explore this type of solutions; Fuerst suggests further research on how this would affect the phased retirees' eligibility for health care under the new Affordable Care Act and Social Security benefits.[B-3]

2. Other options

In addition, the following recommendations should also be closely considered by employers.

- Flexible schedule
  - Since people work 50+ years over their lifetime, Gary Mooney noted how employment in their elongated work years cannot be 49 weeks annually with only three weeks off.[B-2]
  - Sally Hass noted how out of 200 interviewed U.S. pre-retirees, the majority not only wanted a reduced work schedule, but flexibility as well that allowed them to work 10 hours one week, 40 the next, none the week after and so on. To introduce flexible scheduling, Hass recommends employers change their benefit eligibility rules. For example, instead of stating pre-retirees have to work 25 hours a week, it should state they have to be scheduled to work 25 hours a week, but variations are possible and should be discussed with their manager.[B-2]
  - Robert Brown recommends employers redefine their pension system, as current payout structures, including those of defined benefit plans, discourage use of a flexible schedule with decreased retirement benefits.[B-2]
  - To accommodate these flexible schedules, perhaps youth, whose unemployment rates remain high, can fill in the gaps. If this approach is taken, software and models already exist that can handle a variety of work situations where people do not work many hours (e.g., flight crews).[B-2]
- As adults, especially women, are retiring early due to the need to provide elder care support for their parents, companies should consider enhancing their employee assistance programs with improved elder care support benefits. Knowing their loved ones are being taken care of will allow pre-retirees to work longer.[B-3]
- Long-term care insurance can be officered to employees and also their parents.[B-3]
- Monetary incentives, research shows, do not have significant effects on the retention of a worker.[B-3]
- Companies should provide more meaningful work to the employee—and keep in mind that "meaningful" is subjective.[B-3]

## 4.2.2 Social security and public support for retirement

> Social benefit programs are very important to the welfare of older citizens. As population demographics change and people live to older ages, pay-as-you-go programs must be adjusted to reflect the emerging reality. Raising retirement ages is a common part of proposed adjustments. This is often politically very difficult.
>
> Anna Rappaport, FSA, MAAA, FCA, EA, Anna Rappaport Consulting

Past trends in longevity have brought challenges to the financial health of social security and public support for retirement across multiple geographies around the globe. These challenges are only expected to continue as increasing longevity trends are forecasted to be sustained for the foreseeable future.

Most notably, the balance between retirees and non-retirees has been changing across multiple geographies due to various factors including declining fertility and mortality rates. This is particularly evident in the U.S. where such decline occurred after baby boomers began to retire, and now presents serious financial concerns for the U.S. Social Security system. Concerns also exist regarding people's failure to properly save for retirement, as well as the quality of the public program's benefits.

Social support systems are structured very differently among countries, both in the way they are funded and in the way benefit payments are structured. Social security systems may be supplemented by other programs to help targeted groups of aging citizens. Many countries, both in the developed and developing world, are facing challenges as they prepare to address the impact of increasing longevity on their retirement systems.

### 4.2.2.1 Challenges faced by social security systems

Increasing longevity affects a fundamental balance in society—the balance between contributors (workers who provide goods and services) and beneficiaries (retirees who consume without working). Upsetting that balance by increasing the number and proportion of retirees creates a growing burden for governments that offer retirement income systems and other social supports.[A-20], [A-63]

1. Societal support for retirement in developed nations

In the United States, the historical declines in mortality and fertility have endangered the solvency of the Social Security Old-Age and Survivors Insurance program. The program, which began in 1935, named 65 as the normal retirement age when life expectancy at birth was 61 years and life expectancy at age 65 was 12.5 years. Currently, there are many who argue the program is not sustainable now that the life expectancy at birth is 77 years and life expectancy at age 65 is 18 years.[A-63]

Furthermore, the oldest old currently receive nearly half their income from Social Security while only 18.3 percent comes from pensions and retirement benefits.[A-142] Partly as a result of Social Security, the percentage of men in the United States older than 65 who have retired has increased from 25 percent to more than 80 percent from the beginning to the end of the 20th century. However, there has been a recent reversal in the long-term pattern of declining work-place presence of the retired although the term "retired" seems more ambiguous with part-time work during retirement becoming more common.[A-140]

In particular, Stephen Goss, chief actuary for the U.S. Social Security Administration, noted how a larger part of the population older than 25 will be comprised of seniors as baby boomers continue retiring until 2030. Even after baby boomers die, the proportion of elderly people is only expected to increase. Goss noted how this higher proportion of elderly people will be the cause of the main challenges to be faced by the U.S.'s Social Security Administration.[B-8]

In Canada, long-term projections show the country's public retirement-income provision is currently financially sustainable. Population aging will naturally increase public pension spending, but both the rate of growth and current expected lifetime are lower than those of many OECD countries. Moreover, the earnings-related schemes (Canada/Quebec Pension Plans) have built up substantial reserves to meet these future liabilities. In contrast, private pensions, especially among low- and mid-level earners, are less than complete. While the lowest earners will achieve target replacement rates via public pensions, mid-level earners will not. While mid-level earners should be able to fill their pension gaps with voluntary retirement savings, there are still concerns about the government plan's shortcomings.[A-99]

This debate has implications for the most vulnerable populations: Elderly women living alone experience some of the highest poverty rates in the United States. Existing financial products that can mitigate this risk are not attractive to many people. The challenge will be to develop vehicles for pooling longevity risk that will appeal to these individuals.[A-66]

There have been comparisons on the adequacy of societal coverage in the form of retirement income, health care and long-term care (LTC) across Canada, England, France, Germany, Sweden and the United States. These countries are some of the richest in the world and have social programs in place to provide assistance to their aging populations. Although all of these countries provide pension income at least equal to 50 percent of general living expenses, some of these countries, namely the United States and England, appear to be inadequate. The basis of this result is the ratio of the state pension (S.P.) in relation to general living expenses (GLE) and drug and care expenses, together making up total expenses (T.E.).[A-141]

Figure 24: Adequacy of societal coverage for LTC[A-141]

| Comparison | Score | Label |
|---|---|---|
| S.P. < 50% GLE | 0 | Completely inadequate |
| 50% GLE ≤ S.P. < 100% GLE | 0.33 | Somewhat inadequate |
| 100% GLE ≤ S.P. < T.E. | 0.67 | Somewhat adequate |
| 100% T.E. ≤ S.P. | 1 | Completely adequate |

| Identifier | Canada | England | France | Germany | Sweden | U.S. |
|---|---|---|---|---|---|---|
| C.N. | 0.33 | 0.33 | 1.0 | 1.0 | 1.0 | 0.33 |
| C.Y. | 0.67 | 0.33 | 0.67 | 1.0 | 1.0 | 0.33 |
| S.N. | 0.33 | 0.33 | 1.0 | 0.33 | 0.33 | 0.33 |
| S.Y. | 0.67 | 0.33 | 0.67 | 1.0 | 1.0 | 0.33 |
| Index score | 0.5 | 0.33 | 0.84 | 0.84 | 0.84 | 0.33 |
| Label | Not adequate or inadequate | Often inadequate | Mainly adequate | Mainly adequate | Mainly adequate | Often inadequate |

Legend

C.N. = Couple not requiring LTC
C.Y. = Couple with one member requiring LTC
S.N. = Single female not requiring LTC
S.Y. = Single female requiring LTC

There is also a discussion of sustainability from the perspective of the state as current adequacy is meaningless if it is not a sustainable long-term solution. For example, France currently provides adequate benefits but is unlikely to be able to continue providing similar benefits even with reasonable reform.[A-141]

2. Societal support for retirement in developing nations

Although the tide may be shifting, in Mexico in the recent past, there have been two main predictions for population dynamics: rapid demographic aging and continued migration to the United States.[A-65]

Mexico's retirement income system is insufficient in coverage and quality of benefits. One large problem with the system is its heavy allocation of benefits to citizens least in need. Pensions mimic the country's uneven income distribution, with the richest citizens collecting more benefits than the average citizen.[A-65]

In recent history, Mexico transformed its pensions from defined benefits to defined contributions, hoping to provide universal coverage, job creation and income. However, it became evident that the reform has been unsuccessful, as it has failed to make significant improvements in any of those areas.[A-65]

Census reports indicate India's population has approximately tripled during the last 50 years, and the number of elderly Indians has increased more than fourfold. In addition, India is experiencing rapid urbanization and an increasing number of women are participating in the workforce. These factors have led to the erosion of the joint family system and the emergence of nuclear families. In addition, the Indian population seems more likely to spend its financial resources on the education of its children than on its own retirement savings. Finally, unhealthy lifestyles are causing widespread tuberculosis, asthma, cancer and cardiovascular problems among elderly Indians, reducing their ability to work into old age. The Planning Commission of India found that approximately 92 percent of working Indians do not receive any formal old age income at retirement and are at risk of sinking below the poverty line without access to adequate post-retirement income. In response to this startling statistic, author Prakash Bhattacharya argued India must make pensions more available, invite the participation of private players in the pension space, introduce need-based pension products and increase consumer awareness about retirement income.[A-34]

Bhattacharya identified that in India, the success of a government-sponsored retirement income system depends on two critical factors. First is the ability and willingness of the working class to make adequate savings to maintain the same standard of living during their old age. Second is the availability of the economic, financial and regulatory frameworks that meet the expectations of the savers by offering risk-adjusted returns. To encourage retirement savings, financial experts must design suitable retirement schemes for the major percentage of Indian workers that are no less attractive than any other saving instrument. The buildup of assets in these funds can be used judiciously to build up infrastructure facilities, develop debt and capital markets, arrange education, etc. The availability of better infrastructure facilities imparts a higher level of efficiency to the business entities. The inflow of large sums for a long duration would reduce the volatility of the stock markets, which are presently dominated by foreign institutional investors and the speculators. The principal financial markets would then be expected to impose better corporate governance, leading to higher risk-adjusted returns to those holding pension assets.[A-34]

It is important to note that while countries with emerging markets, like India and China, do not currently have many retirement income obligations, they must plan carefully for the future when they will. If they fail to do so, their government-sponsored programs will eventually suffer. Previous attempts at solving these types of problems, like prefunding, will fall short because of the working class's resistance to sacrificing its own pay for the elderly. Experts will need to develop innovative solutions to avoid retirement income crises.[A-116]

#### 4.2.2.2 Suggestions to address challenges faced by social security systems

1. Tying retirement eligibility age to remaining expected lifetime

Geoff Rashbrooke concluded pay-as-you-go pensions are not as financially feasible in countries with aging populations. One way to address this issue is to increase the retirement age so that eligibility for government-sponsored retirement income benefits is delayed among older populations.[A-102]

Jacob Seigel suggested increasing the retirement age to where an individual retiring has a life expectancy of 10 to 15 years corresponds much more closely to the survival expectancies at age 65 of the U.S. population when Social Security was introduced than the current survival expectancy at age 65.[A-63] This idea is also supported by changes in the type of work that we do: The current generation of elderly individuals is able to remain in the workforce for longer periods of time than were the comparable populations of 1935 who worked hard, lived hard and died at an earlier age.

However, tying general retirement eligibility age to a longevity-related factor might prove unfair and unreasonable in the U.S. without considering the following factors.

- People at lower income levels haven't experienced as pronounced improvements in their standard of living, health status and life expectancy as people at higher income levels.[B-8]
- In contrast with the rest of the population, the least educated subgroups are not experiencing increasing longevity, but rather their life expectancies are decreasing.[B-2]
- Dr. Sandra Timmermann noted how the mental health and functional capability of elderly workers should also be considered. Currently, many people retire early due to health reasons. Tying retirement eligibility age to remaining expected lifetime does not necessarily imply the resulting retirement eligibility age is one where the elderly worker is still able to both physically and mentally demanding work. Dr. Timmermann concluded there is a clear need to tie these health observations to longevity in new, innovative methods.[B-2]

Some believe raising the retirement age in the U.S. will not solve the retirement income problem, claiming individuals in need of more retirement money will not be responsible enough to save adequately, even if given more working years to save.[A-20]

2. Gradually increasing the retirement eligibility age

Brian Burnell, author of "Retirement and Retirement Ages in Canada Revisited," examined the effect of a gradual increase in retirement ages to attempt to maintain the "senior dependency ratio" at or close to its current level. This ratio refers to the proportion of the population at or above the customary retirement age (currently 65) to the number of people in the "working age group" (currently 18 to 64).[A-70]

He uses the Canadian population to show that after allowing for continuing immigration at relatively high levels, the customary retirement age would need to increase to 70 by 2025 for this ratio to remain close to its current level. A "customary retirement age" as high as 74 may be necessary by 2050 to maintain a 20 percent senior dependency ratio.[A-70]

In the United States, the age for receiving full benefits under Social Security is being raised from 66 in 2009 to 67 in 2027 in two-month increments. This increase in the age of retirement is consistent with the facts regarding historical increases in longevity.[A-63] However, there are consequences to increasing the retirement age. It has been shown, using the U.S. system as a proxy, that extending the age of eligibility has a significantly greater adverse effect on those with low socioeconomic status. Furthermore, these results hold under arguably optimistic assumptions as to future movement in mortality rates. Only in the case of eventual convergence is there any reduction in the unfairness, and the literature discussed here is not particularly hopeful in this regard.[A-102]

3. Phased retirement strategies

The encouragement of phased retirement programs (refer to section 4.2.1.4 for more details) is becoming a high priority for developed nations, as a vehicle for a much greater degree of flexibility in retirement arrangements in general. However, for fundamental changes in the provision of benefits from government-sponsored retirement income programs to succeed, there will need to be some major changes in the outlook and attitude of employers and employees and to the rules and regulations that govern the operation of pension plans in Canada (for the purposes of this article) and other developed nations.[A-70]

Historically, men have experienced a substantial long-term decline in labor force participation at higher ages for both voluntary and involuntary reasons. This trend has recently reversed, but more time is needed to see its impact across generations. Continued changes to the status quo in the U.S. with reforms such as the Age Discrimination in Employment Act (ADEA) and amendments to Social Security (increased retirement ages) will be critical in creating a sustainable retirement plan as longevity continues to expand. Alternative plans to

transition from full-time work to part-time work before a total exit from the labor force are becoming more common, although often informal. This can be seen in the rising percentage of those age 65+ who are working—13.2 percent in 2008 versus 10.4 percent in 1990 for males and 8.9 percent in 2008 versus 7.0 percent in 1990 for females.[A-140]

4. Proposed introduction of micro-pensions in India as a retirement savings vehicle

India is undergoing a period of social change; there has been a shift from the joint family system, leaving an increasing number of the elderly vulnerable in the absence of a broad government retirement income system.

Author Prakash Bhattacharya postulated India might benefit from micro-pension plans that would cover the large segment of people from the unorganized sector. A small contribution from each member into a common fund, or set of funds, would provide a measure of retirement security. At the same time, the combined contribution balance would support India's continued economic liberalization: It would generate a pool of assets that could be reinvested to generate economic growth or fund infrastructure projects. The accumulation of a large amount of funds would be consumed as regular income in retirement. The successful outcome would be that these people may be saved from the threat of poverty during their old age, although many of them are maintaining a satisfactory standard of living during their working life.[A-69]

5. Government-supported solutions

The U.S. government currently sells Treasury inflation-protected securities that partially address the retirement income needs of retirees. Jonathan Forman noted that delaying the receipt of Social Security benefits until full retirement age or later is equivalent to purchasing an annuity from the Social Security Administration. It then seems plausible for the government to offer starter retirement savings accounts and to issue annuities (or provide guarantees):[A-142]

- Retirement savings accounts: The U.S. Treasury could sell no-fee retirement bonds for workers to build secure retirement savings.
- Longevity bonds: The U.S. Treasury could issue bonds with coupons varying by longevity relative to a certain benchmark.
- Annuities, pooled annuities and tontines: The government is in an optimal position to sell pooled annuities so that participants share in the longevity risk because they already collect data on every person who currently receives benefits.

#### 4.2.2.3 The implications of longevity on societal support for retirement

With the changes that longevity brings to retirement income, governments will need to re-evaluate their fiscal burdens to plan for the future. If they do not, they will simply lack the funds needed to pay benefits owed to citizens. A thorough re-evaluation that considers all institutions relevant to retirement income will be necessary.[A-116]

So what are some of the most important changes longevity will bring? First, if governments are unable to afford to pay retirement income benefits to an increasing number of elderly people, workers will be forced to defer retirement. Second, the economy will restructure to fit the changing needs of society. For example, with more elderly people—one of the most illness-prone groups in a population—there will be higher demand for health care services and professionals. This example reveals yet another issue—that governments will need to reassess their distribution of care because of significant, longevity-induced changes to the health care industry. There will be other political changes too. One obvious one is the increase in elderly voters. This will lead to the emergence of more pro-elderly politicians who will push for a number of new programs or continuation of underfunded programs, like elderly friendly entitlement programs.[A-116]

### 4.2.3 Challenges for retirement systems

> When retirement ages are fixed and life spans increase, periods of benefit payment under [defined benefit] plans also increase. That is like a continuing plan improvement and may be one of the factors contributing to the decline of DB plans. In contrast, if retirement ages were set to reflect a period to the end of life, they would gradually increase and the value of benefits would stay about the same. I believe that if retirement benefits had been defined in that way, there would be more DB plans today. One way to deal with this gradual increase in benefits has been to switch to DC plans and avoid dealing directly with the issue.
>
> Anna Rappaport, FSA, MAAA, FCA, EA, Anna Rappaport Consulting

Increasing longevity and lack of proactive behavior from the public has created financial security concerns for retirement systems. The shift away from defined benefit plans have led to pre-retirees being exposed to the risk of outliving one's assets, as well as risks within the financial markets. People are failing to effectively plan for retirement, in part due to lack of education regarding retirement planning and misunderstanding of retirement programs, including Social Security.

In response to this lack of proper retirement planning, financial advisers have heavily relied on rules of thumb to communicate more effectively with their customers. However, these rules of thumbs should be used with caution as retirement needs and solutions are unique to each individual.

#### 4.2.3.1 Challenges faced by retirement systems

In many developed countries, the retirement world of the future is challenging because of the decline in defined benefit plans, low savings rates in the United States, increased longevity and the failure of many people to effectively plan for retirement.

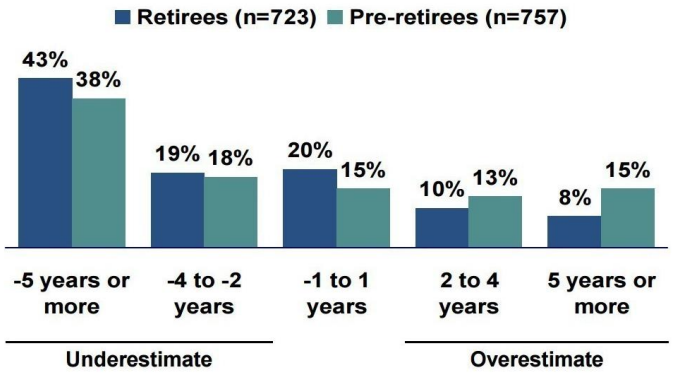
1. The employee's perspective

As the shift from defined benefit plans to defined contribution plans continues, more employees are being exposed to the recently volatile markets and taking on the risk of retiring without enough money. This has raised the need for employees to take initiative and start planning actively for their retirement. However, research on what the U.S. population knows about retirement and retirement planning shows significant gaps in knowledge and many misperceptions.[A-31], [A-97]

- There is relatively little understanding of longevity risk. Many retirees do not recognize outliving assets as an issue.
- Pre-retirees misunderstand what their primary sources of income will be in retirement. They underestimate the importance of Social Security and overestimate the level of retirement resources provided by personal savings.
- People tend to underestimate both their out-of-pocket medical expenses and their own need for long-term care, believing others will be more likely to incur these expenses.
- The number of people who think buying risk-management products—for example long-term care insurance, health insurance and annuity products—is a good idea is greater than the number of people who actually buy these products.
- While many individuals are now heavily responsible for managing their own retirement assets and planning, many have basic misunderstandings about the financial market and investment products. Their understanding of how to invest may also decline with increasing age if they have any dementia.

- Many people retire earlier than they plan to, sometimes for reasons of health, sometimes because of job loss and sometimes for other reasons.
- Robert Painter noted a study that revealed the U.S. population has a low level of financial literacy. When surveyed, however, individuals self-rated themselves as having a high level of understanding of financial literature. This disconnect results in people not investing enough resources to their financial education.[B-9]
- Many employees use their savings account balance as a decisive factor when determining their retirement date, instead of focusing on their prospective income during retirement.[B-9]
- People are reluctant to buy an annuity for life due to the long-term commitment and uncertainty on how long they will actually need to live to make financial sense of the product. This creates a challenge for security at very high ages. However, they have identified their interest in protecting themselves against longevity risk.[B-2]
- Anna Rappaport shared how, when respondents were asked to estimate the population life expectancy, the majority underestimated it. This was consistent across retirees and pre-retirees. Figure 25 shows the number of years respondents underestimate or overestimate population life expectancy.[A-147]

Figure 25: Respondent estimates of population life expectancy[A-147]




- Despite it being more advantageous to claim Social Security later in life, many people claim Social Security early and do not evaluate their options objectively. In particular, out of the oldest baby boomer population segment, currently age 67, 85 percent had been identified to have claimed their Social Security benefits, with the majority of them having taken it when they were 62.[B-2]
- Sixty percent of pre-retirees and retirees have admitted to not being familiar with annuity products.[B-9]
- Empirical evidence from the U.S. shows that older women have very low levels of financial literacy and that the majority of them have not planned for retirement.[A-148]

Even with all of the information, selecting the best product(s) in the U.S. for managing an individual's retirement income is not always straightforward. The optimal strategy depends on each individual's personal situation and risk preferences, and experts do not necessarily agree on what strategy is best for a given personal profile and set of risk tolerances.[A-106]

Broad guidelines can be established within the United States. The authors of "Living to 100: Survival to Advanced Ages: Insurance Industry Implication on Retirement Planning and the Secondary Market in Insurance" used stochastic analysis to determine the optimal allocation of insurance and investment products for an individual. It was shown the optimal solution incorporated a significant number of immediate annuity products, a portfolio that combined insurance and investment products almost always outperformed a

portfolio of strictly investment products, and the optimal solution always included the purchase of catastrophic illness protection.[A-52]

However, for those within the U.S. who have decided to purchase a specific type of product, there remain challenges. Individuals choosing to buy financial products have to make trade-offs. For example, the purchase of an annuity offers a guarantee of lifetime income, but the buyer gives up control over the assets, liquidity and the potential of a bequest. There are variations of annuity products that offer several types of guarantees including lifetime income, inflation protection, protection from investment risk, etc. Each type of risk protection has a price attached to it, and some of the buyers who experience the risk will make out much better because they chose the product. Other buyers will make out less well. For example, people who live very long will do better with annuities, and people who die quickly will do poorly.[A-106]

A paper from the 2014 symposium, "Perspectives on SOA Post-Retirement Risk Research and What it Tells About the Implications of Long Life," also shares perspectives on key issues from the middle-class lens in the United States:[A-147]

- Most of the financial services industry focused on providing retirement advice is financially incentivized to concentrate on clients with greater income and wealth. As a result, there is a gap in the availability of helpful advice for much of the middle market.
- Rules of thumb are often promoted but, when taken in the wrong context, can lead to costly missteps. Many of the misconceptions were discussed in a report issued in 2005 called "Public Misperceptions About Retirement Security."
- Lack of interest in annuitizing wealth is largely driven by a protection bias to protect their assets.
- There is a lack of disability coverage, which potentially leads to derailment of one's planned retirement security.

Robert Painter, global head of insurance and annuities at a global financial institution, noted how since insurance is commissioned more than annuities in the U.S., distributors discourage their clients from annuitizing when it might actually ensure their financial stability during retirement. Although the point of sale should be the point of recurring education, the current fee structure encourages the distributor to make the point of sale the first and last interaction with the client. This contrasts from other commission structures, such as in Australia where advisors get paid when they follow-up with their client every two years.[B-9]

David Blanchett noted that in the U.S., utility is maximized by planning savings and consumption such that lifetime consumption is as smooth as possible. Therefore, it is critical to determine an appropriate estimate of the total amount of savings required to fund retirement, which is often not easy.[A-124] For additional details, see section 4.2.3.2.

Despite numerous informative presentations to 401(k) plan participants, one company found they consistently failed to transfer the importance of current issues with financial planning. The participants, who recognized the existence of the issues, expected their financial advisors to fix them. The investment firm also concluded the success of target-date funds can be attributed to lack of interest from the public in understanding equities; they prefer products without as much financial literature so they can divert their attention elsewhere, which is an essential feature of target-date funds.[B-9]

As the modern-day employee is busy with competing priorities, society has taken the approach of simplifying knowledge for their convenient consumption and not relying on employees' proactiveness. Consequently, there are detrimental effects to this approach in the U.S.

- Financial rules of thumb (i.e., 4 percent rule) have been created to simplify the time-consuming retirement planning process. However, many employees take this as a golden rule and fail to

recognize this generalization can vary across individuals. It is still optimal for them to perform self-assessments and determine their own needs and solutions.[B-9]

- Automatic enrollment in 401(k), as well as target-date retirement funds, has given employees the false impression that their retirements are taken care of.[B-3]
- Despite all the consequences that come with simplifying retirement solutions, considering 80 percent of the population is probably never going to get a financial planner, the need for these simplifying approaches exists and is better than having none at all. For example, the 4 percent rule can quickly put things into perspective for an employee with no motivation to invest time in retirement planning. This is perhaps the best way to penetrate the general, nonproactive population.[B-9]

Finally, individuals seeking advice or buying financial products in the U.S. need to be careful of fraud. There are many scams and people seeking to defraud older people who are trying to manage their money. It is important to be careful that the advisor is focused on your interests and is not simply focused on the product with the highest commission or fee.[A-106]

2. The employer's perspective

> It is very difficult for individuals preparing for retirement to decide how to structure their financial portfolio to best protect themselves from outliving their assets. It is just as difficult to compare products across carriers as there is very little consistency in mortality assumptions from carrier to carrier. The more accurate information that we can circulate on mortality and longevity, the better decisions people can make.
>
> Inconsistencies between how an individual views their own mortality and how an insurance company views the mortality of a similar group of individuals can greatly influence decision-making. Overestimating—or more commonly underestimating—life expectancy can lead an individual to make inferior decisions.
>
> Scott Witt, FSA, MAAA, insurance advisor

Flexibility for employers to undertake innovative approaches in the U.S. is somewhat constrained, mainly due to employee benefit legislation, regulation and potential lawsuits arising from current legislations:[B-9]

- U.S. pensions are subject to extensive regulation which limits plan sponsor options and can create complexity. The Employee Retirement Income Security Act and other legislation sets forth a number of requirements designed to protect the interests of employees. When requirements are ambiguous or where the environment is changing, the combination of legislation, regulations and potential for litigation serve as a barrier to innovation.
- Benefit plans are sponsored by employers, including businesses, not-for-profits, and public sector entities. Benefits are designed to support the human resources philosophy of the organization, and its need to attract and retain the employees needed for the organization. While some employers use innovative benefits to support their employment proposition, many do not. For a large number of U.S. employers today, changes are implemented as required and only to the extent necessary. They prefer to follow others and not take risks with regard to regulatory penalties and legislation.
- Although it is possible to include annuities as a form of payout in defined contribution plans, the steps required from the employer to implement this change require care and attention to detail. There is also uncertainty with regard to possible legal liability. There is a clear need for legal safe-harbors that would make this process much easier.
- Flexibility given to employers on innovative retirement strategies has proven successful in the past. For instance, employers' transition from mutual funds to target-date funds was undertaken only

when the Department of Labor announced they will grant employers legal safe-harbors against lawsuits if they move to a more target-date balance approach.

Other challenges faced by U.S. employers include:[B-3]

- Spiking abuses in retirement benefits, particularly within the public sector: As retirement income from defined benefit plans are determined from an employee's salary in their last working years, there is the risk of employees working excessive overtime in order to have this additional pay counted into such average.
- Dominance from Finance departments when it comes to crucial decision making: Haig Nalbantian noted how companies' decision to move away from defined benefit plans is influenced mainly by feedback from Finance. He also recommended employers to be careful in not allowing human capital management decisions to be influenced extensively by any sole department.
- Although the shift from defined benefit plans to defined contribution plans has reduced the volatility of employers' financial statements, this benefit does not come without its negative consequences. As this shift starts exposing more employees to the volatile markets, pre-retirees are becoming concerned with leaving the firm and not having enough money. As a result they end up staying and decreasing the number of promotions and lateral moves available to younger employees. Consequently, the low number of open positions will hurt companies that rely on "built-talent-from-within" strategy as statistical modeling has shown high-potential, high-performing people will be more likely to exit the organization if they encounter these choke points. Young talent will leave and then when these temporary senior workers leave, the company will lack both talent and experience.

As the U.S. population ages, the labor force will also age. While there has been relatively little adaption to major changes in life spans over the past 100 years, the authors' view is that these changes in life spans and the changes in population age mix will require much greater changes in the years to come.

#### 4.2.3.2 Suggestions to address challenges faced by retirement systems

There are several ways the U.S. population can enhance their futures in retirement. They include:

- Retirement and retirement savings plan designs that recognize people need help in saving for retirement. Within the context of defined-contribution plans, this would include features such as automatic enrollment, sound default investment options and automatic provisions to direct pay increases into the savings plan. These default options will address the need to build assets for retirement but not the need to manage funds after retirement.[A-31]
- Increased education and supporting research to ensure program designs are effective. It is important this education covers management of investments and withdrawals in the distribution phase.[A-31]
- Maintaining an appropriate level of employer contributions to retirement programs whether they are defined benefit or defined contribution.[A-31]
- Guaranteeing Social Security to provide a sound basic layer of benefit. The studies reinforce the importance of Social Security and the need to moderate reliance on individual efforts.[A-31]
- Not claiming Social Security benefits early but claiming them later and consequently receiving a higher income stream. This relates to how the majority of the U.S. population considers the retirement age to be 62. The public should start considering retiring later than 62 as both a possibility and a strong recommendation.[B-2]
- Supporting integration of phased retirement strategies into employer-sponsored benefit plans.[A-70]
- Correctly estimating the total amount of savings required to fund retirement. The common approach is to apply a generic replacement rate to pre-retirement income, such as 80 percent, to get the retirement income needed. That need is assumed to increase annually at the rate of inflation for the

duration of the retirement, generally assumed to be a fixed period such as 30 years. In the study "Estimating the True Cost of Retirement," David Blanchett argued the assumption that growing retirement needs can be estimated linearly with inflation is not the best and it is important to not oversimplify the projected post-retirement expenses. In particular, he noted:[A-124]

- While a replacement rate between 70 percent and 80 percent may be a reasonable starting place for most households, the actual overall replacement rate can vary considerably, from less than 54 percent to more than 87 percent depending on the level of pre-retirement household income and expenses that discontinue after retirement.
- Real retiree expenditures are not constant and they do not rise in nominal terms simply as a function of inflation. The retirement consumption path will be a function of the household-specific consumption basket as well as total consumption and funding levels.
- Households not consuming retirement funds optimally will tend to adjust them during the retirement period.
- While many retirement income models use a fixed time period (e.g., 30 years) to estimate the duration of retirement, modeling the cost over the expected lifetime of the household and incorporating the actual spending curve can results in a required account balance at retirement that can be significantly less than the amount required using traditional models.
- Assuming a constant expenditure level after retirement is too conservative; a more accurate model would show post-retirement consumption decrease. Blanchett's Monte Carlo simulation model goes on to predict a target savings rate up to 25 percent lower than traditional models.
- It is noted how current models for retirement expenditure, which typically assume a simple target replacement rate, do not account for pre-retirement income increasing with age throughout a person's work life.

- Written commitment for increasing their financial contribution for the next year. Christine Fahlund identified employees as unwilling to increase their contribution for the current year due to perceived affordability issues, yet they were willing to do it for the upcoming year.[B-9]
- Focusing on income needed during retirement as opposed to accumulating a meaningless number by the start of retirement with little understanding as to what retirement income quantity is actually implied by that number.[B-9]
- Becoming more accountable as they start allocating more money into defined contribution plans and individual retirement accounts.[B-9]
- Speaking with a financial advisor.[B-9]
  - Only 28 percent of consumers without an advisor believe they are prepared for retirement. In contrast, consumers engaged with an advisor are two to three times more likely to express their retirement preparedness.
  - Retirees have been found to be short-term focused, often not considering what may impact them in the long term. Since advisors are focused on long-term issues (health care and longevity), they can complement retirees' current perspective and provide for a more thorough approach to retirement planning.
  - Due to differing time horizon perspectives between advisors and retirees, it is vital for advisors to address the short-term issues before engaging in the ensuing long-term discussions.
- Letting employers know there are solutions for incorporating annuity options into defined contribution plans. Anna Rappaport suggested a guide for employers on how to incorporate annuity options, annuitization and income into defined contribution plans.[B-2]

The U.S. government could also consider the following to address the challenges faced by retirement systems.

- There is a need for introducing a broader set of guaranteed products (including annuities) into the defined contribution space. This requires the government to recognize its benefits from a social perspective, and expand the Pension Protection Act as a result. In particular, the government has to heavily limit sponsors' liabilities if they incorporate guaranteed products in their portfolio.[B-9]
- New regulations and infrastructure should be implemented that require the public to contribute to their retirement.[B-9]
    - In particular, Australia's superannuation system requires a certain portion of wages paid by the employer to go into externally managed trusts that people can choose from. With the current contribution rate being 9 to 10 percent of income, soon to be 12 percent, these funds cannot be accessed until age 60.
    - Australia also has essentially aligned advisor incentives with their clients as there is no upfront fee for consultation; advisors get paid when they contact their client every two years. This discourages advisors from constructing client solutions that give them the best commission and may not be the most optimal for the client's needs.
- The Financial Industry Regulatory Authority (FINRA) has to review their legislation on information disclosure. Christine Fahlund noted how when one firm adopted the Monte Carlo approach for stochastic simulation on investment returns for more accurate results, FINRA required them to provide a full, lengthy disclosure on Monte Carlo's incorporation as most people do not know this mathematical approach. However, the firm was not required to provide any disclosure if they assume a constant return on investments, which is unrealistic.[B-9]

For product innovations from the private industry to address challenges within the retirement systems, see section 4.2.6.

Ultimately, if consumers cannot be encouraged to further self-educate over retirement planning, the need is created for the government, private sector and public sector to find ways to better educate consumers.

### 4.2.4 Challenges for long-term care systems[5]

> As people age, many will need long-term care. With greater numbers of older people living longer, the demand for long-term care will certainly increase. Long-term care is provided and financed by a combination of personal, public and private programs with very different solutions in different countries. There are many unresolved problems in the United States, with few people having good plans for financing long-term care in place. In addition, these programs are proving very costly for governments and insurers to support. As a result of the poor experience to date and uncertain, but projected continuing high future costs, there are fewer and fewer risk transfer vehicles available as time passes. The result is that more and more of the cost burden is shifting to the individual and, by extension, to the Medicaid program. This is not sustainable for the long term given the current and projected state and federal budget deficits.
>
> Loretta Jacobs, FSA, MAAA, vice president of actuarial services, CNO Financial Group

There are products and approaches for managing long-term care costs in the U.S. available to individuals outside government programs: in particular, LTC insurance and continuing care retirement communities. The costs of these options can be greatly reduced to the extent that care can be provided at home by family members and friends. The Affordable Care Act in the U.S. included the Community Living Assistance Services and Supports (CLASS) Act, an attempt to improve the situation with regard to long-term financing. This was found to be unfeasible and was repealed in 2013. A national discussion of these issues continues.

It is difficult for governments to offer LTC programs as well due to concerns over how to optimize the program and be fair to the public at the same time. Furthermore, the U.S. insurance industry is experiencing substantial challenges offering LTC insurance due to higher claims and lower investment returns than assumed in the original pricing. This has led to poor financial experience and multiple rounds of rate increases throughout the industry.

Most developed countries are showing the signs of an aging population. One sign is an increasing number of seniors, some of who are becoming less able to perform the activities of daily living (ADLs) or the instrumental activities of daily living (IADLs), often because of cognitive decline or dementia. Surveys indicate many respondents are concerned about the potential costs of LTC and believe the government should help individuals cover LTC costs.[A-78]

There is a growing need for solutions to address the challenges described in the following sections. Common themes include facilitating the aging of the population at home and encouraging informal support networks within communities. LTC challenges for the public can be greatly alleviated if people are informed and educated on their long-term care options and how to effectively manage the risks.

#### 4.2.4.1 Challenges for long-term care systems

Considering that 70 percent of people age 65 will one day have some long-term care need that they will have to pay for, it is vital for the government and private sector to collaborate on more innovative and affordable products for the benefit of society.[B-6]

1. Challenges for the public

5 Additional resources include the SOA's report "Managing the Impact of Long-Term Care Needs and Expense on Retirement Security," which can be found at https://www.soa.org/Library/Monographs/Retirement-Systems/managing-impact-ltc/2014/mono-2014-managing-ltc.aspx.

It is challenging for individuals in the United States to choose and afford the right set of products that best suit their situation.

Confidence in U.S. insurance companies with regards to LTC has been shaken due to insurers having difficulty producing accurate assumptions when pricing their LTC products. Higher than expected claim costs, coupled with persistently low interest rates, has led to multiple premium rate increases on their LTC products.[B-6]

In addition to choosing a product within the U.S. that optimally fits the individual's need, consideration has to be given to the financial strength of the company selling the product and how much experience they have with this line of business. All of these products require payment of benefits far into the future. As a result, it is common to see insurance companies selling off LTC blocks of business.[A-106]

Within the United States, there will be a higher demand for home care workers as women, the traditional home care workers for their families, continue to make up a large part of the workforce. In addition, there is expected to be a shortage of direct care workers to take care of the baby boomer generation, which will reach their 80s by the mid-21st century. The Alliance for Healthcare Reform is projecting 10 to 12 million direct care workers will be needed in the next 10 years.[B-6]

Primary residences and their associated equity have the potential of funding an entire retirement through reverse mortgages in the U.S. However, there exist concerns that as boomers continue aging, the number of homes up for sale may far outpace the number of homes being bought. Consequently, real estate prices may decrease, with studies predicting a loss of about a third of home equity for individuals. The value of home equity also depends greatly on the economy, such as what happened during the 2008 financial crisis.[B-6]

2. Challenges for the government

Creating a viable program is a difficult task. In the United States, Congress created the CLASS Act to relieve financial strain on Medicaid LTC and to provide more in-home care for the elderly. However, because of easy access to other social programs, like Medicaid, which provide similar benefits, CLASS was not able to be structured as its proponents originally expected.[A-80] Demonstrating the difficulty of establishing a viable program, CLASS was repealed in 2013.

With regard to social programs, governments are faced with the challenge of not being able to distinguish taxpayers from each other. This has led to the implementation of one-size-fits-all social programs, not necessarily an optimal solution needed by the taxpayers.[B-6]

#### 4.2.4.2 Suggestions to address challenges faced by long-term care systems

1. Individuals

Within the United States, the hospitalization and health care cost of seniors falling has been projected to reach $55 billion by 2020. Falls, which are one of the main drivers of long-term care incidences, are mainly attributed to lack of accessible bathrooms in seniors' homes. For those approaching retirement, it is recommended for them to make home modifications (e.g., stair lift, handrails) early on, as opposed to doing it later on in retirement when it might not be financially feasible. Cindy Hounsell also found that, out of those who sold their homes, the happiest seniors were those who gave up their homes by choice instead of being forcibly removed due to not being able to meet their financial obligations.[B-4]

If retirees are having trouble meeting their financial obligations in the U.S., the following should be considered:[B-6]

- Move in and living with their offspring.
- Secure a reverse mortgage and use the payments to supplement their pension.

- Sell their primary residence and move into active adult qualified housing. This would cost less than the sold property, and they could use the extra proceeds to supplement their income.

Informal support networks in the U.S. are an option for those who cannot financially afford long-term care for their loved ones but are willing to exchange time and favors with each other. Coordinating between neighbors and friends for quick favors when they are not around is one possibility. Another is participating in a time bank system where they exchange hours of service with each other.[B-4]

2. Government

In the United Kingdom, a substantial portion of the senior population may need long-term care protection. A mandatory (social) insurance program, financed by the government, may do well to protect the population from LTC-related financial problems. Over the next 40 years, a 10 percent increase in tax revenue could cover LTC costs in the United Kingdom, assuming conservative projections into the future.[A-78]

The majority of the U.S. population are not aware of the difficulty associated with becoming eligible for Medicaid, and thus, do not invest as much time into retirement planning as they are under the impression of Medicaid being a fail-safe. There is a great need for the U.S. government to inform the population on the difficulty of becoming eligible for Medicaid.[B-6]

Since two out of every three seniors buy Medigap coverage when they enroll in Medicare, the government could consider placing long-term care insurance coverage in a similar Medigap-type product. In comparison, only 5 percent of the public buys long-term care insurance. However, since 80 percent of the elderly receive home health care informally by family, it should also be considered how this percentage will be impacted by the addition of long-term care insurance.[B-6]

The U.S. government could explore programs that encourage people to age at home, and in turn, saves the government money from offering government-subsidized housing. An example is Medicaid Cash and Counseling, a program that provides cash assistance which is then used on care providers of their choice.[B-2]

The financial burden of Medicaid on the U.S. government has the potential to be reduced. Legislation exists within Texas and other states that require Medicaid applicants, prior to their enrollment confirmation, to sell their life insurance to help finance their own long-term care needs.[B-6]

The U.S. government could also consider implementing federal legislation that mandates adult children take care of their parents if they are in need of care. Already implemented in Pennsylvania and other states, it would pose a relief to the increasing demand for home care workers.[B-6]

3. Private sector

If aging at home in the U.S. becomes strongly encouraged among retirees, this will create new jobs for home remodelers and case managers. The private sector should be ready to fill in these jobs as the demand will be inevitably created if baby boomers decide to age at home. The broader range of services provided by the private sector and the resulting competition will likely lead to lower prices.[B-2]

With 9 in 10 people in the United States wanting to live in their homes as long as possible, the need remains for innovations from the private sector that facilitate aging at home. With 80 percent of elderly wanting services in their home, the demand for innovative products, such as self-taken blood pressure tests, is higher than ever.[B-4]

A developing interest in the U.S. LTC industry is the potential opportunity for collaboration between the private sector and the government. Governments could subsidize lower-income individuals and support informal home care programs.[B-6]

For solutions regarding affordable housing options, see section 4.2.6.1.

### 4.2.5 Challenges for health care systems

> As the population ages, they need more medical care. At the same time, medical research is leading to new technologies and opportunities for improved care. A great deal more surgery is feasible on an outpatient basis, and smaller and hand-held devices are make diagnostic equipment more accessible and portable. New drugs are also helping many people. We need to seek out ways to make medical care more efficient as we capitalize on these developments.
>
> Anna Rappaport, FSA, MAAA, FCA, EA, Anna Rappaport Consulting

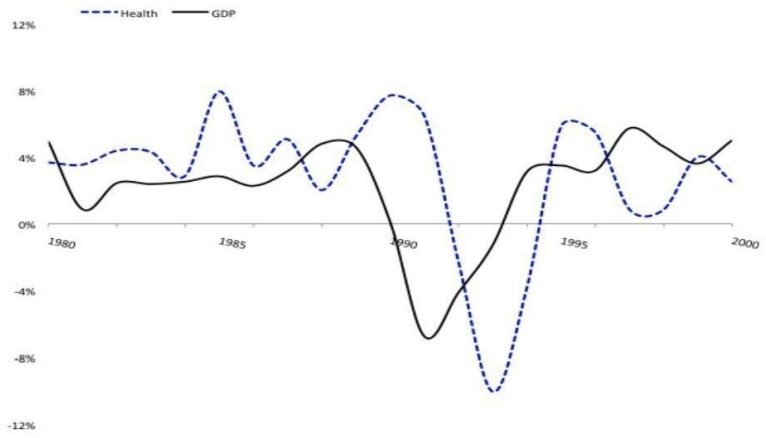
The changing age structure in industrialized countries is raising concern among policymakers over the funding of social security programs, including health care. The aging of the population has worried governments about increases in public spending on health care. Furthermore, longer life spans will have large health care implications and, in particular, a higher cost to society.[A-32]

According to the research of one author, the United States is shown to lead all other industrialized nations in the share of economic output devoted to health care. In 2007, approximately $2.25 trillion—one-sixth of America's gross domestic product and more than the entire economy of all other countries save Japan and Germany—was spent on this endeavor. By one account, more than 90 percent was spent on treating illness and less than 10 percent on preventative care.[A-47]

Within the U.S., there is a need for providing health care at a reasonable cost to the public as some can't afford the high deductibles in their plans. There is a clear need for optimizing the use of funds and coverage for different socioeconomic groups.[B-6]

It should also be noted that in one reported study there existed a lag between the variance in total economic activity and health care activity. This is evident in Finnish studies where a correlation between a three-year moving average GDP and health expenditures lagged by two years. Figure 26 illustrates this lag for a past Finnish recession. One of the main causes for such lags is the complex and cumbersome systems by which medical care is financed.[A-150]

Figure 26: Effects of Finnish recession on health expenditures[A-150]



#### 4.2.5.1 Challenges for health care systems

In the United Kingdom, population aging raises some difficult questions about the ability of health care systems to achieve their objectives: Can satisfactory care be delivered at a reasonable cost? Can the health of the population be protected and maintained? Can access to health care and opportunities for a long and healthy life be accessible equitably?[A-119]

Given the growing size of health care expenses, a debate around the allocation of resources between health care and other priorities also exists in the U.K. The question exists as to whether it is better to pay more for improvements in health care as science and technology help make them available, or to apply those resources to public goods of equal or greater importance that require us to limit health care expenditures—or at least to limit public expenditures, if not also private.[A-119]

To quantify the increase in health care costs, the author of "What if Mortality Was to Diminish Much More Than Was Forecast? Implications for Financing Social Security" looked to Canada and, in particular, the province of Quebec where the age effect is evident when comparing various components of per capita public spending. In 2003, public per capita spending on social security represented less than CA$5,000 for people younger than 55 (excluding education), and rose sharply to more than CA$25,000 for people age 85 and older. In the latter group, health care and social services costs represented 65 percent of total public spending on social security, compared with 25 percent for the 65 to 69 age group.[A-32]

In addition, an increasing shortage of doctors and nurses in Canada may lead to a change in government policy—for example, allowing doctors to practice across disciplines, easing licensing for immigrants in certain professions, and changing the delivery method for services (public versus private, inpatient versus outpatient). In addition, research is needed to assess the social and economic benefits of preventative care as a means to relieve pressure on the existing health care systems. Lastly, these are challenges not unique to the developed world; therefore, it will be important to determine how best practices and efficiencies that emerge from developed countries will be cascaded most effectively to developing countries.[A-110]

Numerous studies—both those presented at the symposia and elsewhere—have associated lower mortality beyond age 50 with possible reductions in health care costs because medical interventions at the end of life are usually more costly for young people who receive treatment with the most advanced technology. Still, even with an aging population, governments must anticipate a future increase in health care spending because home care and LTC costs will drive health care costs up as an increasing number of elderly people demand them.[A-32]

Given this Canadian context, it is important to examine the consequences of changes in cohort size and lower mortality when financing social security with pay-as-you-go systems, which are favored by governments. Population aging will accelerate in the near future, resulting in a heavier burden on the working population, which has to foot the bill.[A-32]

The level of an individual's healthiness, unlike death, is difficult to assess. Even if questions are standardized across the population such that relativeness of answers is possible, there is still a lack of consistency across answers. James Vaupel commented on how U.S. males assess themselves at a higher health level than women, yet males have a lower life expectancy than females. This type of inconsistency exists not only across gender, but also across countries and cultures.[B-1]

Increased health expenditures do not necessarily imply a poorer overall health of the population. Within the U.S., Vaupel noted how increased health expenditures can be observed if the population experiences a lower mortality rate; these additional individuals that are "saved" then contribute to higher health costs through their needed pacemakers and artificial limbs to survive, which would result in less deceased people but higher health costs.[B-1]

Similarly within the U.S., increased government expenditure on health care does not imply an improved population health. Robert Brown stated how increased spending on health care implies the government is cutting back on other social services that provide health and income equality. These reduced services would then be main drivers for a decrease in the life expectancy of those affected.[B-2]

There is a need for optimizing use of funds and coverage for differing socioeconomic groups in the U.S. In particular, the poor have been identified by Steve Schoonveld as not being able to afford the $12,000 out-of-pocket cost required under the Affordable Care Act for certain health conditions.[B-6]

#### 4.2.5.2 Suggestions to address challenges for health care issues

Health expectancy, or the expected future healthy lifetime, may be a resource for doctors and other health care professionals in providing useful information on the future health needs of a population. It may also be a useful resource to help individuals think about planning for future needs and product developers think about financing products. Health expectancy technology allows meaningful calculations to be done for any combination of age, gender and ailment. For example, in the paper "Health Expectancy," the authors use this information to develop incidence rates to predict the need for assisted living and skilled nursing facilities in the United States.[A-115]

In addition, health expectancy technology can also be used to counsel seniors. In particular, the authors make the following observations within the U.S.[A-115]

- Healthy periods are generally far longer than expected by the subjects, even where ailments exist.
- Healthy periods are generally about the same for males and females, but unhealthy periods are longer for females than for males.
- Health expectancy at ages 90 and 95 continues to be very favorable for seniors; even at 95, the healthy period ahead is 2.50 years for males and 2.42 years for females.

This information can help the U.S. elderly make informed decisions about housing, their ability to continue to drive, their ability to continue to work and the likelihood of their need for assisted living and skilled care, and, finally, may encourage healthy habits as alternate calculations can show the effects of losing weight, quitting smoking, medical treatments and improving socioeconomic conditions.[A-115]

### 4.2.6 Innovation within the private industry

*Although the 2014 symposium focused more on social adaptations to longevity, views and ideas are limited. The views noted below may not be consistent with each other as this section aims to be a compilation of the perspectives presented. Unless otherwise specified, all views described below are within the U.S. context.*

As society continues to experience the effects of longevity risk, higher health and retirement costs, and changing population demographics, both individual consumers and corporations will look toward the private sector to create innovative solutions that meet their evolving needs.

In particular, prospective insurance policyholders have been identified to want flexible, affordable products with guaranteed income. Furthermore, they also want insurance products that can effectively manage longevity risk and remove the risk of outliving one's assets. Employers are also readily participating in pension de-risking for removing longevity risk from their pension obligations. Mortality indices are a possibility as well for transferring longevity risk to the financial markets.

Actuaries, the traditional risk managers of the insurance industry, will be tasked with designing and properly pricing such innovations. This will require significant forecasting improvements to involve emerging longevity trends and predictors (see section 4.1), the impact of medical breakthroughs and potential epidemics. Professionals and innovators from other industries will play an important role in these efforts.

However, this innovation process is hindered by possible lawsuits arising from strict legislations and regulations. Furthermore, financial advisors in the U.S. may not act in their client's best interest due to current compensation structures.

#### 4.2.6.1 Innovative housing and accessibility

As people age, they become increasingly more dependent on others for care and assistance if they choose to do so at home. Consequently, the need is created for housing programs to facilitate the aging-at-home process. The following innovative housing designs for seniors have been identified.

- Continuing care retirement communities: Communities with housing and sometimes community centers, specially designed and constructed for elderly residents. As of the 2014 symposium, there were 1,900 continuing care retirement communities across the U.S., with 80 percent of these communities being nonprofit sponsored. The stable and predictable monthly fees provide the residents with housing, easy access to caregivers, low maintenance lifestyles and other readily available services (e.g., groceries, dining, medical needs, elderly activities, transportation). In addition to giving seniors their independence away from becoming a burden on their families, it also provides social interaction between seniors that, according to a study, significantly increased their life spans relative to those with limited social interaction.[B-9]

- Universal design communities: Architect-designed community centers with products and environments accessible to senior residents. These designs are constructed using funds from the senior communities in the area and benefit from the services offered by the community center.[B-4]

- Village model: National community-based membership model that draws on volunteers and community resources for supporting the aging at home of the community's elderly. The members of the community determine what services they will periodically pay for, which are then shared by all members (e.g., meals, home modifications, medical needs, elderly activities, transportation).[B-2]

- Co-housing: Community of homes for seniors, gathered around a shared space.[B-4]

There's also been innovation around increasing the accessibility of buildings for seniors. Cindy Hounsell noted how in the past, making buildings accessible to seniors involved rewiring the entire building to install

lifesaving supports. Hounsell expects the retrofitting of old buildings with wireless technology, a more economical method, will be possible within the next two decades.[B-4]

#### 4.2.6.2 Innovative insurance products

As consumer demand continually changes in today's fast-paced world, the private industry has the opportunity to capitalize on emerging markets and capture customers of tomorrow with optimal solutions for their needs.

Nigel Nunoo, investment senior vice president of a U.S. life insurance company, noted how defined benefit and defined contribution plans present business opportunities for the aging population; longevity risk in defined benefit plans are better managed by insurance companies, while defined contributions generally lack guarantees that can be provided by insurers.[B-4]

In constructing products and strategies for consumers, the private industry has to study their customers carefully and identify their concerns and needs. These include:

- Desire for guaranteed products: Consumers are afraid of products without principal protection.
  - Most life annuities purchased by consumers include guaranteed payments between 10 and 20 years. In comparison, only 12 percent want a pure life annuity with the highest payout, and an even lower portion wanted an annuity with cost of living/consumer price index (CPI) increase-adjusted payments.[B-9]
  - Downside protection could be offered in case of severe market crashes.[B-4]
  - Guaranteed lifetime income could be offered while still giving policyholders the opportunity to have growth in their portfolios.[B-4]
- Products middle-income families can afford.[B-6]
- Flexible premium options: This is particularly important if trying to target younger populations with products mainly meant for elderly populations, such as long-term care insurance. Younger populations will be targeted more effectively if given flexible premium schedules.[B-6]
- Products without unexpected modifications during the policy's life. For example, LTC products have experienced more premium rate increases than policyholders were expecting.[B-6]
- Solutions that take away uncertainty in how long they need their retirement income until death. In particular, products that start paying at a high age (i.e., 85) are desirable as policyholders will know with more certainty how long their money has to last. For example, a retiree at age 65 who purchases a product that starts paying sufficient payments at age 85 will know the leftover income from the purchase only has to last 20 years.[B-9]

The private sector will also need to identifying what types of products the general public understands and are familiar with as opposed to what new products might be confusing and discouraging customers from purchasing them, even if they are more beneficial than existing products.[B-6]

In particular, the following should be considered for annuity products:

- The average age of immediate annuity buyers is 73, while younger buyers in their late 50s usually opted for the variable annuity with a guaranteed lifetime withdrawal benefit attached to it.[B-9]
- Joseph Montminy identified 75 percent of income annuity purchasers are satisfied, with five out of six purchasers willing to recommend the annuity product to a friend or family member.[B-9]
- The top reason for buying an annuity product is to supplement Social Security income or pension income. The purchasers' main concern was to fill the gap created by the difference from their income payments and expenses.[B-9]

- According to Montminy, survey results suggests the market potential for guaranteed lifetime income products may be as high as $650 billion.[B-9]

Product solutions created (or to be created) by insurers include:

- Combination life or annuity and long-term care insurance product: In any given scenario, the policyholder will receive one of the following: death benefit, long-term care benefit or cash value of the policy. This is ideal for middle-income families who can afford it and enjoy it due to its dual purpose.[B-6]
- Unfamiliar products disguised as familiar products: Having noticed their consumers understand health care products much more than long-term care products, one insurer constructed their long-term care product to resemble a health care product to obtain consumers' trust and their purchase of the product.[B-6]
- Tontines: Popular in the 17th century, tontines were an annuity-type product that offered a lifetime of income which would increase as other members of the tontine pool died off and their money was distributed to survivors; this would effectively pass on longevity risk to the participants. In the study "Optimal Retirement Tontines for the 21st Century: With Reference to Mortality Derivatives in 1963," Moshe Milevsky and Thomas Salisbury argue the following.[A-126]
    - A tontine provides the infrastructure for policyholders to pool their individual longevity risks without guarantees. It also allows policyholders to use their own self-assessment of personal health for a possible information advantage when choosing the optimal product structure.
    - Depending on a policyholder's risk aversion, a modern tontine may actually be a better choice than a fixed annuity. However, more research still has to be done, such as product design and the optimal age to purchase a tontine.

    In addition, Kai Kaufhold noted how re-launching this product should take into account the mortality variances across different socio-economic groups. Since tontines let policyholders retain the longevity risk, it is important from both a regulatory and a consumer-protection point of view to account for uncertainties in the best-estimate mortality assumptions.[B-10]
- Deeply deferred annuities: This would include annuities with a payout period that begins at an advanced age past retirement (i.e., 85).[B-9]

    Targeted at defined contribution participants, these annuities can be bought to ensure all expenses past the advanced age are covered. This significantly reduces longevity risk as now the policyholder's main concern is managing the money remaining from the purchase until the payments start.
- Pension de-risking: Companies managing their employees' defined benefit portfolios are seeking solutions to avoid volatile financial statements in unstable markets while still committing to their promise. Actuaries are being recognized as being able to effectively manage the liability risk of defined benefits, including contingencies around the benefit, participant behavior, salary increases, inflation risk and longevity risk. This is particularly important when life expectancy has increased 20 to 30 percent for males and females over the past 30 years.[B-4] In response, the insurance industry has created the following solutions for de-risking the sponsor's pension plan.[A-140]
    - Buy-ins: The pension plan assets and the plan itself remains on the balance sheet, but the longevity, financial and demographic risk is transferred to the insurer through use of annuities. Essentially, the plan sponsor has their variable pension plan assets replaced by fixed asset amounts determined by the insurer.
    - Buy-outs: Insurers take a single premium upfront from the plan sponsor in exchange for the insurer taking full responsibility of meeting the pension plan's future obligations. This removes the plan from the sponsor's balance sheet.

- Longevity swap: Transfers longevity risk to the insurer by exchanging a fixed set of payments for actual pension benefit payments. Q-forwards in particular transfer payments based on the realized mortality rate. The plan remains on the balance sheet.

- Mortality indices: The emergence of longevity risk as an asset class has been slow, mainly due to the lack of transparency for investors and hedgers alike. The authors of "The CBD Mortality Indices: Modeling and Applications" proposed a model-based mortality index framework, akin to the implied volatility indices (VIX) on the Chicago Board of Options Exchange, as a solution. In particular, they consider the original CBD model that possesses the key criteria of being invariant with respect to new data and able to represent the varying-age pattern of mortality improvements. This criteria creates its potential to enhance the transparency and intuitiveness of mortality to investors and, consequently, facilitates the introduction of longevity-type derivatives.[A-125], [B-10]

As the effects of longevity continue to unfold and the social implications become clearer, consumers will look to the private industry to formulate innovative solutions.

#### 4.2.6.3 Challenges posed by legislation and regulation

One of the main challenges with creating innovative products is ensuring they comply with government legislations and regulations. This creates a number of obstacles for the private sector, which introduces the need for governments to revise legislation with input from the private industry and identify how to serve today's society in the most optimal manner.

1. U.S. regulations on defined contribution plans

U.S. regulations include a variety of barriers for innovative solutions in the defined contribution context.[B-9]

- Harrison Weaver suggested a small amount from employees' paychecks be automatically invested into a longevity insurance contract. By having employees estimate their desired retirement income, actuaries can calculate how much money needs to be withdrawn from each paycheck to meet these future payments. However, the Pension Protection Act does not allow this type of model. In addition, current tax implications have required minimum distributions (RMDs) in qualified money, meaning retirees are required by law to start withdrawing by age 70; this defeats the purpose of a longevity insurance contract.

- Expansion of the Pension Protection Act, as suggested by Robert Painter, would be required to introduce a broader set of guaranteed products into the defined contribution space. As of 2012, annuities made up less than 1.2 percent of the total asset distributions for 401(k)s. Currently, sponsors including guaranteed products in their employees' plans take on liabilities associated with their inclusion. To have more guaranteed products in the defined contribution area, Painter recommended the government limit sponsors' liabilities associated with their inclusion. Otherwise, sponsors have no incentive to take on this non-revenue generating liability.

- The current steps required by employers to include annuities in their defined contribution plans has been labeled by Painter as numerous and complex. There is a need for automating the process, which will consequently encourage more sponsors to include these beneficial products into their plans.

2. Lack of objective risk classification

Some laws and regulations do not allow for insurance companies to distinguish between ethnic mortalities or, in some states, by gender. Robert Brown stated how this restriction, coupled with differing longevity trends among ethnicities and genders, can introduce inaccurate liability projections for insurers and, consequently, high pricing to mitigate probability of a loss. To be able to price annuities correctly and attract more demand, especially for deeply deferred annuities, objective risk classification needs to be allowed. Brown also commented on how the U.K. has developed a large profitable market through allowing risk classification.[B-8]

#### 4.2.6.4 Other challenges within the private industry

1. Distribution channels

Multiple symposia authors have noted that the current compensation structure in the U.S. for brokers and financial advisors can discourage them acting in their clients' best interest in order to maximize their own commission. For example, Harrison Weaver commented on how longevity insurance contracts give agents a larger commission than annuities, except for indexed annuities, which can retrieve twice as large a commission due to it being a heavily commissioned product. Weaver noted how the current compensation structure can lead financial advisors to not recommending the right products for their clients.[B-9]

2. Solvency of pension plans

With respect to the potential insolvency of pension plans, Sally Hass commented on how employees are leaning more toward lump sum payouts from their pension plans as opposed to an annuity. In fear of their pension plans going insolvent, employees are opting more for an option where they avoid that possibility. Consequently, Hass believes these lump sums are not being annuitized when they should be.[B-2]

### 4.2.7 Relevant symposia materials

For additional information on the topics discussed in this section, see the following papers.

| *Appendix reference* | **Paper** |
|---|---|
| A-20 | Living to 100 and Beyond: Implications of Longer Life Spans<br>http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-rappaport.pdf |
| A-31 | High-Age Implications of Postretirement Risks<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xvii.pdf |
| A-32 | What if Mortality Was to Diminish Much More Than Was Forecast? Implications for Financing Social Security<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iv.pdf |
| A-34 | Implications of an Aging Population in India: Challenges and Opportunities<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iii.pdf |
| A-47 | Health, Wealth and Wisdom—Living Long, Living Well: An Actuary Muses on Longevity<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-cowell.pdf |
| A-52 | Living to 100: Survival to Advanced Ages: Insurance Industry Implication on Retirement Planning and the Secondary Market in Insurance<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5a-ranasinghe.pdf |
| A-63 | Typology and Review of Measures of Human Aging, Longevity and Superlongevity, With Applications to U.S. Data and Some Implications for U.S. Public Programs<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4b-siegel.pdf |
| A-65 | Economic Sustainability of Retirement Pensions in Mexico: Is There a Link With the Mexican-Origin Population in the United States?<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2a-chande.pdf |
| A-66 | Evaluation of Approaches to Reducing Women's Longevity Risks<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3b-orth.pdf |
| A-69 | Micro Pension Plan: Indian Perspective<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1b-bhattacharya.pdf |
| A-70 | Retirement and Retirement Ages in Canada Revisited<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1b-burnell.pdf |
| A-78 | Is Long-Term Care Social Insurance Affordable in Developed Countries?<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-andrews.pdf |

| *Appendix reference* | **Paper** |
|---|---|
| A-80 | The CLASS Act and the Future of Long-Term Care Financing<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-moses.pdf |
| A-97 | How to Survive Living to 100: Ways to Improve the U.S. Retirement System<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4a-orth.pdf |
| A-99 | Pension Reform in Canada in Canada—An Actuarial Perspective<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4a-brown.pdf |
| A-102 | Is Raising the Age of Eligibility Fair to All? An Investigation of Socio-Economic Differences in Mortality Using Population Data<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g5-rashbrooke.pdf |
| A-105 | Living to 100: Challenges and Opportunities for Employers<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5a-billings.pdf |
| A-106 | Risk Management Issues for Individuals With Special Emphasis for Women<br>http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5a-rappaport.pdf |
| A-110 | Will There Be Enough Doctors, Nurses and Hospitals for Our Aging Populations?<br>http://www.soa.org/files/pd/2011-orlando-living-100-andrews-gs6.pdf |
| A-115 | Health Expectancy<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-albert.pdf |
| A-116 | Summary of Panel Discussion on Implications of Increasing Life Spans for the Private Sector<br>http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxviii.pdf |
| A-119 | Health Policy Challenges of Population Aging: Perspectives From the Oxford Institute of Ageing<br>http://www.soa.org/files/pd/2011-orlando-living-100-howse-keynote.pdf |
| A-124 | Estimating the True Cost of Retirement<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-blanchett.pdf |
| A-125 | The CBD Mortality Indexes: Modeling and Applications<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-chan.pdf |
| A-126 | Optimal Retirement Tontines for the 21st Century: With Reference to Mortality Derivatives in 1693<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-milevsky.pdf |
| A-140 | How Well Have Retirement Systems Adapted to Longer Life?<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-rappaport.pdf |
| A-141 | Mapping the Adequacy of Care and Support for the Elderly in Developed Countries<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-andrews.pdf |
| A-142 | Supporting the Oldest Old: The Role of Social Insurance, Pensions and Financial Products<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-forman.pdf |
| A-146 | Living to 100: Socioeconomic Implications of Increased Longevity<br>https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-gorvett.pdf |

| *Appendix reference* | **Paper** |
|---|---|
| A-147 | Perspectives on SOA Post-Retirement Risk Research and What it Tells About the Implications of Long Life https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-rappaport.pdf |
| A-150 | Modeling Medical Cost Trends for Advancing Age in the Long Run https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-getzen.pdf |
| B-1 | The Advancing Frontier of Human Survival (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1-soa-informal-discussant.pdf |
| B-2 | Perspectives and Implications to Stakeholders of Increasing Longevity (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1c-soa-informal-discussion.pdf |
| B-3 | Developing a Winning Strategy to Address the Good, the Bad and the Wrinkled of Our Aging Workforce (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2c-soa-informal-discussion.pdf |
| B-4 | Innovative Business Solutions to Respond to the Aging Society (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2-soa-informal-discussant.pdf |
| B-5 | Data Sources and Projection Methods for Successfully Supporting the Needs of the Senior Market (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3c-discussion.pdf |
| B-6 | Proactive Strategies for Managing Long-Term Care Needs in Retirement (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4c-soa-informal-discussion.pdf |
| B-7 | Could Moses Live to Be 120? (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4-soa-informal-discussant.pdf |
| B-8 | Mortality Projections From a Social Security Perspective (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| B-9 | Leaving Worries Behind: Risk Management Strategies for Individuals to Address the Economic Issues Related to Increased Longevity (informal discussion transcript) https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5c-discussion.pdf |
| B-10 | Discussant comments for session: Innovative Retirement Products https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-kaufhold-discussant.pdf |

## 5. Closing Remarks

As you read through the material presented at the Living to 100 symposia, it becomes clear that while much has been done, there remain gaps in our collective perspective which should be filled through future research.

To reiterate and to add to those highlighted in the sections above, there is a fundamental need to address the following ideas:

- How can we improve the quality of our data? How can we better identify the difference between the *drivers* of older age mortality and the *symptoms* of aging?
- How can we better understand the complex aging mechanisms and explain the influence of genetics on longevity?
- Given the limitations of the data currently available, how can we make sure our projections of future mortality are useful to industry and government professionals?
- How can actuaries viably project future mortality rates and other technical manipulations ensuring their usefulness and relevance to industry and government professionals?
- How can we determine the appropriate rate of improvement for a given population? What is a reasonable ultimate age at which it is appropriate to assume a mortality table should end, if at all?
- How can we work together as a profession to create a set of basic tools or methodologies that can be used as a starting point for everyone? How should we augment and use those tools for pension, insurance and long-term health products? How can we work, or leverage, the general insurance community and the international actuarial community?
- How can actuaries use these tools to help inform the discussion at the societal level? At the regulatory level?
- How will society adapt to the aging population? What should be the roles of the public and private sectors in addressing longevity's societal implications?
- What are the catalysts needed to solve the challenges facing the long-term care and pension industries in light of increasing longevity?

As the SOA prepares for the next Living to 100 symposia, we encourage practitioners to focus their attention on filling the gaps in our collective knowledge so we can move toward answering these crucial questions.

# Appendix A: Census of articles

A-1 Title: Pensioner Mortality in the New York State Public Retirement Systems

Author(s): James Fox

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-fox.pdf

This article looks at New York's mortality data going back to 1921. When analyzed, a smooth asymptotic trend is noticed in mortality rates; forecasts were then made for the New York State Retirement System. The results showed a steady increase over the next 30 years, adding four years on average to the life span of a 62-year-old. This change would not represent an immediate burden on the system.

A-2 Title: Mortality at Advanced Ages in the United Kingdom

Author(s): Adrian P. Gallop

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-gallop.pdf

While mortality rates have fallen in the United Kingdom significantly over the last 100 years, calculating mortality rates for people older than 85 has proven difficult since that information is not published. More recent years have the gap in data starting at 90, which is still creating problems for advanced-age calculations. This article provides a summary of the data available and discusses some of the problems that have arisen due to lack of data for advanced ages. Also discussed is the recent work by the U.K. Government Actuary's Department to construct a database of mortality rates.

A-3 Title: Mortality of the Extreme Aged in the United States in the 1990s, Based on Improved Medicare Data

Author(s): Bertram M. Kestenbaum, ASA, and B. Reneé Ferguson

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-ferguson.pdf

The U.S. Medicare program provides the most extensive and high quality data for very old individuals in North America. This data is used for constructing the U.S. life tables for older ages every 10 years. The authors articulate that even though this is the best available data, there are still errors which have a greater effect on older ages. This paper looks at ways to correct these errors and presents them with their adjusted life tables.

A-4 Title: Reported Deaths of Centenarians and Near-Centenarians in the U.S. Social Security Administration's Death Master File

Author(s): Kenneth Faig Jr., FSA

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-faig.pdf

The Social Security Administration maintains the largest collection of publicly accessed death records, the Death Master File. This article discusses the sources of information in the Death Master File's public release in 2000. Geographically, specific centenarian samples drawn from the Death Master File's public release can be validated using other resources.

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|---|---|---|
| A-5 | Title: | Data Mining Techniques for Mortality at Advanced Age |
| | Author(s): | Lijia Guo, ASA, Ph.D., and Morgan C. Wang, Ph.D. |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-guo.pdf |
| | | This article discusses issues and methods for advanced-age mortality using data mining. Data mining is an emerging new technology and interactive information discovery process with massive actuarial potential. Several factors were looked at in this study, and their influence on advanced-age mortality distributions is discussed. Using logistic regression techniques, models were built to project advanced-age mortality distribution. |
| A-6 | Title: | Estimating Mortality of Insured Advanced-Age Population With Cox Regression Model |
| | Author(s): | Zhiwei Zhu, Ph.D.; Michael Hoag, FSA; Stéphane Julien, FSA; and Sufang Cui, Ph.D. |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-zhu.pdf |
| | | The authors use the Cox model to estimate the mortality of advanced age (≥60) populations. A total of 66,989 policies issued from 1997 to 2000 from 14 insurances companies were used, and the mortality rate impact from multiple risk factors (issue age, product, gender, smoking status and duration) was modeled and compared both to actual data and the Society of Actuaries 1990-95 mortality table. The authors find that a limitation of the Cox model is that only count of claims can be generated through the estimation process. |
| A-7 | Title: | Detection and Significance of Frailty in Elderly Insurance Applicants |
| | Author(s): | Dr. Robert J. Pokorski, FACP |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-pokorski.pdf |
| | | The author summarizes and identifies risk factors attributable to frailty through various studies. The author concludes the risk factors to identify frailty are age, gender, functional and cognitive impairment, nutritional status, comorbid impairments, self-reported function, and difficulties with mobility, balance and aerobic capacity along with country-specific factors. |
| A-8 | Title: | Analysis of Mortality in a Small Sample of Older Adults |
| | Author(s): | Bruce L. Jones, FSA, FCIA, Ph.D.; Hyuk-Sung Kwon; Donald H. Paterson; David A. Cunningham; and John J. Koval |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-jones.pdf |
| | | The authors analyze mortality in a sample of 441 adults from London, Ontario, Canada, age 55 to 85 at the time the study was conducted. The authors used a proportional hazards model along with a kernel estimator to obtain a semi-parametric model that describes how mortality varies by age and gender. The paper also concludes that while cardiorespiratory fitness was significantly related to mortality, further research is needed to develop models that fit cardiorespiratory fitness into mortality. |
| A-9 | Title: | Mortality for Retired Federal Employees and Their Survivors |
| | Author(s): | Michael R. Virga, ASA, EA, MAAA |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-virga.pdf |

This paper presents data on the mortality, and mortality improvement trends, for 1.64 million retired U.S. Civil Service employees and their survivors from 1980 to 2000, and analyzes the relationship to such factors as salary, annuity, total service, duration on the annuity rolls, retiree vs. beneficiary, and disability vs. nondisability.

A-10 Title: Emergence of Supercentenarians in Low Mortality Countries

Author(s): Jean-Marie Robine and James W. Vaupel, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-robine.pdf

This paper uses data from the International Database on Longevity, which warehouses supercentenarian data in low mortality countries, to analyze mortalities for ages 110 to 115. The authors show that the mortalities between ages 110 and 115 fall far below a ceiling of 0.6, a value previously proposed by other researchers. They conclude their results strongly support the finding that mortality does not increase according to the Gompertz curve at the highest ages.

A-11 Title: Mortality at Advanced Ages in Spain

Author(s): Maria Dels Àngels Felipe Checa

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-checa.pdf

This paper explores and provides a statistical description of Spain's national centenarian data. Data inconsistency for higher ages proved to be a significant problem in the study. The author concludes that in light of the analyzed trends, it would be acceptable to forecast an increase in the centenarian population in Spain.

A-12 Title: Dealing With Problems in Data Quality for the Measurement of Mortality at Advanced Ages in Canada

Author(s): Robert Bourbeau, Ph.D., and Bertrand Desjardins, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-bourbeau.pdf

Data quality is severely compromised when dealing with advanced ages. The authors explore various methods to terminate life tables. One involves finding ways to validate a sufficient number of unbiased high ages at death to produce an accurate measure with the "generation method." Another is to establish convincing evidence as to the pattern of survival at the very high ages; mathematical techniques can then be used to generate the rates as an extension of mortality at ages 70 to 90 or 100. The authors postulate that it is clearly advisable to extend to the highest ages possible the exact measure of mortality based on bias-free observations.

A-13 Title: Using Dynamic Reliability in Estimating Mortality at Advanced Ages

Author(s): Fanny L. F. Lin, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-lin.pdf

The author compares Gompertz mortality law and a model based on reliability theory using eight Taiwan Complete Life tables.

A-14 Title: Approaches and Experiences in Projecting Mortality Patterns for the Oldest Old

Author(s): Thomas Buettner, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-buettner.pdf

The author describes first the use of a relational mortality model with a standard proposed by Himes, Preston and Condran to extend life tables beyond age 80. The author then focuses on the projection of mortality using the method proposed by Lee and Carter. After a description of each method, an assessment of their performance and robustness is undertaken. A final section adds observations regarding possible future trends in survival among the oldest old and necessary improvements of empirical data.

A-15 Title: Oldest-Old Mortality Rates and the Gompertz Law: A Theoretical and Empirical Study Based on Four Countries

Author(s): Ching-Syang "Jack C." Yue

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-yue.pdf

The author uses a standard operating procedure for testing the Gompertz assumption using yearly age-specific mortality data.

A-16 Title: Living to Age 100 in Canada in 2000

Author(s): Louis G. Doray, ASA, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-doray.pdf

Statistical models are fit to Canadian data sets, using maximum likelihood theory to estimate the parameters of the models and obtain estimates of the standard error for the mortality rates. Mortality rates are then projected for people who will attain age 80 in the future.

A-17 Title: Underlying and Multiple Cause Mortality at Advanced Ages: United States 1980-1998

Author(s): Eric Stallard, ASA, FCA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-stallard.pdf

From 1980 to 1998, there were substantial improvements in the health and mortality of people 65 and older. This paper evaluates age- and gender-specific patterns of change in underlying and multiple cause-of-death reports. The mortality measures used will be underlying cause of death, multiple cause death rates, associated cause death rates, and death rates based on the joint occurrence of multiple cause conditions. The results of these evaluations are discussed in the context of existing models and used to forecast future mortality patterns.

A-18 Title: Plastic Omega

Author(s): Gene Held, FSA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-held.pdf

The progress of the Human Genome Project is resulting in a rapidly increasing knowledge about life at its most fundamental level. The head of the project believes that by 2030 the genes which control aging will be mapped and clinical trials for drugs to slow aging could be underway. This paper discusses the subject of science's effect on aging as well as provides references for more detailed information. Staying on top of these types of advancements is critical to actuaries as they could invalidate our assumptions, which may result in cascading errors in future projections.

A-19 Title: Longevity Determination and Aging

Author(s): Leonard Hayflick, Ph.D.

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| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-hayflick.pdf |
| | | The paper discusses the importance of research into aging rather than research on age-associated diseases. The author states that if aging research is to advance, it will not only be necessary to distinguish biogerontology from geriatric medicine but also to distinguish aging from longevity determination. |
| A-20 | Title: | Living to 100 and Beyond: Implications of Longer Life Spans |
| | Author(s): | Anna Rappaport, FSA, EA, FCA, MAAA, and Alan Parikh, FSA, EA |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-rappaport.pdf |
| | | This paper discusses the impact of increased longevity on spouse, family members, business opportunities and society as a whole. The authors use statistics from the Social Security Administration and U.S. Census Bureau to frame their argument. |
| A-21 | Title: | Some Background From Census 2000 |
| | Author(s): | W. Ward Kingkade |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxxiv.pdf |
| | | This paper presents the breakdown and background of the 2000 U.S. census. |
| A-22 | Title: | Application of Mortality Models to Japan |
| | Author(s): | Masakazu Ozeki |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xiv.pdf |
| | | Using the Japan Life Table as input, four models—Heligman-Pollard, mixed Weibull, Lee-Carter and a simulation—are examined and their parameters determined. The strengths and limitations of each model are discussed. |
| A-23 | Title: | The Lee-Carter Model for Forecasting Mortality Revisited |
| | Author(s): | Siu-Hang "Johnny" Li, Ph.D., and Wai-Sum Chan, FSA, Ph.D. |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xi.pdf |
| | | Mortality data from the United States and Canada is used to perform time-series outlier analysis on the key component of the Lee-Carter model: the mortality index. |
| A-24 | Title: | Living to 100 and Beyond: An Extreme Value Study |
| | Author(s): | Zhongxian "Jerry" Han |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-vii.pdf |

This paper describes parametric modeling for the elderly and oldest population. A classic threshold model is fitted to the data of each year using maximum likelihood methodology, separated by categories of year and gender. Then a model with transformed generalized Pareto distribution is fitted using a hyperbolic transformation, where the limiting age is introduced as a new parameter. The third model, a transformed exponential distribution, is shown to fit the data best. Log-likelihood functions for all models are given to find parameter estimations together with their confidence intervals. Last-k-years thresholds are specifically used to do a time series analysis of the limiting age in the 20th century. As a direct application, continuous mortality rates functions above the threshold can be derived from the model.

A-25 Title: An Extreme Value Analysis of Advanced Age Mortality Data

Author(s): Kathryn A. Robertson; Debbie J. Dupuis, Ph.D.; and Bruce L. Jones, FSA, FCIA, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxxiii.pdf

The authors explain r-largest and peaks-over-threshold approaches to extreme value modeling. Generalized extreme value and generalized Pareto distributions are fit to the life span data.

A-26 Title: "Makeham-Type" Mortality Models

Author(s): Marie Redina L. Mumpar-Victoria, Ph.D.; Augusto Y. Hermosilla, Ph.D.; and Ronnie M. Mirandilla

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xiii.pdf

The author analyzes the inverse Makeham model and the modified Makeham select model. The models' effectiveness in exhibiting patterns of mortality is tested by simulating the nonlinear models and estimating the parameters via non-linear regression using NLIN and SAS.

A-27 Title: Data Quality of Oldest-Old Population in Taiwan: 2003 Census Ages 89 and Above

Author(s): Ching-Syang "Jack C." Yue

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxxi.pdf

Historically, census data has been insufficient for older ages because of low response rates. To address the problem, the Taiwan government conducted face-to-face interviews with people older than 89 for a special 2003 census and compared the results to the older age data acquired in the 2000 general census. The author uses the data to test the parameters of the Gompertz law using the bootstrapping method.

A-28 Title: Seasons and Longevity: Mortality Trajectories Among the Oldest Old

Author(s): Jean-Marie Robine; Siu Lan K. Cheung, Ph.D.; and Fred Paccaud

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxiv.pdf

Using data from Switzerland, the authors analyze seasonal mortality. Results indicate that excess mortality occurs in the winter months (December through March) and that the mode and standard deviation of individual life durations is lower in the winter than summer.

A-29 Title: Number of Centenarians in the United States Jan. 1, 1990, Jan. 1, 2000, and Jan. 1, 2010 Based on Improved Medicare Data

Author(s): Bertram M. Kestenbaum, ASA, and B. Reneé Ferguson

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxvi.pdf

Medicare Part B data is allowing a more reliable study of the centenarian population in the United States. The authors show that the centenarian population has grown 4 percent annually between 1990 and 2000 and that the fraction of centenarians to those age 75+ is larger than previously thought.

A-30 Title: IDL, the International Database on Longevity

Author(s): Jean-Marie Robine, Amandine Cournil, Jutta Gampe and James W. Vaupel, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxiii.pdf

Since the first symposium, Living to 100 and Beyond: Survival at Advanced Ages, held in 2002, a collaborative effort has been made to assemble an international database on longevity, gathering validated longevity records for people having reached at least their 110th birthday. Different validation processes were then undertaken by the participating teams. By March 2004, more than 500 validated records had been gathered. This paper first evaluates the quality of data according to several criteria, such as the country of residence or the validation process undertaken, and then provides an estimation of the mortality trajectory up to age 114.

A-31 Title: High-Age Implications of Postretirement Risks

Author(s): Anna M. Rappaport, FSA, EA, FCA, MAAA, and Monica Dragut

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xvii.pdf

This paper focuses on the risks of retirement and special issues that can arise for those at more advanced ages. Major risks at advanced ages include outliving your retirement resources, unexpected health care costs and inflation. Economic risks (i.e., inflation) become more severe as life span increases and are particularly important for people at advanced ages. The article concludes that public knowledge about retirement planning contains many misconceptions, and any system in which people are left too much on their own will result in difficulties, especially at advanced ages. The authors believe the best solutions to these problems are an increase in education, strong employer contributions and the maintenance of Social Security.

A-32 Title: What if Mortality Was to Diminish Much More Than Was Forecast? Implications for Financing Social Security

Author(s): Robert Bourbeau, Ph.D.; Bertrand Desjardins, Ph.D.; and Jacques Légaré

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iv.pdf

This article discusses the importance of examining the risks associated with financing Social Security with pay-as-you-go systems. As under this model, the increasing age of a population causes a heavier burden on the working population, the authors postulate that the model no longer fits today's demographic profile. A pressing issue for policymakers today should be implementing a fairer system to help ease these burdens.

A-33 Title: Shapes and Limits of Longevity in Mexico

Author(s): Roberto Ham-Chande

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-ii.pdf

The author discusses the levels and forms that mortality and survivorship are taking for the oldest old in Mexico, using population census from 1930 to 2000 and projects the population from 2010 to 2050. Then the author compares and analyzes the 100+ mortality pattern under Gompertz law and Hayward & Gorman. Finally, he suggests that research using better instruments to determine the maximum longevity in Mexico and the trends of life expectancies at all the ages is required.

A-34 Title: Implications of an Aging Population in India: Challenges and Opportunities

Author(s): Prakash Bhattacharya

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iii.pdf

This article addresses the aging population in India. Elderly Indians currently experience higher rates of certain severe medical conditions due to bad habits and unhealthy lifestyles as well as increased poverty from poor financial planning. These challenges are further complicated by inadequate health care facilities for older Indians. The author believes that many of the problems facing older Indians can be remedied by better education on the retirement planning front. The investments they make could not only allow them to retire more comfortably and receive better care, but could help boost India's economy to one of the strongest in the world.

A-35 Title: Coping With Longevity: The New German Annuity Valuation Table DAV 2004 R

Author(s): Ulrich Pasdika and Jürgen Wolff

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xvi.pdf

Given the increased financial exposure to longevity risk, a subcommittee of the German Actuarial Society (DAV) examined in detail the adequacy of the current industry annuity valuation table DAV 1994 R, after which it was determined that a new industry table was required. The authors describe the development of the German Annuity Valuation Table DAV 2004R, which has been used for the pricing and valuation of annuity business since Jan. 1, 2005.

A-36 Title: Mortality at Advanced Ages in the United Kingdom

Author(s): Adrian P. Gallop and Angus S. Macdonald

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxi.pdf

The paper considers the problems encountered in estimating mortality rates at old ages in the United Kingdom for both the general population and those taking out insurance. It describes the current and past methodologies used to construct mortality rates at advanced ages for official population life tables and the Continuous Mortality Investigation Bureau (CMIB) mortality tables of insured lives. Possible methods for projecting mortality rates at advanced ages are also discussed.

A-37 Title: The Interdependency of Increasing Life Expectancy and Driving Life Expectancy of Elderly Populations

Author(s): Chao-Chun "Vickie" Leng and Min-Ming Wen

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-x.pdf

This paper analyzes the impacts of increasing longevity on driving life expectancy by gender and age group. Further, it estimates the mobility dependency and suggests better public policies should be developed to help the mobility of seniors.

A-38 Title: Trajectories of Disability and Mortality Among the U.S. Elderly Population: Evidence from the 1984–1999 NLTCS

Author(s): Eric Stallard, ASA, FCA, MAAA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxvii.pdf

This paper employs a longitudinal form of the Grade of Membership (GoM) model to specify and estimate a multivariate model of the trajectories of disability and mortality among elderly respondents to the National Long-Term-Care Survey (NLTCS) of 1984 to 1999. The author shows that the model can be fitted to existing data and that the results are interpretable as generalizations of fixed frailty with linearly declining vitality.

A-39 Title: Search for Predictors of Exceptional Human Longevity: Using Computerized Genealogies and Internet Resources for Human Longevity Studies

Author(s): Natalia S. Gavrilova and Leonid A. Gavrilov

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-v.pdf

This paper analyzes data taken from computerized genealogies, the Social Security Administration, census and Internet resources to find predictors and determinants for centenarians. The paper starts with the detailed description of the data collection and verification process and then uses summary statistics and (multiple) logistic regression to find the correlations. The paper concludes that family factors (birth orders, region of residence and household property) and early life conditions are key determinants for exceptional human longevity. Finally, the paper analyzes the mortality patterns at advanced ages using the SSA Death Master File.

A-40 Title: The Great Debate on the Outlook for Human Longevity: Exposition and Evaluation of Two Divergent Views

Author(s): Jacob S. Siegel

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xv.pdf

This paper summarizes the debate of two views of human longevity in the United States: a life expectation (at birth) of 100 years will be reached in the industrialized countries by the year 2060 and life expectation is not likely to exceed 85 years by 2060. The topics to support the views also include the extension of the average recorded human life span, the existence of limits to human life span and life expectancy, the form of the trajectory of age-specific mortality rates at the highest ages of life, and the utility of developing projections of mortality on the basis of causes of death.

A-41 Title: An Investigation of Select Birth Cohorts

Author(s): Richard MacMinn, Ph.D.; Krzysztof Ostaszewski, FSA, CFA, Ph.D.; Ranee Thiagarajah, ASA, Ph.D.; and Frederik Weber

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxx.pdf

The actuarial term “mortality improvement” known as an increase in longevity has been a worldwide phenomenon throughout the 20th century. While this is an achievement for public health in general, it creates increasing risks for the providers of retirement benefits. This article discusses whether select birth cohorts of unusually high improvements in longevity exist and, if so, where they exist within various countries. The article discusses the criteria for defining the cohorts and how to identify them, then studies their effect.

A-42 Title: The Impact of the Equity Risk Premium and Population Aging on the Canadian Retirement Saving System

Author(s): Doug Andrews, FSA, CFA, FCIA, MBA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-i.pdf

This article discusses the impact of increasing longevity on retirement systems in Canada; in particular, attention is paid to the rate of return on investments. Since most plans invest in equities, the return on the equity markets over the lifetime of retirees is extremely important. This paper reviews research regarding the equity risk premium, combines it with projected mortality data and applies it to the Canadian retirement income system. The paper concludes that if lower estimates of equity risk premium materialize, when combined with increasing longevity of Canadian population, it will cause significant challenges to the retirement system.

A-43 Title: The Effects of Advanced Age Mortality Improvement on the Valuation of Variable Annuities With Guaranteed Death Benefits

Author(s): Lijia Guo, ASA, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxxv.pdf

Variable annuities with guaranteed death benefits are difficult to price given improvements in advanced-age mortality. The hybrid mortality model presented in the paper offers a more accurate way to help value the products.

A-44 Title: Analysis of Trends in the Age-Specific Shape of Mortality Curves for Populations in the United States and Japan

Author(s): Christine Dugan, Hande Gulumser, Richard Humble and Daniel Ryan

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xx.pdf

This paper discuss longevity trends in the United States and Japan by using the age-specific data from the Human Mortality Database. The authors fit models to past trends and then project future mortality based on forward projections of those trends. The paper concludes that the Weibull distribution provides a valuable model of age at death and the logistic function provides a valuable model of mortality rates for ages 50 and older.

A-45 Title: Ending the Mortality Table

Author(s): Edwin C. Hustead, FSA, EA, MAAA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-ix.pdf

The author summarizes four common methods to end mortality tables and then describes the shapes of the mortality curves at old ages. The impact on a pension plan of each of these methods is demonstrated. Finally, the financial impact of using the first three methods on U.S. Social Security data was presented. The author concludes that the chosen method does not have significant financial impact on large plans until the age of 115.

A-46 Title: Estimates of the Incidence, Prevalence, Duration, Intensity and Cost of Chronic Disability Among the U.S. Elderly

Author(s): Eric Stallard, ASA, FCA, MAAA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3b-stallard.pdf

This paper estimates the burden of chronic disability on the U.S. elderly population using gender-specific measures of long-term care service use, intensity and cost. Death rates were computed and analyzed for differences by age and gender whereas rates of service use, intensity and cost were conditional on age and gender. This paper concludes that the Health Insurance Portability and Accountability Act criteria effectively target the high-cost disabled subpopulation and that a substantial gender difference exists as females outspend males in a ratio of 2.8 to 1.

A-47 Title: Health, Wealth and Wisdom—Living Long, Living Well: An Actuary Muses on Longevity

Author(s): Michael J. Cowell, FSA, ALM

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-cowell.pdf

This paper deals with the health costs associated with long lives. The United States leads all nations in health care spending with an annual outlay of one-sixth of gross domestic product. Also discussed is the correlation between heath, wealth, geographic location and education. The article then combines biological and environmental factors using a mathematical approach and closes by examining the implications of uncontrolled increasing costs on our society.

A-48 Title: Human Behavior: An Impediment to the Future Mortality Improvement: A Focus on Obesity and Related Matters

Author(s): Sam Gutterman, FSA, FCAS, HonFIA, MAAA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-gutterman.pdf

This paper focuses on human behavior and its effect on mortality with a focus on obesity; trends in different age, gender and racial groups are examined. The article also touches on how the long-term health effects of adolescent obesity are offset by medical advances and reductions in smoking. Understanding human behavior and its contributions to mortality is essential to accurate projections.

A-49 Title: Is the Compression of Morbidity a Universal Phenomenon?

Author(s): Jean-Marie Robine; Siu Lan K. Cheung, Ph.D.; Shiro Horiuchi; and A. Roger Thatcher

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-04-cheung.pdf

This paper discusses the idea of morbidity compression. The studies examined produced varied results but overall showed a compression of morbidity at older ages.

A-50 Title: New Findings on the International Relationship Between Income Inequality and Population Health

Author(s): Robert L. Brown, FSA, ACAS, FCIA, HonFIA, and Steven G. Prus

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2a-brown.pdf

This paper tests the hypothesis that higher levels of income inequality are directly related to lower levels of population health and examines the inequality-health relationship across life. Using data from about 2000 and correlation techniques, the relationship between income inequalities for various age groups was tested. The two data sets used were wealthy countries and a combination of wealthy and nonwealthy. Overall the data for wealthy nations did not support the hypothesis that higher levels of income inequality resulted in lower levels of population health.

A-51 Title: Challenges on Improved Life Spans in India—The Actuarial Implications

Author(s): N.V. Subramanyan

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| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2a-subramanyan.pdf |
| | | This paper analyzes the life expectancy trend in India and compares it to other countries in the world. The author indicates that for ages 85+, the principles for smooth graduation of $q_x$ (Balducci assumption and Gompertz-Makeham's law) do not strictly hold true. The author also examines the social and economic implications of the increased life span in India. |
| A-52 | Title: | Living to 100: Survival to Advanced Ages: Insurance Industry Implication on Retirement Planning and the Secondary Market in Insurance |
| | Author(s): | Jay Vadiveloo, FSA, CFA, Ph.D.; Peng Zhou, FSA, Ph.D.; Charles Vinsonhaler, ASA, Ph.D.; and Sudath Ranasinghe, Ph.D. candidate |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5a-ranasinghe.pdf |
| | | The authors discuss the optimal allocation of assets so that the financial objectives of retirees are met. The objectives are to maximize current spending levels and maximize estate value at death. The authors conclude the optimum allocation involves both immediate annuities and investment products. The life settlement industry is also discussed. |
| A-53 | Title: | Longevity Risk Pricing |
| | Author(s): | Jiajia Cui |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5a-cui.pdf |
| | | Longevity risk is a serious solvency threat to pension plans and insurance companies. Longevity-linked securities are desirable instruments for buyers and sellers but are difficult to price and, therefore, not frequently traded in financial markets. Using the equivalent utility pricing principle, the author develops the minimum risk premium required by the longevity insurance seller and the maximum acceptable risk premium by the longevity insurance buyer for various longevity-linked securities. The author's pricing method allows for a tighter range of premiums and flexibility with securities with different payoff structures. |
| A-54 | Title: | A Study of the Lee-Carter Model With Age-Shifts |
| | Author(s): | Ching-Syang "Jack C." Yue, Sharon S. Yang and Hong-Chih Huang |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6a-huang.pdf |
| | | The authors explore analyzing an age-shift model to modify the Lee-Carter model to deal with the issue of non-constancy in parameters. |
| A-55 | Title: | Data Validation and Measurement of Cohort Mortality Among Centenarians in Quebec (Canada) According to Ethnic Origin |
| | Author(s): | Mélissa Beaudry-Godin; Robert Bourbeau, Ph.D.; and Bertrand Desjardins, Ph.D. |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-bourbeau.pdf |
| | | The authors perform an analysis of mortality estimates based on ethnic origin in Canada. |
| A-56 | Title: | Inference for Logistic-Type Models for the Force of Mortality |
| | Author(s): | Louis G. Doray, ASA, Ph.D. |
| | URL: | http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4a-doray.pdf |

Using Canadian mortality data, the author finds the parameters for Kannisto's model using a weighted least-squares estimator and for Perks' model parameters by using Taylor series expansion.

A-57 Title: Is There a Limit to the Compression of Mortality?

Author(s): Jean-Marie Robine; Siu Lan K. Cheung, Ph.D.; Shiro Horiuchi; and A. Roger Thatcher

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-03-cheung.pdf

The authors examine the subject of mortality compression using historical data from European countries. This paper discusses the notion of a limit for the compression of mortality and examines alternative hypotheses such as the shifting mortality model.

A-58 Title: Mortality Measurement at Advanced Ages: A Study of the Social Security Administration Death Master File

Author(s): Leonid A. Gavrilov and Natalia S. Gavrilova

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4b-gavrilov.pdf

This paper addresses three challenges of estimating hazard rates at extremely old ages. First, the observed mortality deceleration may be at least partially an artifact of mixing different birth cohorts with different mortality (heterogeneity effect); second, standard assumptions of hazard rate estimates may be invalid when risk of death is extremely high at old ages; and third, ages of very old people may be exaggerated.

A-60 Title: On Simulation-Based Approaches to Risk Measurement in Mortality With Specific Reference to Binomial Lee-Carter Modelling

Author(s): Steven Haberman and Arthur Renshaw

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6a-haberman.pdf

This paper develops the binomial version of the Lee-Carter model and provides a comparative study of simulation strategies for assessing risk in mortality rate predictions and associated estimates of life expectancy and annuity values in both period and cohort frameworks.

A-61 Title: Physical and Socioeconomic Characteristics at Young Age as Predictors of Survival to 100: A Study of a New Historical Data Resource (U.S. WWI Draft Cards)

Author(s): Natalia S. Gavrilova and Leonid A. Gavrilov

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-gavrilov.pdf

The authors explore whether people living to 100 and beyond were any different from their peers at their middle age (30 years) in terms of their physical characteristics (height and body build), occupation and marital status.

A-62 Title: Predictive Modeling for Advanced Age Mortality

Author(s): Lijia Guo, ASA, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4a-guo.pdf

The paper provides both the theoretical frameworks and the application aspects of the predictive modeling process. As the result, a mortality risk score was derived in differentiating the mortality risk for the advanced-age population.

A-63 Title: Typology and Review of Measures of Human Aging, Longevity and Superlongevity, With Applications to U.S. Data and Some Implications for U.S. Public Programs

Author(s): Jacob S. Siegel

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-4b-siegel.pdf

A multi-way typology of measures of aging, longevity and superlongevity is presented, with measures classified as measures of aging and longevity, direct and indirect measures of aging and longevity, and measures based on population data, death statistics and life table functions. The author postulates that measurement of time to death serves as a new way of looking at aging and longevity, and use of it could provide a degree of control over the fiscal consequences of increasing longevity on public programs.

A-64 Title: Testing Deterministic Versus Stochastic Trends in the Lee-Carter Mortality Indexes and Its Implications for Projecting Mortality Improvements at Advanced Ages

Author(s): Wai-Sum Chan, FSA, Ph.D.; Siu-Hang "Johnny" Li, Ph.D.; and Siu-Hung Cheung, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6a-chan.pdf

The authors investigate the dynamics of the Lee-Carter mortality index and perform statistical hypothesis tests to examine whether the mortality indexes are best described by stochastic trends or deterministic trends.

A-65 Title: Economic Sustainability of Retirement Pensions in Mexico: Is There a Link With the Mexican-Origin Population in the United States?

Author(s): Roberto Ham-Chande

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2a-chande.pdf

This author analyzes the relationships between Mexicans and people living in the United States of Mexican origin from a demographic and social security perspective. The lower mortality rate, decreasing fertility and migration to the United States are contributing to a population aging among Mexicans. The author discusses the challenges and impacts of an aging population, specifically as it relates to social security systems.

A-66 Title: Evaluation of Approaches to Reducing Women's Longevity Risks

Author(s): Beverly J. Orth, FSA, J.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3b-orth.pdf

This article discusses the longevity risk of women in the United States. Elderly women living alone have some of the highest poverty rates in the United States largely because their longevity risk is greater than men's. Since existing financial products that can mitigate risk are not very attractive to most people, the author discusses alternative vehicles for pooling longevity risk and compares their effectiveness and viability.

A-67 Title: Living to 100 and Beyond in Canada with Dignity

Author(s): Doug Andrews, FSA, CFA, FCIA, MBA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1b-andrews.pdf

This author looks at increasing life expectancy of Canadians and suggests that government policy should be focused on allowing the elderly to live with dignity. This paper suggests that the population of 2031 will be very different than it is today. It poses the question: Is living longer a worthwhile goal if it is accompanied by inadequate wealth or loss of mental faculties? This paper outlines the best ways to enhance living with dignity such as replacing the Old Age Security benefit, better integrating retirement communities and legalizing medically assisted suicide.

A-68 Title: Living to 100—A Woman's Issue

Author(s): Anna M. Rappaport, FSA, EA, FCA, MAAA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3b-rappaport.pdf

This paper deals with issues facing women at advanced ages. It covers topics such as Social Security payment issues, working in retirement, need for long-term care and several others broken down by gender. The article also discusses the biggest pitfalls facing women such as divorce, overspending, under-saving and retiring too early. The author stresses that many of these problems do not arise until advanced ages when it is already too late to make the necessary corrections.

A-69 Title: Micro Pension Plan: Indian Perspective

Author(s): Prakash Bhattacharya

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1b-bhattacharya.pdf

This article discusses the current challenges India faces from a growing economy and an aging population. The author suggests that micro-pension plans are needed to cover the large segment of the population not covered under social security. The author believes that even small contributions from each person would generate a vast amount of funds that could be used to grow the economy, develop infrastructure and stabilize the stock market. The best result of this plan would be that it would save a large amount of people from poverty late in their lives without making a significant difference in their current standard of living.

A-70 Title: Retirement and Retirement Ages in Canada Revisited

Author(s): Brian L. Burnell, FSA, FCIA, FIA

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1b-burnell.pdf

The author discusses the combination of lower birth rates and higher life expectancy in Canada. This change in demographic is projected to cause the senior dependency ratio to almost double from its current 20 percent in the next 20 years. The author examines the effect of gradually increasing the retirement age to stabilize this growing problem. The author concludes major changes are required in the near term and suggests phased retirement programs and a greater degree of flexibility in retirement agreements. The author postulates that the changes must be recognized and acted upon by employees, employers and the Canadian government.

A-71 Title: Mortality Projections for Social Security Programs in Canada

Author(s): Michel Montambeault and Jean-Claude Ménard

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-02-menard.pdf

This paper examines past mortality trends in Canada 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 in Canada, and the results include assumed annual rates of mortality improvement and projected life expectancies. Finally, the stochastic time-series method autoregressive integrated moving average (ARIMA) is discussed as a projection model.

A-72 Title: Mortality Projections for Social Security Programs in the United States

Author(s): Alice Wade

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-02-wade.pdf

This paper examines past mortality trends in the United States 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 used to quantify the variability in mortality rate projections.

A-73 Title: Mortality Projections in the United Kingdom

Author(s): Adrian P. Gallop

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-02-gallop.pdf

This paper discusses the key forces likely to influence U.K. mortality in the 21st century, and describes the methodology and assumptions used in the latest projections of U.K. mortality. The paper also describes recent tables of mortality rates published by the Continuous Mortality Investigation, based on the experience of people taking out insurance contracts and the approaches taken in projecting these.

A-76 Title: The Biology of Human Longevity, Aging and Age-Associated Diseases

Author(s): Leonard Hayflick, Ph.D.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-03-hayflick.pdf

This article discusses the biology of human longevity. Factors such as genes guide longevity and processes like natural selection must retain structure and function or the species will vanish. A fundamental problem in the field is the failure to distinguish age changes from disease, which blurs the efforts to understand the biology of aging. The author concludes by asking why more resources are not devoted to understanding aging as the leading cause of death.

A-77 Title: Putting the Brakes on Aging: Beginning the Pharmaceutical Era

Author(s): Steven Austad

URL: http://www.soa.org/files/pd/2011-orlando-living-100-austad-gs1.pdf

This presentation discusses the advancements in pharmaceuticals and their effect on aging. Several new agents have shown promise against a variety of late-life diseases although their side effects have not yet been detected. In tests on animals, their life span has been increased even when beginning the medicine at more advanced ages. The presentation shows that slowing human aging is no longer a pipe dream but is becoming a reality.

A-78 Title: Is Long-Term Care Social Insurance Affordable in Developed Countries?

Author(s): Doug Andrews, FSA, CFA, FCIA, FIA, Ph.D.

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| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-andrews.pdf |
| | | Long-term care insurance is important for the financial health of elderly populations, but many countries find LTC to be too expensive to fund as a social program. The author looks at whether or not LTC is viable financially as a social program, and if so, whether it should be public or private, and how the definition of LTC changes by country. The impact of future demographic shifts and taxes on affordability is also discussed. The author concludes that LTC is feasible as a social insurance program and is prudent for countries to take on. |
| A-79 | Title: | The Relationship Between Cognitive Impairment and Mortality Rates Among Long-Term Care Insurance Applicants |
| | Author(s): | Marc A. Cohen, Ph.D.; Xiaomei Shi, M.S.; and Jessica Miller, M.S. |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-cohen.pdf |
| | | Using data from long-term care insurance applicants, the authors show that a classification of cognitive impairment increases mortality in individuals when holding other factors constant. The results show that an applicant classified as cognitively impaired has a death hazard rate that is 1.52 greater than someone without the impairment. The two cognitive screens used were Delayed Word Recall (DWR) and Enhanced Mental Skill Test (EMST). |
| A-80 | Title: | The CLASS Act and the Future of Long-Term Care Financing |
| | Author(s): | Stephen A. Moses |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-moses.pdf |
| | | Medicaid handles the majority of long-term care claims, which is putting stress on the financial solvency of the social program. Early policies encouraged the elderly to use Medicaid for LTC coverage; this has had undue consequences on reimbursement rates and quality of care. The Community Living Assistance Services and Support (CLASS) Act was created in the hopes of providing the elderly with more options for in-home care versus nursing home institutionalization. |
| A-81 | Title: | Temporal Evolution of Some Mortality Indicators. Application to Spanish Data |
| | Author(s): | A. Debón, F. Martínez-Ruiz and F. Montes |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1b-debon.pdf |
| | | This paper looks at Spanish mortality data and the properties of the indicators life expectancy, Lorenz curve, Gini index, modal age at death, standard deviation above modal age and shortest age interval for 50 percent of deaths. The authors then discuss the Lee-Carter model and bootstrapping techniques to calculate confidence intervals. |
| A-82 | Title: | Mortality Compression and Longevity Risk |
| | Author(s): | Ching-Syang "Jack C." Yue |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1b-yue.pdf |
| | | Instead of fitting stochastic models for mortality rates, this study explores increasing life expectancy by examining the basic properties of survival curves. The curves are examined to check for mortality compression. |
| A-83 | Title: | Mortality Compression |
| | Moderator: | Thomas Edwalds, FSA, ACAS, MAAA |
| | Panelist(s): | Leonid A. Gavrilov, Natalia S. Gavrilova, Allen Klein, Ching-Syang "Jack C." Yue and Jean-Marie Robine |
| | URL: | http://www.soa.org/files/pd/2011-orlando-living-100-cheung-1b.pdf |

The authors present research on their papers: "Temporal Evolution of Some Mortality Indicators. Application to Spanish Data," "Mortality Compression and Longevity Risk" and "Patterns of Old-Age Mortality, Emergence of the Centenarians and the Compression of Death Above the Mode."

A-85 Title: Obesity: Status and Effects

Author(s): Sam Gutterman, FSA, FCAS, HonFIA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-gutterman.pdf

This article discusses the migration away from using stored fat as an energy source and the resulting negative impact on life expectancy. Discussed are the major contributions and causes of obesity. While U.S. obesity numbers appear to be stabilizing, they are still disturbingly high. Obesity has played a significant role in the increase of U.S. health care costs and although studies differ as to the magnitude of the increased cost, it has been shown to be anywhere from 5 to 16.5 percent. The paper concludes with ideas on how to remedy the problem of obesity.

A-86 Title: The Impact of Obesity and Diabetes on LTC Disability and Mortality: Population Estimates From the National Long Term Care Survey

Author(s): Eric Stallard, ASA, FCA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-stallard.pdf

This article attempts to estimate the impact of obesity and diabetes on disability and mortality for those older than 65. Current obesity was associated with large increases in diabetes, non-significant increases in disability, and substantial decreases in mortality among the elderly. Obesity at age 50 and diabetes were both associated with large increases in disability among the elderly; tests of the interaction between these risk factors did not rule out either additive or multiplicative models.

A-87 Title: The Role of Social and Health-Related Characteristics in Determining Survivorship Among the U.S. Oldest Old

Author(s): Hiram Beltrán-Sánchez, Ph.D., and Jennifer Ailshire, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2a-alishire.pdf

This paper addresses the socioeconomic and demographic characteristics, health status and health behaviors associated with oldest-old mortality and survivorship. Data is used from a 1990–91 mortality study and then followed up on through 2002 to find trends. The study only looks at those who lived beyond age 65 and checks for patterns in their data that can help predict longevity beyond 65. The study results indicate that activity limitation and exercise status, when combined with education, play a very important role in surviving from 65 to 85, but have a much smaller effect beyond age 85. The study also notes that numbers for people 90–94 were very small, which could lead to unstable results and should be used with caution.

A-88 Title: Projection of Mortality Rates at Advanced Ages in Canada with a New Lee-Carter Type Model

Author(s): Louis G. Doray, ASA, Ph.D., and Kim O. Tang

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2b-doray.pdf

The authors describe how modeling and forecasting of advanced-age populations can be improved by combining features of the logistic model for the force of mortality and the Lee-Carter model.

A-89 Title: Assessing and Extending the Lee-Carter Model for Long-Term Mortality Prediction

Author(s): Xiaoming Liu and Hao Yuy

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2b-liu.pdf

The authors examine the prediction performance of the Lee-Carter model for forecasting long-term mortality. Two issues are addressed: robustness and drift uncertainty. The authors share suggestions on handling parameter estimation.

A-90 Title: Coherent Mortality Modeling for a Group of Populations

Author(s): Sharon S. Yang, Ching-Syang "Jack C." Yue and Yu-Yun Yeh

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-2b-yang.pdf

The authors address coherent mortality modeling by combining a group of populations with similar period effects. The Lee-Carter model is employed to illustrate the feasibility of coherent mortality modeling using U.S. and Canadian data from the Human Mortality Database.

A-91 Title: Longevity Risk and Regular Discount Sequence

Author(s): Hsin Chung Wang and Ching-Syang "Jack C." Yue

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-3b-wang.pdf

The authors adapt the idea of a regular discount sequence in the bandit problem, and use it to interpret life expectancy, as well as to develop a model for survival probabilities. They found that many frequently used mortality models, such as the Gompertz law and the Coale-Kisker model, and famous mortality assumptions (uniform distribution of death, constant force and hyperbolic assumption) all satisfy the requirement of regular discount sequence. In addition, they use the Brownian motion stochastic differential equation to model the discount sequence to predict future mortality rates and life expectancy.

A-92 Title: Simultaneous Prediction Intervals: An Application to Forecasting U.S. and Canadian Mortality

Author(s): Siu-Hang "Johnny" Li, Ph.D., and Wai-Sum Chan, FSA, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-3b-li.pdf

The primary objective of this paper is to demonstrate how simultaneous prediction bands can be created for prevalent stochastic models.

A-93 Title: Age-Related Changes in Factors Associated With Loss of Good Health

Author(s): Robert L. Brown, FSA, ACAS, FCIA, HonFIA; Andrew MacKenzie; and Steven G. Prus

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-brown.pdf

This study looks at factors associated with loss of good health in age groups 20 to 44, 45 to 64, and 65 and older. The study found the factors affecting different groups were not the same. Younger and middle-aged individuals were more affected by socioeconomic factors like income and the area they live, whereas a major factor affecting older people was social involvement. Consuming alcohol and being active socially helped prevent a decline of health at older ages. This study points out that better understanding the reasons for health decline for various age groups can help develop more effective policies and programs to keep people healthy.

A-94 Title: The Likelihood and Consequences of "Living to 100"

Author(s): Leonard Hayflick, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-hayflick.pdf

This essay discusses the impact on human life if science discovered a way to slow the aging process. The author believes that while it sounds good to have an average life expectancy of 100, the consequences for society and the individual would outweigh the benefits. The author believes there are several serious unforeseen complications that could arise especially if aging is slowed in children before full development. Another point of emphasis is the burden on an already overpopulated planet. If life were extended, not only would people live longer, but a woman who began treatment pre-menopause could reproduce for a longer period of time.

A-95 Title: Early-Life Predictors of Exceptional Longevity in the United States: Why Centenarians are Different from Their Shorter-Lived Siblings

Author(s): Leonid A. Gavrilov and Natalia S. Gavrilova

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g4-gavrilo.pdf

This study explores the effects of early-life factors (birth order, paternal age, maternal age, month of birth) on the likelihood of survival to advanced ages. Centenarians are compared to their shorter-lived siblings using a within-family approach. In contrast to the authors' 2005 study, birth order has no significant effects. However, the paper suggests that the parental age at a person's birth and the month of birth affect survival to age 100.

A-96 Title: Living to 100 and Liking It—Research of Relevance from the National Institute on Aging

Author(s): Marie Bernard

URL: http://www.soa.org/files/pd/2011-orlando-living-100-bernard-keynote.pdf

This presentation discusses how the aging of the U.S. population can be associated with increased chronic illness and disability. The author asserts that research and neuroscience discoveries can modify health and the human life span. Behavioral science also plays a major role and could help influence people to make optimal choices for healthy lifestyles. While some of the causes of longevity are genetic, the author believes that with more research and lifestyle changes, we could have greater control over our longevity.

A-97 Title: How to Survive Living to 100: Ways to Improve the U.S. Retirement System

Author(s): Beverly J. Orth, FSA, J.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4a-orth.pdf

This article discusses ways to improve retirement by addressing the challenges workers face in saving enough money to last their lifetime. While insurance options are available to protect one's assets, many people will still have trouble with their long-term expenses if they live to be very old or require long-term care. The author concludes that our current retirement system needs incremental changes in Social Security, annuitization in qualified retirement plans, and the development of more attractive long-term care policies to help retirees meet the financial difficulties of increased longevity.

A-98 Title: The Impact of the Automatic Balancing Mechanism for the Public Pension in Japan on the Extreme Elderly

Author(s): Yosuke Fujisawa

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4a-fujisawa.pdf

The author reviews Japanese mortality and life expectancy, emphasizing the growth in the extreme aged, and explains the underlying longevity issues that led to the automatic balancing mechanism used by the public pension program. Second, by means of stochastic mortality and fertility modeling, the author analyzes how a mortality decline, particularly at extreme ages, will affect the future of public pensions in Japan. Third, the author demonstrates, on the basis of the stochastic projections, how the automatic balancing mechanism will affect the financial security of people older than 100. The author concludes that significant further research is needed to solve the public pension problem in Japan.

A-99 Title: Pension Reform in Canada—An Actuarial Perspective

Author(s): Robert L. Brown, FSA, ACAS, FCIA, HonFIA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4a-brown.pdf

This paper discusses pension reform in Canada. The author first explains how the existing Canadian Income System is structured within the government-sponsored and private sector. The article then integrates a report from the Canadian Institute of Actuaries' Task Force in response to a debate on reform of the Canadian system. The report concludes that amendments to several rules in the Income Tax Act and in the various Pension Benefit Acts would greatly assist the existing pension system. Further, the fewer restrictions placed on the system, the better the level of participation and the more successful the program.

A-100 Title: Mortality Improvement in the USA: Analysis, Projections and Extreme Scenarios

Author(s): Joseph Lu and Wun Wong, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-lu.pdf

This paper looks at the mortality improvement trends used in the development of Scale AA, a set of annual rates of mortality improvement by age and gender. The author examines Scale AA's historical performance and, using stochastic models, compares the projection of mortality improvement with figures from Scale AA.

A-101 Title: Recent Adult Mortality Trends in Canada, the United States and Other Low Mortality Countries

Author(s): Nadine Ouellette, Ph.D., and Robert Bourbeau, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-ouellette.pdf

This paper examines recent changes in the age-at-death distribution at older ages in Canada, the U.S. and eight additional low-mortality countries. For several consecutive years in that timeframe, US females and males have both recorded important declines in their modal age at death and their level of old-age mortality remains high compared to the other countries. Further analysis of changes in the age-at-death distribution at older ages by socioeconomic group or by region could improve our current understanding of the latest mortality dynamics recorded among US adults.

A-102 Title: Is Raising the Age of Eligibility Fair to All? An Investigation of Socio-Economic Differences in Mortality Using Population Data

Author(s): Geoff Rashbrooke, FIA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g5-rashbrooke.pdf

This paper draws on New Zealand research that has matched individual death records to census records to derive mortality tables by adapting New Zealand Māori and non-Māori population mortality data to reflect differences in socioeconomic status. This adapted data is used as a basis to explore the implications of differential mortality in assessing the equity of increases in the pension age of eligibility. The paper concludes with suggestions as to how the imperatives for fiscal sustainability might be tempered with actions designed to mitigate the equity shortcomings indicated by the paper's analysis.

A-103 Title: Patterns of Aging-Related Changes on the Way to 100: An Approach to Studying Aging, Mortality and Longevity From Longitudinal Data

Author(s): Anatoliy I. Yashin, Konstantin G. Arbeev, Svetlana V. Ukraintseva, Igor Akushevich and Alexander Kulminski

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g5-yashin.pdf

This paper examines the average age trajectories of indices describing physiological states for different groups and their established mortality risk. Indices include body mass index, blood pressure, pulse rate, glucose level, etc. The data evaluated is the Framingham Heart Study. The results showed different indices have different age patterns and properties.

A-104 Title: A Study on Emerging Health Conditions Among the Elderly in India and the Sufficiency of Medical Framework and Health Insurance

Author(s): N.V. Subramanyan

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5a-subramanyan.pdf

The six decades after independence have been eventful for India, with all-around growth in economic terms, life expectancy and global recognition. There has been change in the social fabric with the number of people older than 60 steadily increasing. The gradual shift from an agrarian base to an industrial economy has had a telling effect. Prevalence of lifestyle diseases such as diabetes and cardiovascular diseases has increased considerably with resultant morbidity severely affecting the quality of life. The inadequacy of health care infrastructure in India further compounds the problem, and absence of a credible social health care policy and health insurance setup makes this a serious issue needing immediate attention. This paper presents the situation, analyzes and estimates the economic impact of changing demographics, and identifies opportunities for insurers.

A-105 Title: Living to 100: Challenges and Opportunities for Employers

Author(s): Mary Nell Billings and Anna M. Rappaport, FSA, EA, FCA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5a-billings.pdf

This paper deals with challenges facing employers to help their employees plan for old age. Many factors are coming together such as longer-term talent challenges, the need to work longer and rising health care costs, which make planning for retirement more difficult. While some jobs offer the flexibility of working beyond age 65, jobs that involve manual labor can be difficult even well before the normal retirement age. This paper discusses the issues today's work environment will face in the future and concludes that two very important things are needed: job options and innovation.

A-106 Title: Risk Management Issues for Individuals With Special Emphasis for Women

Author(s): Anna M. Rappaport, FSA, EA, FCA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5a-rappaport.pdf

The author deals with risk management issues primarily affecting women. Women face more difficult challenges because they tend to live longer than men. The author looks at issues regarding long life and managing risk for women while drawing on research done by the SOA. The author concludes that later retirement will be increasingly important in more advanced years and retirement age will likely increase one to two years per decade. Other points of emphasis are fixing gaps in individuals' knowledge of retirement, like explaining trade-offs and encouraging long-term and balanced planning.

A-107 Title: Mortality Measurement and Modeling Beyond Age 100

Author(s): Natalia S. Gavrilova and Leonid A. Gavrilov

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5b-gavrilova.pdf

This study uses data from the Social Security Administration Death Master File to show that mortality deceleration in humans observed at advanced ages may be an artifact caused by age exaggeration, data heterogeneity or use of improper estimates of hazard rate. The model comparison using Bayesian information criterion shows that in the age interval 88 to 106 years and for data with reasonably good quality, the Gompertz model shows better fitting of hazard rates than the logistic model.

A-108 Title: Mortality Rates at Oldest Ages

Author(s): R.C.W. "Bob" Howard, FSA, FCIA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5b-howard.pdf

This paper presents a method for using death records to infer exposure on non-extinguished cohorts, thereby allowing the development of a credible table for high ages. The method uses Whittaker-Henderson graduation in a number of unusual ways. The paper also validates the method by applying it to stochastically generated sets of death records for which the underlying mortality and improvement tables are known.

A-109 Title: Making the Most of Experience Data: An Augmented Beta-Binomial Approach

Author(s): P.J. Sweeting

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5b-sweeting.pdf

Credibility is an important way of combining the results of experience and risk rating. The author introduces an augmentation to the beta-binomial approach that not only allows for the information contained in ages near to the age under analysis but also for variation in risk types across the different ages.

A-110 Title: Will There Be Enough Doctors, Nurses and Hospitals for Our Aging Populations?

Moderator: Timothy F. Harris, FSA, MAAA

Panelist(s): Douglas Andrews, William Peck and Noreen Siba

URL: http://www.soa.org/files/pd/2011-orlando-living-100-andrews-gs6.pdf

This presentation focuses on the aging population and the capacity to care for them in Canada. The speakers discuss the increasing supply of medical professionals and the extent to which Canadians are engaged in medical tourism; similar issues in the United Kingdom are covered. The presentation also asks the question: Has, in an aging society, preventative health care become a necessity?

A-111 Title: Distinguishing Health Status for Advanced Ages

Moderator: Craig M. Baldwin

Panelist(s): Faye S. Albert, Dr. Thomas Ashley, Dr. Robert Gleeson and Dr. Stephen K. Holland

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-1a-baldwin.pdf

This discussion addresses the increasing healthy aging population and how it affects health practitioners. The speakers touch on the future use of biomarkers to predict the areas of decline in old age with an eye to prevention; the topic of health expectancy by bifurcating the healthy and unhealthy portions of life; assessing cognitive function in the elderly; and long-term care underwriting in the oldest of ages.

A-112 Title: Implications of Longer Life Spans: What Does This All Mean to Us?

Moderator: Anna M. Rappaport, FSA, EA, FCA, MAAA

Panelist(s): Timothy F. Harris, Dawn E. Helwig, Valerie A. Paganelli, David K. Sandberg and Steven G. Vernon

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-g1-rappaport.pdf

This session focuses on the implications of longer life spans. It deals with the effect on the private sector and the people actuaries serve. The speakers discuss the behavioral challenges that can negatively impact one's health; the impact of increased longevity and the need for long-term care services; and the supply and demand of health care as demographics change.

A-113 Title: Emerging Definitions on Retirement

Moderator: Anna M. Rappaport, FSA, EA, FCA, MAAA

Panelist(s): Doug Andrews, Steven Haberman, Valerie A. Paganelli, Anna M. Rappaport and Steven G. Vernon

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-2b-rappaport.pdf

This discussion addresses redefining retirement, in particular, the growing portion of the population who consider themselves retired and still working. These people tend to focus more on what they want to do and not how much they can make. The presenters also mention a possible bias: Since most of their clients are wealthy, they are unsure as to how the poor view retirement. The topic of premature retirement risk is also covered.

A-114 Title: Social Insurance Follow-up: Methodologies and Implications

Moderator: Sam Gutterman, FSA, FCAS, HonFIA, MAAA

Panelist(s): Stephen C. Goss, Danita L. Pattemore and Alvin K. Winters

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3a-gutterman.pdf

This session deals with a broad variety of actuarial topics dealing with social insurance methodologies and implications of changes in longevity. One topic highlighted is the cause of deceleration in mortality by cause of death. The presentation covers a variety of actuarial models used to generate mortality rates and includes a comparison of life expectancy at age 65 for people in the United States, United Kingdom and Canada broken down by gender.

A-115 Title: Health Expectancy

Author(s): Faye S. Albert, John M. Bragg and James C. Brooks Jr.

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-6b-albert.pdf

This paper looks at a different approach to measuring health expectancy in the elderly population. This new actuarial approach, which incorporates a medical impairment profile, is explained along with several illustrations. Medical impairment is broken down into the categories of healthy, needs assisted living and needs skilled care. This paper also discusses mortality results for those older than 90 and the beneficial aspects of health expectancy.

A-116 Title: Summary of Panel Discussion on Implications of Increasing Life Spans for the Private Sector

Author(s): Steven C. Siegel

URL: http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-xxviii.pdf

The panel—moderated by Jack Paddon and comprised of Peter Heller, Anna Rappaport and Dr. Robert Gleeson—focused on global issues relating to longevity trends. The idea that governments will need to re-evaluate the programs which are a financial burden was discussed. Social Security and other entitlement programs would need restructuring for the current longevity trends. One of the speakers suggested a change in the definition of retirement itself: More and more retirees are working part time or consulting with their former companies and this trend tends to complicate long-term entitlement solutions.

A-117 Title: Mortality Experience of Three Senior Populations

Author(s): Vincent Granieri, FSA, EA, MAAA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-granieri.pdf

This paper examines senior mortality in three distinct populations. It looks at the Medicare database from the Centers for Disease Control and Prevention, the life settlement population of an independent life settlement underwriter and the SOA's 2008 Valuation Basic Table. While these three populations exhibit varying characteristics with respect to early duration survival, the rates of all three converge within 10 years. A clear effect of wealth is shown on survival as evidenced by survival rates increasing with socioeconomic status.

A-118 Title: Patterns of Older-Age Mortality, Emergence of the Centenarians and the Compression of Death Above the Mode (Tribute to Roger Thatcher)

Author(s): Jean-Marie Robine; Siu Lan Cheung, Ph.D.; and Shiro Horiuchi

URL: http://www.demographic-research.org/volumes/vol22/18/

This paper uses the Human Mortality Database to investigate the compression of old-age mortality by combining a simple version of logistic model with Kannisto's analytical tools. The authors present their methodology and show the results of its application to time series of official life tables for England and Wales and life tables for six selected countries in the HMD.

A-119 Title: Health Policy Challenges of Population Aging: Perspectives From the Oxford Institute of Ageing

Author(s): Kenneth Howse

URL: http://www.soa.org/files/pd/2011-orlando-living-100-howse-keynote.pdf

This presentation covers the challenges to health policy caused by an aging population in the United Kingdom. The presentation shows the aging trends and discusses the challenges of protecting and maintaining health. Also discussed is the importance of better management and prevention of chronic disease. One key discussion point is the greatly increased risk of dementia as people live much longer than expected. The presentation concludes with questions like "How should we revise priorities and refine objectives for health care systems under conditions of population aging?"

A-120 Title: Comparison of U.S., U.K. and Canadian Annuity Mortality Tables and Studies

Moderator: Allen Klein

Panelist(s): Doug Doll, Nick Dumbreck and R.C.W. "Bob" Howard

URL: http://www.soa.org/files/pd/2011-orlando-living-100-doll-3a.pdf

This presentation compares U.S., U.K. and Canadian mortality tables to address mortality improvement in the U.S. and internationally. The presenters exhibited charts detailing different modeling methods and results. Also shown are causes of decreased mortality including circulatory disease, drastic increases in the treatment of cancer and heart disease.

A-121 Title: Increasing Genetic Contribution to Exceptional Longevity With Increasing Age

Author(s): Dr. Thomas T. Perls, MPH, and Paola Sebastiani, Ph.D.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g4-perls.pdf

This paper looks at the impact of genetics on longevity. Based on twin studies, the heritability of longevity has been noted to be about 20 percent, but many papers have incorrectly extrapolated these results to extreme old age. The authors also postulate that the longevity disparity for men and women has not been properly taken into account, skewing the results. Accurate associations are important in that they will reveal genetic associations with some age-related illnesses which could help develop prevention methods.

A-122 Title: Social Insurance: Perspectives and Implications

Moderator: Sam Gutterman, FSA, FCAS, HonFIA, MAAA

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|---|---|---|
| | Panelist(s): | Chresten Dengsoe, Sam Gutterman and Jean-Claude Ménard |
| | URL: | http://www.soa.org/files/pd/2011-orlando-living-100-dengsoe-gs7.pdf |
| | | This presentation begins with small population mortality projections in Denmark. The conclusion drawn from the first portion of the presentation is that there was a life expectancy gain of 40 years from 1835 to 2006, half of which was from reduction in infant and child mortality. The second portion of the presentation focuses on modeling Canadian mortality. The authors conclude that if mortality rates decrease consistently with the last 15 years, a life expectancy of 100 could be attained in 140 years for males and 120 years for women. |
| A-123 | Title: | Living and Dying Beyond Age 100 in Japan |
| | Author(s): | Jean-Marie Robine; Yasuhiko Saito, Ph.D.; and Carol Jagger |
| | URL: | http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-saito.pdf |
| | | This paper deals with the increase in the extremely old in Japan. Female life expectancy in Japan is approaching an assumed limit of 85, which is providing valuable information on demographic changes concerning the oldest of the population. Death rates for those between 100 and 105 have been clearly decreasing. A study referenced in this paper suggests that in the winter months, environmental interventions could further decrease death rates. |
| A-124 | Title: | Estimating the True Cost of Retirement |
| | Author(s): | David Blanchett, CFA, CFP |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-blanchett.pdf |
| | | A common practice of estimating one's required retirement fund is to apply a rate of inflation on the annual amount you expect to begin withdrawing at retirement for a fixed duration. In this paper, the author establishes that this method would provide an overestimated cost of retirement and demonstrates that to estimate the true cost of retirement, additional considerations are needed. First, the replacement rate (percent of earnings needed post-retirement) is likely to vary considerably by retiree household. Second, the author notes that retiree expenditures on average do not increase by inflation but instead vary by total consumption and funding level. When consumption and funding levels are combined and correctly modeled, the true cost of retirement becomes highly personalized. |
| A-125 | Title: | The CBD Mortality Indexes: Modeling and Applications |
| | Author(s): | Wai-Sum Chan, FSA, Ph.D.; Siu-Hang "Johnny" Li, Ph.D.; and Jackie Li |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-chan.pdf |
| | | This paper discusses using the widely used stochastic mortality model, Cairns-Blake-Dowd (CBD) model, to construct mortality indices. The authors demonstrate that the time-varying model parameters in the CBD model are most suitably used as indices to indicate levels of longevity risk at different time points because they are able to represent a varying age-pattern of mortality improvement, they are new-data-invariant and they are interpretable. The authors also illustrate that the cross-correlations between the CBD mortality indices can be captured by a vector autoregressive integrated moving-average (VARIMA) process. Finally, the authors propose to resolve the uncertainty surrounding the use of two CBD mortality indices simultaneously with a joint prediction region. It is demonstrated that such a region can be used as a graphical longevity risk metric, which allows practitioners to compare the longevity risk exposures of different portfolios readily. |
| A-126 | Title: | Optimal Retirement Tontines for the 21st Century: With Reference to Mortality Derivatives in 1693 |

Author(s): Moshe A. Milevsky and Thomas S. Salisbury

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-milevsky.pdf

This paper discusses tontines, an annuity that offers a lifetime of income which increases as other members of the tontine pool die off and their money is distributed to survivors. Historical tontines have generally been structured to offer fixed cash flows. The authors conclude that a tontine scheme in which interest payments to the pool are structured to decline over time is the optimal structure. Under this structure, the utility loss is smaller than an actuarially fair life annuity, and the authors conclude tontines should be re-introduced and allowed to co-exist with life annuities. Technical derivations of the optimal tontine structure are also included.

A-127 Title: Mortality, Health and Marriage: A Study Based on Taiwan's Population Data

Author(s): Hsin Chung Wang and Ching-Syang "Jack C." Yue

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1b-wang.pdf

The article explores the explanatory power of marriage status in determining health and longevity. Taiwan's marital data for the entire population (married, unmarried, divorced/widowed) is used to evaluate whether marital status could be a preferred criteria now and in the future. The authors have modeled mortality improvements under Lee-Carter and age-period-cohort models using both an autoregressive model and an intrinsic estimation method to obtain parameters. The article concludes that, based on Taiwan's marital data, the married have significantly lower mortality rates than the single and, if converting the difference into a life insurance policy, the discount amount is even larger than that for smokers/nonsmokers.

A-128 Title: Logistic Regression for Insured Mortality Experience Studies

Author(s): Zhiwei Zhu, Ph.D., and Zhi Li, ASA, CERA, Ph.D.

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-zhu.pdf

In this paper, the authors discuss using a logistic regression-based model for insured population mortality estimation. The authors conclude that properly designed logistic modeling processes can more effectively utilize available data to deliver solutions for the following needs: testing mortality drivers' statistical significances in explaining mortality variations; estimating normalized mortality slopes and mortality differentials such as how morality increases by duration or varies between underwriting classes while product and attained-age distributions are controlled; and addressing analytical challenges such as extrapolating for ultimate mortality, smoothing between select and ultimate estimations, and constructing multidimensional basic experience tables.

A-129 Title: Predictors of Exceptional Longevity: Effects of Early-Life Childhood Conditions, Midlife Environment and Parental Characteristics

Author(s): Leonid A. Gavrilov and Natalia S. Gavrilova

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-gavrilov.pdf

The authors conducted an ongoing study of the simultaneous effects of three factors on longevity: parental characteristics, early life conditions and midlife environment. Using multivariate logistic regression, the authors found that parental longevity and certain midlife characteristics are significant factors which impact longevity, while the impact of early life conditions is less critical. The authors also found both general and gender-specific predictors of human longevity. A further comparative study of biological and nonbiological relatives of centenarians is also conducted. The findings demonstrate that shared familial environment and lifestyle play an important role in longevity.

A-130 Title: Liars, Cheaters and Procrastinators: How They Upset Mortality Studies

Author(s): R.C.W. "Bob" Howard, FSA, FCIA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-howard.pdf

This paper discusses the impact of poor quality data on mortality curves. The author examines three specific deteriorations of data: overstatement of age (liars), failure to report deaths (cheaters) and late reporting of deaths (procrastinators). The author demonstrates how the three types of deteriorations can cause mortality deceleration at extreme ages for U.S. males. Finally, the author argues that the impact of late reporting of deaths is not material for ages under 85, but at higher ages, an adjustment for incurred but not reported claims is recommended.

A-131 Title: Obesity and Morality

Author(s): Sam Gutterman, FSA, CERA, FCAS, MAAA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-obesity-gutterman.pdf

This paper presents a discussion on the relationship between obesity and mortality. It provides a background of the obesity epidemic and then explores many issues and reported experiences associated with obesity and mortality. The author also discusses the relationship between obesity and health care costs and disability.

A-132 Title: Causes-of-Death Mortality: What Do We Know on Their Dependence?

Author(s): Séverine Arnold (-Gaille) and Michael Sherris

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-arnold.pdf

This paper discusses modeling the dependency between various causes of death using vector error correction models. In the study, the authors studied the dependency between five causes of death (diseases of the circulatory system, cancer, diseases of the respiratory system, external causes, and infectious and parasitic diseases) among 10 countries. Two key conclusions are drawn. First, the authors demonstrate that dependencies do exist between the five competing risk over recent years. Second, different countries have different experiences in cause-of-death mortality trends. Therefore, applying results from one country to another may be misleading.

A-133 Title: Mortality of Smoking by Gender

Author(s): Sam Gutterman, FSA, CERA, FCAS, MAAA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-gutterman.pdf

In this paper, the author compares smoking prevalence and cessation by gender and considers its effect on projection of mortality rates. The author observes that the trends in smoking prevalence and consequential mortality by gender are important factors to consider in any long-term mortality projection. He also argues that consideration of the effect of smoking and smoking cessation should be made in any mortality projection. A few approaches include incorporating a cause-of-death-based projection or an adjustment to a statistical technique.

A-134 Title: Genetically Informed Longevity

Author(s): Tom Bakos, Marc Klibanow, Nicholas Schork, Ali Torkamani and Ashley Van Zeeland

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-bakos.pdf

This paper provides an overview of the role of genetics and how it could change the way practitioners think about longevity. It discusses concepts such as "aging," "senescence" from a genetic perspective and the use of genetic information to reduce morbidity risks in each individual. The authors also discuss genetic testing, its costs, risk assessments and data privacy challenges in the United States.

A-135 Title: How Genes Modulate Patterns of Aging-Related Changes on the Way to 100: Lessons From Biodemographic Analyses of Longitudinal Data

Author(s): Anatoliy I. Yashin, Konstantin G. Arbeev, Deqing Wu, Alexander Kulminski, Liubov Arbeeva, Irina Kulminskaya, Igor Akushevich and Svetlana V. Ukraintseva

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-yashin.pdf

This paper reviews a number of genome-wide association studies to clarify the mechanism of genetic regulation of human aging and longevity. It identifies the inability of such studies to address the problem of how genetic influences are mediated by physiological variables and other biomarkers over the human life span. The authors use longitudinal genetic data to compare average age trajectories of physiological indices between carriers and noncarriers of selected genetic variants, using stochastic longevity models to investigate the genetic influence on hidden biomarkers of aging. The results demonstrate the benefits of using bio-demographic principles and integrative statistical models of mortality risks in genetic studies of human longevity.

A-136 Title: Contribution of Familial Longevity to Living to 100

Author(s): Paola Sebastiani, Ph.D.; Stacy L. Andersen; Avery I. McIntosh; Lisa Nussbaum; Meredith D. Stevenson; Leslie Pierce; Samantha Xia; Kelly Salance; and Dr. Thomas T. Perls, MPH

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-sebastiani.pdf

In this paper, the authors update estimates of sibling-relative risk of living to extreme ages using data from more than 1,700 sibships (offspring having the same parents) in the New England Centenarian Study. The authors examined the trend for heritability for different birth-year cohorts and built a network model to understand the effects of paternal and maternal longevity on an individual's chance to live to an extreme age.

A-137 Title: Coherent Projections of Age, Period and Cohort Dependent Mortality Improvements

Author(s): Matthias Börger and Marie-Christine Aleksic

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-borger.pdf

This paper introduces an age-period-cohort model, including its estimation and application to derive coherent projections for several populations. The authors observe that the incorporation of information on the mortality experience of other populations can have a significant impact on the projection for another given population. Their proposed methodology is benchmarked to other models and back-tested with historical data from Germany. The paper also discusses uncertainties in the proposed projection approach and how to account for them.

A-138 Title: Measurement of Mortality Among Centenarians in Canada

Author(s): Nadine Ouellette, Ph.D., and Robert Bourbeau, Ph.D.

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-oullette.pdf

This paper replicates centenarian mortality studies using a highly reliable set of data on French-Canadians centenarians to examine the impact of aggregating data for several birth cohorts and of inaccurate data at such old ages. The authors note that, while the aggregation of several birth cohorts is not responsible for the late-life mortality deceleration observed in the studied data, the studied data supports the existence of such deceleration.

A-139 Title: Mortality Trajectories at Extreme Old Ages: A Comparative Study of Different Data Sources on U.S. Old-Age Mortality

Author(s): Natalia S. Gavrilova and Leonid A. Gavrilov

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-gavrilova.pdf

This paper provides analyses of the authors' refutation of mortality deceleration in late ages (i.e., Gompertz law), using independent data sets of the United States population and alternative statistical approaches. The authors also analyze an alternative approach for studying mortality patterns at advanced ages based on calculating the age-specific rate of mortality change after age 80. Simulation studies demonstrate that the apparent decline of life table aging rates after age 80 found in earlier studies may be related to biased estimates of mortality rates measured in a wide five-year age interval. The authors also discuss possible reasons for finding apparent mortality deceleration in earlier studies.

A-140 Title: How Well Have Retirement Systems Adapted to Longer Life?

Author(s): Anna M. Rappaport, FSA, EA, FCA, MAAA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-rappaport.pdf

The article goes through the history of the seemingly ubiquitous 65 retirement age and the effects on labor participation by the old. Following the introduction of Social Security and pension plans, many people were seen retiring in their late 50s and early 60s. However, in recent years, the labor force participation at older ages has increased and, with limitations on earnings removed from Social Security, work is becoming accepted as a part of retirement. The author addresses the risk of longevity on retirement and the inadequate link between mortality improvement and retirement age. That solution of sharing longevity risk with participants is an alternative to the actions taken by many of terminating existing defined benefit plans.

A-141 Title: Mapping the Adequacy of Care and Support for the Elderly in Developed Countries

Author(s): Doug Andrews, FSA, CFA, FCIA, FIA, Ph.D.

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-andrews.pdf

This report looks at six developed countries (Canada, England, France, Germany, Sweden and the United States) and assesses the adequacy of their coverage for elders (65+) in social security, health care and long-term care. The study points out similarities and differences between the chosen countries and makes connections to country-specific factors including social norms, taxation and government responsibility. The author displays aggregate adequacy across the six countries, as well as their current and potential sustainability for the three areas studied. Additionally, he provides actionable recommendations based on the findings from the study.

A-142 Title: Supporting the Oldest Old: The Role of Social Insurance, Pensions and Financial Products

Author(s): Jonathan Barry Forman

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-forman.pdf

The article goes through a broad spectrum of social programs in place for the old, and how it might be enhanced to provide for a population surviving to oldest old ages. In particular, the oldest old receive nearly half of their income from Social Security and only 18.3 percent from pensions and retirement. Many elderly Americans also partake in Medicare. The author explores retirement products such as pension plans as well as financial products like lifetime annuities and longevity insurance and speaks to the products' abilities to supplement income for the elderly. The article also speaks to potential mechanisms involving these products and social change that may enhance income for the oldest old.

A-143 Title: A Study of Measuring the Mortality Compression

Author(s): Ching-Syang "Jack C." Yue

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-yue.pdf

In this paper, the author explores statistical methods for evaluating mortality compression, with explicit consideration of data quality issues. The author proposes optimization methods for estimating the standard deviation of age-at-death probability distribution, comparing estimation results with raw and graduated data. The author notes there is not enough evidence to conclude if there is mortality compression based on the proposed nonlinear maximization method.

A-144 Title: Modal Age at Death: Mortality Trends in England and Wales 1841–2010

Author(s): Emily Clay

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-clay.pdf

This report studies the modal age at death in England and Wales by smoothing mortality rates used to construct period life tables using a p-spline non-parametric method. The author notes that mortality has compressed into a shorter age interval. Mortality above the mode has also compressed but is now stagnating for females. The report shows that the modal age at death has become more prevalent over time for these two countries and the author recommends that mode should be used to complement the study of mortality changes in low mortality countries.

A-145 Title: Compression of Morbidity and Mortality: New Perspectives

Author(s): Eric Stallard, ASA, FCA, MAAA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-stallard.pdf

This paper introduces the concepts of mortality compression and morbidity compression and speaks to their relationship, their role in changes to mortality and morbidity, and their potential implications for the future. The author uses data from the National Long Term Care Survey to formulate his morbidity analysis and data from the Social Security Administration database to formulate his mortality analysis. The author keys in on the components necessary to observe morbidity compression: survival increment (the change in mortality survival) and morbidity decrement (the change in the prevalence of disability). The observed data sets indicate mortality compression had run its course by the latter half of the 20th century while there was significant morbidity compression. The author believes future mortality improvement is likely to take the form of right-shifting survival with limited future rectangularization.

A-146 Title: Living to 100: Socioeconomic Implications of Increased Longevity

Author(s): Rick Gorvett, ASA, CERA, ARM, FCAS, FRM, MAAA, Ph.D.

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-gorvett.pdf

While mortality in the past has decreased due mainly to improvements in infant mortality, this paper explores categorical implications of late-life mortality changes. The report explores positive and negative effects should large decreases in mortality take place, effectively redefining the lifecycle paradigm as we know it today. The article goes through multiple aspects of life that may see change including emphasis on education, multiple careers and increased job expertise, marriage, pensions and retirement planning.

A-147 Title: Perspectives on SOA Post-Retirement Risk Research and What it Tells About the Implications of Long Life

Author(s): Anna Rappaport, FSA, EA, FCA, MAAA

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-rappaport.pdf

This report serves as an aggregating piece bringing together a wide array of past SOA projects. Specifically, the research this report summarizes includes works concerning the economy, women's issues, retirement planning, working in retirement, longevity and long-term care. Primarily, the reports focus on these issues through a middle class lens. The author reasons that many low-income Americans depend mostly on public programs while the economics of retirement planning simply make it more profitable to serve higher income individuals, leaving much of the middle market unserved.

A-148 Title: Subjective Survival Probabilities and Life Tables: Evidence From Europe

Author(s): Franco Peracchi and Valeria Perotti

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-peracchi.pdf

This article aims to evaluate how subjective probabilities of survival to specific target ages provided by respondents compare with objective data from life tables. As the data set for the analysis stems from the Survey of Health, Ageing and Retirement in Europe, the authors go through data considerations including focal values in responses, correlations between attrition and the subjective probabilities, and panel conditioning. Life table counterparts of the subjective survival probabilities are created using period life tables, and the results from the findings detail gender and age differences in the relationships observed between subjective survival probabilities and objective life table probabilities. Additional cohort attributes are studied and observed in relation to the subjective probabilities.

A-149 Title: Survival Characteristics of Three Senior Populations, With a Focus on Life Settlements

Author(s): Vincent Granieri, FSA, EA, MAAA, and Gregory P. Heck

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-granieri.pdf

This report studies three populations of aging adults and explores survival experience surrounding early settlements on life insurance policies. The study includes seniors who have considered an early settlement on their insurance policy, who have accepted a settlement on their policy and who have a college education (this last group may or may not have an insurance policy). Using these groups, the study attempts to expose a sense of selection among seniors that differs from their underwriting status. Specifically, the report focuses on the survival experience of the two groups considering or have elected a settlement option.

A-150 Title: Modeling Medical Cost Trends for Advancing Age in the Long Run

Author(s): Thomas E. Getzen

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-getzen.pdf

This article observes health expenditures in the U.S. over a varying range of time. Health care is a slow moving vehicle and costs tend to lag changes in the macro environment (such as policy changes and gross domestic product growth). This lag is attributable to cumbersome medical systems and the third-party payment structure ingrained in the U.S. market. To gain an understanding of the path health care costs have taken over time, a long-term view must be used to see slow-developing trends. Over the past century, costs have formed an S-shaped logistic growth curve (rapid growth occurred from 1950 to 2000 aided by the inception of Medicare and employer-sponsored health plans). Individually, aging presents a natural and unavoidable rise in spending; however, at the national level the ebb and flow of aggregate births and deaths stabilize this value. The cost ratio (distribution of resources between old and young), plays a key role in collectively funding elderly health care. The article states that the largest uncertainties and factors in modeling future health care costs include the rate of growth in GDP, the rate of increase in health costs in excess of GDP, technological advances and the aggregate cost ratio.

A-151 Title: Sex Differences in Predictors of Health Decline: Results From a 16-Year Longitudinal Cohort Study

Author(s): Steven G. Prus

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-prus.pdf

This article discusses the results of a study on gender differences for health decline in adult Canadians over a 16-year self-reported longitudinal survey. The author studies certain key predictors, broadly grouped by socioeconomic, behavioral and psychological factors, to understand gender differences arising from the data. The findings show the factors associated with health decline in males do not necessarily agree with what is observed in females, and vice versa. Instances of this include observations on obesity and years since immigration.

A-152 Title: Cognitive, Psychological and Social Drivers of Longevity

Author(s): Gordon Woo and Anne Bruce

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-woo.pdf

This paper evaluates the cognitive, psychological and social drivers of longevity by reviewing recent longitudinal studies. It analyzes the latest research on brain plasticity, positive psychology and elderly cohort survival, as well as new geriatric psychological theories on successful aging. It provides a quantitative assessment of the actuarial implications of these drivers in modeling the mortality of elderly annuitants, and offers new insights into what factors keep people progressing purposefully into advanced age, beyond avoiding disease.

A-153 Title: Is Secondary Prevention of Alzheimer's Disease Possible? A Discussion of Studies in the Alzheimer's Disease Field

Author(s): Heather M. Snyder, Dean Hartley, Keith N. Fargo and Maria C. Carrillo

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-snyder.pdf

This paper provides an overview of the new generation of Alzheimer's disease clinical studies on volunteers with a potentially increased risk or certainty for developing Alzheimer's disease.

A-154 Title: Mortality Projections for Social Security Programs in Canada

Author(s): Office of the Chief Actuary

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs4-chief.pdf

This report presents an overview of the methodology and assumptions used by the Office of the Chief Actuary in Canada for projecting population mortality for the purpose of actuarial valuations of the Canada Pension Plan and Canada's Old Age Security program. It examines past mortality trends in Canada and discusses how these trends may change over the next 75 years. This paper also discusses mortality by causes of death, provides international mortality comparisons, and looks at stochastic time series methods that are used to help quantify the variability in the mortality rate projections.

# Appendix B: Census of discussions

B-1 Title: The Advancing Frontier of Human Survival (informal discussion transcript)

Moderator: Timothy F. Harris, FSA, MAAA

Panelist(s): James Vaupel, Ph.D.

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1-soa-informal-discussant.pdf

This discussion focuses on mortality evidence suggesting senescence is being postponed on a global basis over the last three centuries. Also, linear extrapolation is discussed as a possible technique for future life expectancy and validated by being the only projection method able to pass the historical forecasting test. Future biomedical and technological possibilities that might lead to additional mortality improvements are also mentioned.

B-2 Title: Perspectives and Implications to Stakeholders of Increasing Longevity (informal discussion transcript)

Moderator: Timothy F. Harris, FSA, MAAA

Panelist(s): Robert L. Brown, Jennifer A. Haid, Sally Hass and Dr. Sandra Timmermann

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1c-soa-informal-discussion.pdf

This panel covers implications of longevity to the general population. In particular, modifications to the traditional retirement structure are discussed, as well as the need for both private and governmental entities to step in and tend to the needs of a growing elderly population. Restrictive federal regulations and lack of public education are identified as recurring themes in hindering society's adaptation to an aging population.

B-3 Title: Developing a Winning Strategy to Address the Good, the Bad and the Wrinkled of Our Aging Workforce (informal discussion transcript)

Moderator: Anna Rappaport, FSA, EA, FCA, MAAA

Panelist(s): Don Fuerst, Sally Hass, Haig Nalbantian and Tim Driver

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2c-soa-informal-discussion.pdf

This discussion focuses on the roles employers will play in adjusting to an elderly population and, in particular, a more senior workforce. New retirement structures, including phased retirement, are discussed, as well as barriers to desirable solutions of employment for the aging baby boomers. Also, the panelists identify what type of employers will be more willing to adapt for an aging workforce than others.

B-4 Title: Innovative Business Solutions to Respond to the Aging Society (informal discussion transcript)

Moderator: Anna Rappaport, FSA, EA, FCA, MAAA

Panelist(s): Tim Driver, Nigel W. Nunoo and Cindy Hounsell

URL: https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2-soa-informal-discussant.pdf

This panel focuses on how the aging society affects businesses and creates opportunities. The speakers identify challenges senior workers will face in seeking employment and how employers should be made aware of the benefits in having a more senior workforce. New opportunities for

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| | | the financial industry services are identified, as well as the evolving issues and challenges of housing for seniors. |
| B-5 | Title: | Data Sources and Projection Methods for Successfully Supporting the Needs of the Senior Market (informal discussion transcript) |
| | Moderator: | Jean-Marc Fix, FSA, MAAA |
| | Panelist(s): | Louis Adam, W. Ward Kingkade and Jean-Marie Robine |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3c-discussion.pdf |
| | | This panel discusses challenges in retrieving data of good quality, as well as how to overcome those challenges. The speakers also identify trends in past mortality improvements and considerations to take when applying projection techniques. |
| B-6 | Title: | Proactive Strategies for Managing Long-Term Care Needs in Retirement (informal discussion transcript) |
| | Moderator: | John W. Paddon |
| | Panelist(s): | John Cutler, J.D.; Steve Schoonveld, FSA; and Dr. Sandra Timmermann |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4c-soa-informal-discussion.pdf |
| | | This group focuses on incoming long-term care needs from the aging baby boomers. Challenges associated with long-term care plans are identified, as well as their importance in ensuring the financial security of seniors. Solutions for addressing the long-term care crisis are discussed. |
| B-7 | Title: | Could Moses Live to Be 120? (informal discussion transcript) |
| | Moderator: | Timothy F. Harris, FSA, MAAA |
| | Panelist(s): | Dr. Nir Barzilai |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4-soa-informal-discussant.pdf |
| | | This speaker focuses on aging and its close connections with longevity. The presenter identifies aging as the underlying factor of all age-related diseases, and how its postponement would have higher mortality improvements than cures for other age-related diseases. Challenges in studying aging are identified, with the most prominent being how to measure aging. The session also discusses the role of genetics in longevity and factors shown to elongate life spans. |
| B-8 | Title: | Mortality Projections From a Social Security Perspective (informal discussion transcript) |
| | Moderator: | Sam Gutterman, FSA, CERA, FCAS, MAAA |
| | Panelist(s): | Adrian P. Gallop, Stephen C. Goss and Jean-Claude Ménard |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5-dicussion.pdf |
| | | Prominent actuaries from the U.S. Social Security Administration, Canada's Office of the Superintendent of Financial Institutions and the U.K. Government Actuary's Department discuss key factors and issues associated with mortality projections on a global scale. The shifting age structure, which refers to the increasing ratio of elderly to nonelderly, is identified as a major issue that has not been studied as thoroughly yet. |
| B-9 | Title: | Leaving Worries Behind: Risk Management Strategies for Individuals to Address the Economic Issues Related to Increased Longevity (informal discussion transcript) |

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| | Moderator: | Arnold Dicke |
| | Panelist(s): | Christine Fahlund, Joseph E. Montminy, Robert A. Painter, William Silbert and Harrison C. Weaver |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5c-discussion.pdf |
| | | This group focuses on risk management strategies to deal with arising longevity issues. Recommended financial products and services include deeply deferred annuities, longevity insurance and riders that allow for desirable flexibility, as well as continuing care communities. Challenges associated with these strategies include restrictive legislations, misalignment of incentives for brokers within annuity space, and lack of education of the public when it comes to retirement. |
| B-10 | Title: | Discussant comments for session: Innovative Retirement Products |
| | Discussant: | Kai Kaufhold |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1a-kaufhold-discussant.pdf |
| B-11 | Title: | Discussant comments for session: Happily Ever After, Marriage and Old Age Mortality |
| | Discussant: | Jean-Marc Fix, FSA, MAAA |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-1b-fix-discussion.pdf |
| B-12 | Title: | Discussant comments for session: From Population to Insured Lives, Finding Longevity Drivers |
| | Discussant: | Thomas Edwalds, FSA, ACAS, MAAA |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2a-edwalds-discussant-comments.pdf |
| B-13 | Title: | Discussant comments for session: Behavior and Causes of Death: Impact on Mortality and Mortality Modeling |
| | Discussant: | S. Jay Olshansky |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-2b-olshansky-discussant-comments.pdf |
| B-14 | Title: | Discussant comments for session: Learning from Genetics |
| | Discussant: | Leonard Hayflick, Ph.D. |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-hayflick.pdf |
| B-15 | Title: | Discussant comments for session: Learning from Genetics |
| | Discussant: | Tom Bakos (reply to Leonard Hayflick from B-14) |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-gs3-bakos-reply.pdf |
| B-16 | Title: | Discussant comments for session: Mortality Age Patterns: Trends and Projections |
| | Discussant: | Siu-Huang “Johnny” Li, Ph.D. |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3a-lid-discussant-comments.pdf |
| B-17 | Title: | Discussant comments for session: Societal Changes and Adaptations as a Result of Longer Life Spans |

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| | Discussant: | Robert L. Brown, FSA, ACAS, FCIA, HonFIA |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-3b-brown-discussant-comments.pdf |
| B-18 | Title: | Discussant comments for session: The Changing Age Distribution of Deaths |
| | Discussant: | Jean-Marie Robine |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4a-robine-discussant-comments.pdf |
| B-19 | Title: | Discussant comments for session: Longevity and Lifestyle |
| | Discussant: | Arnold Dicke |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-4b-dicke-discussant-comments.pdf |
| B-20 | Title: | Discussant comments for session: Aging and Changes in Health Status |
| | Discussant: | Eric Stallard, ASA, FCA, MAAA |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5a-stallard.pdf |
| B-21 | Title: | Discussant comments for session: Longevity and Cognitive Impairment |
| | Discussant: | S. Jay Olshansky |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-olshansky-discussant-comments.pdf |
| B-22 | Title: | Discussant comments for session: Longevity and Cognitive Impairment |
| | Discussant: | Dr. Robert Pokorski, FACP |
| | URL: | https://www.soa.org/Library/Monographs/Life/Living-To-100/2014/mono-li14-5b-pokorski.pdf |

# Appendix C: Categorization of articles by practice area and analytical phase

To help the reader better understand the breadth and coverage of the symposia material, we have developed a heat map to organize the material by practice area—retirement, health, life and other—and by analytical phase.

This heat map illustrates areas for which there is broad coverage and areas where future research is required.

| | | Analytical Phase | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Data | Development of Raw Rates | | Projection of Future Rates | | Implications and Opportunities | | Other |
| Practice Area / Focus | | Sources and Due Diligence | Best Estimates | Enhancements - Older Ages | Numerical Extrapolations | Driver-Based Approaches | Business | Policy | |
| General Population | | 2, 3, 4, 11, 21, 27, 29, 30, 33, 61, 127, 129, 130, 138, 139, 148 | 2, 3, 11, 29, 33, 55, 61, 71, 72, 73, 127, 136, 138, 139, 144 | 2, 3, 11, 27, 30, 33, 51, 55, 71, 72, 136, 138, 139 | 1, 11, 33, 40, 41, 55, 71, 72, 73, 122 | 9, 33, 40, 41, 55, 73, 127, 129, 152 | 33 | 33 | 146, 148 |
| Retirement, Annuity | Government | 36, 70, 102, 154 | 36, 63, 82, 102, 114, 154 | 45, 54, 82, 91, 114 | 42, 54, 67, 82, 90, 91, 98, 100, 154 | 114, 154 | 70, 116, 126, 142 | 32, 37, 42, 65, 67, 69, 70, 98, 102, 116, 140, 141, 147 | |
| | Corporate | | | | | | 20, 31, 34, 66, 68, 82, 97, 105, 113, 140 | 20, 31, 34, 68, 97, 99, 105, 106, 113, 140, 147 | 124 |
| | Individual Annuity | 35, 36 | 35, 36, 82 | 35, 54, 82, 91 | 35, 43, 54, 82, 90, 91, 100 | 35, 151 | 43, 52, 82, 126, 142, 147 | | 124, 147 |
| General Health | | 47, 50, 87, 101, 117, 131 | 47, 50, 103, 131 | 121, 123 | 48, 77, 120 | 48, 50, 87, 93, 95, 101, 103, 117, 120, 121, 123, 151 | | 47, 93, 94, 121 | 76 |
| Health Insurance | Government (Medicare/Medicaid/ LTC) | 46, 49 | 46, 63 | | | 86, 96, 119 | 34, 104, 147, 150 | 34, 78, 80, 85, 96, 104, 110, 119 | 150 |
| | Private (LTC/Major Medical) | 38, 46, 49 | 46, 115 | 115 | 38, 111 | 79, 86, 111, 112 | 97, 111, 112, 150 | 78, 97, 110 | 150 |
| Life Insurance | Life (Group/Individual) | 36, 149 | 6, 36, 82, 149 | 6, 54, 82, 91 | 6, 54, 82, 90, 91, 100, 111 | 6, 7, 62, 111 | 52, 82, 111, 149 | 149 | |
| Other | Reinsurance * | | | | | | | | |
| | Banking/Capital Markets | 36 | 36, 82 | 54, 82 | 54, 82 | | 53, 82, 125 | | |
| Theoretical (has the potential to be applied across all practice areas) | | 5, 12, 13, 14, 28, 39, 58, 107, 108, 109, 129, 132, 133 | 5, 16, 22, 23, 24, 26, 28, 39, 44, 56, 58, 107, 109, 118, 128, 133, 145 | 5, 10, 12, 13, 14, 15, 16, 22, 23, 24, 25, 26, 39, 44, 56, 57, 58, 60, 64, 88, 107, 108, 118, 143, 145 | 5, 12, 13, 14, 15, 16, 17, 22, 23, 24, 25, 26, 44, 56, 57, 58, 60, 64, 81, 88, 89, 92, 108, 118, 128, 137, 143, 145 | 5, 8, 17, 39, 132, 133 | | | 18, 19, 134, 135, 147 |

Key:

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| green: good coverage |
| yellow: some coverage |
| red: little or no coverage |
| white: other |

* Reinsurance practitioners are active in research and writing, but it is generally in a consulting role to life and other industries rather than about applications specific to reinsurance itself.