Actuaries
Risk is Opportunity.®

Living to 100

Insights on the Challenges and Opportunities of Longevity

Literature Review: 2002 through 2011

JANUARY 2013

SPONSORED BY

Committee on Life Insurance Research
Product Development Section
Committee on Knowledge Extension Research

Society of Actuaries

PREPARED BY

Jennifer A. Haid, FSA, MAAA, CFA
Michael K.Y. Chan, FSA, MAAA
Christopher G. Raham, FSA, MAAA

Ernst & Young LLP

Table of Contents

1. Introduction

Living to 100 is a research effort featuring triennial international research symposia as a means to share knowledge. Sponsored by the Society of Actuaries (SOA) with many partners, the symposium brings together a diverse group of professionals—including scientists and academics—so they can share what they know about aging. More specifically, they discuss the latest scientific information on how and why we age; they examine recent increases in survival rates and make projections for the future; and they ponder the resulting implications for social, financial, retirement and health care systems. To date there have been four Living to 100 symposia, which were conducted in 2002, 2005, 2008 and 2011. Each has produced a lasting body of research (referred to below as the "symposia material") that can educate and aid professionals and policymakers in understanding advanced-age longevity and its potential consequences.

The SOA commissioned Ernst & Young LLP (EY) to prepare a literature review based on the material presented at the four Living to 100 symposia. This paper provides an overview of the technical material related to data sources, validation techniques and methodologies used by practitioners to develop mortality estimates for present and future periods. A summary of the discussions regarding business, policy and social implications of increasing longevity is also presented.

In particular, this report aims to do the following:

- Provide an overview of the research presented at the symposia; highlight areas of consensus or disagreement within the research presented; and identify obvious gaps that are apparent.
- Provide an overview of the techniques presented for modeling mortality and compare a subset of those techniques by illustrating the result of their application to U.S. general population data.
- Provide an overview of the techniques presented for forecasting older-age mortality and compare a subset of those techniques by illustrating the result of their application to U.S. general population data;
- Share the difficulties we encountered when applying the techniques and the strategies we considered to overcome them.
- Provide commentary from interviews in which practicing actuaries (both industry and consulting) discuss the lessons they have learned implementing advanced-age mortality models in their work.
- Provide a catalyst to the actuarial community to look beyond the modeling and forecasting aspects of old-age mortality, start conceptualizing the global and societal implications of increased longevity, and to bring that thinking to policymakers and regulators.
- Provide an overview of papers that offer ideas about implications. It should be noted that several other activity areas of 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. For major other work in this area, check the work of the SOA Committee on Post-Retirement Needs and Risks, the Pension Section, the Long Term Care Section and the Health Section.

In the body of the report, we have presented various techniques for determining base mortality rates and for forecasting older-age mortality. We hope that this validates for you, the reader, the practical applications of these techniques in your work, provides insight into the thought process you must go through before applying these models and lastly gives you insight into the questions you must ask when interpreting your results.

The Living to 100 symposia have produced an abundance of information on the future of longevity and its related issues. We believe that the symposia efforts have generated a lasting and valuable body of work that will help actuaries and others better understand competing views on longevity, approaches to estimating future longevity, and a societal lens through which to understand the impacts of our work as actuaries.

This report is divided into two parts:

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

Section 1	Overview
Section 2	Data Selection and Validation
Section 3	A Priori Expectations
Section 4	Assessing Trends in Underlying Mortality
Section 5	Identifying Possible Predictors of Changes in Future Improvement Patterns
Section 6	Selecting the Appropriate Projection Model

Part 2 focuses on articles that discuss global increases in longevity and the resulting implications for industry and government.

Section 1	Societal Support for Retirement
Section 2	Challenges for Retirement Systems
Section 3	Challenges for Long-Term Care Systems
Section 4	Challenges for Health Care Systems

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, finally, any gaps in knowledge that have been identified and may present opportunities for future research.

At the end of each section we list referenced articles, along with links to their full text on the SOA website. Furthermore, we highlight the articles that provide broad context for each section. Readers who need to familiarize themselves with background information should examine the highlighted articles before reading this paper. Appendix A houses a full listing of the symposia material, with links to their full text on the SOA website and a short synopsis of each article's content. Articles are referenced throughout this document by the key [A-XX]; these references are unique to each article and can be used to find other references to the paper within this document and to find the paper's summary information in Appendix A. Appendix B contains a heat map which has been developed to organize the symposia material by practice area—retirement, health, life, and other—and by analytical phase.

We note that this review is limited to material presented at the symposia. No effort has been made 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 in an effort to potentially provide direction for future research.

2. Acknowledgments

EY would like to acknowledge and thank a number of other individuals who contributed to the success of this study:

- Ronora Stryker and Jan Schuh from the Society of Actuaries for providing leadership and coordination
- The Project Oversight Group (POG) for guidance throughout this project. The members of the POG are:

Tom Edwalds, FSA, ACAS, MAAA
AVP Mortality Research
Munich American Reassurance Co
Chair

Jason Goldstein, ASA
Financial Advisor
1847 Financial

Crispina Caballero, FSA, MAAA
Director, Fiscal & Economic Planning
Worksafe NB

Timothy F. Harris, FSA, MAAA
Principal
Milliman Inc

Alex Faynberg, FSA, MAAA
Head of Global A&H Actuarial
Chartis

Anna Rappaport, FSA, MAAA
Anna Rappaport Consulting

Jean-Marc Fix, FSA, MAAA
VP, Research & Development
Optimum Re Insurance Co

- Those members of the academic and professional communities who took the time to offer their perspective on the impact of longevity on their research/business:

Robert L. Brown, FSA, ACAS, FCIA, HONFIA
Advisor, EvidenceNetwork.ca
Professor of Actuarial Science at the
University of Waterloo (retired)
Past President of the Canadian Institute of
Actuaries

Larry Pinzur, FSA, EA, Ph.D.
Managing Actuary
Aon Hewitt

Eric Stallard, ASA, FCA, MAAA
Research Professor, Social Science Research
Institute;
Associate Director of the Center for Population
Health and Aging in the Duke Population Research
Institute

Scott Witt, FSA, MAAA
Witt Actuarial Services, LLC

3. Executive Summary

Longevity is an important issue: the implication of increasing longevity has far-reaching effects for our social programs; and for our financial security as we grow into old age. It is also a trend which actuaries are well suited to analyze: we have unique training and experience that allows us to distill large volumes of data into key elements that can inform predictions of future events. As we partner with other experts, we are helping to shape the discussion on the implications of increasing longevity: in developing the Living to 100 symposia, the SOA is helping to collect the key elements of that discussion and to shape the conversation going forward.

As one reads the symposia material, a few key threads appear consistently throughout the discussion.

First, around the globe people are living longer. While there is evidence that the rate of improvement is different between men and women, and between people of different races, geographies and social statuses, the evidence remains that we are all living longer.

Secondly, our understanding of what factors have a material effect on our expected lifetime is growing, but it is not complete. In particular, our understanding of older age mortality is limited, in part because the data at older ages is sparse and of varying quality. There are open questions related both to the rate of improvement and the ultimate age at which it is appropriate to assume a mortality table should end.

Thirdly, 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 that should be used to forecast those rates into the future. This creates challenges for practitioners who must develop their own projections; inefficiencies 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 future mortality. Having said this, the actuarial community has dealt with issues of this magnitude in the past: We need to begin to hone in on techniques that will allow us to become comfortable with the wide variances that can be produced by our projection models. As evidenced by the material presented in the body of this report, there are techniques—stress testing, scenario testing, risk heat maps, screening systems—that we can use to give us insight into what base mortality rates and improvement factors could be.

Lastly, there are broad socioeconomic implications for our governments, social institutions, businesses and for ourselves that must be addressed as our lifetime increases: the support 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. As that expectation changes, our personal and social safety nets will be forced to adapt. In addition, our expectation around the amount of time we allocate between work and other pursuits is changing: as we grow older we must work with our governments and employers to identify the terms on which we leave the workforce.

We 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

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

- Sparse data, often of poor quality at the oldest ages, is a significant hurdle for research; analytical and practical solutions exist but have a range of cost/benefit profiles.
- Many sources for mortality/longevity data exist, especially from governments (social insurance, census), but practitioners need to consider whether the underlying population is consistent with the planned application; life, annuity and pension practitioners need additional sources.
- Researchers segment the data in various ways to understand correlations and establish appropriate subgroupings; gender and smoking status are standard; in addition, actuaries in government and insurance company settings 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 that is included in a given database.
- Practitioners accept that calibrating the extrapolation to different time periods will lead to significantly different results.
- Companies should be explicitly or implicitly incorporating the effects of current and recent medical advancements, but major future developments (such as a cure for cancer) are difficult to predict and model.
- Demographic shifts are increasing social insurance burdens worldwide, so pay-as-you-go programs are becoming harder to maintain.
- Employers are reducing their roles, reducing benefits, shifting to defined-contribution plans; therefore, income responsibilities post-retirement are increasingly falling onto the individual rather than onto the government or employer. Retirees (and especially women) face many risks, so consumers need 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 will be changing needs for health and long-term care services, and challenges around financing and providing such services. Important societal and individual decisions will need to be made about who gets what and how it is paid for.
- The age at benefit entitlement and how people retire are very important issues across many societies.
- Finding ways for individuals to continue effectively in the workforce is important from a societal and individual perspective.

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

- How can the profession improve data collection for insured and annuitant populations? There is obviously a significant difference from the general population, but many companies do not participate in the voluntary data submissions to SOA/American Academy of Actuaries (AAA) research, so the resulting tables are not necessarily comprehensive of the industry. How can we apply lessons learned from the United Kingdom's Continuous Mortality Investigation [A-36]? From Germany's efforts [A-35]?
- How can the profession acquire data segmented by cause of death, and what are some 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?
- What are some mechanisms for assessing the utility of finer subgroupings of the populations?
- Could more detailed correlations—for example, seasonal effects or birth characteristics—have a place in actuarial practice?
- Which graduation methods are most appropriate for older ages?

- Can we validate a wealth/longevity effect at the oldest ages, especially for disability income and long-term care business?
- 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 can that be incorporated in modeling and planning?
- How can we manage systemic mortality risk?
- What can other practice areas learn about predictive modeling from property and casualty (P&C), reinsurance, capital markets, life settlements, or from the Canadian space, other international bodies? Can this lead to guides or practices that can be used by regulators? Banks have tighter regulation on modeling decisions; what can we learn from them?
- What lessons can be learned from the challenges facing public pension plans?
- What are some key articles/areas in which practitioners can learn from the academic community?

Finally, there is a significant body of research that has been compiled in support of the Living to 100 symposia. These papers serve to provide a good foundation from which one can develop a working knowledge of the research that has been conducted to date in this important area. In addition to the key themes we have identified above, there are a few pieces that could be used as an "accelerated" learner's guide.

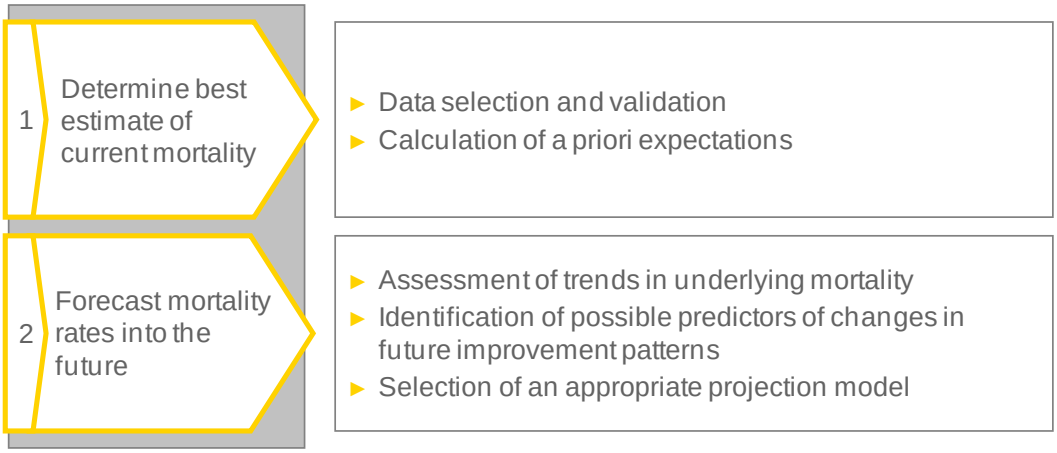
- IDL, the International Database on Longevity [A-30]
- Mortality Compression and Longevity Risk [A-82]; Mortality at Advanced Ages in the United Kingdom [A-36]
- Search for Predictors of Exceptional Human Longevity: Using Computerized Genealogies and Internet Resources for Human Longevity Studies [A-39]
- The Lee-Carter Model for Forecasting Mortality Revisited [A-23]; A Study of the Lee-Carter Model with Age-Shifts [A-54]
- High-Age Implications of Postretirement Risks [A-31]
- What if Mortality Was to Diminish Much More than Was Forecast? Implications for Financing Social Security [A-32]
- Is Long-Term Care Social Insurance Affordable in Developed Countries? [A-78]

4. Summary of Literature Reviewed

4.1 Part 1: The Analytical Process

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 sub-steps.



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

- Data sources and due diligence
- A priori expectations
- Assessing trends in underlying mortality
- Identifying possible predictors of changes in future improvement patterns
- Selecting an 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 those data sources, and data validation methods that exist 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 below raises several important questions that may provide opportunities for future research:

- When data is compared across countries, should we assume that country-specific trends will continue, or will differences diminish (or widen) over time?
- 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 don't necessarily provide a comprehensive view of the industry.
- 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 to use?
- Where should actuaries add more rigor to data scrubbing/analysis processes, or to predictive modeling, or any other component?

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 Ernst & Young, members of the Project Oversight Group or the Society of Actuaries on the data sources that should be used in studying old age mortality. Note it is also likely 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 and final 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 persons 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, and these errors are most prevalent among subjects of older ages.

2. The Death Master File (DMF) maintained by the Social Security Administration [A-4]

The 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 over 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 that there is strong evidence that 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 super-centenarianism.

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 of age or older. More than 15 countries, including the United States, Canada, and Japan, along with European countries, have been participating in this "super-centenarian" project. Collaboration with national statistical offices and/or health departments has allowed investigators to obtain complete lists of alleged super-centenarians 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 S. Gavrilova and Leonid A. 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: (a) persons should have birth and death date information and a life span of 100 years and over, (b) persons should be born in the United States after 1875, and (c) persons 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 non-blood relatives, number and gender of children and timing of their birth, place of birth, and information about residence during the life course.

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

Data from the 1990-1991 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 that are 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 persons aged 20 to 44, 45 to 64, and 65 and over. The data shows that about 30 percent of persons aged 20 to 44 lost their good health over this period, compared to about 50 and 80 percent of middle- and old-age persons, respectively.

7. Framingham Heart Study (FHS) [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.[A-103]

4.1.2.2 Challenges Related to Using Publicly Available Data Sources

1. Inconsistencies in underlying data:

Data gleaned from government sources is sometimes not ideal because of 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 the 1979 to 1999 period, 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]

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. 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.

- Age reporting at extreme ages may be inaccurate.
- 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 numbers 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 assumptions such as the Gompertz law.
- 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.

3. Lack of consistency in the approach to develop life tables impedes ability to consolidate data sources

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

4. Non-standard nomenclature

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 duplicate information, incorrect ages and unreported deaths.

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

(1) 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.

(2) Evaluate and react to data anomalies: Various files were compared to the Master Beneficiary Record in order to correct missing or invalid birth/death dates and to identify further duplicate records for alleged super-centenarians. Verification of birth dates was accomplished by checking recorded data against early U.S. census records collected when the alleged super-centenarians were children or young adults.

(3) Person-level records of utilization of Medicare services were linked to the Master Beneficiary Record in order to infer death at extreme ages from protracted non-utilization.

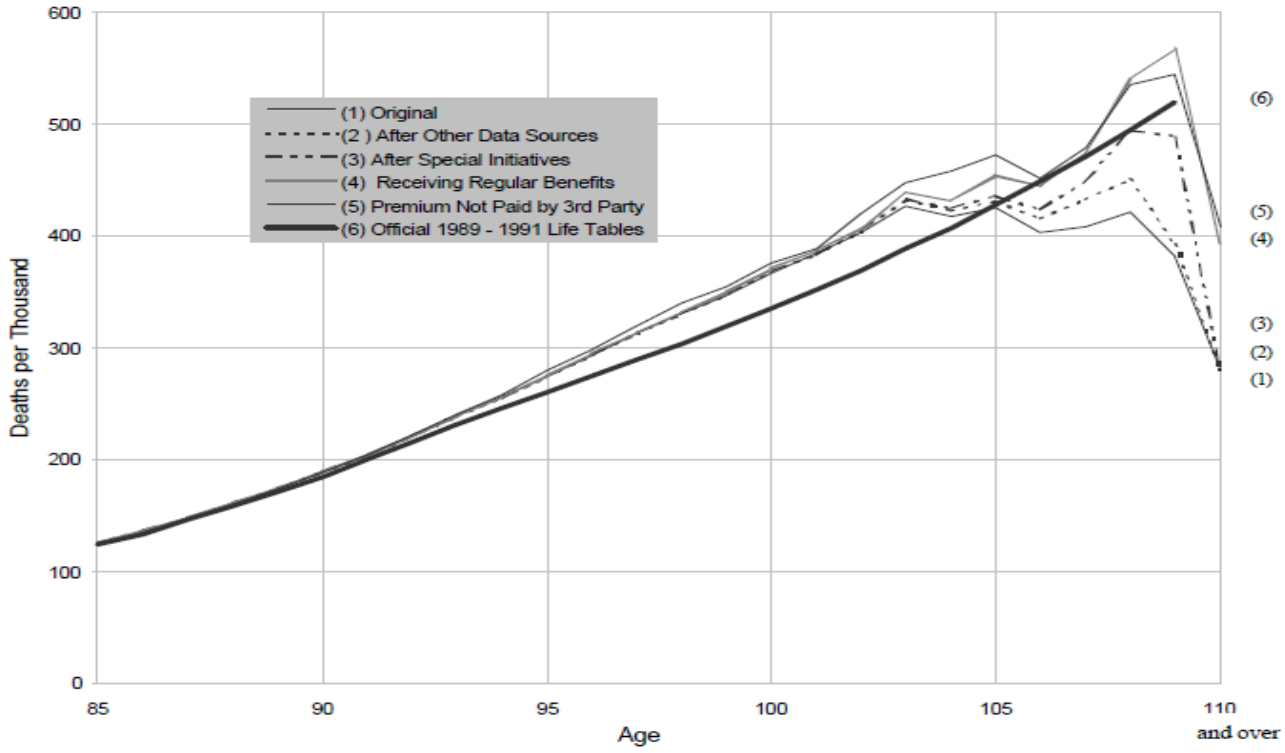
These are the three most common validation techniques, but there are other, less known methods as well. They include:

(1) Draft registration cards: In order to validate records in the SSA of men exhibiting exceptional longevity, one study compared a random representative sample of 240 men who were born in 1887 and 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 S. Gavrilova and Leonid A. 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]

(2) 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 as demonstrated by Mélissa Beaudry-Godin, Robert Bourbeau, and Bertrand Desjardins.[A-55]

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 1989–1991 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 1989–1991 Life Tables. Note that the effects of the validation techniques were most prominent between the ages of 105 and 110.

Figure 01: Male Deaths per Thousand at the Oldest Ages [A-3]



4.1.2.4 Related Symposia Materials

For additional information on the topics discussed in this section, please 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 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 http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5b-

Appendix Reference	**Paper**
	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) 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 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 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-103]	Patterns of Aging-Related Changes on the Way to 100: An Approach to Studying Aging, Mortality and Longevity From Longitudinal Data http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g5-yashin.pdf

4.1.3 A Priori Expectations

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

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 set of data. 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. The lack of consensus has led to debates over two key questions: (1) Are there limits to mortality rates? and (2) Is there a limit to life expectancy? Disagreement over these questions has revealed the need for research in the following areas:

- Whether or not economic status should be considered (in addition to gender and smoker status) when considering risk for people of older ages
- An assessment of which graduation methods may be most appropriate for people of older ages.

There are many stakeholders with vested interests in the outcome of this research. Balancing these interests 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.

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 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, Greenwood and 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]

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 during 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 below provides a summary of parametric models that were 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). Note that this table is not intended to be a complete list of all mortality curves which may be used by practitioners, but is presented as a summary of approaches discussed at prior 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	$\mu_x = \alpha e^{-\beta x}$	μ_x= force of mortality α = baseline mortality, shape 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	$\mu_x = \alpha e^{-\beta x} + \gamma$	μ_x= force of mortality α = baseline mortality, shape β = aging component 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 There are three components: A, B, C = mortality from birth to first year of life (A and B), then decrease in mortality rates through childhood (C) D, E, F = Mortality from ages 10-40 (captures the "accident hump") 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. 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 α, θ = baseline mortality β = aging component 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	$\mu_x = \frac{\alpha e^{-\beta x}}{\theta e^{-\beta x} + 1}$	μ_x= force of mortality α, θ = baseline mortality 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 $\frac{\mu_x}{1-\mu_x} = \alpha e^{-\beta x}$	μ_x= force of mortality α = baseline mortality β = aging component	- Similar to Beard, but down to two parameters - 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.	

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 γ = position parameter t0 = scale parameter 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		$S(t) = \sum_{i=1}^{4} p_i \exp\left[-\left(\frac{Max(t-\gamma_i,0)}{t_{0i}}\right)^{m_i}\right]$ where $\sum_{i=1}^{4} p_i = 1 \quad (p_i > 0) \quad mix\,ratio$	μt= force of mortality γ = position parameter t0 = scale parameter 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 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 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 m_x = central rate of death for the table intended for extrapolation 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 the table below is graphed with U.S. population data from the U.S. Social Security Administration (SSA) 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—Figure 02, Figure 03 and Figure 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 ages over 95.

Figure 02: Parametric Models
Makeham (fitted through age 95)

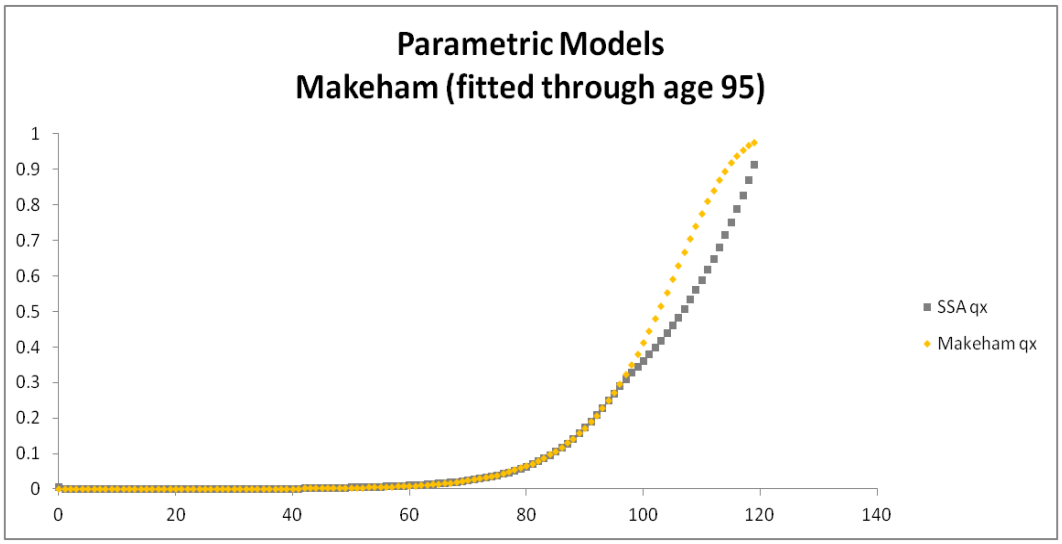


Figure 03: Parametric Models
Gompertz (fitted through age 95)

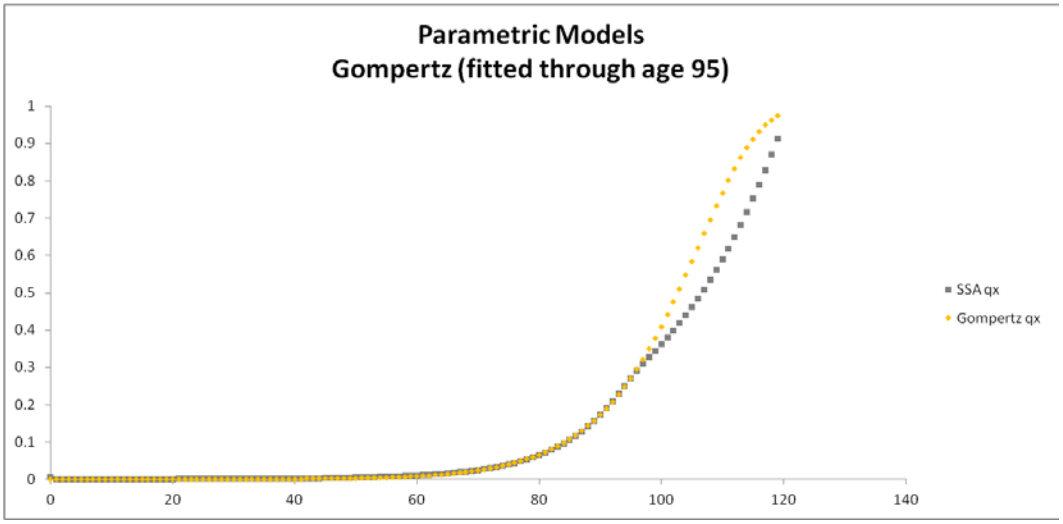
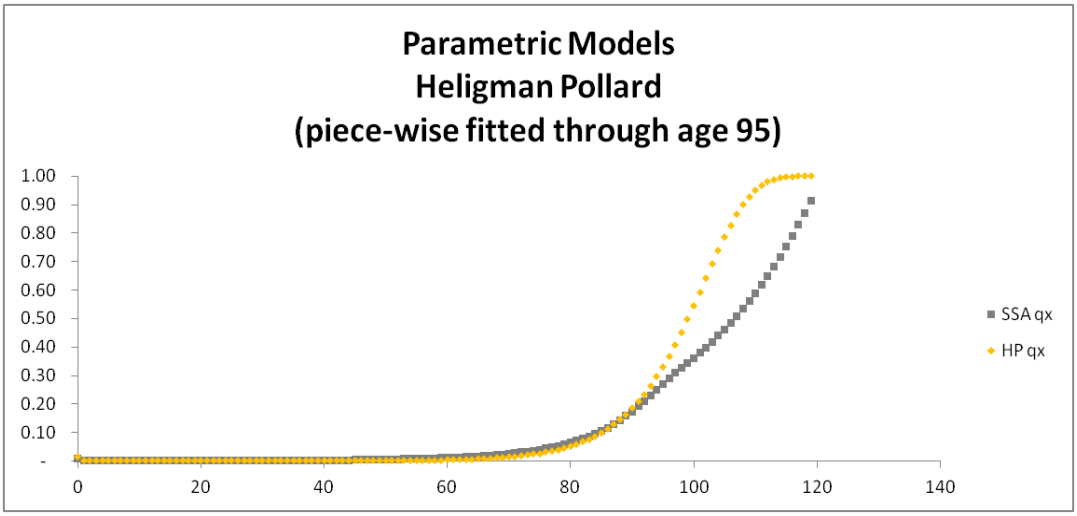


Figure 04: Parametric Models
Heligman Pollard
(piece-wise fitted through age 95)



The next series of charts—Figure 05, Figure 06, Figure 07, Figure 08 and Figure 09—shows 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)

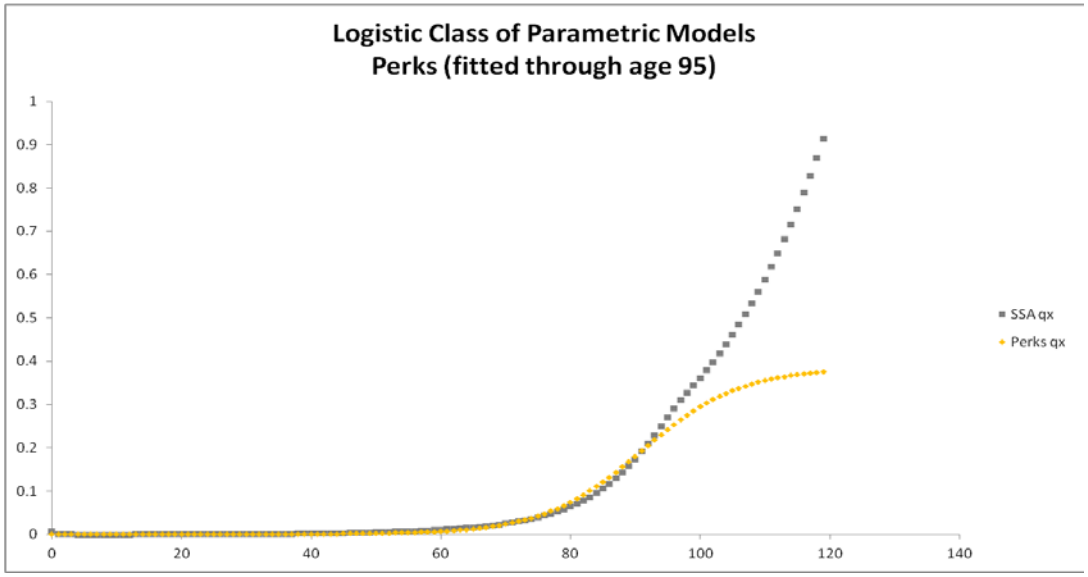


Figure 06: Logistic Class of Parametric Models
Beard (fitted through age 95)

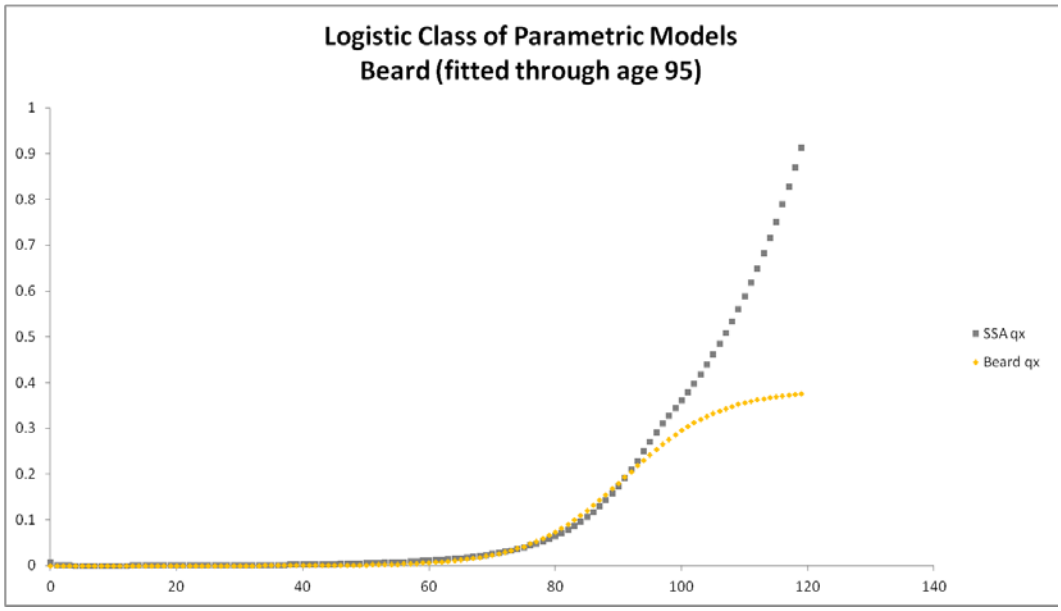


Figure 07: Logistic Class of Parametric Models
Kannisto (fitted through age 95)

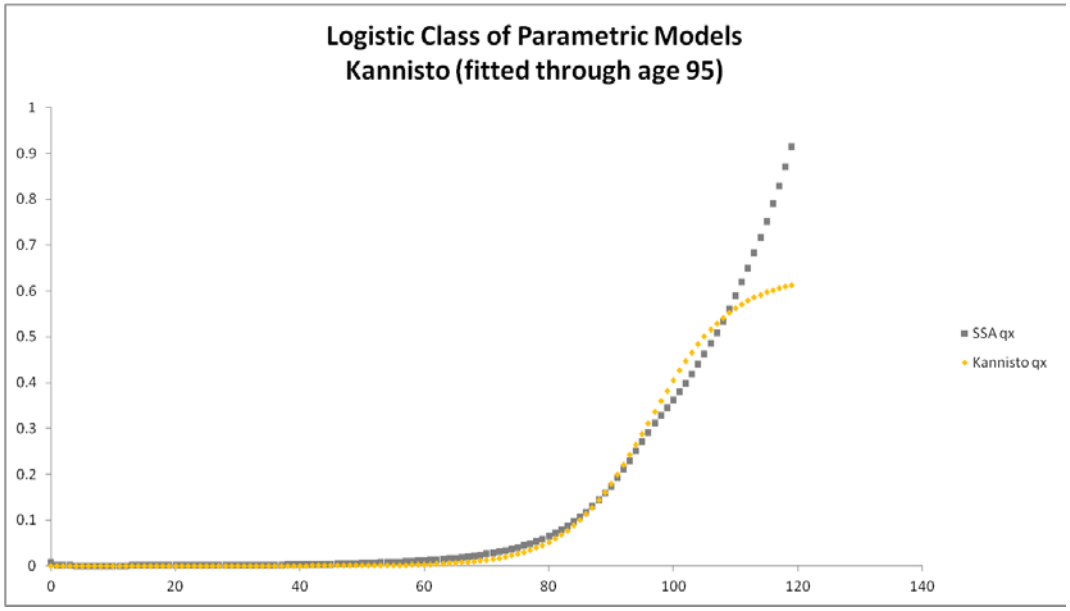


Figure 08: Weibull Models
Weibull (fitted through age 95)

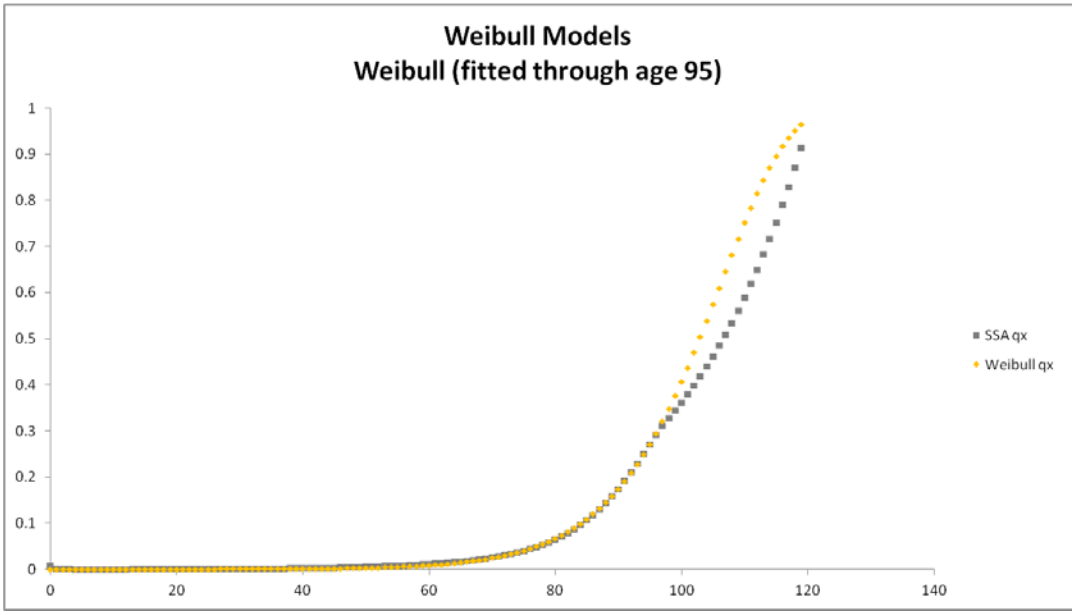
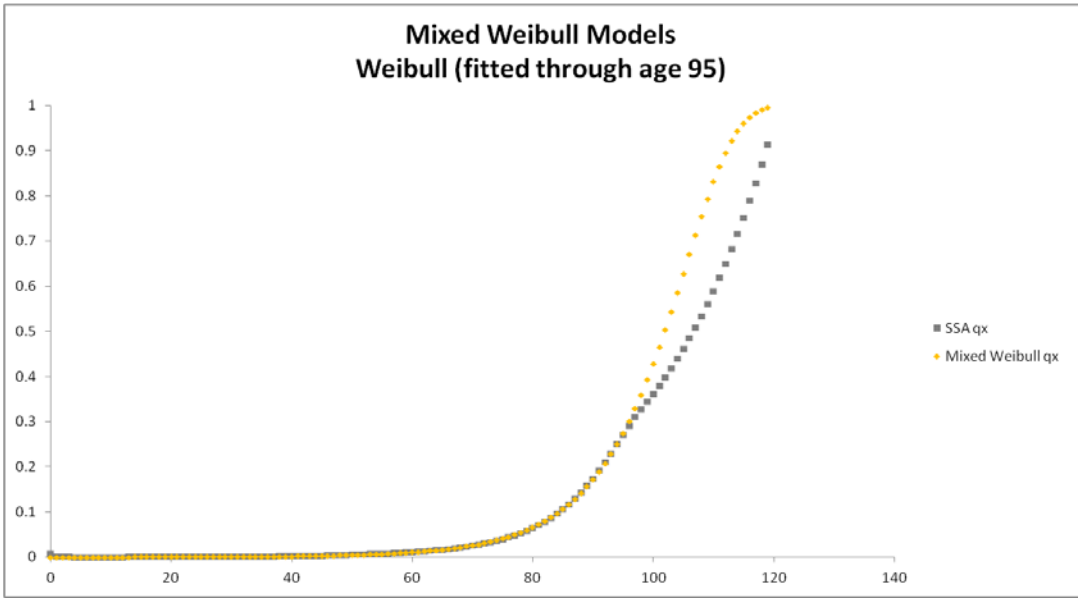


Figure 09: Mixed Weibull Models
Weibull (fitted through age 95)



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.

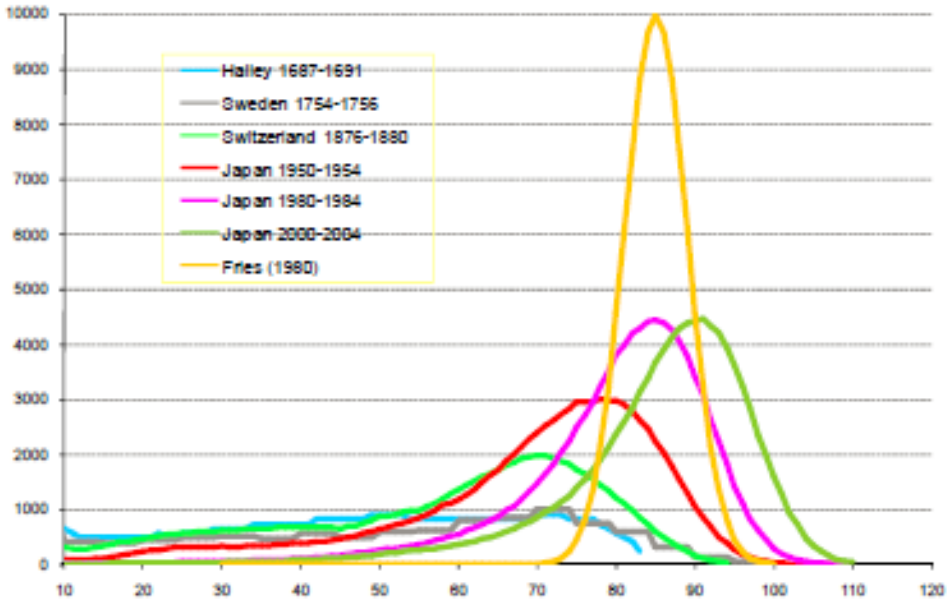
Even though both groups arrive at very different conclusions, they both assume the same cultural, technical and biological conditions (those of today) in their studies. Their large difference in opinion has serious social and economic consequences, especially for managing health services and Social Security.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

There are several forces that may cause change in human 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 below shows that by comparing Swiss data in 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.

Figure 10: Evidence of Mortality Deceleration



The compression of mortality, which has occurred in almost all low-mortality countries during the whole period since World War II, seems to have ceased in Japan for the last 10 to 20 years. 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]

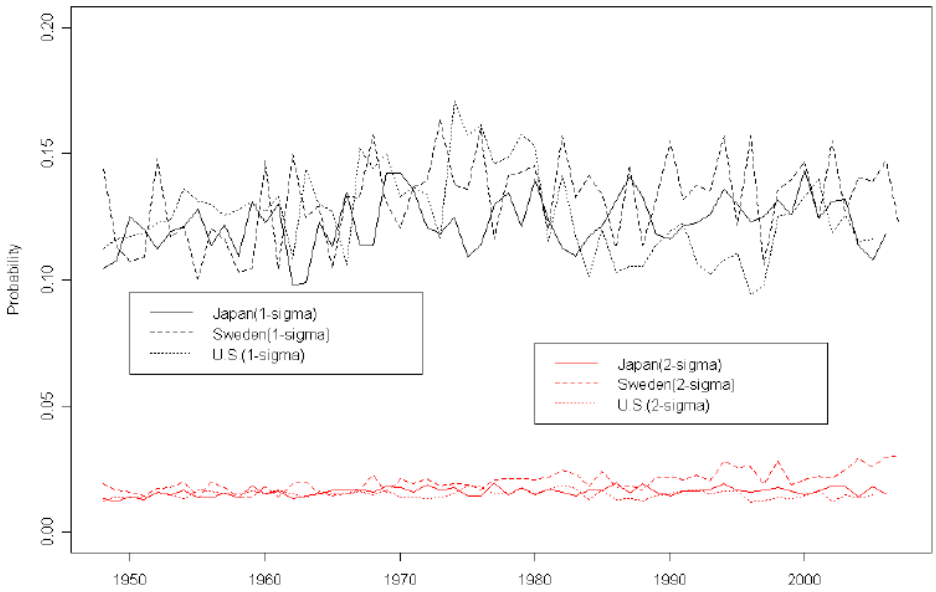
The evidence against compression

Social Security DMF data allowed the reconstruction of cohort life tables describing survival patterns after age 80 years 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 persons 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 years with almost no obvious signs of expected mortality deceleration. After age 105, the mortality estimates become less reliable because of significant statistical noise.

In addition, data for extremely long-lived individuals are scarce and subjected to age exaggeration. Therefore, in order to obtain good-quality estimates of mortality at advanced ages, researchers are forced to pool data for the several calendar periods. Therefore, one explanation for observed cases of mortality deceleration in other studies might be a result of data heterogeneity. Thus, more research to obtain reliable estimates of mortality at advanced ages would be beneficial. [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 below shows the results of one such analysis.

Figure 11: Evidence Against Mortality Deceleration:
The Probability of Survival Beyond a High Age (Male) [A-82]



2. The debate over when to end the life table

The decision as to when to end the life table is an area that is 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 that it is not possible to reach life expectancies of 100 or more unless two events happen: a) people modify their lifestyles in such a way that all causes of death currently listed on death certificates disappear; and b) 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 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]

3. 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]

4.1.3.3 Validation Techniques

None of the symposia materials focused specifically on validation techniques; however, in each article the author, or authors, assessed the fit of the model by comparing the data they were attempting to fit with the model in question.

4.1.3.4 Related Symposia Materials

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

Appendix Reference	**Paper**
A-6	Estimating Mortality of Insured Advanced-Age Population with Cox Regression Model 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 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 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 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 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 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 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? 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 http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1b-yue.pdf

4.1.4 Assessing Trends in Underlying Mortality

This section is devoted to papers that support the trend of mortality improvement around the globe. These papers focus on longevity patterns in North America, Europe and Asia—and in both developed and still-developing countries.

This section is divided into three subsections. The first subsection summarizes papers that show support for increasing longevity, focusing on this trend one geographic region at a time. 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. The third and final subsection presents techniques for validation of the base tables in light of observed trends.

4.1.4.1 Overview of Trends in Longevity

Global overview

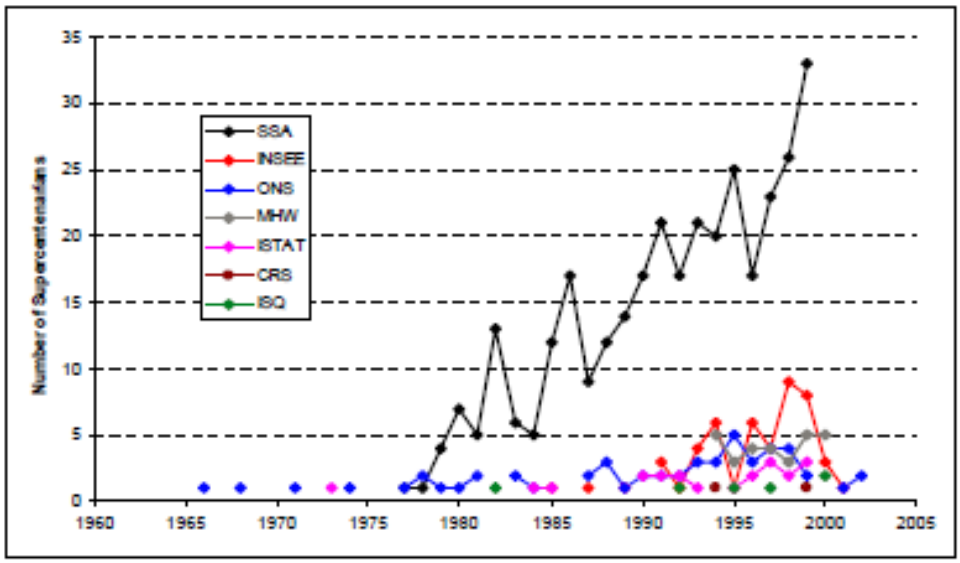
Based on studies that used data from the International Database on Longevity (IDL), it has been shown that mortality rates for people between the ages of 110 and 114 have not increased over the study period (or increased very slightly). The study includes 660 death records collected from 1892 to 2003 for the 16 participating countries. The people who performed these studies believe that their findings reject the exponential trajectories of Gompertz and Makeham. However, the findings cannot distinguish between logistic and quadratic trajectories, as the latter only diverges from observations for subjects with more than 115 years of age (Robine and Vaupel, 2002). 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]

In a separate study, researchers obtained data for Denmark, Sweden and France in order to assess the growth of centenarians in these countries during the 1990s. The studies showed increases in the centenarian populations of all three countries: Denmark by 50 percent, Sweden by 60 percent, and France by more than 100 percent. (Another study illustrated similar trends in the United States, whose centenarian population grew by 60 percent.)[A-29]

Although the exponential increase in the number of centenarians is well documented in Europe and Japan today, this is still not the case for older persons of 105 years (semi-super-centenarians) and 110 years (super-centenarians) of age. However, it is still clear that the number of semi/super-centenarians has been increasing, just like that of the regular centenarians. The number of super-centenarians 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 super-centenarians has increased, so too has the maximum life span for humans, which has gone from 112 to 122 years. [A-10]

Figure 12 on the following page shows the number of persons who have attained 110 years of age for countries that have submitted data to the IDL.

Figure 12: Number of Persons Having Reached 110 Years of Age by Year [A-30]
(International Database on Longevity, March 2004, Persons Deceased at Age 11 and Over)



Legend

SSA:	USA
INSEE:	France
ONS:	England & Wales;
MHW:	Japan;
ISTAT:	Italian;
CRS:	Denmark;
ISQ:	Quebec (Canada)

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 that past trends would continue into the future, the study showed that, 30 years from now, mortality rates for pensioners over age 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 to 1998), when there were substantial improvements in the health and mortality of the elderly (age 65+), the old-old (age 75-85), and the oldest-age (age 85+). Interestingly, the authors found that the improvements in life expectancy at age 75 (which overall, 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]

Canada

Authors in the province of Quebec used parish registers to establish a computerized database with the basic demographic parameters of the French-Canadian population, beginning at its origin. 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 what might have been expected, the data seems to show that the progression of mortality remains approximately exponential until the oldest ages where the data becomes erratic because of limited observations. The authors concluded that nature of the selections which would produce a slowing down of the rate of increase in mortality for the elderly today were not present a few centuries ago.[A-12]

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 1964–1968 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]

After examining data for cohorts born before 1947, the authors of a separate 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 reasons for these differences in mortality improvement remain unknown. They could be the result of something generation specific (e.g., upbringing during the war years) or something entirely different. [A-36]

Spain

Authors collected data on those who passed away between the years of 1975 and 1995 and analyzed the number of people over the age of 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 over the age of 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 over the age of 100 from the total population was approximately 34.32 percent more in 1999 than it was 19 years previously. [A-11]

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]

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]

Women and minorities

It is interesting to note the growing predominance of women within older age groups. The 2000 census reports that roughly one-third of women older than age 65 were living alone, while the corresponding figure for men was one-sixth. [A-21]

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]

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.

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]

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]

Narrow the age intervals to monthly time steps: In particular, in the article referenced, the 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 datasets of higher data quality. [A-107]

4.1.4.4 Relevant Symposia Materials

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

Appendix Reference	**Paper**
A-1	Pensioner Mortality in the New York State Public Retirement Systems 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 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 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 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 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 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 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 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 http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iii.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-107	Mortality Measurement and Modeling Beyond Age 100 http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-5b-gavrilova.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

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 non-genetic 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

In order 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?
- 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 the advancements in pharmaceuticals and their effect on aging into our projections of future mortality? [A-77]

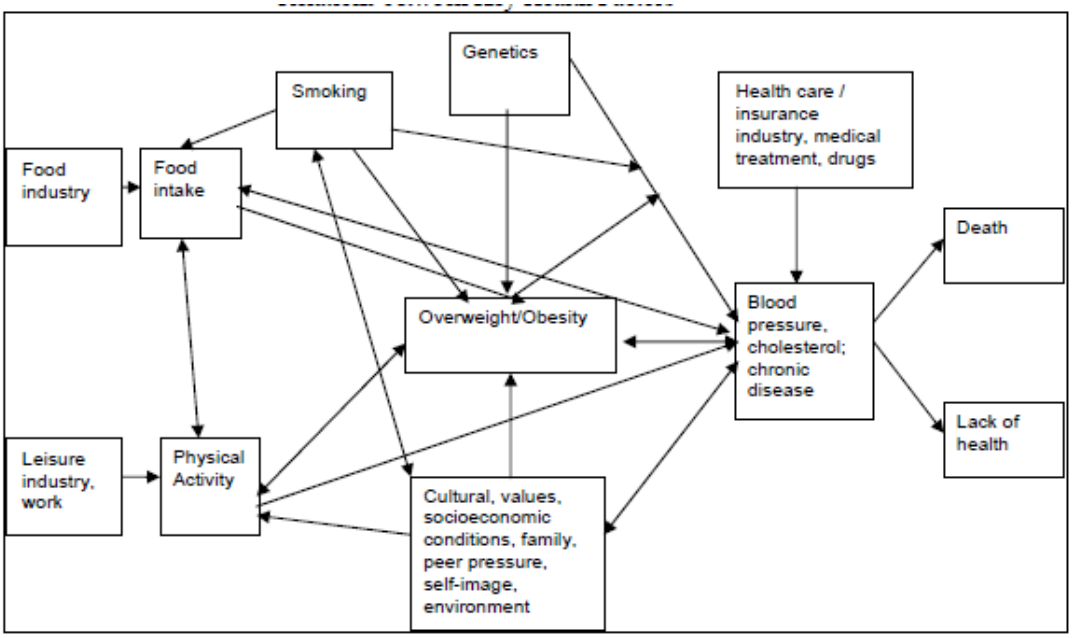
The information in the sections below summarizes the symposia information that addresses these topics.

4.1.5.1 Determining the Predictors of Mortality and Morbidity

Figure 13 below is an illustration of factors that contribute to the health of an individual. These factors fit into five 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 13 for simplicity's sake only). [A-48]

Figure 13: 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 four main approaches to judge the significance of predictor variables. These include:

1. Cox Proportional Hazards Model: [A-8], [A-79] This approach is the most common approach 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. [A-8], [A-79]

2. 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.

3. 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 that 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:

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]
- 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]
- Obesity: Adults who suffer from obesity at a young age (30 years) are three times less likely to reach age 100 than adults who are of the same age, but who are not obese. [A-61]

  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 future technological developments will offset each other in the future. [A-48]

  A final paper discusses 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]
- Lifestyle: Symposia papers demonstrate that activity limitation, exercise status and education 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]
- 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]
- Cardiorespiratory fitness: [A-8] This factor is shown to be correlated with age; therefore, while it is demonstrated that cardiorespiratory fitness is correlated with mortality, the strength of the effect is masked by other age-related factors.

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] However, it should be noted that Gavrilova and Gavrilov found marital status to be less important as a predictor of future longevity than physical characteristics such as body build. [A-61]
- Number of children (4+): Having a large number of children (4+) at age 30 increases the chances of exceptional longevity of the parent by 100 to 200 percent. [A-61]
- Parents who grew up in a farming community: According to one study, having parents who were raised in a farming community increases the chances of exceptional longevity by 100 to 200 percent. [A-61] According to a second study, the combination of having parents raised in a farm community and oneself being raised in the western United States may be predictive for survival to age 100. [A-39]
- 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. (Seeing that contemporary families tend to be small, this is very pertinent information for people today.) [A-95]

- Hereditary feedback: 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. The increasing body of demographic, genetic and medical data being generated from studies of centenarians suggests an increasingly greater genetic contribution to the ability to survive to ages beyond 100. A possible increasing level of homogeneity in functional history and medical histories amongst centenarians beyond the age of 105 years 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 such as dementia. [A-121]

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 do not support the hypothesis that higher levels of income inequality are directly related to lower levels of population health. [A-50], [A-117]

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 that there may be a threefold difference in chances of survival to 100, depending on location of childhood residence. [A-39]
- 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 that first-born daughters are three times more likely to survive to age 100 than daughters of higher birth orders (7+). Similarly, first-born sons are two times more likely to become centenarians than sons of birth orders four through six. Interestingly, last-born sons (9+) 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]

The symposia papers also discussed variables that do not have predictive power. These include immigration status [A-61] and 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 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, there is significant uncertainty in the estimation of future mortality patterns and their relationship to obesity. [A-48]

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 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 his/her 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 which reference 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 lethal sequelae 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]

4. Our understanding of the aging process

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]

4.1.5.3 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 control groups. [A-39]

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

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]

Distant blood relatives (e.g., first cousins), or non-blood 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]

4.1.5.4 Relevant Symposia Materials

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

Appendix Reference	**Paper**
A-7	Detection and Significance of Frailty in Elderly Insurance Applicants 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 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 http://www.soa.org/library/monographs/life/living-to-100/2002/mono-2002-m-li-02-1-stallard.pdf
A-18	Plastic Omega

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

4.1.6 Selecting the Appropriate Projection Model

Increased 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, however, 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 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 that are 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 the Lee-Carter model.
- Practitioners in different countries use different methods and assumptions for projecting mortality: refer to paper [A-36] for further information on the methods adopted by the CMIB (United Kingdom); and paper [A-35] for further information on the methods employed by Germany.
- In the United States especially, there appears to be no consensus as to what constitutes an appropriate population mortality improvement scale.
- There are different opinions as to the appropriate size and use of age cohorts.
- There is limited consensus on what the key drivers of projected mortality will be and whether these will vary by age group.

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

- 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 P&C, 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?

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.

4.1.6.1 Selecting an Appropriate Model

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

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

In the United Kingdom, [A-36] 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.

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, relied 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.

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. Still, some good papers on the subject do already exist, like the *North American Actuarial Journal* 2009 paper of the year (vol. 13, no. 1), which compares eight different projection models and their fit across U.S., English, and Welsh populations.

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.

- 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 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 that a practitioner wishes to capture. As a result, it is suggested that 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]

- 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]

- Parameter uncertainty: There is inherently 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]

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.

Prediction Intervals [A-89]

Following the symposia papers' instructions, we implemented the time-simultaneous prediction interval and Chebyshev bands for both the Lee-Carter model and the CBD model (M5) and compared the results to the point-wise prediction interval originally provided by the Lee-Carter (1992) paper.

Figure 14 on the following page compares the projected mortality rates using a Lee-Carter model for a person aged 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 worth noting here are:

- 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 over 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 14: The Prediction Interval Generated by the Lee-Carter Model

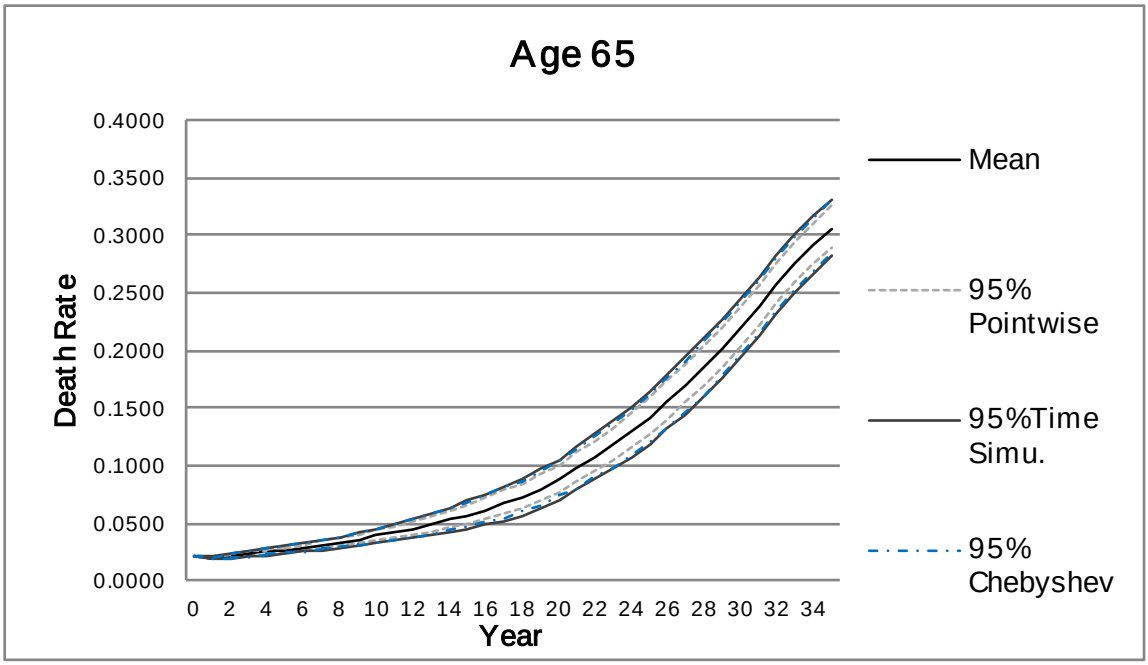
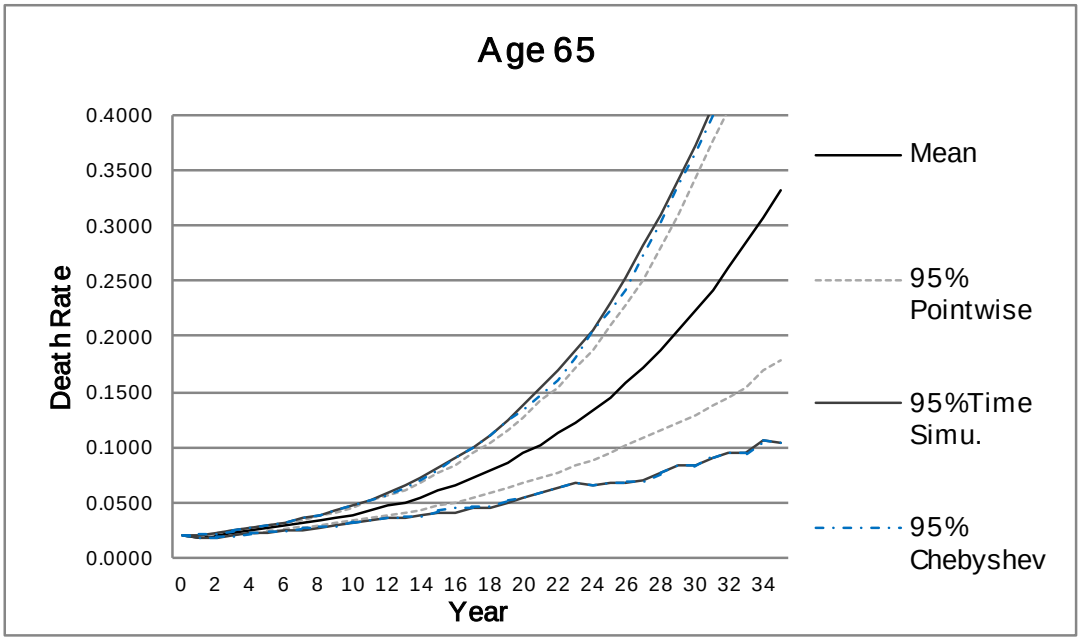


Figure 15 on the following page shows the corresponding results for the CBD model (M5), which is similar to the Lee-Carter model but incorporates "period" effects in addition to "age" effects. The 2.5th and 97.5th percentile bands are shown using the point-wise method, as well as the time-simultaneous and Chebyshev methods.

Again, 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 over 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 15: The Prediction Interval Generated by the CBD (M5) Model



Another area that was 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, which 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 symposia paper's authors, Siu-Hang Li and Wai-Sum Chan, propose that professionals estimate parameters in extrapolation models by using quantile regression rather than the more typical least squares regression, arguing that 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 that is not influenced by extreme events.

Under QR, the mortality index is fit to ARIMA(0,1,0), and the drift parameter is 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, just 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). We used data from the Social Security Administration's 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:

	Drift (□μ)	Drift Uncertainty (□σ)
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 the following graphs—Figure 16 and Figure 17—we use the same data set to show the difference in mortality rate estimation (q_x) under both QR and LS approaches.

Figure 16: Difference between QR and LS by Age

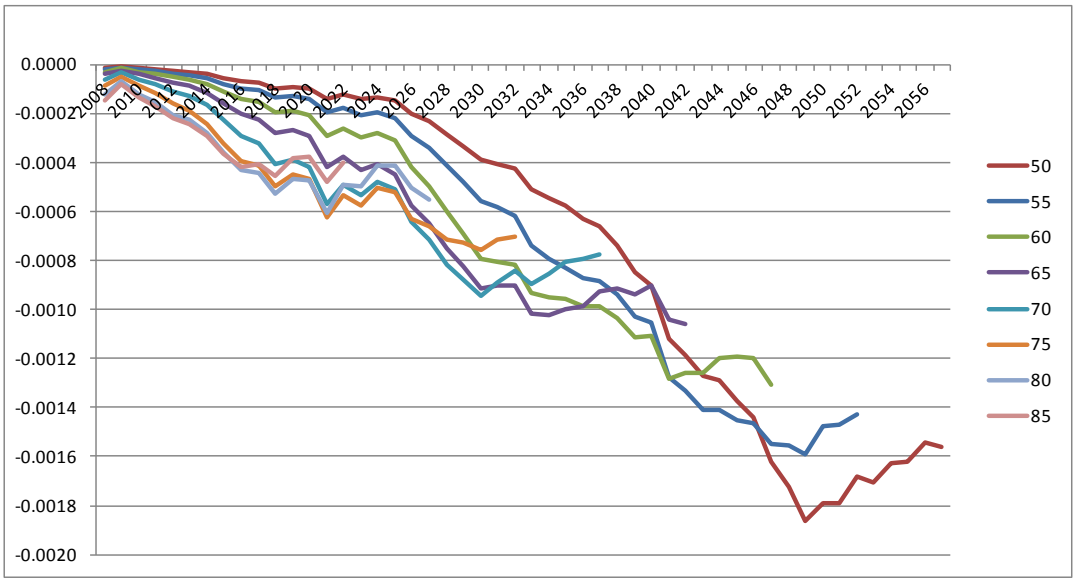
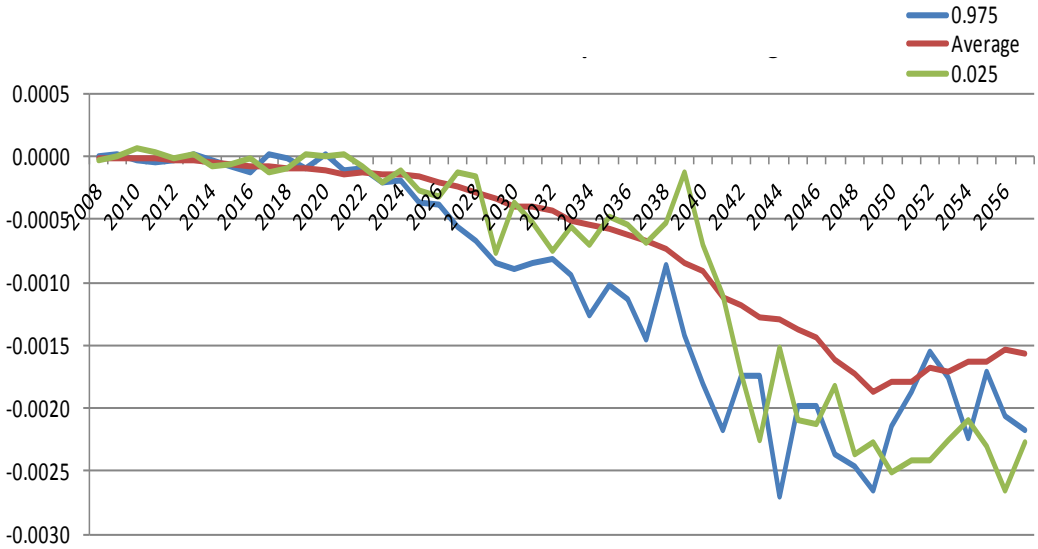


Figure 17: Difference between QR and LS at Age 50



Above, 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 9.75 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 18 and 19, we show the impact of both models in life expectancy for newborns:

Figure 18: 2007 Newborn Life Expectancy Distribution

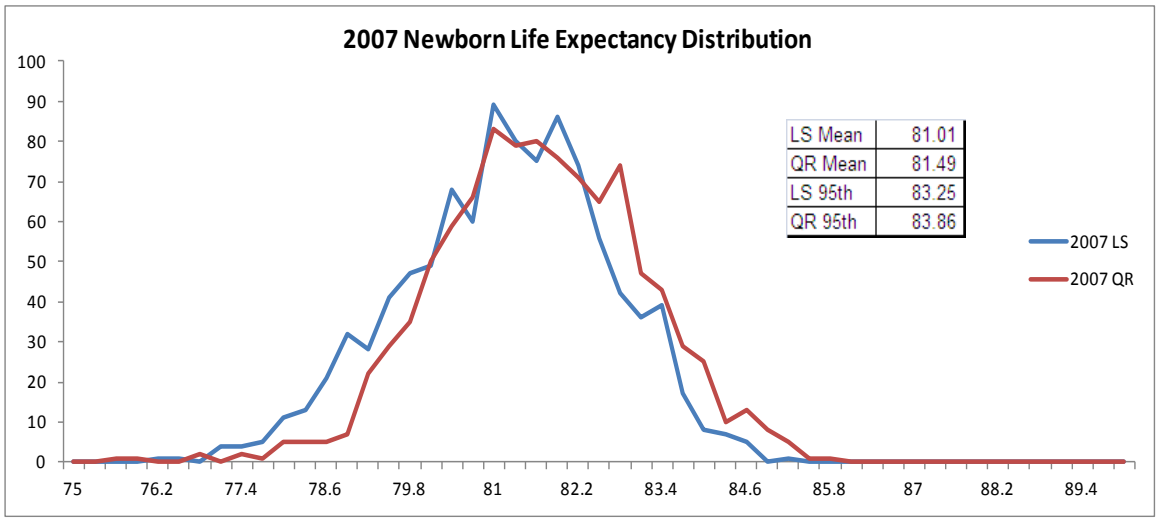
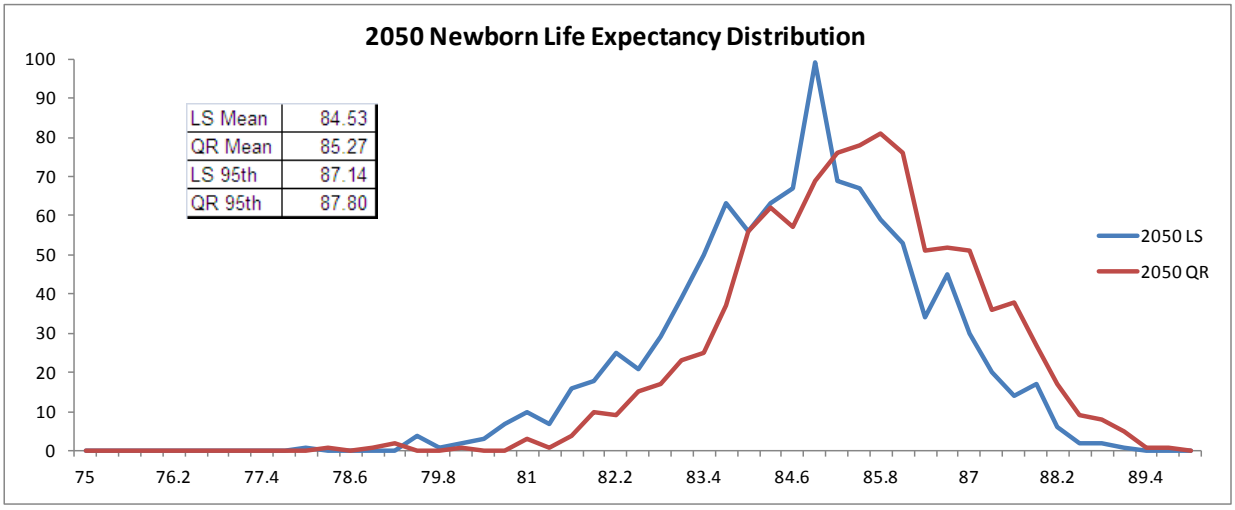


Figure 19: 2050 Newborn Life Expectancy Distribution



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 (σ) 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; perhaps as a result, many of the technical papers focused on selecting the appropriate model and on using different techniques to enhance the predictive power of the resulting forecast.

Having said this, there are a limited number of tools available. Certain papers referenced the use of back-testing to validate the baseline forecast; and others, the use of cause of death analysis to validate the width of prediction intervals at certain percentiles.

4.1.6.4 Relevant Symposia Materials

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

Appendix Reference	**Paper**
A-23	The Lee-Carter Model for Forecasting Mortality Revisited 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 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 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 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 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 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 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 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 http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-3b-li.pdf

4.2 Part 2: The Social and Economic Implications of an Aging Population

The implications of changing life spans are important throughout society, and the Living to 100 project includes implications as part of its work. The Society of Actuaries Committee on Post-Retirement Risks, and the Pension, Health, and Long Term Care Sections also study the implications of longer life in their research. That work is beyond the scope of this literature review, but the reader interested in considering the implications of longer life is also encouraged to focus on that work as well.

Unlike the extensive research on mortality data, trends and modeling, the papers submitted to Living to 100 in the area of implications touch on a few of the key issues, but do not offer a comprehensive look at the opportunities and challenges created by longer life.

In addition, it is important to note that the views expressed in this report are those of the authors who presented their work at the symposia and do not necessarily reflect those of Ernst & Young, the members of the Project Oversight Group, or the Society of Actuaries.

Increasing longevity is creating new challenges and opportunities for society at large and particularly for business and the retirement income industry in many countries around the globe. As a result, people will have to rethink how they allocate individual, family and societal resources so that we can most effectively support our growing life spans. They will also need to think about what the labor force will look like and the products and services needed in society. One symposia paper, "Living to 100 and Beyond: Implications of Longer Life Spans," highlights a number of trends that have, or are expected to result from continuing increases in longevity. These include:

- Large increases in the number of elderly and the proportion of elderly in the population of developed countries
- Changes in the type of economic activity, housing, social services and population that form the infrastructure of our communities
- Growth, change, and increasing cost and utilization for the health care systems
- Increasing burdens on society to care for the frail and disabled elderly members of a population
- The growth of financial markets, like annuity, long-term care insurance, and, in some countries, health insurance, that offer products that target elderly needs
- The strain on private pension and retirement savings plans as engines for savings and capital accumulation
- Increasing liabilities on corporate balance sheets for pension and other post-retirement benefits
- Strain on public pension systems and other programs offering support for the elderly as they compete for public resources
- Strains on long-term care programs and increasing shortages of both family and paid caregivers.

These changes will have large impacts on all of society, but they will be particularly troublesome to the vulnerable elements of societies. These vulnerable elements include the oldest of the elderly (who are most likely female, unmarried and poor), then the rest of the elderly and those age 80 and over (who are almost twice as likely to have a severe disability as their younger counterparts). [A-20]

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:

- How should society allocate resources to various support systems?
- Should the standard retirement age change, and at what pace? How and when will people retire and what will retirement mean?

- What is the appropriate role of government, employers and individuals in providing retirement income and support for health and long-term care?
- What role should annuitization play, and how does this vary by country?
- 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]
- As people need to work longer, will jobs and the employment relationship be adapted to fit the evolving labor force and how?
- How does the family fit into sharing risks and support?

People entering and navigating through their retirement years face a variety of risks; for example, loss of a spouse; inability to find work; outliving accumulated assets; incurring significant costs related to health or long-term care; and the inflation and investment risks associated with maintaining their asset portfolios. Some of these risks can be mitigated by social programs and employee benefits, and some are the responsibility of the individual and family. Some of the risks can be transferred and pooled, whereas others cannot. [A-106]

The following sections summarize the implications of longevity for retirement income programs, long-term care programs and health care systems to the extent presented in symposia materials. We note that considerable research has been done by the SOA 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.

4.2.1 Societal Support for Retirement

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 societal 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.

4.2.1.1 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]

Societal support for retirement in developed nations

In the **United States**, the historical decrease in mortality and increase in fertility have endangered the solvency of the Social Security Old-Age 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]

In **Canada**, long-term projections show that 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 (C/QPP) 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]

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
Anna Rappaport Consulting

Societal support for retirement in developing nations

There are a variety of systems in different countries, with different structures and challenges. The Living to 100 papers offer insight into some examples of the issues. The comments reflect the views of the authors and should be taken in historical context: Papers were published from 2002 to 2011.

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]

Ten years ago, Mexico transformed its pensions from defined benefits to defined contributions, hoping to provide universal coverage, job creation and income. However, after 10 years, it is 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 that the Indian 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 in its own retirement savings. Finally, unhealthy lifestyles are causing widespread tuberculosis, asthma, cancer and cardiovascular problems amongst 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, one symposia paper argues that 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]

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 in order 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. In order 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 the foreign institutional investors (FIIs) and the speculators. The principal financial markets would then be expected to impose better corporate governance in the Indian corporate world, 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. As a result, experts will need to develop innovative solutions to avoid retirement income crises. [A-116]

4.2.1.2 Suggestions to Address Challenges Faced by Social Security Systems

1. Tying retirement eligibility age to remaining expected lifetime

As noted at the beginning of Part II, the author of this paper concludes pay-as-you-go pensions are not 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]

When the U.S. Social Security retirement program went into effect in 1935, naming age 65 as the normal retirement age, life expectancy at birth was only 61 years and life expectancy at age 65 was only 12.5 years. Today, newborn babies have a life expectancy 16 years greater than in 1935 and persons 65 years of age have a life expectancy of about 18 years. Therefore, the author suggests that increasing the retirement age to where an individual retiring has an expectancy of life of 10 to 15 years corresponds much more closely to the survival expectancies of the U.S. population at age 65 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 better 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.

Some believe that raising the retirement age will not solve the retirement income problem, though, claiming that 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

The author of the paper "Retirement and Retirement Ages in Canada Revisited" examines the effect of a gradual increase in retirement ages in order to attempt to maintain the "senior dependency ratio" at or close to its current level. The term "senior dependency 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 deemed to be 18 to 64). [A-70]

The author 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 in order 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 gradually from age 66 in 2009 to age 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 is felt to be a high priority for developed nations, as a vehicle for a much greater degree of flexibility in retirement arrangements in general. However, in order 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]

4. The 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 away from the joint family system, leaving the increasing number of persons in old age vulnerable in the absence of a broad government retirement income system.

The author postulates that 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 the 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]

4.2.1.3 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 to funds to pay benefits owed to citizens. A thorough, holistic reevaluation that considers all institutions relevant to retirement income will be necessary. [A-116]

So what are some of the most important changes that 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]

4.2.2 Challenges for Retirement Systems

4.2.2.1 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.

The employee's perspective

Research on what the public 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.
- When surveyed, retirees indicate that they prefer lifetime income, but when given an actual choice, plan participants in qualified plans often choose lump sums. Taking payments in lump sums creates challenges for security at very high ages.
- 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 that 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.

Even with all of the information, selecting the best product(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. The authors of the paper "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 that the optimal solution incorporated a significant number of immediate annuity products; that a portfolio that combined insurance and investment products almost always outperformed a portfolio of strictly investment products; and that the optimal solution always included the purchase of catastrophic illness protection. [A-52]

However, for people 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]

Finally, individuals seeking advice or buying financial products need to be careful about 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]

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
Witt Actuarial Services, LLC

The employer's perspective

Long life opens up a number of questions for employers as they manage their talent and offer employee benefits. There are several competing forces that need to be considered: longer-term talent challenges particularly in some skill sets, the needs of individuals to work longer, rising health care costs, and the higher cost of offering benefits that provide lifetime protection to retirees. In order to prepare themselves for the future, employers need to ask themselves a number of challenging questions: [A-105]

- What are the priorities and concerns of employers?
- What are the priorities and concerns of employees?
- What challenges does the aging society and changing workforce create for the management of talent? What opportunities?
- What challenges does this create for the management of active employee and retiree benefits?
- Does the aging of parents create special challenges for the employers of their children, who may be part of the sandwich generation?
- To what age is it realistic for people to work?

- Are there barriers to employers who want to innovate?
- What factors support successful adaption to new work and retirement patterns?
- Is phased retirement a good idea and how should it be supported?

As the 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.

4.2.2.2 Suggestions to Address Challenges Faced by Retirement Systems

There are several ways that Americans can enhance their futures in retirement. They include:

- Retirement and retirement savings plan designs that recognize that people need help in saving for retirement; within the context of defined-contribution plans, 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 that program designs are effective. It is important that 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 that Social Security provides a sound basic layer of benefit. The studies discussed here reinforce the importance of Social Security and the need to moderate reliance on individual efforts. [A-31]
- Supporting the integration of phased retirement strategies into employer-sponsored benefit plans.[A-70]

In addition, given the economic situation of many people today who are on the verge of retirement, it is likely that in the future many people will want or need to work longer and employers will need their talent. Employers will need to consider the following steps and adjust their policies accordingly.

- Gradually increasing retirement ages.
- Helping people keep skills up to date and build new ones so that they remain employable.
- Providing options for different work schedules, enabling individuals to find an option that fits their needs and capabilities while meeting employer needs.
- Updating disability benefits to fit new retirement patterns and to work side by side with defined-contribution plans.
- Re-engineering retirement programs.
- Developing phased retirement programs.

4.2.3 Challenges for Long-Term Care Systems

There are many differences in approaches to providing and financing long-term care (LTC) costs in different countries and many differences in opinion about the most appropriate and workable solutions. The papers presented at Living to 100 provide insight into some of the issues and the views of the individual authors. The summary presented here reflects the content of the papers and the situation at the time they were written.

Most developed countries are currently showing the signs of population aging. One sign is an increasing number of seniors, some of whom 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 that many respondents are concerned about the potential costs of LTC and believe that the government should help individuals cover LTC costs. [A-78]

A substantial portion of the senior population may need LTC. If this were to occur, it would be financially devastating for seniors. One symposia author, Doug Andrews, believes that a mandatory (social) insurance program, financed by the government, will best protect the population from LTC-related financial problems. Over the next 40 years, he shows that, in the United Kingdom, a 10 percent increase in tax revenue would cover LTC costs, assuming the worst projections (i.e., the highest costs) for LTC in the future. [A-78]

Creating a viable program is a difficult task. In the United States, politicians created the Community Living Assistance Services and Supports (CLASS) Act to relieve financial strain on Medicaid LTC and to provide more in-home care for elderly Americans. However, because of easy access to other social programs, like Medicaid, which provide similar benefits, CLASS has not been as successful as its proponents originally expected. [A-80] Demonstrating the difficulty of establishing a viable program, subsequent to the publication of this article, CLASS has been eliminated prior to implementation.

There are products and approaches for managing LTC costs that are available to individuals outside of 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. In the United States, Medicaid programs pay for some of the cost of LTC for many people without assets or income. However, as Medicaid programs are funded by a combination of federal and state funds, they are under severe financial pressures.

It is challenging for the individual to choose the right set of product that best suits his situation. LTC financial products come with a variety of different provisions and guarantees in them which makes them difficult to compare without the assistance of a specialist. However, the assistance of a specialist does not always guarantee the best outcome for the individual as the compensation structure for many agents and advisors varies depending on the product sold. In addition to choosing a product that fits individual needs well, the buyer needs to be concerned about 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. It is not unusual in recent years for companies to sell off blocks of business to other insurance companies. [A-106]

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
Ernst & Young

The Society of Actuaries' Long Term Care Section is working to explore better solutions. The papers in the Living to 100 discussions add to the dialogue.

4.2.4 Challenges for Health Care Systems

As is the case for LTC, there are many differences in approaches to providing and financing health care costs in different countries and many differences in opinion about the most appropriate and workable solutions. The papers presented at Living to 100 provide insight into some of the issues and the views of the individual authors. The summary presented here reflects the content of the papers and the situation at the time they were written.

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. [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 GDP and more than the entire economy of all other countries save Japan and Germany—was spent on this endeavor. By one account, over 90 percent was spent on treating illness and less than 10 percent on preventative care. [A-47]

In addition, this portion of the budget devoted to health care costs is growing. "If spending is allowed to continue growing at this pace, then, by the middle of this century—about the same time that some economists predict the U.S. economy will be eclipsed by China's—Medicare, Medicaid and Social Security could exceed 100 percent of the projected Federal budget. In the opinion of the Comptroller General, the most serious threat to the very survival of the nation is … our own fiscal irresponsibility." [A-47]

4.2.4.1 Challenges for Health Care Systems

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; and 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. 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 CAN$5,000 for people under age 55 (excluding education), and rose sharply to over CAN$25,000 for people aged 85 and over. 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 increasingly elderly population may lead to a shortage in doctors and nurses. This 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 that are 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. However, the increase in health care costs should be significantly lower than the increase due strictly to the increase in the number of elderly people and general population aging. [A-32]

Given this 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, a managing mode 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]

4.2.4.2 Suggestions to Address Challenges for Health Care Systems

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. [A-115]

In addition, health expectancy technology can also be used to counsel seniors. In particular, the authors make the following observations:

- 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 elderly make informed decisions about housing; their ability to continue to drive; their ability to continue to work; 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, improving socioeconomic conditions, etc. [A-115]

4.2.5 Relevant Symposia Materials

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

Appendix Reference	**Paper**
A-20	Living to 100 and Beyond: Implications of Longer Life Spans 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 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 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 http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2005/january/m-li05-1-iii.pdf
A-52	Living to 100: Survival to Advanced Ages: Insurance Industry Implication on Retirement Planning and the Secondary Market in Insurance http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-5a-ranasinghe.pdf
A-57	Is There a Limit to the Compression of Mortality? http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-03-cheung.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 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? 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 http://www.soa.org/library/monographs/retirement-systems/living-to-100-and-beyond/2008/january/mono-li08-3b-

Appendix Reference	**Paper**
	orth.pdf
A-69	Micro Pension Plan: Indian Perspective 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 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? http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-andrews.pdf
A-80	The CLASS Act and the Future of Long-Term Care Financing http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-moses.pdf
A-94	The Likelihood and Consequences of "Living to 100" http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-hayflick.pdf
A-97	How to Survive Living to 100: Ways to Improve the U.S. Retirement System 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 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 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 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 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? http://www.soa.org/files/pd/2011-orlando-living-100-andrews-gs6.pdf
A-115	Health Expectancy 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 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 http://www.soa.org/files/pd/2011-orlando-living-100-howse-keynote.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 are gaps in our collective perspective that should be filled by future research.

In addition 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 identify the difference between the drivers of older age mortality and the symptoms of aging?
- Given the limitations of the data currently available, how can we make sure that our projections of future mortality are useful to industry and government professionals?
- How do we best ensure that the mortality projections are relevant to industry and to government?
- 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?
- 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, the international actuarial community?
- How can we use these tools to help inform the discussion at the societal level? At the regulatory level?
- How can society adapt to the aging population? What is the role of actuaries in helping society adapt?

As the SOA prepares for the next in the Living to 100 series, we invite practitioners to focus their attention on filling the gaps in our collective knowledge in that hopes that we can move toward answering these important 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; and then forecasts were 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 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 over 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 that is 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): Bert Kestenbaum, ASA; B. Renee 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 persons in North America. This data is used for constructing the U.S. life tables for older ages every 10 years. The author articulates that even though this is the best available data, there are still errors that have a greater effect on older ages. This paper looks at ways to correct these errors and present them with their adjusted life tables.

A-4 Title: Reported Deaths of Centenarians and Near-Centenarians in the 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 called 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 public release can be validated using other resources.

A-5 Title: Data Mining Techniques for Mortality at Advanced Age

Author(s): Lijia Guo, Ph.D., ASA 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 interactive information discovery process that is an emerging new technology 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; 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 author uses 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 SOA 90-95 table. The author finds 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): Robert J. Pokorski, M.D., 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 that are attributable to frailty though 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, Hyuk-Sung Kwon, Donald H. Paterson, David A. Cunningham, John J. Koval

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

The author analyzes mortality in a sample of 441 adults from London, Ontario, Canada, aged 55 to 85 at the time the study was conducted. The author 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 still 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, MAAA, EA

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 1,640,000 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. non-disability.

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

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

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 concluded that 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 (people who live beyond 100 years). 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 and Bertrand Desjardins

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

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 Bases on Four Countries

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

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, 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 over. 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 that 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.

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 it will also be necessary to distinguish aging from longevity determination.

A-20 Title: Living to 100 and Beyond: Implications of Longer Life Spans

Author(s): Anna Rappaport, Alan Parikh

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 SSA 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-xxiv.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 Li and Wai-Sum Chan

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. Dupruis, Bruce Jones

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

The authors explain the use of 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.

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): 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 over 89 for a special 2003 census and compared the results to the older age data acquired in the 2000 general census. The authors used 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 Cheung, 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 analyzed 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): Bert Kestenbaum, B. Renee 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 aged 75+ is larger than previously thought.

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

Author(s): Jean-Marie Robine, Amandine Cournil, Jutta Gampe, James Vaupel

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; 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 author feels 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, Bertrand Desjardins, 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 author postulates 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, 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 discusses 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 CMIB (Continuous Mortality Investigation Bureau) 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 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, 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, SSA, 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 DMF.

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: (1) a life expectation (at birth) of 100 years will be reached in the industrialized countries by the year 2060; (2) 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.; Richard MacMinn, Ph.D.; Krzysztof Ostaszewski, Ph.D. FSA, CFA, MAAA; Ranee Thiagarajah, Ph.D., ASA, MAAA; 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, how to identify them, and 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 then 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 over.

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 the 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 HIPAA 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 spend of one-sixth of GDP. 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, MAAA, HonFIA

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, 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 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 around 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 non-wealthy. 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

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 qx (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, Peng Zhou, Charles Vinsonhaler, Sudath Ranasinghe

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 as stated are: Maximize current spending levels and maximize estate value at death. The author concludes 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 authors develop 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. Their pricing method allows for a tighter range of premia and flexibility with securities with different payoff structures.

A-54 Title: A Study of the Lee-Carter Model with Age-Shifts

Author(s): 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, Bertrand Desjardins

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, Ph.D., ASA

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, 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 the three challenges of estimating hazard rates at extremely old ages. (1) The observed mortality deceleration may be at least partially an artifact of mixing different birth cohorts with different mortality (heterogeneity effect); (2) Standard assumptions of hazard rate estimates may be invalid when risk of death is extremely high at old ages; (3) 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): Steve 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 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

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, Siu-Hang Li and Siu-Hung Cheung

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, JD, FSA

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. 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, MBA, FCIA, FSA, CFA

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, 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 don't 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 that is not covered under social security. The author feels 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, FCIA, FIA, FSA

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 (ARIMA (0,1,0)) 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 that are used to help quantify the variability in the mortality rate projections

A-73 Title: Mortality Projections in the United Kingdom

Author(s): Adrian 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 a disease which blurs the efforts to understand the biology of aging. The author concludes by asking why more resources aren't 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 N. 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 actually becoming a reality.

A-78 Title: Is Long-Term Care Social Insurance Affordable in Developed Countries?

Author(s): Doug Andrews, Ph.D., FIA, FCIA, FSA, CFA

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-andrews.pdf

LTC 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., Jessica Miller, M.S.

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-1a-cohen.pdf

Using data from LTC 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 LTC 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) hopes to provide 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, 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 the 50 percent of deaths. It then discusses the Lee-Carter model and bootstrapping techniques to calculate confidence intervals.

A-82 Title: Mortality Compression and Longevity Risk

Author(s): 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

Author(s): Leonid Gavrilov, Natalia Gavrilova, Allen Klein, Jack Yue, Jean-Marie Robine; Moderator Thomas Edwalds

URL: http://www.soa.org/files/pd/2011-orlando-living-100-cheung-1b.pdf

Paper authors present research on the following topics: "Temporal Evolution of Some Mortality Indicators. Application to Spanish Data," "Mortality Compression and Longevity Risk," "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

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

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 over 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 1990–1991 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 results of the study 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 from 85 and older. The study also notes that numbers for people 90 to 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, 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, Jack C. Yue, 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, 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): Johnny Siu-Hang Li and Wai-Sum Chan

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, Andrew MacKenzie, Steven G. Prus

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g3-brown.pdf

This study looks at the factors associated with loss of good health in the age groups 20 to 44, 45 to 64, and 65 and older. The study found that 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 in, whereas a major factor affecting older people was social involvement. Consuming alcohol and being active socially helped to prevent a decline of health in older individuals. 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 discussed the impact on human life if science discovered a way to slow the aging process. The author feels 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 feels 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 if an individual began treatment pre-menopause, she 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 explored the effects of early-life factors (birth order, paternal age, maternal age, month of birth) on the likelihood of survival to advanced ages. Centenarians were 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: 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 feels 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, JD, FSA

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 for 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 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 over age 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 In Canada—An Actuarial Perspective

Author(s): Robert L. Brown

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 ITA and in the various PBAs 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, 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. 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 and Robert Bourbeau

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-4b-ouellette.pdf

The author examines three populations: U.S. population through a CDC sample, a life settlement population of an independent life settlement underwriter, and the population implied by the SOA's 2008 VBT. The author concludes that mortality/survival rates seem to converge after 10 years.

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, 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 BMI, 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, Anna M. Rappaport

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, 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 Society of Actuaries. 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, 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 (BIC) 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 authors introduce 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?

Author(s): Douglas Andrews, William Peck, Noreen Siba

URL: http://www.soa.org/files/pd/2011-orlando-living-100-andrews-gs6.pdf

This presentation discusses 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 whether, in an aging society, preventative health care become a necessity.

A-111 Title: Distinguishing Health Status for Advanced Ages

Author(s): Craig M. Baldwin, Faye S. Albert, Thomas Ashley, Robert Gleeson, 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 presentation addresses the increasing healthy aging population and how it affects health practitioners. One of the speakers touches on the future use of biomarkers to predict the areas of decline in old age with an eye to prevention. Another speaker discusses the topic of health expectancy by bifurcating the healthy and unhealthy portions of life. A third speaker discusses assessing cognitive function in the elderly. The final speaker discusses long-term care underwriting in the oldest of ages.

A-112 Title: Implications of Longer Life Spans: What Does This All Mean to Us?

Author(s): Anna M. Rappaport, Timothy F. Harris, Dawn E. Helwig, Valerie A. Paganelli, David K Sandberg, 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 discusses the implications of longer life spans. It deals with the effect on the private sector and the people that actuaries serve. One of the speakers discusses the behavioral challenges that can negatively impact one's health. Another speaker discusses long-term care; the impact of increased longevity and the need for these services. The last speaker discusses the supply and demand of health care as demographics change.

A-113 Title: Emerging Definitions on Retirement

Author(s): Anna M. Rappaport, Doug Andrews, Steven Haberman, Valerie A. Paganelli, 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 presentation 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

Author(s): Sam Gutterman, Stephen C. Goss, Danita L. Pattemore, 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 presentation deals with a broad variety of actuarial topics dealing with social insurance methodologies and implications of changes in longevity. One topic that is highlighted is the cause of deceleration in mortality by cause of death. The presentation covers a variety of actuarial models that were 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 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 over the age of 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

This presentation discusses global issues relating to longevity trends. The idea that governments will need to re-evaluate the programs that are a financial burden was discussed. Social Security and other entitlement programs would need restructuring for the current longevity trends. The speaker 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

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 CDC, 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, 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 Human Mortality Database.

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 ageing?"

A-120 Title: Comparison of U.S., U.K., and Canadian Annuity Mortality Tables and Studies

Author(s): Doug Doll, Nick Dumbreck, Bob Howard, Allen Klein

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): Tom Perls, Paola Sebastiani

URL: http://www.soa.org/library/monographs/life/living-to-100/2011/mono-li11-g4-perls.pdf

This article looks at the impact of genetics on longevity. Based on twin studies, the heritability of longevity has been noted to be around 20 percent, but many papers have incorrectly extrapolated these results to extreme old age. The author also postulates that the longevity disparity for men and women hasn't 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

Author(s): Chresten Dengsoe, Sam Gutterman, Jean-Claude Menard

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.

Appendix B: Categorization of Articles by Practice Area and Analytical Phase

In order 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 helps illustrate 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 - core ages	Enhancements - older ages	Numerical extrapolations	Driver-based approaches	Business	Policy	
General population		2, 3, 4, 11, 21, 27, 29, 30, 33, 61	2, 3, 11, 29, 33, 55, 61, 71, 72, 73	2, 3, 11, 27, 30, 33, 51, 55, 71, 72	1, 11, 33, 40, 41, 55, 71, 72, 73, 122	9, 33, 40, 41, 55, 73	33	33	
Retirement, annuity	Government	36, 70, 102	36, 63, 82, 102, 114	45, 54, 82, 91, 114	42, 54, 67, 82, 90, 91, 98, 100	114	70, 116	32, 37, 42, 65, 67, 69, 70, 98, 102, 116	
	Corporate						20, 31, 34, 66, 68, 82, 97, 105, 113	20, 31, 34, 68, 97, 99, 105, 106, 113	
	Individual annuity	35, 36	35, 36, 82	35, 54, 82, 91	35, 43, 54, 82, 90, 91, 100	35	43, 52, 82		
General health		47, 50, 87, 101, 117	47, 50, 103	121, 123	48, 77, 120	48, 50, 87, 93, 95, 101, 103, 117, 120, 121, 123		47, 93, 94, 121	76
Health insurance	Government (Medicare / Medicaid / LTC)	46, 49	46, 63			86, 96, 119	34, 104	34, 78, 80, 85, 96, 104, 110, 119	
	Group benefits (disability / life / indemnity)								
	Individual health (LTC / DI / major medical)	38, 46, 49	46, 115	115	38, 111	79, 86, 111, 112	97, 111, 112	78, 97, 110	
Life insurance	Individual life	36	6, 36, 82	6, 54, 82, 91	6, 54, 82, 90, 91, 100, 111	6, 7, 62, 111	52, 82, 111		
Other	Reinsurance *								
	Banking / capital markets	36	36, 82	54, 82	54, 82		53, 82		
Theoretical (has the potential to be applied across all practice areas)		5, 12, 13, 14, 28, 39, 58, 107, 108, 109	5, 16, 22, 23, 24, 26, 28, 39, 44, 56, 58, 107, 109, 118	5, 10, 12, 13, 14, 15, 16, 22, 23, 24, 25, 26, 39, 44, 56, 57, 58, 60, 64, 88, 107, 108, 118	5, 12, 13, 14, 15, 16, 17, 22, 23, 24, 25, 26, 44, 56, 57, 58, 60, 64, 81, 88, 89, 92, 108, 118	5, 8, 17, 39			18, 19

Key:

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.