Developing A Consistent Framework For Mortality Improvement

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Executive Summary

The Society of Actuaries' (SOA's) practice areas currently utilize a variety of different mortality projection methodologies. The model described in this Report, denoted MIM-2021[1], along with two simultaneously released Excel-based tools[2], represent a single structure that practitioners can use to base their mortality improvement projections with consistency across a range of applications and SOA practice areas.

The conceptual framework presented here is modeled after the approach developed by the SOA's Retirement Plans Experience Committee (RPEC). The MIM-2021 Application Tool using RPEC parameters will replicate most of the RPEC mortality improvement scales[3], while adding flexibility for other actuarial practitioners.

The application of this conceptual framework for the construction of mortality improvement scales involves consideration of a wide range of issues. Some of these issues have been identified as appropriate for future enhancements of the MIM-2021 Application Tool, which are given in Section V of this report. An annual updating process for the MIM-2021, (and associated tools) is anticipated. Practitioners are encouraged to submit comments and suggestions.

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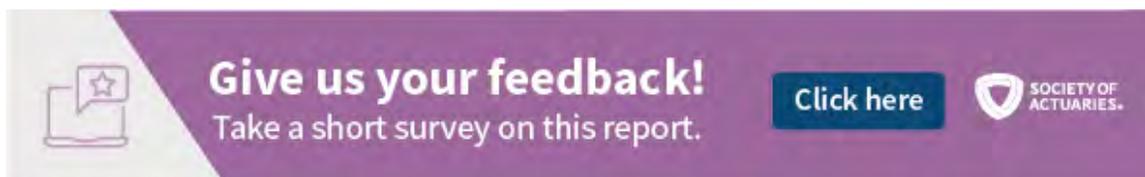
Section 1: Developing A Consistent Framework

1.1 SOA'S LONGEVITY INITIATIVE

The actuarial profession's reputation is built on the ability to measure and manage risk, including mortality and longevity, in an objective manner for use by providers of life insurance, annuities, retirement programs, long-term care and social insurance programs. Helping to achieve proper levels of funding and/or reserves, our role is also to ensure the sustainability of these systems.

As part of its 2012 package of strategic initiatives, the SOA Board charged the Longevity Strategy Task Force to develop strategic recommendations for the SOA with regards to mortality and longevity issues. The Board recognized mortality and longevity as key parts of the work performed by actuaries, and the rapidly changing science of their measurement and forecasting. The Board also believed the SOA and the actuarial profession could play a key role in helping public stakeholders (general public, policy makers, and regulators) better understand the drivers of changing longevity patterns. The Board asked the Longevity Strategy Task Force to recommend how the SOA should address these objectives.

In approving the longevity initiative, the SOA Board established the Longevity Advisory Group ("Advisory Group") whose premises echoed the SOA Board's objectives:

- Longevity risk is an issue of social, economic and financial importance;
- Actuaries have a key role to play in the measurement and management of risk to financial institutions and programs (public and private) providing income and benefits in old age;
- Actuaries are best positioned to conduct the needed measurement and analysis; and
- Actuaries need to take a leadership role to educate the public and our profession.

The Advisory Group originally formed in 2014 as a group of SOA members, sponsored a seminar in early 2015 with participation of 75 actuarial and non-actuarial professionals practicing in the longevity space to discuss and identify key longevity issues. As a result of the seminar a list of projects was compiled and prioritized.. Recognizing the current variety of longevity modeling techniques, the Advisory Group identified the development of a consistent framework for the projection of future mortality rates as one of the top-priority projects.

1.2 WHY A CONSISTENT FRAMEWORK

SOA disciplines currently utilize a variety of different mortality projection methodologies. The Advisory Group recognized a single structure could be developed to provide enhanced methodological consistency across a wide range of applications. The Advisory Group has:

1. Developed a consistent framework model, MIM-2021, for mortality improvement (as described in this Report);
2. Designed/released an Excel-based tool, MIM-2021 Application Tool, for practitioners to construct sets of mortality improvement rates under this framework for specific applications (summarized briefly in this Report and described in detail in the MIM-2021 Application Tool User Guide); and
3. Designed/released another Excel-based tool, MIM-2021 Data Analysis Tool, for practitioners to analyze the historical data sets included in the MIM-2021 Application Tool (summarized briefly in this Report and described in detail in the MIM-2021 Data Analysis Tool User Guide).

Modeled after the RPEC methodology (described below), the MIM-2021 Application Tool will replicate RPEC's "MP" mortality improvement scales, while adding flexibility for practitioners dealing with other

applications. The Advisory Group considers this Report and the underlying model to be an ongoing project with anticipated annual updates. Many issues concerning the development of mortality improvement scales were discussed by the Advisory Group. In an effort to release in a timely manner the MIM-2021 Report, MIM2021 Application Tool and User Guide, and MIM-2021 Data Analysis Tool and User Guide, some issues have been left for future enhancements. These issues are outlined in the Section V Items for Future Consideration. Practitioners are welcomed and encouraged to comment on these and offer additional suggestions.

Section 2: Evolution Of Mortality Improvement Model, MIM-2021

Methodologies underlying the projection of mortality rates have become increasingly sophisticated over the last two decades. For example, research performed by the Continuous Mortality Investigation[4] (CMI) of the Institute and Faculty of Actuaries in the UK and the RPEC of the SOA have resulted in the development of mortality improvement models utilizing user-supplied assumptions as inputs to produce arrays of two-dimensional (age and calendar year[5]) mortality improvement factors applied to suitably chosen sets (respective of practice area) of base mortality rates.

2.1 THE CURRENT RPEC MODEL

Prior to 2014, virtually all projections of future mortality patterns used by SOA actuaries in the retirement practice were based on gender-specific "age-only" mortality improvement rates, such as Scale AA[6] (released in 1995) and Scale BB[7] (released in 2012), and did not vary by calendar year. Importantly, the age-only Scale BB was derived from Scale BB-2D, an array of two-dimensional factors developed by applying a CMI-type methodology to Social Security Administration (SSA) mortality experience from 1950 through 2007.

The RPEC model, which was first released in 2014[8], was based on three key concepts underpinning the 2009 version of the CMI model[9]:

1. Short-term mortality improvement rates should be based on recent experience.
2. Long-term mortality improvement rates should be based on expert opinion.
3. Short-term mortality improvement rates should blend smoothly into the assumed long-term rates over an appropriate transition period.

While RPEC believed this conceptual framework for the construction of mortality improvement scales was sound, RPEC concluded certain technical aspects of the CMI methodology were not applicable for most pension-related applications in the United States. As a result, the final RPEC model, denoted RPEC_2014, incorporated several computational techniques intended to be more simplistic and transparent than those used in the CMI model without compromising any conceptual soundness

The RPEC_2014 model is described in the Mortality Improvement Scale MP-2014 Report[10]. The report also discussed how a practitioner could create a mortality projection scale using either the "committee-selected" assumption set, which would produce Scale MP-2014, or an alternative user-selected assumption set. An Excel-based application tool was created to assist practitioners in creating alternate improvement projections with the RPEC_2014 model. This new model had the additional benefit of being relatively easy to refresh, enhancing the prospects for more frequent updates to U.S. mortality improvement scales as needed for retirement-related applications.

The resulting gender-specific model, RPEC_2014, was developed through the following steps:

1. Two-dimensional (age, year) Whittaker-Henderson graduation based on the natural logarithm of historical U.S. population mortality rates (starting from 1950) published by the Office of the Chief Actuary of the SSA in conjunction with the annual releases of the Old-Age, Survivors and Disability Insurance (OASDI) Trustees' Reports.
2. Selection (by the user) of assumptions regarding the long-term level of future mortality improvement rates and the period of time it will take to attain those rates.
3. Projection of future annual mortality improvement rates, after a step-back from the most recent year of graduated rates to mitigate "edge effects" introduced through the graduation process, using two sets of interpolated cubic polynomials. One set projecting future rates horizontally by age and the other projecting future rates diagonally by year-of-birth cohorts.
   Each of the cubic polynomials is determined by two values and two slopes specified as of the beginning and the end of the assumed interpolation period, as follows:

   - The starting value is equal to the most recent gender-/age-specific mortality improvement rate obtained from the graduation, after step-back.
   - The ending value is the assumed long-term rate of mortality improvement for the corresponding age or year of birth[11].
   - The starting slope is determined from the most recent graduated mortality improvement rates (after step-back) subject to a maximum absolute value, along individual ages for the horizontal projection component and along individual year-of-birth cohorts for the diagonal projection component.
   - The ending slope is zero.

4. Blending the values generated by the horizontal and diagonal interpolated polynomials (i.e. user-selected proportional weighting between horizontal and diagonal projections).

Scale MP-2014 was the first of a series of annual "MP" mortality improvement scales, the most recent being Scale MP-2020, published in October 2020[12]. Other than updates for the availability of additional historical mortality data, the basic RPEC_2014 methodology has remained essentially unchanged. RPEC's most significant modifications have been changes to the annual "committee-selected" assumption sets, which when used as inputs to the RPEC_2014 model, produce the corresponding MP scale:

- In Scale MP-2016[13], two committee-selected assumptions were modified from those used in the two prior MP scales in two ways: (1) the convergence period for the horizontal interpolating polynomials was shortened from 20 years to 10 years, and (2) the starting slopes of all interpolating polynomials was set equal to zero. Both of these changes were made by RPEC in an attempt to improve year-over-year stability of the MP scales.
- Scale MP-2020 included an updated committee-selected assumption for the long-term rates of mortality improvement. In addition, the methodology used to taper the mortality improvement rates at the oldest ages was changed to avoid discontinuities that could occur when using certain alternate assumption sets as inputs to the model.

2.2 THE NEED FOR A MORE BROADLY APPLICABLE MODEL

While appropriate for many retirement-related applications, the Advisory Group recognized the RPEC model is less appropriate for use by actuaries in other SOA disciplines. Among other things, retirement-related applications:

- Are frequently "self-correcting" over time, e.g., insufficient funding of a pension program in one year can be "corrected" by increasing contributions to the program in subsequent years,
- Do not generally reflect underwritten populations, and
- Often do not utilize specialized sets of base mortality rates, such as those including select and ultimate and non-smoker/smoker and preferred risk classifications.

Hence, the Advisory Group started a project to develop a model with additional functionality than the existing RPEC model for a wider variety of actuarial applications including retirement programs.

The most recent RPEC model, RPEC_2014_v2020, uses historical mortality data from SSA from 1950 – 2018. The Advisory Group initially anticipated the more generally applicable model could be applied to SOA historical insurance-related experience mortality data (e.g., life insurance, annuity, and long-term care). To do that, the size of the data set used as a starting point was examined. For any projections, the amount of experience is relevant for determining the reliability of mortality improvement projections. Credibility increases as a function of:

- The number of lives covered by the data,
- The number of years of data available, and
- The level of mortality rates – i.e., greater credibility results are achieved for older age cohorts (high mortality rates) than for younger age cohorts (low mortality rates).

Whereas a typical SSA individual gender/age cohort has approximately 2 million lives, the comparable SOA life insurance gender/age cohort has approximately 120,000 lives. The SSA data extends from ages 0 to 100 even though ages 65 and above are more important for its purposes, while the SOA life insurance data is concentrated between ages 40 and 70. In total, the SSA data covers 68 years' worth of experience on up to 300 million lives, whereas the SOA life insurance data covers 7 years' worth of experience on 10 million lives.

As a consequence of substituting the SOA historical life insurance mortality experience in place of the SSA historical mortality data in the RPEC_2014 Model, the RPEC_2014 Model did not produce statistically credible estimates of mortality improvement rates consistent with those produced by RPEC's historical SSA data. Therefore, for the purpose for developing mortality improvement rates. the Advisory Group determined historical U. S. population data might be a superior base for historical insurance-related experience mortality data than SOA historical life insurance mortality experience.

To gain a better understanding of the drivers of mortality improvement, the Advisory Group commissioned two research projects:

1. *Components of Historical Mortality Improvement*[14]. The purpose of this project was to compare and contrast methodologies for allocating historical gender-specific mortality improvement (or deterioration) experience in the U.S. into four components (age, period, cohort, and residual), drawing from the methodologies developed previously by the CMI. This research was completed by a research team led by Johnny S.-H. Li, Ph D, FSA, from the University of Waterloo, Waterloo, Ontario with a two-volume report. Volume 1 provides background information and the modeling work associated with age/period/cohort ("APC") models fit to smoothed mortality improvement rates and the parameters in the estimated models give A/P/C decompositions of historical mortality improvement. Volume 2 documents the modeling work associated with APC models fit to mortality rates and the desired A/P/C decomposition of mortality improvement experience is obtained by transforming the parameters in the chosen APC model.

2. *Analysis of Historical US Population Mortality Improvement since 1950*. The purpose of this study was to identify significant U.S. mortality improvement/deterioration trends since 1950 including, but not limited to, those described in the Components of Historical Mortality Improvement research, using cause-of-death and other relevant data sources to quantify the likely degree of causality. This research was completed by a research team led by Andres Villegas Ramirez from the University New South Wales Business School, Sydney, Australia. Publication by the SOA is forthcoming pending final review.

The Advisory Group deemed it important not to develop just another tool to model mortality improvement rates, but to be sure all practitioners whose work involves mortality measurement, modeling and projection would find the MIM-2021 Application Tool useful. In addition to being able to replicate most RPEC mortality improvement scales, the tool offers additional functionality/flexibility to permit non-retirement practitioners the opportunity to tailor parameters in the tool to better meet their needs. In this regard, the MIM-2021 follows the previously described methodology originally formulated by CMI and reflected in RPEC's model.

Since the SOA data was not sufficient to achieve credible results, the Advisory Group considered using U.S. population data stratified into socioeconomic categories as potential "proxies" for insured data, initiating another research project, namely:

> *Mortality by Socioeconomic Category in the United States*[15]. The purpose of this project was to study trends in mortality by socioeconomic category in the United States from 1999 to 2018 (ultimately extending the historical data to 1982 based on 1980, 1990, and 2000 U.S. Census data). This research was completed by Magali Barbieri, Ph D, at the University of California, Berkeley, Berkeley, California.

As quoted from the project report, "Using data from the Census Bureau, a Socioeconomic Index was calculated for each data year and for each county. Counties were then ranked based on their Socioeconomic Index Scores (SISs), weighted by their population size in each corresponding year, and stratified into ten (deciles) groups of roughly equal population size. Because the relative position of each county on the socioeconomic scale changed from one data year to another, the composition of each decile was not fixed over time and counties were allowed to move across deciles. For each year of the analysis, age-specific mortality rates were calculated separately for males and for females for each county grouping (decile), as well as for the United States as a whole. The resulting mortality rates were used to construct complete life tables by sex, year and decile."

The Advisory Group reasoned for MIM-2021, practitioners might deem it appropriate to make allowance for the relative affluence level of the population for which they desired to project mortality improvement rates and "substitute" as a proxy specific decile (or quintile) population data as the historical mortality experience. For example, if a practitioner was dealing with a highly affluent insured population, perhaps experience for decile 10 (or combined with decile 9 to form an affluent quintile, e.g., quintile 5) could serve as a reasonable base from which to project future mortality improvement rates. If the practitioner was concerned with a "middle market" insured population, perhaps deciles 4 to 7 would be appropriate to project future mortality improvement rates.

The Advisory Group recognizes:

1. At present, available socioeconomic data have not been differentiated by smoking status or preferred risk classifications. Methods applied to accommodate these refinements are considerations for future research.

2. The SSA data and the Socioeconomic Category data, although both are based on U.S. population data, were derived from different sources for ages 65 and over. As a result, the two data sets may not produce the same national-level rates of mortality improvement. In reviewing the Socioeconomic Category results, the Advisory Group observed the data, when combining all deciles to form a national population, showed slightly faster rates of mortality improvements across the period 1982 to 2018 than did the SSA data. Practitioners should be aware of these differences, particularly at ages older than 65.

The differences in q_x values translate into differences in mortality improvement rates. This is explained in a report[16] whose major findings are:

- There is a gap between the life expectancy at birth as estimated by the Social Security Administration (SSA) and by the Human Mortality Database (HMD).
- The gap is attributable to differences in mortality risks at ages 65 and above only.
- It is not due to differences in compilation methods, but rather to differences in the data itself (national statistics for the HMD, Medicare enrollment data for SSA).
- Further investigation would be necessary to determine whether the mortality differences are genuinely different in the two data sets or whether they result from reliability issues in the sources of data.

Even though the Report references the HMD, it relies completely on the National Center for Health Statistics (NCHS) data set (used to develop U. S. population mortality data for the MIM-2021) whereas, SSA relies on the NCHS data set for ages below 65 and Medicare for ages 65 and above. For the remainder of this Report, NCHS will be used to as the reference for the Socioeconomic Category Research Project and HMD data sets.

# Section 3: Overview Of The Mortality Improvement Model

3.1 MIM-2021 STRUCTURE

This section of the MIM-2021 Report summarizes features of the MIM-2021 structure.   The following are the major steps (which will be more aptly described in detail in the MIM-2021 Application Tool User Guide) practitioners can use to produce sets of mortality improvement rates:

1. The user selects the data set of historical mortality improvement (MI) rates. Historical MI rates included in the MIM-2021 Application Tool are based on U.S. population data[17]. The user can select either SSA or NCHS data sets. The NCHS data set is based on assigning to each county a socioeconomic index score based on eleven factors. The NCHS tables are grouped by quintiles and deciles, with the lowest score designated as quintile or decile #1 and the highest score designated as quintile #5 or decile #10. The user can group multiple quintiles or deciles together and decide on the weighting to be used for each group. All historical MI data have been smoothed using a two-dimensional Whittaker-Henderson graduation method of order 3 to reduce volatility in the underlying mortality data. The Advisory Group has decided to continue to use the two-year step back started by RPEC. This means the MIM-2021 jumping off year is 2016, despite the fact historical SSA and NCHS data extends through 2018.
2. The user selects the long-term MI rate structure – the assumed level of long-term MI rates and the assumed timeframe to achieve convergence from the end of the historical MI rates to the selected level of long-term MI rates.

3. The MIM-2021 Application Tool adds flexibility from the RPEC model by allowing the user to select assumptions for an optional intermediate-term MI rate structure – the assumed level of intermediate-term MI rates and the assumed timeframe to achieve convergence from the end of the historical MI rates to the selected level of intermediate-term MI rates.

4. Based on (1) the last several years of historical MI experience and (2) the future MI rate structure selected by the user, two projections are performed – one horizontally along individual ages and another diagonally along individual year-of-birth cohorts. The intervening MI rates, between recent history and the user selected assumed future timeframes are determined through interpolation routines. The user has two interpolation options:

- Basic Interpolation (Figure 1) – family of cubic polynomials[18] between points A and B.
- Advanced Interpolation (Figure 1) – family of cubic polynomials between points A and B, followed by an optional period of flat MI rates between points B and C, then linear convergence to the appropriate long-term MI rate between points C and D.

Figure 1
TWO INTERPOLATION OPTIONS
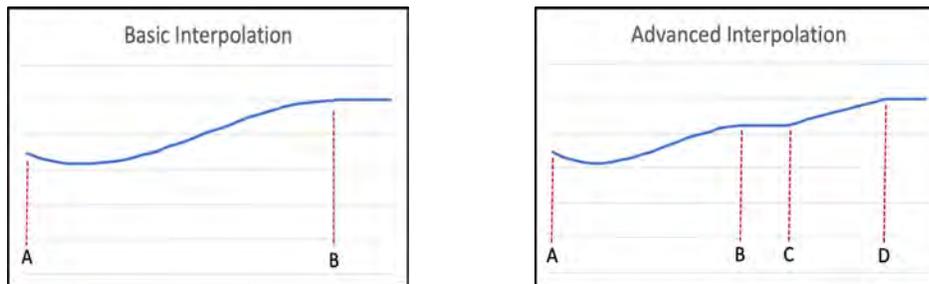
5. The final step is to blend the two projections allowing the user to select the weighting placed on the combination of horizontal (age/period) and diagonal (cohort) projections.

Detailed step-by-step instructions on how to generate MI rates in the MIM-2021 Application Tool and/or gain an understanding of the historical MI data sets in the MIM-2021 Data Analysis Tool can be found in the companion MIM-2021 Application Tool User Guide and the MIM-2021 Data Analysis User Guide, respectively. A detailed description of certain technical aspects of MIM-2021 can be found in the Appendix A.

3.2 COMPARISON OF RPEC_2020 TO MIM-2021

Table 1 illustrates the features of the current RPEC model and the additional flexibility of the MIM-2021.

Table 1
RPEC_2020 VERSUS MIM-2021

Feature	RPEC_2014_v2020	MIM-2021
Separate Horizontal and Diagonal Projections?	Yes	Yes
Historical Mortality Table Options	SSA	SSA, NCHS, various quintile/decile tables
Options of 2D Smoothing of History	W-H Order 3 and Order 2	W-H Order 3
Jumping Off Year	2016	User-selected, but end year not later than 2016
Jumping-off MI value calculation	2015-2016	User-selected, but end year not later than 2016
Jumping-off MI slope calculation	2015-2016	User-selected, but end year not later than 2016
Jumping-off slope limitation	User-selected - absolute value limited to 0.1%	User-selected - absolute value limited to 0.1%
Availability of Intermediate-Term Rates?	No	Yes
Transition Interpolation Methodology	Basic (cubic polynomial)	Basic and Advanced

3.3 MIM-2021 DATA ANALYSIS TOOL, MIM-2021 DATA ANALYSIS TOOL USER GUIDE

The MIM-2021 Data Analysis Tool provides an analysis of historical mortality data from the SSA and the NCHS data sets. This tool facilitates the examination of SSA and NCHS mortality rate trends from 1982 through 2018. The MIM-2021 Data Analysis Tool contains both national-level data for the U.S. population as a whole as well as national-level data subdivided into socioeconomic deciles and quintiles. The companion MIM-2021 Data Analysis Tool User Guide is a step-by-step guide for users wanting a more in depth understanding of the data sets included in the MIM-2021 Application Tool.

Section 4: Considerations For Applying Mortality Assumptions In The MIM-2021

As emphasized throughout this paper, the MIM-2021 has been designed with a variety of actuarial applications in mind, ranging from the measurement of retirement program obligations to the pricing of life insurance and annuity products. How much of the historical data to consider; at what level should the long-term MI rate be set; how long (or short) the transition period should be; how much weight should be applied to age/period versus cohort projection – all of these issues add to the flexibility of the MIM-2021 and MIM-2021 Application Tool. One practitioner's perception of what a value should be or how the model should react are different than how another practitioner would use the model with different assumptions. Because of such flexibility, there are several factors to consider in determining the user inputs needed to develop mortality improvement scales.

In many instances, it is likely the practitioner will need to develop mortality improvement scales for covered population segments. Underlying base mortality tables and mortality experience will vary by these segments due to the demographics of the covered populations, plan features, marketing strategies, underwriting and other company practices. The MIM-2021 Application Tool enables the practitioner to apply the MIM-2021 process to one or more segments.

4.1 HISTORICAL MORTALITY EXPERIENCE

In applying the MIM-2021 methodology, the practitioner will first need to select the appropriate historical mortality data set to be used. As explained in previous sections of this paper, U.S. population mortality data from SSA and socioeconomic quintile and decile data based on data from NCHS have been loaded into the MIM-2021 Application Tool. Understanding the relationships between the covered population plan base mortality rates and exhibited mortality trends to the U.S. population mortality data sources can help determine the appropriate historical mortality input. Functionality has been included in the MIM-2021 Application Tool and MIM-2021 Data Analysis Tool, such as graphs and heat maps, that can be used in performing these comparisons.

4.2 ASSUMPTIONS FOR THE LEVEL OF INTERMEDIATE-AND LONG-TERM MI RATES

Understanding the causes for the mortality trends, how they might change in the future and the impact on mortality is important in setting the other assumptions used to apply the framework, especially those for the projection period. For example, in looking at recent U.S. historical population mortality trends, there have been mortality deterioration seen in middle ages and an overall slowing of mortality improvement. How long will this pattern continue, and will there be a change in human behavior, medical technology, or another cause resulting in a different pattern? The Socioeconomic Category data shows very distinct differences in mortality improvement based on level of socioeconomic index score over the historical period for which it was studied. Will this pattern continue into the future, or could societal changes lead to reversals in the recent historical trends? Long-term U.S. historical mortality improvement has been influenced by a number of distinct drivers. An example is the now over 50-year trend in smoking cessation. New and different drivers will exert influence in the future, likely leading to differing levels and patterns of mortality improvement.

4.3 ASSUMPTIONS FOR TRANSITION FROM NEAR-TERM MI RATES TO LONG-TERM MI RATES

Part of the flexibility of MIM-2021 derives from the user's ability to select various parameters in connection with the interpolating curves. Those parameters include limitations on the absolute value of the slope of the cubic polynomial at the jumping-off year. Although it might seem logical to anticipate some degree of the most recent historical MI slope would continue into the near-term future, back-testing analysis performed by RPEC indicated that reflecting those slopes tends to increase year-over-year volatility in the MP scales[19]. Users who have concerns with excess MI volatility should be careful in the selection of assumptions permitting relatively large slopes in the jumping off year.

The new model also provides users with great discretion in the length of the transition periods (horizontal and diagonal) between the jumping-off year and the year in which the assumed long-term rates are fully attained. Users should be aware that potentially unanticipated MI rates might arise in certain situations where (1) the assumed horizontal/diagonal blending percentage is strictly between 0% and 100%, and (2) the assumed convergence periods for the horizontal and the diagonal projections are relatively far apart. The situation is best explained through the following simplified example.

> Assumptions:
>
> - Interpolation structure: Basic (i.e., cubic only; no intermediate-term rates)
> - Horizontal/diagonal blending percentages: 50%/50%
> - Jumping-off MI value: 0.0%
> - Jumping-off slope: 0.0%
> - Assumed Long-Term Rate: 1.0%
> - Horizontal convergence period: 40 years

- Diagonal convergence period: 10 years

The resulting MI rate ten years after the jumping-off year is equal to 0.58%, which is the result of blending:

- 50% of the MI rate at year 10 of the horizontal projection (0.16%) with
- 50% of the MI rate at year 10 of the diagonal projection (1.0%).

The blended rate of 0.58% results from the attainment of the full set of long-term rates in the diagonal projection much sooner than the attainment of the full set of long-term rates in the horizontal projection. Obviously, the same situation would occur if the disparate time frames for the horizontal and diagonal projections were reversed.

4.4 UNUSUALLY LONG OR SHORT MORTALITY PATTERNS

Fluctuations in mortality deterioration and improvement can occur in, for example, long waves in mortality deterioration like that seen with HIV, and short-term shocks to mortality from pandemics and other causes. These all add to the complexity of developing a mortality improvement framework. Given the nontrivial exercise in applying the mortality improvement framework methodology, the practitioner will want to perform sensitivity testing to better gain an understanding of the MIM-2021 Application Tool, how changes in assumptions impact the resulting mortality improvement scales produced by the MIM-2021 Application Tool, and how reasonable are the results. With the MIM-2021 Application Tool, the practitioner can examine resulting life expectancy as a check on reasonableness.

Section 5: Items For Future Consideration

The Advisory Group is monitoring the unfolding impact of COVID-19 and its potential implications on future mortality experience. Guidance as to how to adjust the framework for COVID-19 mortality and similar short term mortality shocks will be addressed in a future release of the model. Additional insights on how to handle significant wave fluctuations or temporary spikes in mortality in constructing a mortality framework due to a pandemic or other cause will also be considered.
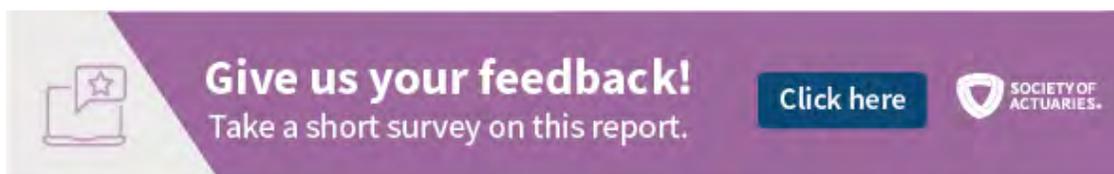
The Advisory Group at present advises practitioners not to use historical mortality experience other than that included in the MIM-2021 Application Tool. Care should be taken to ensure the data is sufficiently relevant and robust, i.e., large enough in size and consistent enough over sufficient periods of time to produce credible results. Credibility of the underlying data is the reason, as noted in Section 2.2., for including historical U.S. population mortality data as the MIM-2021 Application Tool defaults. Even the SOA's insured mortality data coming from numerous insurance companies were not sufficiently large to produce relevant and meaningful mortality improvement results as compared to the consistency of results produced by RPEC's use of SSA data.   Another complication of using pensioner or insured data is the difficulty in distinguishing the cause of the underlying mortality trends, as changes could be due, for example, to changes in company practices rather than other causes impacting the underlying insured/pensioner population mortality.

As noted in the comparison table above, the RPEC model allows the user to select historical MI data graduated by Whittaker-Henderson Order 2 or 3, whereas MIM-2021 historical MI data can only be graduated by Whittaker-Henderson Order 3. The choice of Order 2 graduation will be a consideration as a future enhancement. RPEC introduced Order 2 smoothing in 2018 as an option for users who wanted to further reduce year-over-year volatility.

The Advisory Group has continued RPEC's practice of "stepping back" two years from the edges of the historical graduation process due to potential concerns about the stability of the graduated values at those times. The upshot of the two-year step back is despite collecting historical data through calendar year 2018, the most current year that can be selected for purposes of calculating jumping-off values and slopes in MIM-2021 is 2016. The Advisory Committee plans to undertake analysis in the future to determine whether some loosening of the two-year step-back is appropriate.

The MIM-2021 Application Tool includes committee-selected assumptions developed by RPEC so the MIM-2021 Application Tool will replicate the MP-XXXX mortality improvement scales. The Advisory Group is considering developing "default" assumptions for non-pension products to assist practitioners in building mortality improvement frameworks.

Adjustments may also be needed to the mortality improvement scale produced by the MIM-2021 Application Tool. For example, if composite population data is used, a practitioner may want to adjust the composite mortality improvement scale to create different scales for various risk classes exhibiting different underlying mortality. The Advisory Group is also considering addressing differing risk classes and select and ultimate mortality periods in future versions of the Application Tool. The MIM-2021 Application Tool is not currently designed to accommodate user-supplied select-and-ultimate mortality rates. However, users who wish to apply MIM-2021 mortality improvement rates to select-and-ultimate mortality tables can only do so for a single birth/policy issuance cohort (e.g., those insureds who are issued insurance policies during a specified period at age 30) or all those in their "ultimate" durations after the effects of underwriting selection have worn off.

Section 6: Acknowledgments

Appendix A: Technical Summary

The following heatmap, extracted from the Scale MP-2020 Report, displays the historical[20] and projected future mortality improvement rates for males in the U.S.
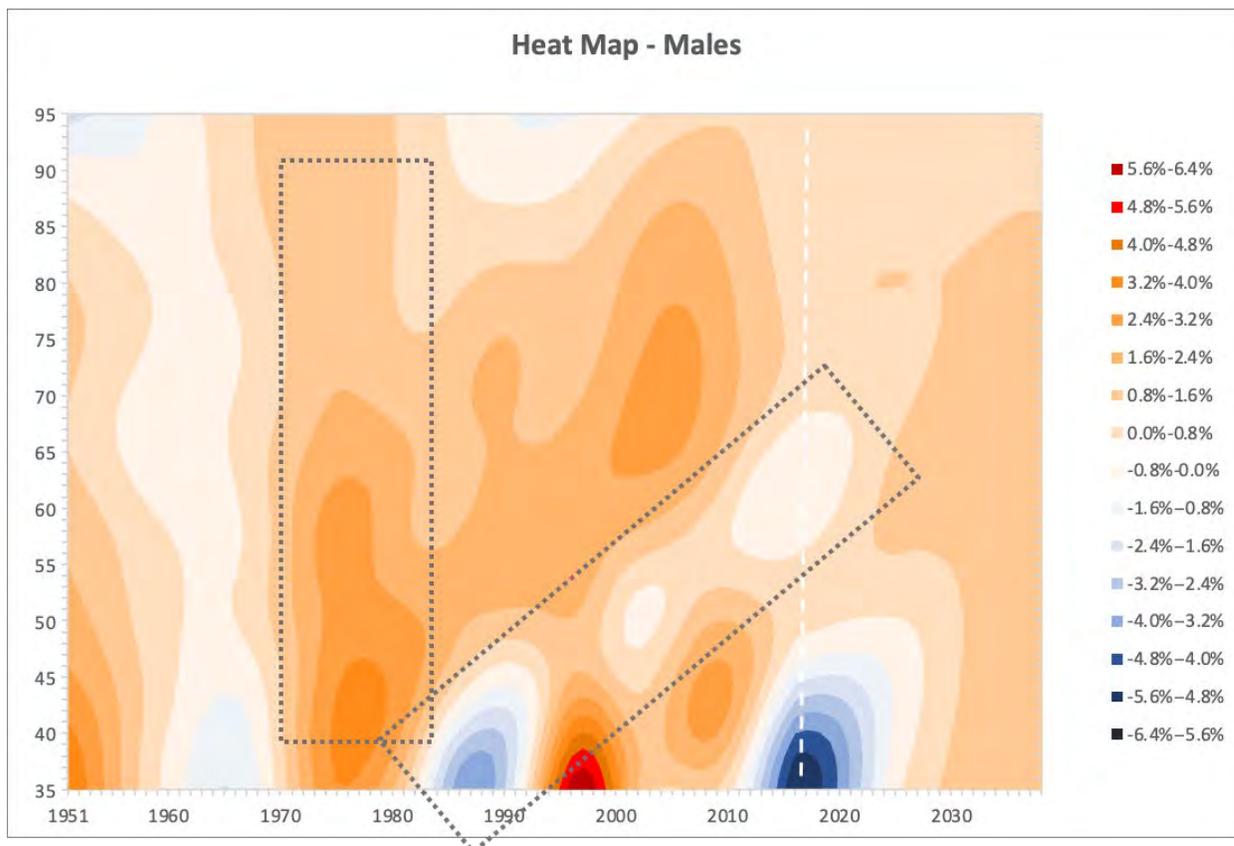
A.1 TWO SEPARATE PROJECTIONS FOR PERIOD AND COHORT EFFECTS

Two types of patterns can be identified in this heatmap:

- Vertical patterns revealing relatively low or relatively high periods of mortality improvement, such as in the mid-1960's and mid-1970's, respectively. These patterns are manifestations of so-called "period effects".
- Diagonal patterns revealing relatively low or relatively high levels of mortality improvement among groups born around the same time, such as men born around 1950 and around 1960, respectively. These patterns are manifestations of so-called "cohort effects".

Like the RPEC model from which the MP-2020 Scale was based, the MIM-2021 model continues the practice of performing two sets of mortality improvement projections, one projecting MI rates purely horizontally along individual ages (to model future period effects) and another projecting future MI rates purely diagonally along individual year-of-birth cohorts (to model future cohort effects). The final MI scale generated by the model is calculated as a linear combination of the two projections, with the appropriate blending percentages selected by the user.

A.2 TWO-DIMENSIONAL SMOOTHING OF HISTORICAL MORTALITY RATES

The sets of historical mortality improvement rates are obtained by graduating separate female and male datasets as follows:

1. Calculating the natural logarithm of the underlying base mortality rates, covering all calendar years 1982 through 2018 and all ages 15 through 97.
2. Using Whittaker-Henderson[21] weights based on U.S. population data obtained from the Human Mortality Database. Normalized weights for each age and calendar year were developed by dividing the individual weights by the sum of weights.
3. Defining Whittaker-Henderson smoothness as the sum of the squares of the third finite differences.
4. Selecting two-dimensional smoothness parameters of 100 in the calendar year direction and 400 in the age direction.

The resulting graduated values, denoted s(x,y) for each age, x, from 15 through 97, and each calendar year, y, from 1983 through 2018, were transformed into smooth mortality improvement rates, f(x, y), using the following formula:

$$f(x, y) = 1 - e^{s(x,y)-s(x,y-1)}$$

So-called "edge effects" are instabilities that arise from the absence of data beyond the edges of the dataset being graduated. One way to mitigate these edge effects is to completely ignore a small segment of the MI results around the margins of the smoothed array. For example, the 2020 version of the RPEC model, as well as MIM-2021, include a two-year step-back, even though the smoothing process included data through 2018. As a result, both models start the projection period in calendar year 2016.

A.3 FORMULA FOR INTERPOLATING CUBIC POLYNOMIALS

Let the MI value and slope at point A be denoted y0 and m, respectively. Let p denote the length (in years) of the end of the cubic interpolation period and let y1 denote the assumed MI value of the point in year A + p. Recall that the desired slope of the cubic at year A + p is zero. Given the time period (p), the two MI values (y0 and y1) and two slopes (m and 0), the general form of the resulting cubic polynomial (in terms of years t, from time A to time A + p) can be expressed as follows:

$$C(t) = y_0 + m(t - A) - \left(\frac{2pm - 3(y_1 - y_0)}{p^2}\right)(t - A)^2 + \left(\frac{pm - 2(y_1 - y_0)}{p^3}\right)(t - A)^3$$

Straightforward calculations show that this cubic polynomial satisfies the four desired conditions, namely:

1. *C(A) = y0*
2. *C(A+p) = y1*
3. *C'(A) = m*
4. *C'(A+p) = 0*

Examples of interpolating cubic polynomials in both the horizontal and diagonal directions can be found in Appendix B of the Scale MP-2014 Report[22].

Endnotes

[1] "MIM-2021" stands for the Mortality Improvement Model released in 2021, which includes historical mortality data through 2018. Anticipated future updates to the model, including those merely adding more current historical mortality data, will include some additional designation to allow practitioners to distinguish among extant versions.

[2] The MIM-2021 Data Analysis Tool and the MIM-2021 Application Tool

[3] RPEC 2014_v2020 allows users to select from two versions of Whittaker-Henderson graduation, order 2 and order 3. The order of the graduation refers to the degree of the finite differences being minimized. [See R.C.W. Howard, "Tools for Whittaker-Henderson Graduation", http://www.howardfamily.ca/graduation/.] The MIM-2021 historical mortality data sets are smoothed with Whittaker-Henderson order 3; the option to select order 2 will be considered as a future enhancement.

[4] The CMI is a U.K. private company that is supported by the Institute and Faculty of Actuaries and provides authoritative and independent mortality and sickness rate tables for U.K. life insurers and pension funds. CMI Working Paper 147: The CMI Mortality Projections Model, CMI_2020. https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-working-papers/mortality-projections/cmi-working-paper-147.

[5] Two-dimensional arrays based on age and calendar year can also be described in terms of age and year-of-birth cohort. This may be a more useful context for thinking about two-dimensional mortality improvement scales, especially when considering potential "cohort effects" in the analysis of large scale mortality patterns. These can also be separately developed based on other variables, such as gender.

[6] Society of Actuaries. 1995. Transactions of the Society of Actuaries, Volume 47 P865. The 1994 Group Annuity Mortality Table and 1994 Group Annuity Reserving Table. https://www.soa.org/globalassets/assets/library/research/transactions-of-society-of-actuaries/1990-95/1995/january/tsa95v471.pdf.

[7] Society of Actuaries. 2012. "Mortality Improvement Scale BB Report". https://www.soa.org/globalassets/assets/files/research/exp-study/research-mortality-improve-bb-report.pdf.

[8] Society of Actuaries. 2014. "Mortality Improvement Scale MP-2014 Report". https://www.soa.org/globalassets/assets/files/research/exp-study/research-2014-mp-report.pdf.

[9] Id. P3.

[10] Id.

[11] See Society of Actuaries. 2014. "Mortality Improvement Scale MP-2014 Report", Appendix B. https://www.soa.org/globalassets/assets/files/research/exp-study/research-2014-mp-report.pdf.

[12] Society of Actuaries. 2020. "Mortality Improvement Scale MP-2020 Report. https://www.soa.org/globalassets/assets/files/resources/experience-studies/2020/mortality-improvement-scale-mp-2020.pdf.

[13] Society of Actuaries. 2016. "Mortality Improvement Scale MP-2016". https://www.soa.org/globalassets/assets/files/research/exp-study/mortality-improvement-scale-mp-2016.pdf.

[14] Li, Johnny S.-H., Rui Zhou, and Yanxin Liu. 2017. "Components of Historical Mortality Improvement". Society of Actuaries. https://www.soa.org/resources/research-reports/2017/2017-comp-hist-mort-impr/.

[15] Barbieri, Magali. 2020. "Mortality by Socioeconomic Category in the United States". Society of Actuaries. https://www.soa.org/resources/research-reports/2020/us-mort-rate-socioeconomic/

[16] Barbieri, Magali. 2018. "Investigating the Difference in Mortality Estimates between the Social Security Administration Trustees' Report and the Human Mortality Database". University of Michigan Retirement research Center Working Paper.
https://mrdrc.isr.umich.edu/pubs/investigating-the-difference-in-mortality-estimates-between-the-social-security-administration-trustees-report-and-the-human-mortality-database/.

[17] A detail description of the historical mortality improvement rates included in the MIM-2021 Application Tool can be found in the "MIM-2021 Data Analysis Tool User Guide".

[18] See Appendix A for technical details about the family of cubic polynomials.

[19] In fact, all MP scales since the 2016 release assume all jumping off slopes are identically zero. Society of Actuaries. 2016. "Mortality Improvement Scale MP-2016".
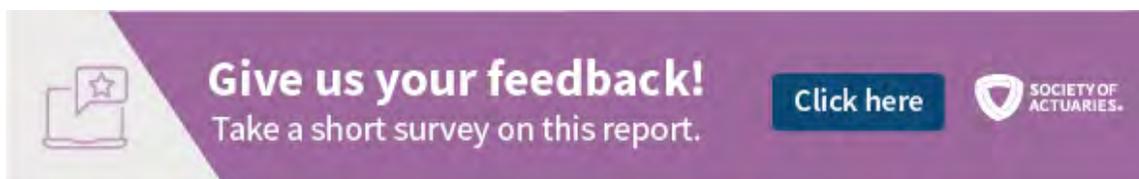https://www.soa.org/globalassets/assets/files/research/exp-study/mortality-improvement-scale-mp-2016.pdf.

[20] The historical mortality improvement rates were calculated from smoothed Social Security Administration population mortality data for years 1951 through 2018.

[21] A detailed description of the two-dimensional Whittaker-Henderson graduation process can be found in Appendix B of the Scale MP-2018. Society of Actuaries. 2018. "Mortality Improvement Scale MP-2018".
https://www.soa.org/globalassets/assets/files/resources/experience-studies/2018/mortality-improvement-scale-mp-2018.pdf.

[22] See Society of Actuaries. 2014. "Mortality Improvement Scale MP-2014 Report", Appendix B.
https://www.soa.org/globalassets/assets/files/research/exp-study/research-2014-mp-report.pdf.

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