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Mortality and Longevity

Developing A Consistent Framework For Mortality Improvement: MIM-2021-v2

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CONTENTS

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Executive Summary

The Society of Actuaries' (SOA's) practice areas currently utilize a variety of different mortality projection methodologies. In April 2021, the SOA released MIM-2021[1], along with two simultaneously released Excel-based tools[2], serving as a consistent starting point for practitioners in projecting mortality improvement.

The conceptual framework was modeled after the approach developed by the SOA's Retirement Plans Experience Committee (RPEC). The MIM-2021 Application Tool using RPEC parameters replicated RPEC's "'MP" scales[3], while adding flexibility for other actuarial practitioners.

When released, an annual updating process for the MIM-2021 (and associated tools) was anticipated and has occurred for 2021 resulting in version MIM-2021-v2[4]. In addition to reflecting an additional year of recent mortality experience, this version has been enhanced to allow for more user flexibility. Using RPEC's committee-selected assumption set, the MIM-2021-v2 Application Tool now reproduces both RPEC's MP-2021 and O2-2021 scales. Changes from the initial MIM-2021 version are summarized below:

- One additional year of historical U.S. population mortality for both the SSA and NCHS data sets are included in the MIM-2021-v2 tools, extending the data period through 2019.
- The option to use a slightly smoother graduation of historical mortality data has been added to the MIM-2021-v2 Application Tool.
- A component has been introduced in the MIM-2021-v2 Application Tool for users to adjust projection scales for the effects of COVID-19.

Included in the initial MIM-2021 release was a list of items the Advisory Group was considering for future MIM-2021 updates. Some of these issues have been addressed in MIM-2021-v2. Others have been identified as appropriate for future enhancements of the MIM-2021 Application Tool. These items are summarized in Section 5 of this report.

Practitioners are encouraged to submit comments and suggestions.

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 replicates RPEC's MP mortality improvement scales, while adding flexibility for practitioners dealing with other applications.

The MIM-2021 report, MIM-2021 Application Tool and User Guide, and MIM-2021 Data Analysis Tool and User Guide were initially released in April 2021. The Advisory Group considers this framework to be an ongoing project with anticipated annual updates. This report reflects the 2021 update, MIM-2021-v2. This version uses the same underpinning as the initial MIM-2021 release but has been refreshed to include another year of historical U.S. population mortality data as well as more user flexibility and functionality to replicate RPEC's MP-2021 and O2_2021 scales. In addition to revising the April 2021 MIM-2021 report to reflect the update, the MIM-2021 Application Tool User Guide and MIM-2021 Data Analysis Tool User Guide have also been modified for the enhancements. Changes from the initial MIM-2021 version to produce MIM-2021-v2 are discussed in Section 2.3.

Many issues concerning the development of mortality improvement scales were discussed by the Advisory Group. While some have been addressed with the release of MIM-2021-v2, other issues have been left for future enhancements. These issues are outlined in the Section 5 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[5] (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[6]) mortality improvement factors applied to suitably chosen sets (respective of practice area) of base mortality rates.

2.1 THE 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[7] (released in 1995) and Scale BB[8] (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[9], was based on three key concepts underpinning the 2009 version of the CMI model[10]:

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[11]. 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[12].
   - 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-2021, published in October 2021[13]. Other than updates for the availability of additional historical mortality data, the basic RPEC_2014 methodology has remained essentially unchanged.

In 2018, RPEC began producing an alternative version of the RPEC_2014 model, denoted the RPEC_O2 model, that uses order-2 rather than order-3 Whittaker-Henderson graduation[14]. This change in finite difference operators produces a generally smoother two-dimensional surface of mortality improvement rates. RPEC's research has indicated that, relative to the order-3 model, the order-2 model tends to result in greater year-over-year stability in pension liability calculations. The potential downside, however, is that the order-2 model could be less sensitive to emerging changes in U.S. mortality patterns. RPEC's O2-2021 mortality improvement scale is the result of applying its 2021 committee-selected assumption set to the REPC_O2 model.

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[15], 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[16] 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.
- The MP-2021 projection scale[17] is based upon historical mortality information through calendar year 2019 that does not reflect the COVID-19 pandemic. Due to uncertainty about the near- and longer-term effects of COVID-19, no adjustments to Scale MP-2021 have been made for the pandemic. Recognizing that practitioners may want to incorporate a COVID-19 adjustment into a projection scale, in collaboration with RPEC, a section has been included in the MIM-2021-v2 Application Tool for this purpose. More information on the adjustment is discussed in Section 2.3 of the report.

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 remedied 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 RPEC_2014 model uses historical mortality data from SSA. 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*[18]. 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 APC decompositions of historical mortality improvement. Volume 2 documents the modeling work associated with APC models fit to mortality rates and the desired APC decomposition of mortality improvement experience is obtained by transforming the parameters in the chosen APC model.
2. *Analysis of Historical U.S. Population Mortality Improvement since 1959*[19]. The purpose of this study was to identify significant U.S. mortality improvement/deterioration trends since 1959 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 Andrés Villegas from the University New South Wales Business School, Sydney, Australia.

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 the MP 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*[20]. The purpose of this project was to study trends in mortality by socioeconomic category in the United States from 1999 to 2019 (ultimately extending the historical data to 1982 based on 1980, 1990, and 2000 U.S. Census data and data from the American Community Survey). 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, the Socioeconomic Index is calculated for each county in 2000. Counties are then ranked based on their Socioeconomic Index Scores (SISs), weighted by their population size in 2000, and stratified into ten (deciles) groups of roughly equal population size. Note that the relative position of each county on the socioeconomic scale remains fixed over the whole study period. For each year of the analysis, age-specific mortality rates are 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 are 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 2019 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[21] 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 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 as the reference for the Socioeconomic Category Research Project and HMD data sets.

2.3 THE DEVELOPMENT OF MIM-2021-v2

MIM-2021 was initially released in April 2021. While it reproduced Scale MP-2020, MIM-2021 did not replicate all of RPEC's mortality improvement scales. In 2018, RPEC began producing a different version of the RPEC_2014 model, denoted the RPEC_O2 model, that uses order-2 rather than order-3 Whittaker-Henderson graduation. In an effort to release MIM-2021 as soon as possible, the Advisory Group decided to delay the integration of the RPEC_O2 model into MIM-2021 for a future date.

In summer of 2021, RPEC notified the Advisory Group of changes needed to MIM-2021 to reflect the forthcoming Scale MP-2021. Work began on updating MIM-2021 to produce a new version of the model, MIM-2021-v2. Based on MIM-2021's original methodology and structure, the objective was for the MIM-2021-v2 Application Tool, using the RPEC's committee-selected assumption set, to reproduce Scale MP-2021 and its order-2 counterpart, O2-2021.

The enhancements made to MIM-2021 for MIM-2021-v2 follow:

- One additional year of historical U.S. population data for both SSA and NCHS data sets are included in the MIM-2021-v2 Application Tool and the MIM-2021-v2 Data Analysis Tool, extending the data period through 2019.
- The MIM-2021-v2 Application Tool user now has the option of selecting order-2 or order-3 Whittaker-Henderson graduation of historical data. With this feature, pension practitioners will be able to replicate RPEC's mortality improvement scales.
- While MIM-2021 does not reflect any historical or potential future effects of COVID-19, a component has been built into the MIM-2021-v2 Application Tool based on methodology developed by RPEC. Individual practitioners can incorporate a COVID-19 adjustment into the mortality projection scales by entering specific mortality loads separately for males and females for each year 2020 through 2024 and separately for 2025 and beyond if a long-term COVID-19 adjustment is desired. An amount entered into this section will be reflected in the resulting projection scale as a percentage load on mortality only for the year listed. A blank or zero load for a subsequent year will cause the model to compute the implied mortality improvement rate that would reset mortality rates for that year to what the model would have otherwise forecast absent any adjustment for COVID-19[22].

  For example, a user inputs a 15% load for an age for 2020 and a zero load in all subsequent years. This assumption means that mortality rates are 15% higher than what they would have been in 2020 absent COVID-19, but that mortality rates in all years after 2020 are unaffected, and will revert to what they would have been if no load had been input. Therefore, 2020 mortality improvement rates become very negative in response to the 15% mortality load. However, because there is no such load for 2021, the 2021 improvement rate becomes large and positive to revert projected 2021 mortality rates to what they would be had no loads been input at all. There are no changes to improvement rates for 2022 and beyond. The MIM-2021-v2 Application Tool User Guide has also been updated and includes additional examples.

  Appendix B of this report includes excerpts from the MP-2021 report that deal with (1) RPEC's analysis of the potential impact of COVID-19 on the projection of US mortality rates beyond 2019 and (2) the evolution and use of the COVID-19 adjustment functionality within the MIM-2021-v2 Application Tool.

Section 3: Overview Of The Mortality Improvement Model

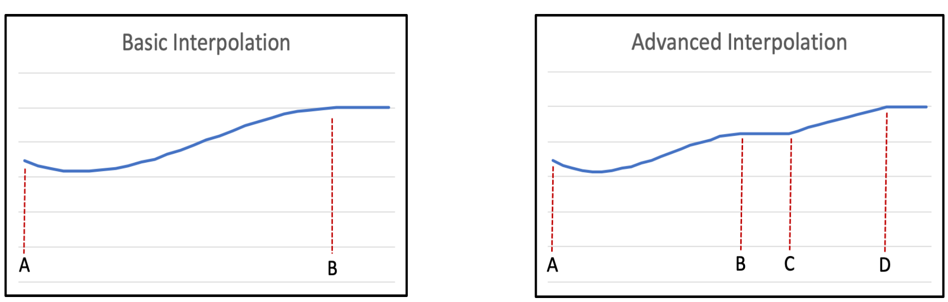
3.1 MIM-2021-V2 STRUCTURE

This section of the MIM-2021-v2 report summarizes features of the MIM-2021-v2 structure. The following are the major steps (which will be more aptly described in detail in the MIM-2021-v2 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-v2 Application Tool are based on U.S. population data[23]. 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 to reduce volatility in the underlying mortality data. Both order-2 and order-3 smoothing is available. The Advisory Group has decided to continue to use the two-year step back started by RPEC. This means the MIM-2021-v2 jumping off year is 2017, despite the fact historical SSA and NCHS data extends through 2019.
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-v2 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; Left side) – family of cubic polynomials[24] between points A and B.
   - Advanced Interpolation (Figure 1; Right side) – 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-v2 Application Tool and/or gain an understanding of the historical MI data sets in the MIM-2021-v2 Data Analysis Tool can be found in the companion MIM-2021-v2 Application Tool User Guide and the MIM-2021-v2 Data Analysis

User Guide, respectively. A detailed description of certain technical aspects of MIM-2021-v2 can be found in the Appendix A.

3.2 COMPARISON OF RPEC_2014 TO MIM-2021

Table 1 illustrates the features of the current RPEC model and the additional flexibility of the MIM-2021-v2.

Table 1
RPEC_2014 VERSUS MIM-2021-v2

Feature	RPEC_2014, RPEC_O2	MIM-2021-v2
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 and order-2
Jumping Off Year	2017	User-selected, but end year not later than 2017
Jumping-off MI value calculation	2016-2017	User-selected, but end year not later than 2017
Jumping-off MI slope calculation	2016-2017	User-selected, but end year not later than 2017
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-v2 DATA ANALYSIS TOOL, MIM-2021-v2 DATA ANALYSIS TOOL USER GUIDE

The MIM-2021-v2 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 2019. The MIM-2021-v2 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-v2 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-v2 Application Tool.

Section 4: Considerations For Applying Mortality Assumptions In The MIM-2021-v2

As emphasized throughout this paper, the MIM-2021-v2 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-v2 and MIM-2021-v2 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 that 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-v2 Application Tool enables the practitioner to apply the MIM-2021-v2 process to one or more segments.

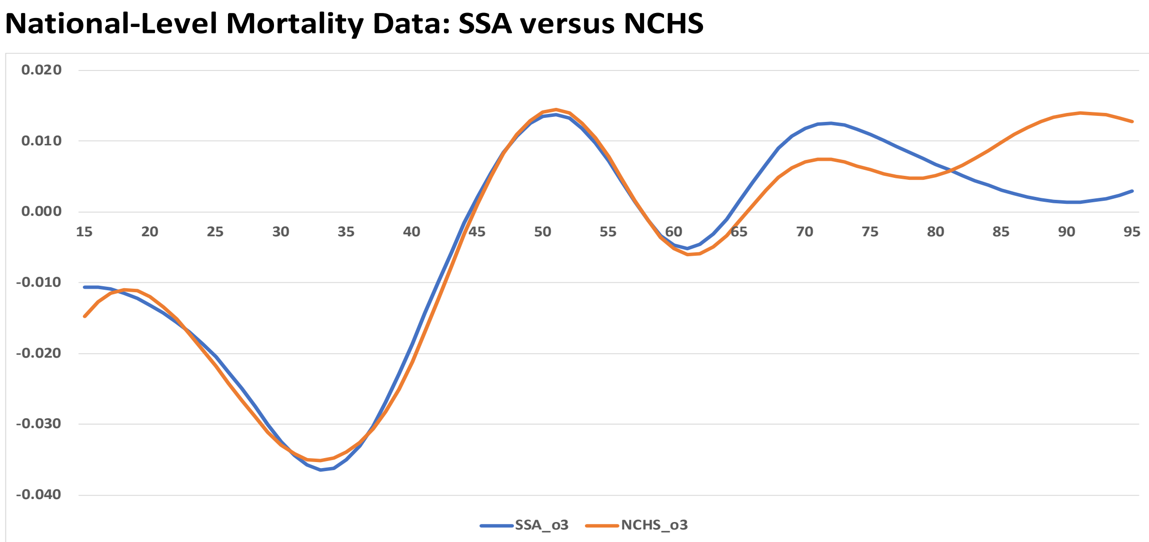
4.1 HISTORICAL MORTALITY EXPERIENCE

In applying the MIM-2021-v2 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-v2 Application Tool. While other data is used to segment the NCHS mortality data into socioeconomic deciles and quintiles, as discussed in Section 2.2, these data sets are labeled "NCHS" in the MIM-2021-v2.

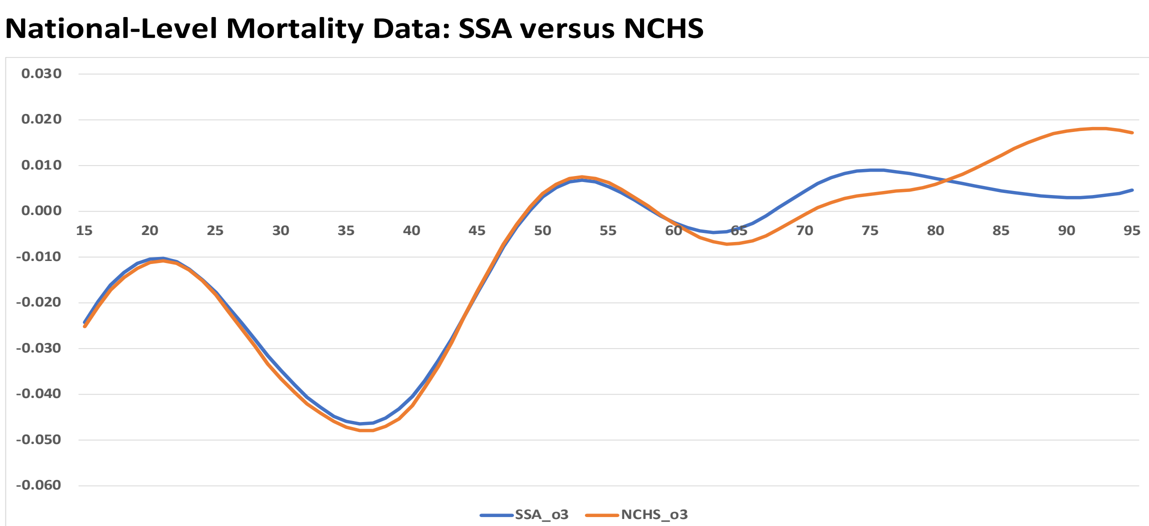
Understanding the relationships between the covered population plan base mortality rates and exhibited mortality trends to the U.S. population mortality data sources can help determine the appropriate historical mortality input. Functionality has been included in the MIM-2021-v2 Application Tool and MIM-2021-v2 Data Analysis Tool, such as graphs and heat maps, that can be used in performing these comparisons.

As noted in Section 2.2, practitioners should be aware of the differences in the underlying SSA and NCHS datasets, particularly at ages older than 65. The MIM-2021-v2 Data Analysis Tool can also provide insight into the differences. Figure 2 shows the NCHS and SSA improvement rates, using order-3 Whittaker-Henderson smoothing, for the most recent five years of data, which are the most important historical years for determining the interpolating cubic polynomials for Scale MP-2021[25].

Figure 2
SSA AND NCHS ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT, FEMALES, 2015–2019



SSA AND NCHS ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT, MALES, 2015–2019

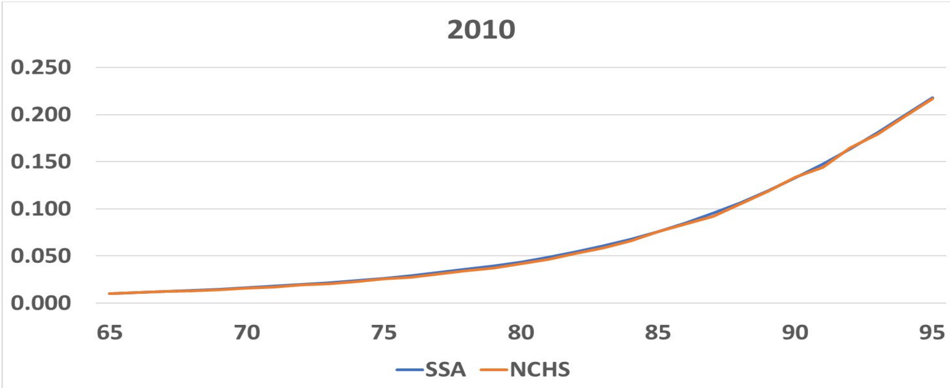


While differences exist, RPEC continues to utilize the SSA historical mortality data for MP-2021 and O2-2021 scales for the following reasons as stated in its MP-2021 report[26]:

- All persons covered by Medicare and Medicaid are required to verify their ages, and for this reason, RPEC has considered the CMS data to be more reliable for ages 65 and older, which are especially relevant for pension valuations.
- The NCHS data relies upon deaths from the National Vital Statistics System and exposure counts from the Census Bureau, which means that the NCHS mortality rates in MIM-2021 are based on data from two different sources. In contrast, CMS exposures and deaths for ages 65 and older in the SSA data come from the same source, which the RPEC believes is important when assessing year-over-year mortality improvement.

- The annual population counts published by the Census Bureau are estimates based on the 2010 census. Post-censal estimates for 2011–19 are derived from the 2010 census using birth and mortality statistics from NCHS and international migration rates by sex and age for each year. When the 2020 census information is published, the Census Bureau will re-estimate population counts for the years 2011-2019. In contrast, the exposure counts from CMS are based on the number of people enrolled in Medicare[27]and are not estimates.
- The NCHS and SSA mortality rates for ages 65 and older appeared to be quite close in 2010 but have increasingly diverged over the course of the decade, with the rates based on the NCHS data decreasing substantially relative to the SSA data, as shown in Figures 3.1 – 3.3[28]. A similar divergence was noted by SSA over the course of the 2000-2009 decade until the 2010 census resulted in true-ups of the Census Bureau population counts for 2001 through 2009 that brought the two sets of mortality rates closer in line. Due to this precedent, RPEC anticipates that forthcoming intercensal adjustments to Census Bureau population estimates for 2011-2019 may noticeably change NCHS mortality rates from those implied by the data currently available.

Figures 3.1
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR YEAR 2010



Figures 3.2
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR YEAR 2015

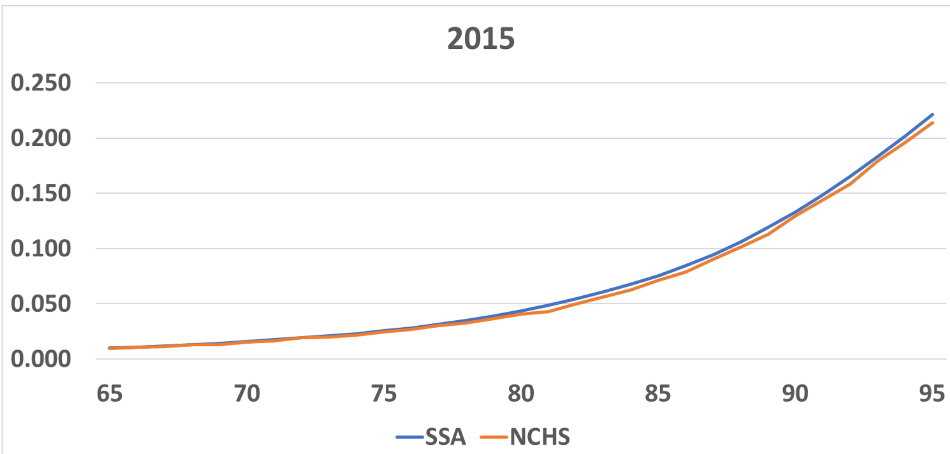
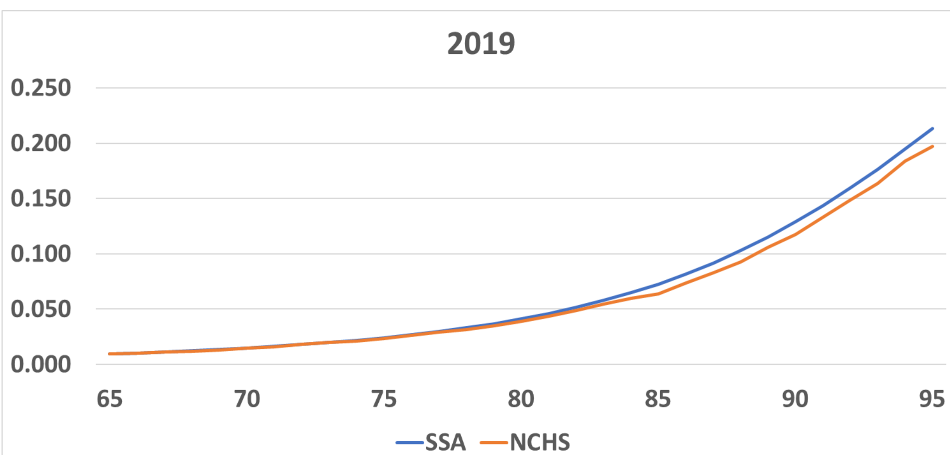


Figure 3.3
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR YEAR 2019



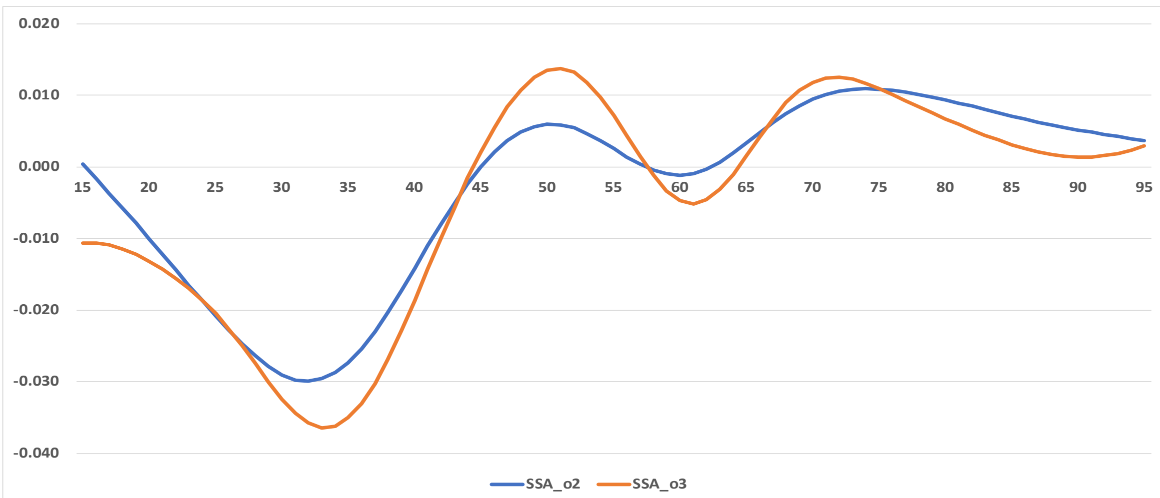
Appendix C of this report includes excerpts from RPEC's MP-2021 report that address additional considerations for pension practitioners utilizing the MIM-2021-v2 tools.

4.2 ORDER-2 VS. ORDER-3 WHITTAKER-HENDERSON SMOOTHING

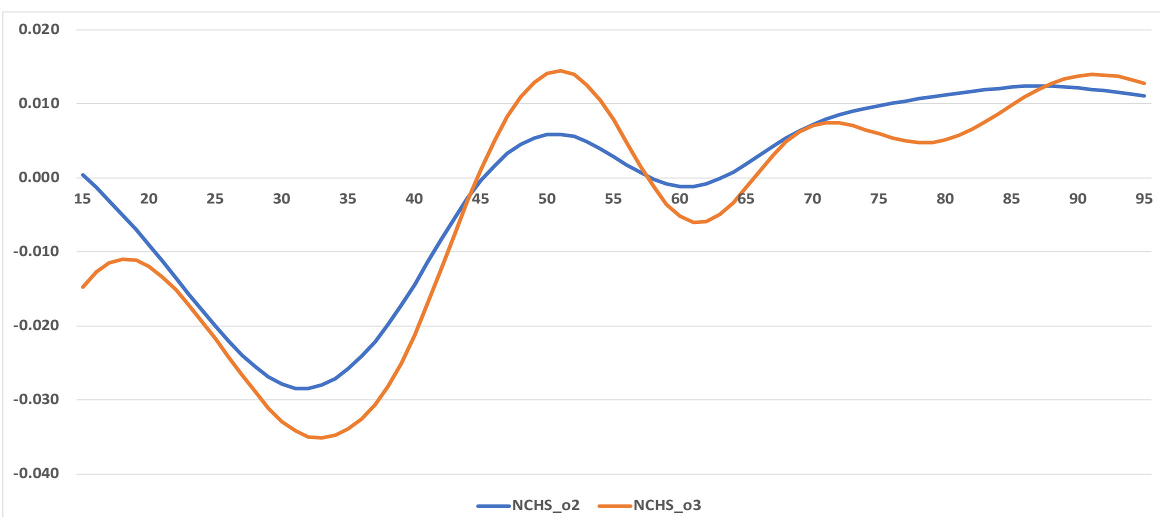
As mentioned throughout the paper, in MIM-2021-v2 all historical MI data is smoothed using a two-dimensional Whittaker-Henderson graduation method to reduce volatility in the underlying mortality data. The user will need to select the degree of the finite difference operators used in the smoothness components of the two-dimensional Whittaker-Henderson objective function. Order-2 (“o2” in MIM-2021 tools) and order-3 (“o3” in MIM-2021 tools) are the available options in the MIM-2021-v2 Application Tool. The MIM-2021-v2 Application Tool and MIM-2021-v2 Data Analysis Tool graphs and heat maps can be used in performing comparisons. For example, Figure 4 shows the differences in smoothing for both SSA (Top) and NCHS (Bottom) improvement rates for females for 2015-2019.

Figure 4

SSA ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT, FEMALES, 2015–2019



NCHS ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT, FEMALES, 2015–2019



4.3 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.

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

Part of the flexibility of MIM-2021-v2 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[29]. 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-v2 Application Tool, how changes in assumptions impact the resulting mortality improvement scales produced by the MIM-2021-v2 Application Tool, and how reasonable are the results. With the MIM-2021-v2 Application Tool, the practitioner can examine resulting life expectancy as a check on reasonableness.

Section 5: Items For Future Consideration

Although MIM-2021-v2 includes functionality to adjust projection scales for COVID-19, guidance as to how to adjust the framework for COVID-19 mortality and similar short term mortality shocks has been intentionally left to the individual user. Given much uncertainty remains on COVID-19's short and long-term effects, the Advisory Group continues to monitor the unfolding impact of COVID-19 and its potential implications on future mortality experience to provide insightful direction on COVID-19 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-v2 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-v2 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.

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 2019, the most current year that can be selected for purposes of calculating jumping-off values and slopes in MIM-2021-v2 is 2017. 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-v2 Application Tool includes committee-selected assumptions developed by RPEC so the MIM-2021-v2 Application Tool will replicate the MP-2021 and O2-2021 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-v2 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-v2

Application Tool is not currently designed to accommodate user-supplied select-and-ultimate mortality rates. However, users who wish to apply MIM-2021-v2 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

The authors' deepest gratitude goes to those without whose efforts this project could not have come to fruition: the volunteers who generously shared their wisdom, insights, advice, guidance, and arm's-length review of this study prior to publication. Any opinions expressed may not reflect their opinions nor those of their employers. Any errors belong to the authors alone.

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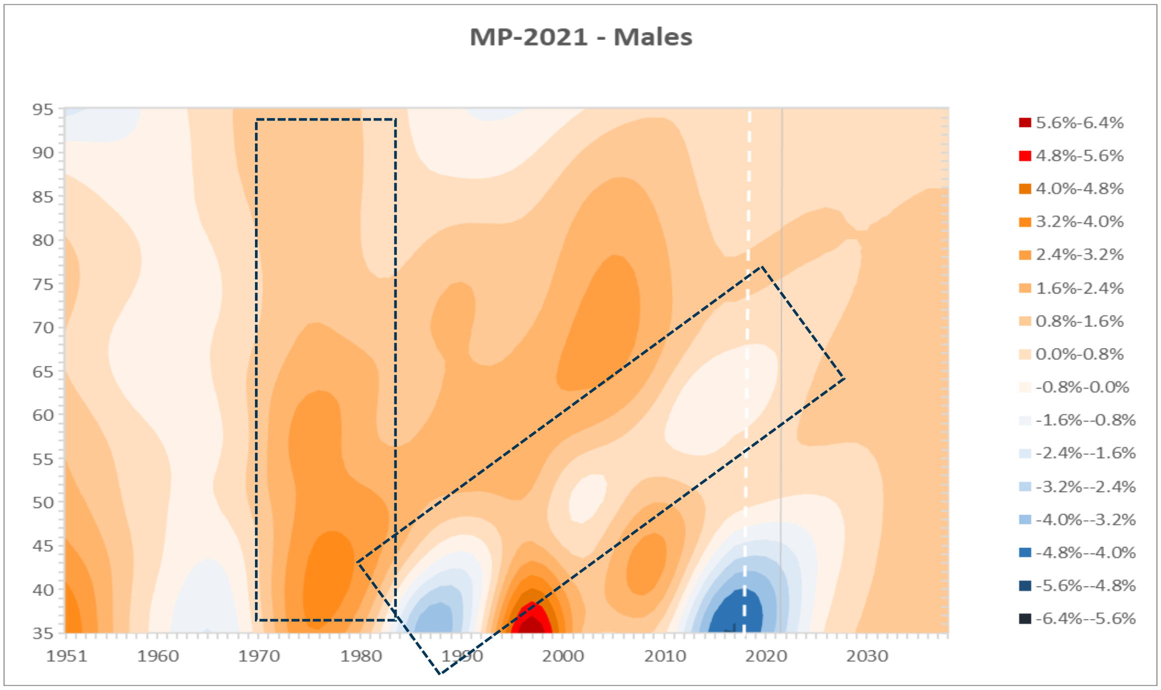
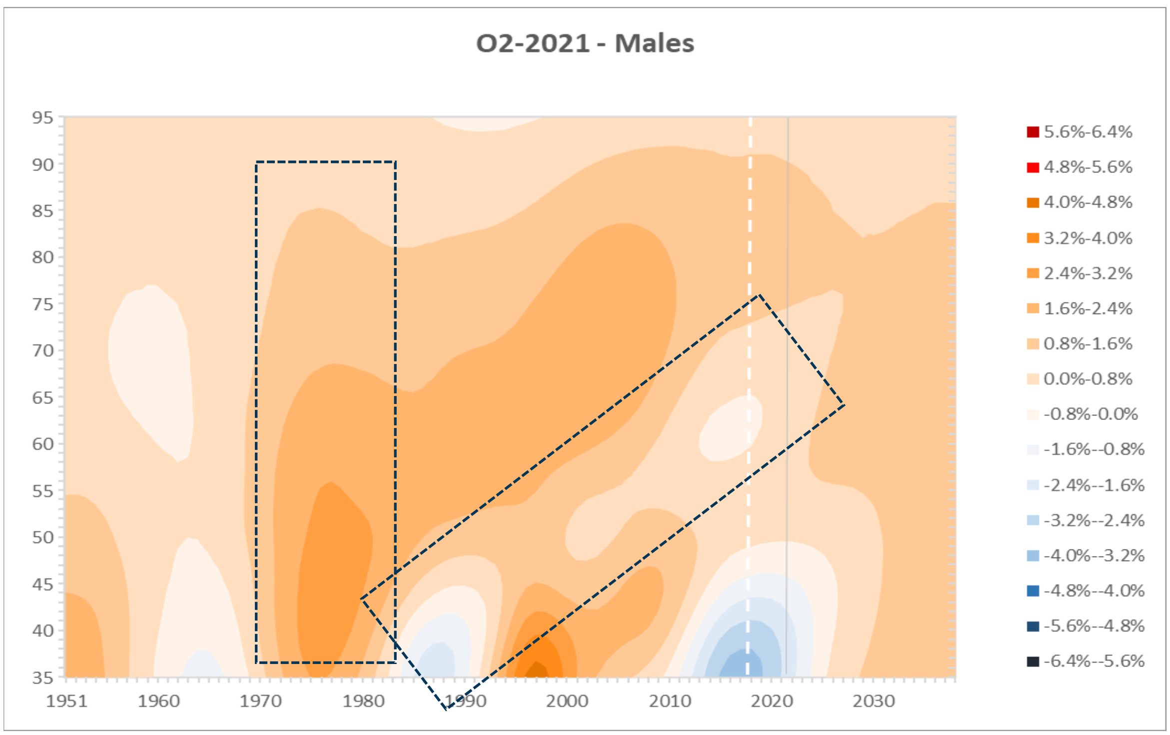
Appendix A: Technical Summary

The following heat maps, extracted from the Scale MP-2021 report, displays the historical[30] and projected future mortality improvement rates for males in the U.S. For the MP-2021 scale order-3 Whittaker-Henderson smoothing is used. For the O2-2021 scale order-2 Whittaker-Henderson smoothing is used.





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-2021 and O2-2021 scales were based, the MIM-2021-v2 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 2019 and all ages 15 through 97.
2. Using Whittaker-Henderson[31] 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 second ("order-2") or third ("order-3") 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 2019, 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 2019. As a result, both models start the projection period in calendar year 2018, with 2017 being the last year of historical data.

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 (y_0 and y_1) 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. *$C(A) = y_0$*
2. *$C(A+p) = y_1$*
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[32].

Appendix B: Section 5 and Appendix D of MP-2021 Report Related to COVID-19

This is a reprint of Section 5 and Appendix D from "Mortality Improvement Scale MP-2021" published by the Society of Actuaries in October 2021[33].

Section 5: Considerations Related to COVID-19

5.1 Mortality Experience in the United States during the COVID-19 Pandemic

COVID-19 has greatly affected mortality rates in the United States since March 2020. The pandemic continues to exert significant impact on population mortality through the date of this report's authorship. The impact of COVID-19 on mortality rates, however, has not been evenly dispersed by geography, race, gender, or socio-economic level. The excess death rates have also varied substantially from period to period with pronounced peaks and less-elevated valleys.

The SOA has conducted extensive research into the impact of the pandemic on mortality rates. This research includes an analysis of population mortality data (Leavitt 2021). This analysis, updated in May 2021, calculates excess mortality rates by age and gender.[1] Table 5.1 shows the actual-to-expected (A/E) mortality ratios from that analysis.

Table 5.1
EXCESS MORTALITY RATES FOR THE 40 WEEKS MARCH 22, 2020 THROUGH DEC. 26, 2020

	Females			Males		
Age	**Total A/E**	**COVID-19**	**Exc. COVID-19**	**Total A/E**	**COVID-19**	**Exc. COVID-19**
15–24	119.0%	3.6%	115.4%	125.3%	2.1%	123.2%
25–34	118.7%	6.3%	112.4%	122.5%	4.7%	117.9%
35–44	124.0%	9.4%	114.6%	128.9%	10.1%	118.8%
45–54	122.8%	12.7%	110.2%	128.7%	15.8%	112.9%
55–64	116.4%	13.7%	102.6%	121.2%	15.9%	105.3%
65–74	120.4%	16.6%	103.9%	122.8%	19.2%	103.7%
75–84	121.2%	17.7%	103.5%	123.5%	20.8%	102.7%
>84	119.5%	17.0%	102.5%	119.4%	18.9%	100.4%
All ages	119.7%	16.0%	103.7%	122.3%	17.5%	104.8%

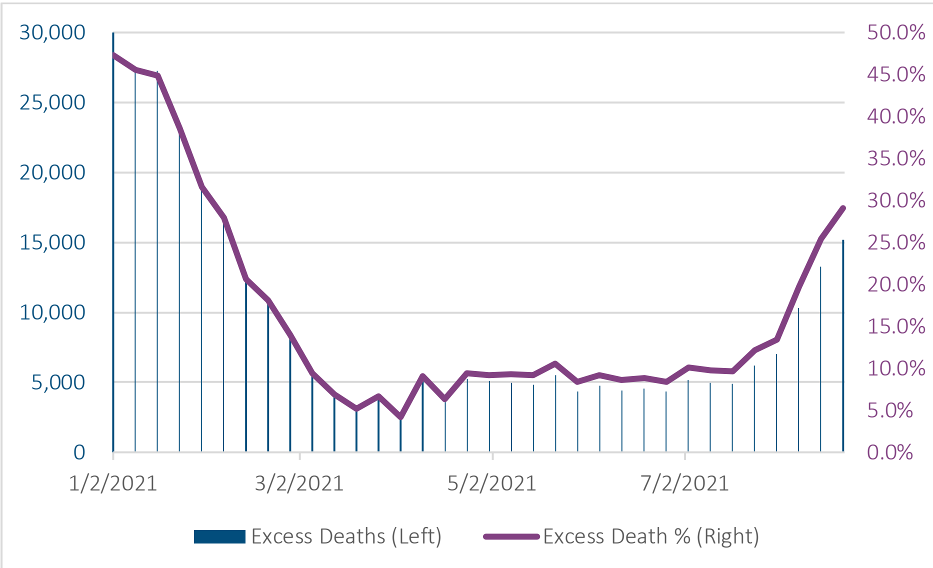
The data compiled in the Leavitt paper showcase that mortality rates were higher than expected among nearly all age groups. While rates ascribed to COVID-19 were materially higher in those over age 65, excess mortality of more than 15% was present for both males and females and all age groups above age 15. Males, overall, exhibited higher excess mortality and a higher rate of death from COVID-19.

Significant excess mortality has continued into 2021. Figure 5.1 shows weekly excess deaths for 2021 through Aug. 21. The rate of excess deaths in January and February peaked at more than 45%. During the spring/early summer, the excess death rate moderated significantly as the roll out of vaccines protected many of the most vulnerable groups. Nonetheless, due to incomplete inoculation rates and the advance of

[1] Excess mortality rates are determined as the percentage increase in observed mortality over expectations. These expectations were developed using trends for mortality rates and population counts by sex and age.

the delta variant, excess deaths increased significantly during late July and approached 30% by the week ended Aug. 21.

Figure 5.1
2021 WEEKLY EXCESS DEATHS AND EXCESS MORTALITY RATES THROUGH AUG. 21



Based on data available from the CDC, in many states the first six months experienced greater excess death rates than the full year of 2020 (NCHS 2021b). For the 34-week period through Aug. 21, 2021, excess deaths in the U.S. were approximately 16.8%, which compares to 16.2% for all of 2020. More recent data from the CDC for the month of September shows a moderation in excess death rates; however, recent weeks' data is less complete and, consequently, the degree to which the recent wave has ebbed remains uncertain.

5.2 COVID-19, Scale MP-2021 and the MIM-2021 Projection Model

As stated in subsection 2.1, the MP-2021 projection scale is based upon historical mortality information through calendar year 2019, before the COVID-19 pandemic. Accordingly, MP-2021 does not reflect any historical or potential future effects of COVID-19.

The Committee discussed at length whether to include COVID-19 effects in the standard MP-2021 scale. Currently there remains a good deal of uncertainty within the actuarial community and more broadly about the near and long-term effects of COVID-19. The degree to which vaccines and treatments will be able to control the pandemic long term has yet to be determined, and the frequency and severity of future variant strains is unknown. It is also uncertain how COVID-19 infections may affect a person's health long term.

Accordingly, the Committee decided that it would be best if the effects, if any, of COVID-19 on future mortality improvement for a particular pension population were an assumption chosen by individual practitioners. To facilitate this, the MIM-2021 Application Tool includes a COVID-19 adjustment section so that users could more easily incorporate their COVID-19 adjustments into a projection scale. The COVID-19 adjustment section of the MIM-2021 Application Tool can be found in "Step 4b" of the input section on the "1. model" tab.

The COVID-19 adjustment section is set up such that users can enter specific loads on mortality for each year 2020 through 2024 and separately for 2025 and beyond (if a long-term COVID-19 adjustment is desired). These adjustments can be defined differently for each combination of age and sex. Amounts entered into this section for 2020 through 2024 will be reflected in the resulting projection scale as a percentage load on mortality only for the year listed and will be automatically reversed out in the subsequent year unless mortality loads are also entered for the subsequent year. Blank cells will be interpreted by the MIM-2021 Application Tool as a 0% load.

For instance, if users wanted to load 2020 mortality levels for males and females for all ages by 18%, load 2021 mortality levels by 10% and apply no load for all subsequent years, they would enter 18% for all ages under the 2020 column and 10% for all ages under the 2021 column. In this example, the improvement rates for 2022 in the resulting scale would include an adjustment to reset 2022 mortality projections to what they would have been had the COVID-19 adjustment section been left blank.

Additional, detailed examples of how to use the COVID-19 adjustment section of the MIM-2021 Application Tool are provided in Appendix D.

Appendix D: Examples of COVID-19 Adjustments in MIM-2021 Application Tool

The MIM-2021 Application Tool allows users to specify loads for **mortality rates** (note: not **improvement** rates) due to the COVID-19 pandemic. These rates are input on a select-and-ultimate basis, with individual loads that can be specified by age and sex for each individual calendar year from 2020 through 2024, with a load (by age and sex) that will apply for calendar years 2025 and beyond.

These loads should be input in "Step 4b. COVID-19 Loads". This appendix details examples of how various inputs to these loads affect the resultant mortality improvement rates. These examples are merely illustrations of how the tool responds to the input and should **not** be considered recommendations for mortality loads.

These examples will focus on the mortality improvement rates for females from Scale MP-2021. Below are select Scale MP-2021 mortality improvement rates for females age 49–51 with no adjustment for COVID-19.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
49	0.0103	0.0094	0.0084	0.0073	0.0063	0.0054	0.0047	0.0042	0.0041	0.0042
50	0.0113	0.0107	0.0099	0.0090	0.0080	0.0070	0.0063	0.0057	0.0053	0.0053
51	0.0115	0.0113	0.0108	0.0101	0.0093	0.0084	0.0077	0.0070	0.0066	0.0064

Example 1. Single Load for 2020

Suppose a user inputs a 15% mortality load for 2020 (note: this can be varied by age but is the same for all ages in this example) and leaves all the remaining load cells blank. This assumption means that mortality rates are 15% higher than what they would have been in 2020 absent COVID-19, but that mortality rates in all years after 2020 are unaffected and revert to what they would have been if no load had been input.

Step 4b. COVID-19 Loads

Applied after base MI rates
"10.00%" means 1.10 times mortality rate
Blanks indicate a 0% load

	Female					
	2020	2021	2022	2023	2024	2025+
49	15.00%					
50	15.00%					
51	15.00%					

Below are the resultant improvement rates that correspond to this input:

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
49	0.0103	0.0094	-0.1403	0.1368	0.0063	0.0054	0.0047	0.0042	0.0041	0.0042
50	0.0113	0.0107	-0.1386	0.1382	0.0080	0.0070	0.0063	0.0057	0.0053	0.0053
51	0.0115	0.0113	-0.1376	0.1392	0.0093	0.0084	0.0077	0.0070	0.0066	0.0064

Note that the 2020 improvement rate becomes very negative in response to the 15% mortality load for 2020. However, because there is no such load for 2021, the 2021 improvement rate becomes large and positive to revert projected 2021 mortality rates to what they would be had no loads been input at all. There are no changes to improvement rates for 2022 and beyond.

Example 2. Gradual Wear-off

Suppose instead that the user inputs the below loads to model a gradual wear-off of the effects of COVID-19 for females, with some persisting long-term effects.

Step 4b. COVID-19 Loads

Applied after base MI rates
"10.00%" means 1.10 times mortality rate
Blanks indicate a 0% load

	Female					
	2020	2021	2022	2023	2024	2025+
49	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
50	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
51	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%

This input creates gradually decreasing loads from 2020 through 2025. Note that the 2.00% load input for 2025 applies for all years 2025 and beyond. Below are the resultant improvement rates from these COVID-19 loads to Scale MP-2021.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
49	0.0103	0.0094	-0.1403	0.0505	0.0244	0.0330	0.0236	0.0139	0.0041	0.0042
50	0.0113	0.0107	-0.1386	0.0520	0.0260	0.0346	0.0252	0.0153	0.0053	0.0053
51	0.0115	0.0113	-0.1376	0.0531	0.0273	0.0360	0.0266	0.0167	0.0066	0.0064

The 2020 improvement rate becomes the same as in Example 1. However, the 2021 through 2025 improvement rates have significantly increased from the Scale MP-2021 values. A 15% load on 2020 mortality rates and a 10% load on 2021 mortality rates create a situation in which mortality is substantially lower in 2021 than 2020, so the 2021 improvement rate is high and positive. Similar logic applies for the other years of the wear-off, albeit to a smaller degree in this example. Note that improvement rates for 2026 and beyond will not change from their Scale MP-2021 values even though the long-term mortality rates have increased. The reason is because the 2% load is a constant multiplier to mortality for all years 2025 and after, so the ratio of mortality rates in consecutive years after 2025 remains the same as if there were no input loads.

The below table shows the development of the above mortality improvement rates using the example of mortality rates computed using the Pri-2012 Total Dataset mortality rate for a female age 50 and Scale MP-2021. Note that the adjustments to improvement rates are independent of the underlying mortality table chosen.

Table D.1

EFFECT OF COVID-19 LOADS ON MORTALITY IMPROVEMENT;
FEMALE AGE 50 USING PRI-2012 TOTAL DATASET AND SCALE MP-2021 WITH LOADS SHOWN

Year	Mortality Rate	Improvement	Mortality Load	Mortality with Loads	Improvement with Loads
2017	0.00261			0.00261	
2018	0.00258	0.0113		0.00258	0.0113
2019	0.00256	0.0107		0.00256	0.0107
2020	0.00253	0.0099	15.00%	0.00291	-0.1386
2021	0.00251	0.0090	10.00%	0.00276	0.0520
2022	0.00249	0.0080	8.00%	0.00269	0.0260
2023	0.00247	0.0070	5.00%	0.00260	0.0346
2024	0.00246	0.0063	3.00%	0.00253	0.0252
2025	0.00244	0.0057	2.00%	0.00249	0.0153
2026	0.00243	0.0053	2.00%	0.00248	0.0053
2027	0.00242	0.0053	2.00%	0.00246	0.0053

Appendix C: Section 3 of the MP-2021 Report on Considerations for Use of MIM-2021 Application Tool

This is a reprint of Section 3 from "Mortality Improvement Scale MP-2021" published by the Society of Actuaries in October 2021[34].

Section 3: Considerations for Use of the MIM-2021 Application Tool

3.1 DATA SOURCES

Since the release of Scale MP-2014, RPEC has relied upon releases of historical data supplied by the SSA as described in subsection 2.1. The MIM-2021 Application Tool allows for selection of alternative historical datasets to use for mortality improvement projections, with the intent of allowing practitioners in various areas the latitude to choose which one they deem most appropriate for their specific purpose. For these alternative datasets, deaths are taken from the National Vital Statistics System of the National Center for Health Statistics (NCHS) and exposures are taken from the Census Bureau. For the duration of this report, the NCHS deaths, Census Bureau exposures, and the resultant mortality rates will be collectively referred to as "NCHS data."

A key reason for the inclusion of the NCHS data in the model is the ability to stratify the NCHS data into socioeconomic deciles using geographical indicators, as described in subsection 2.2 of the MIM-2021 report. This allows users to not only produce mortality improvement scales based on the aggregate NCHS data, but particular socioeconomic deciles (or blends thereof) that might be applicable to a particular population. This level of granularity is not currently available in the SSA dataset.

Since the release of the original RPEC_2014 model, RPEC has elected to use the SSA historical mortality data rather than the NCHS data due to the SSA's use of data from CMS for ages 65 and above. RPEC continues to utilize the SSA historical mortality data for its MP scales for the following reasons:

- All persons covered by Medicare and Medicaid are required to verify their ages, and for this reason, RPEC has considered the CMS data to be more reliable for ages 65 and older, which are especially relevant for pension valuations.

- The NCHS data relies upon deaths from the National Vital Statistics System and exposure counts from the Census Bureau, which means that the NCHS mortality rates in MIM-2021 are based on data from two different sources. In contrast, CMS exposures and deaths for ages 65 and older in the SSA data come from the same source, which the Committee believes is important when assessing year-over-year mortality improvement.

- The annual population counts published by the Census Bureau are estimates based on the 2010 census. Post-censal estimates for 2011–19 are derived from the 2010 census using birth and mortality statistics from NCHS and international migration rates by sex and age for each year. When the 2020 census information is published, the Census Bureau will re-estimate population counts for 2011–19. In contrast, the exposure counts from CMS are based on the number of people enrolled in Medicare[2] and are not estimates.

- The NCHS and SSA mortality rates for ages 65 and older appeared to be quite close in 2010 but have increasingly diverged over the course of the decade, with the rates based on the NCHS data decreasing substantially relative to the SSA data, as shown in Figures 3.1 to 3.3.[3] A similar divergence was noted by SSA over the course of the 2000–09 decade until the 2010 census resulted in true-ups of the Census Bureau population counts for 2001 through 2009 that brought the two sets of mortality rates closer in line. Due to this precedent, RPEC anticipates that forthcoming intercensal adjustments to Census Bureau population estimates for 2011–19 may noticeably change NCHS mortality rates from those implied by the data currently available.

[2] Above age 70, SSA uses the population enrolled in Medicare that is also receiving a Social Security or Railroad Retirement Board benefit. However, due to the increasing number of people delaying commencement of Social Security benefits, below age 70, SSA uses all individuals enrolled in Medicare.
[3] Figures 3.1 to 3.3 show how the mortality rates change over the course of the decade for females; the pattern for males is similar.

Figure 3.1
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR 2010

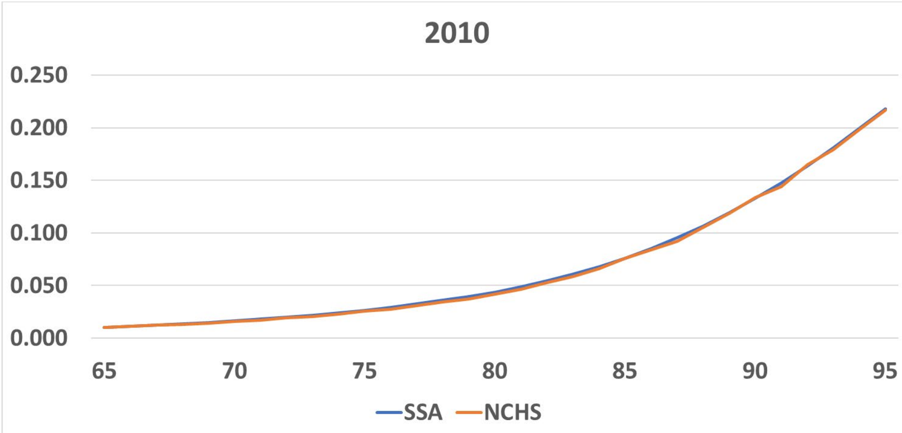


Figure 3.2
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR 2015

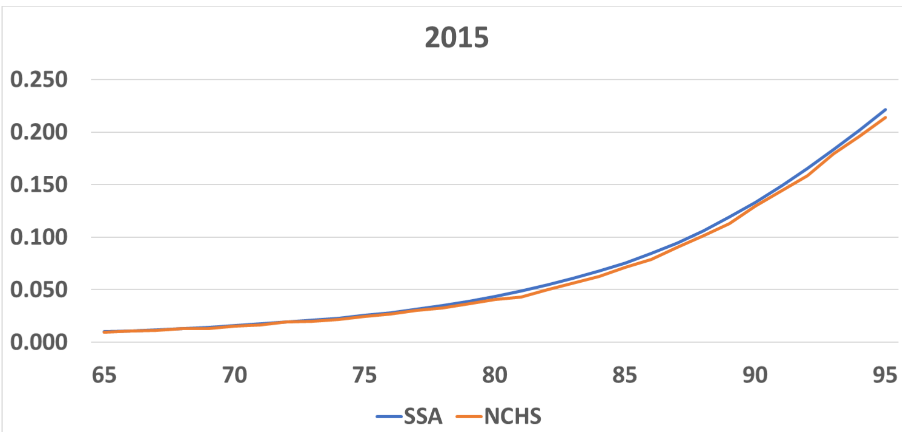
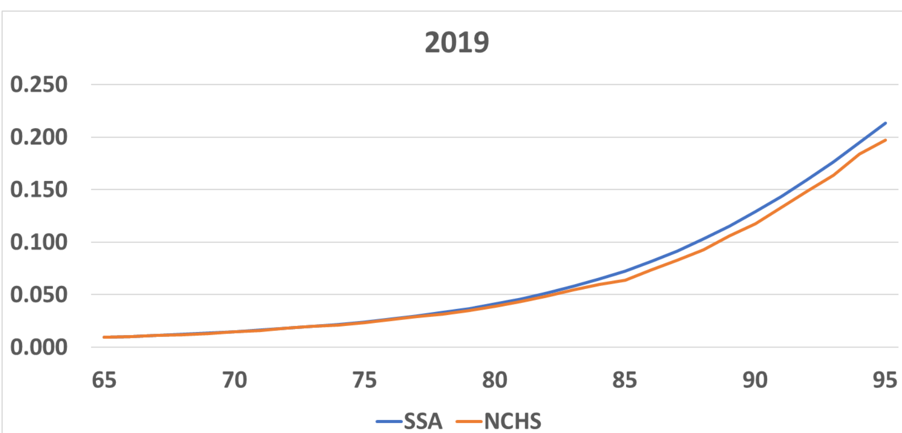
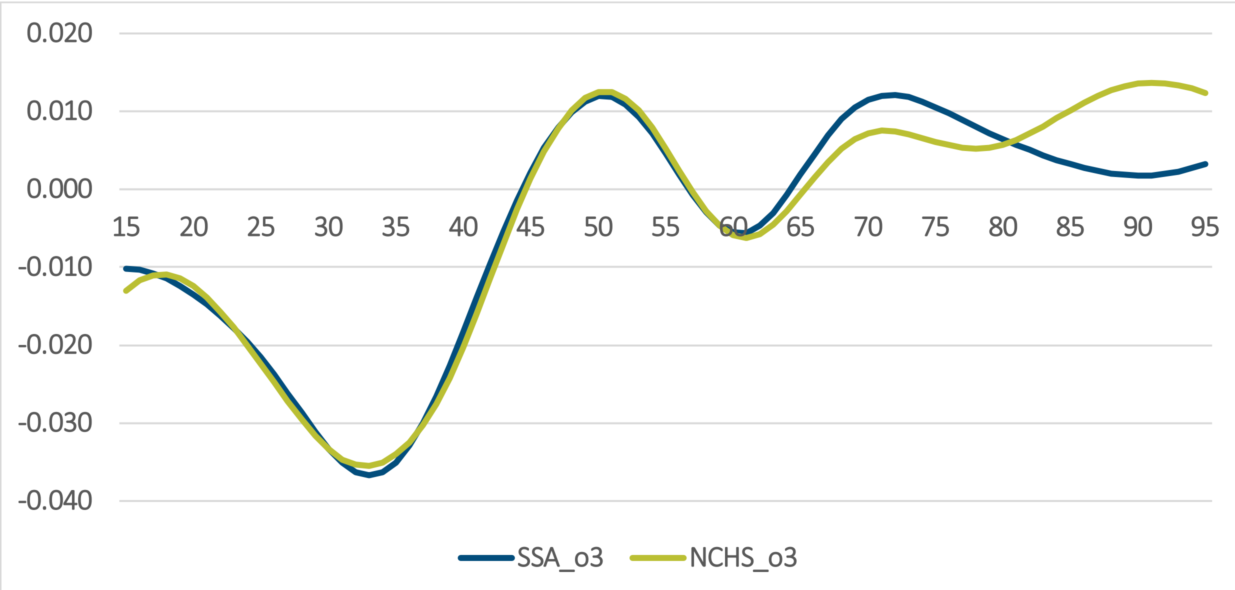


Figure 3.3
SSA AND NCHS FEMALE MORTALITY RATES BY AGE FOR 2019



Along with the MIM-2021 Application Tool, the SOA has released an accompanying MIM-2021 Data Analysis Tool that allows users to plot and compare different historical mortality rates and improvement rates between the datasets available in the MIM-2021 Application Tool, including socioeconomic deciles and quintiles. This Data Analysis Tool can be of particular help in allowing practitioners to analyze how the NCHS data compare to the SSA data underpinning Scale MP-2021. Figure 3.4 shows the NCHS and SSA improvement rates for females for the most recent five years of data, which are the most important historical years for determining the interpolating cubic polynomials for Scale MP-2021.[4]

Figure 3.4
SSA AND NCHS ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT, FEMALES, 2015–2019



The datasets differ in their methods of smoothing mortality rates within calendar years, but the greatest differences in improvement rates are observed above age 65, where the two datasets are based on different sources. A recent University of Michigan Retirement Research Center research paper concluded that differences in the raw exposures and deaths used, rather than differences in the smoothing methodologies, are primarily responsible for the deviation in mortality rates between the two sources (Barbieri 2018). This conclusion is consistent with the observations above showing a divergence in mortality rates over the course of the 2010–19 decade, which may be due to decreasing accuracy of Census Bureau population estimates as more years have elapsed since the 2010 census.

Table 3.1 shows how Pri-2012 annuity factors differ between using the SSA data used to construct Scale MP-2021 and the NCHS historical data with all of the other committee-selected assumptions. The NCHS data produces higher annuity factors, particularly at the oldest ages. This outcome is a result of NCHS mortality rates decreasing by more than SSA mortality rates over the course of the last decade, as illustrated by Figures 3.1 to 3.3.

[4] 2017 is the final year of historical (rather than projected) improvement rates in Scale MP-2021, which is the "jumping off" point for cubic polynomial interpolation described in subsection 3.2. 2015–19 is selected as a five-year period centered around 2017.

Table 3.1

MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JAN. 1, 2021
PRI-2012 PROJECTED GENERATIONALLY

	Age	SSA (MP-2021)	NCHS Data	% Change
Females	25	3.7396	3.7547	*0.40%*
	35	5.4447	5.4649	*0.37%*
	45	7.9383	7.9650	*0.34%*
	55	11.6099	11.6441	*0.29%*
	65	14.2572	14.3030	*0.32%*
	75	10.2580	10.3940	*1.33%*
	85	6.1979	6.5061	*4.97%*
	95	3.3605	3.5577	*5.87%*
Males	25	3.5054	3.5183	*0.37%*
	35	5.1011	5.1173	*0.32%*
	45	7.4405	7.4601	*0.26%*
	55	10.8960	10.9168	*0.19%*
	65	13.3798	13.4029	*0.17%*
	75	9.4558	9.5909	*1.43%*
	85	5.4867	5.8245	*6.16%*
	95	2.8883	3.1188	*7.98%*

3.2 ADDITIONAL NEW FEATURES OF MIM-2021 APPLICATION TOOL

As mentioned in subsection 2.3, MIM-2021 includes the capability to load the committee-selected assumptions and historical SSA dataset used to produce Scale MP-2021. In addition to the assumptions familiar to users of past iterations of the RPEC_2014 model, MIM-2021 includes some new options for users to further customize their projection. First, MIM-2021 introduces the concept of user-defined "intermediate-term" rates of improvement, which are reached at user-specified future years and held constant for a user-specified period before grading linearly to the assumed long-term rates of improvement. Scale MP-2021 does not utilize intermediate-term rates.

Second, past versions of the RPEC-2014 model have relied upon the mortality improvement rates determined from the most recent two years of historical mortality data (after accounting for the two-year step-back referenced in subsection 2.2) and the slope of mortality improvement rates determined from the most recent two years of mortality improvement rates. These two figures have defined the "jumping off" point for the cubic polynomials used for interpolation across the convergence period. The MIM-2021 Application Tool allows the user to base these jumping-off values off of different historical periods than the most recent two years. The initial improvement rates and slopes can also be manually overridden by age.

A third new feature is the ability for users to enter their own adjustments to mortality due to COVID-19. This is described in more detail in subsection 5.2 of this report.

3.3 RELATIONSHIPS BETWEEN SOCIOECONOMIC SUBSETS OF NCHS DATA AND MORTALITY IMPROVEMENT

Should a practitioner choose to model mortality improvement using historical data of an assumed higher or lower socioeconomic level, the MIM-2021 Application Tool allows the functionality to do that. However, the use of NCHS socioeconomic quintiles and deciles will reduce the size of the underlying dataset and may introduce additional volatility into year-over-year annuity factors produced from improvement scales developed using MIM-2021. Practitioners should also be aware that while populations of higher socioeconomic status have generally exhibited lower mortality than populations of lower socioeconomic status, higher socioeconomic status has not always been indicative of higher mortality improvement across all combinations of age, sex and time period. For some of these combinations, mortality improvement has been higher for people of lower socioeconomic status.

The MIM-2021 Data Analysis Tool allows users to plot and compare how different socioeconomic deciles and quintiles compare to the aggregated national data. Figures 3.5 and 3.6 show the annualized geometric rate of improvement for NCHS quintiles and deciles from 1982 through 2019 for females. The lowest socioeconomic group is represented by “q1” in Figure 3.5 and “d1” in Figure 3.6. Though there are exceptions, the higher socioeconomic groups experienced greater mortality improvement than lower socioeconomic groups during this time period.

Figure 3.5

ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT BY NCHS QUINTILES, FEMALES, 1982–2019

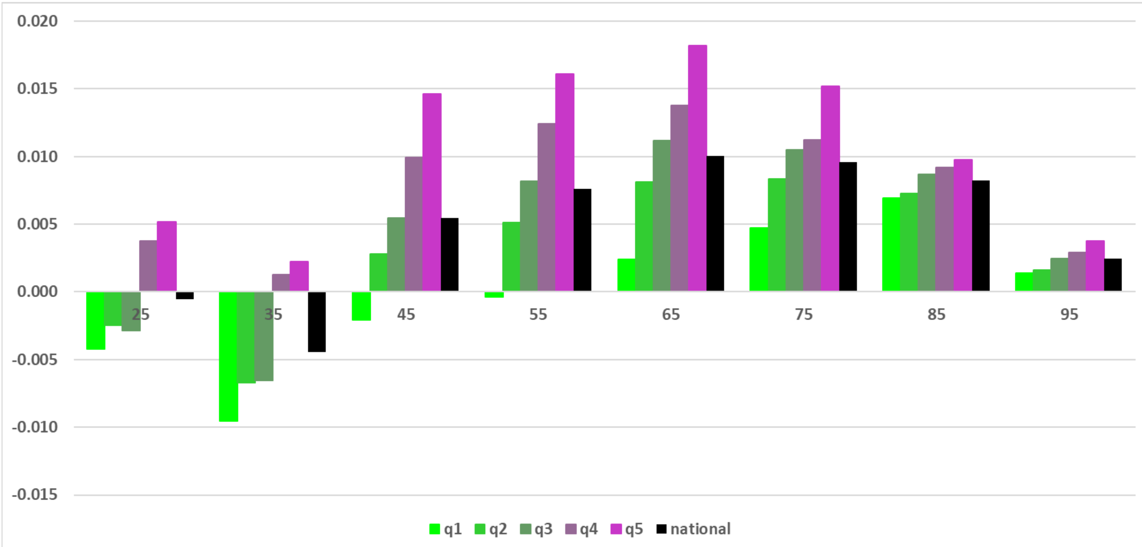
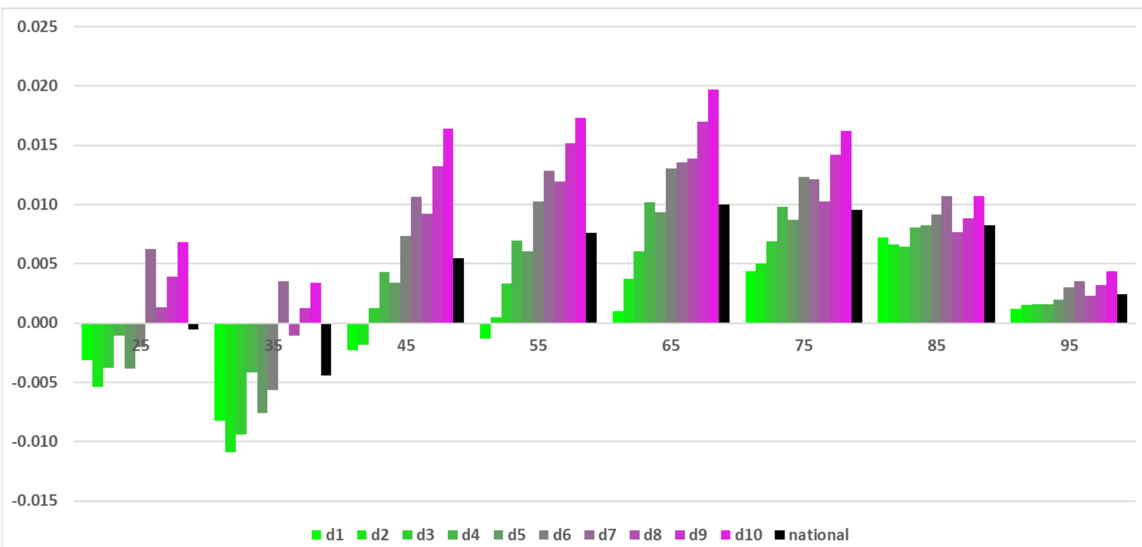


Figure 3.6

ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT BY NCHS DECILES, FEMALES, 1982–2019



Practitioners familiar with the RPEC_2014 model will recall that the future projection of mortality improvement relies upon the most recent two years of historical improvement data, which are influenced most prominently by the most recent years of historical mortality data. Figures 3.7 and 3.8 display the same information as the above Figures 3.2 and 3.3 but include only years 2010–19. It can be seen that in the most recent decade, the relationship between NCHS income groups and mortality improvement is not consistent across ages.

Figure 3.7

ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT BY NCHS QUINTILES, FEMALES, 2010–19

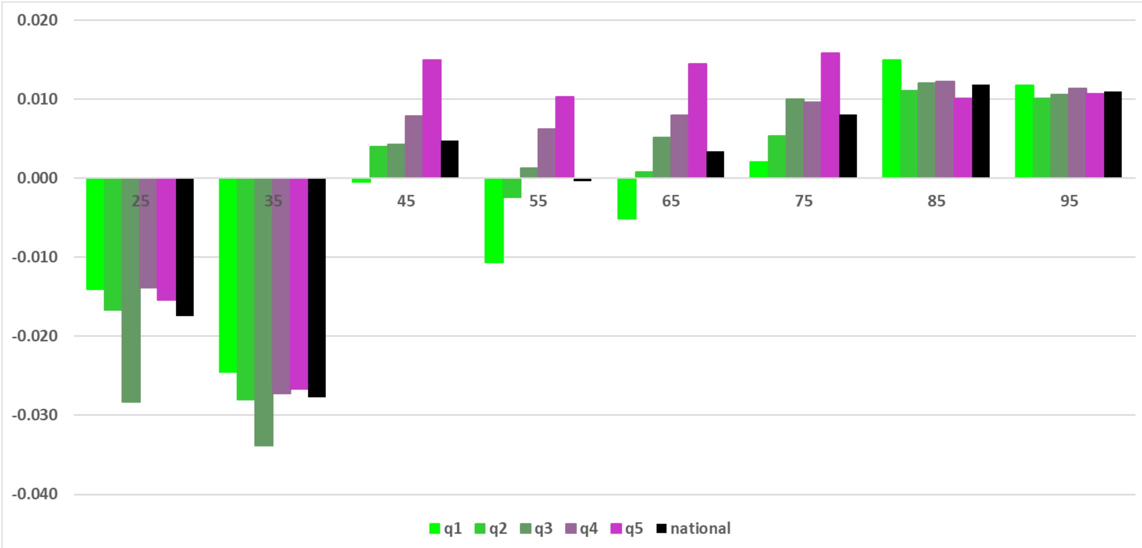
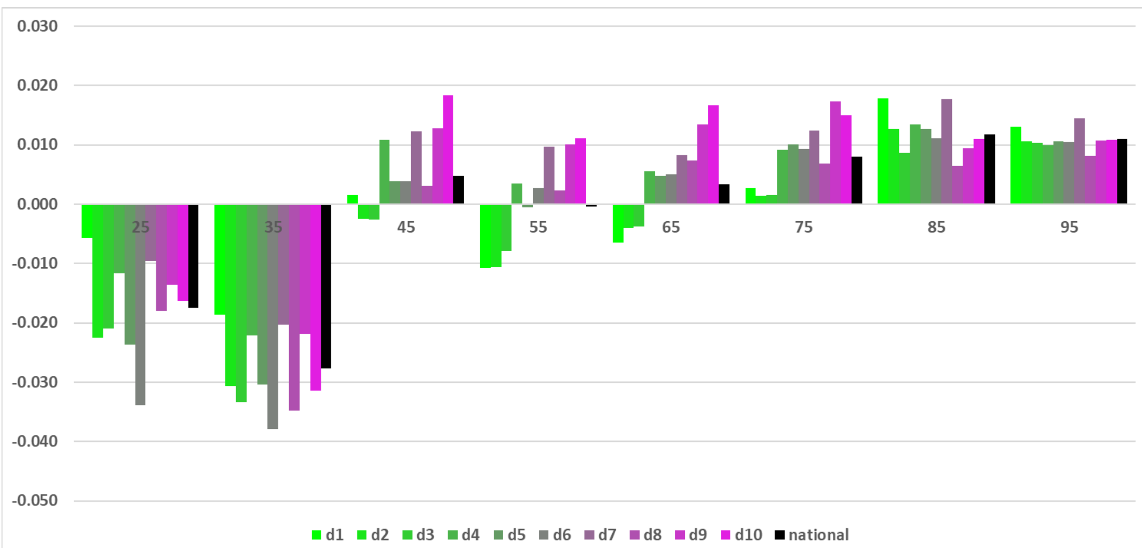


Figure 3.8

ANNUALIZED GEOMETRIC RATE OF MORTALITY IMPROVEMENT BY NCHS DECILES, FEMALES, 2010–19



Users of the MIM-2021 Application Tool considering use of socioeconomic subsets of the NCHS data for mortality improvement projections are encouraged to make use of the MIM-2021 Data Analysis Tool to understand how relationships between NCHS socioeconomic categories and mortality improvement have evolved over time. Practitioners should carefully review how selection of different NCHS socioeconomic categories will influence mortality improvement projections and be aware of the year-over-year volatility that this might introduce.

Another consideration regarding use of socioeconomic subsets of the NCHS data is the forthcoming incorporation of the 2020 census into the estimates for the Census Bureau's 2011-19 population counts. The mortality rates for 2011-19 will be adjusted, which could potentially significantly change the observed levels of improvement over the past decade. The change may disproportionately affect certain socioeconomic strata.

3.4 SETTING THE LONG-TERM RATE OF IMPROVEMENT USING HISTORICAL DATA

The MIM-2021 Application Tool includes an optional feature that allows users to set intermediate- and long-term rates of mortality improvement by computing these values from historical information. Section 5 of the MP-2020 report (SOA 2020) details the process by which RPEC chose its new long-term rate of improvement. Table 3.2 (taken from the Scale MP-2020 report) shows that the long-term rate computed by age group can vary based on the start and end years chosen for the historical data. Practitioners choosing to use this feature should be aware of how changing these input years can influence the results.

Table 3.2

BEST-FIT ANNUAL MORTALITY IMPROVEMENT FOR SELECT 10-YEAR AGE BANDS

Time Period	Age 55-64	Age 65-74	Age 75-84	Age 85-94
1940–2017	1.29%	1.19%	1.08%	0.75%
1950–2017	**1.33%**	**1.24%**	**1.09%**	**0.71%**
1960–2017	1.45%	1.36%	1.13%	0.73%
1970–2017	1.48%	1.43%	1.09%	0.53%
1980–2017	1.39%	1.52%	1.09%	0.40%
1940–1980	0.99%	0.94%	1.06%	0.87%
1950–1990	1.13%	0.99%	1.09%	0.97%
1960–2000	1.48%	1.18%	1.12%	0.94%
1970–2010	1.63%	1.38%	1.05%	0.49%

RPEC ultimately based its selected long-term rate of improvement on data from the 1950–2017 time period. For purposes of computing the long-term rate of improvement from historical data, the MIM-2021 Application Tool includes historical data back to 1982. Table 3.2 indicates that for the age 65–74 band, improvement rates were higher for 1980–2017 than all other periods studied and, for the age 85–94 band, improvement rates were lower for 1980-2017 than all other periods studied. Use of the longest historical time period available in the MIM-2021 model for setting long-term rates of improvement may therefore produce outlier estimates for some ages.

Endnotes

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[1] "MIM-2021" stands for the Mortality Improvement Model initially released in April 2021. 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] "MIM-2021-v2" stands for the second version of the MIM-2021 released in October 2021.

[5] 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.

[6] 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.

[7] 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.

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

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

[10] *Id.* P3.

[11] *Id*.

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

[13] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/.

[14] Society of Actuaries. 2018. "Mortality Improvement Scale MP-2018". https://www.soa.org/resources/experience-studies/2018/mortality-improvement-scale-mp-2018/

[15] 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.

[16] Society of Actuaries. 2020. "Mortality Improvement Scale MP-2020". https://www.soa.org/resources/experience-studies/2020/mortality-improvement-scale-mp-2020/

[17] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/
[18] 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/.
[19] Villegas, Andres, Madhavi Bajekal, Steven Haberman, and Luke Zhou. 2021. "Analysis of Historical U.S. Population Mortality Improvement Drivers 1959-2016". Society of Actuaries. https://www.soa.org/resources/research-reports/2021/analysis-historical-us-drivers/
[20] Barbieri, Magali. 2020/2021. "Mortality by Socioeconomic Category in the United States". Society of Actuaries. https://www.soa.org/resources/research-reports/2020/us-mort-rate-socioeconomic/
[21] 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/.
[22] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/
[23] 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".
[24] See Appendix A for technical details about the family of cubic polynomials.
[25] 2017 is the final year of historical (rather than projected) improvement rates in Scale MP-2021, which is the "jumping off" point for cubic polynomial interpolation described in subsection 3.2. 2015-2019 is selected as a five-year period centered around 2017.
[26] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/
[27] Above age 70, SSA uses the population enrolled in Medicare that is also receiving a Social Security benefit or a Railroad Retirement Board benefit. However, due to the increasing number of people delaying commencement of Social Security benefits, below age 70, SSA uses all individuals enrolled in Medicare.
[28] Figures 3.1 – 3.3 show how the mortality rates change over the course of the decade for females; the pattern for males is similar.
[29] 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.
[30] The historical mortality improvement rates were calculated from smoothed Social Security Administration population mortality data for years 1951 through 2018.
[31] 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.
[32] 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.
[33] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/
[34] Society of Actuaries. 2021. "Mortality Improvement Scale MP-2021. https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/

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