



Mortality  
and Longevity

# MIM-2021-v3 Application Tool User Guide

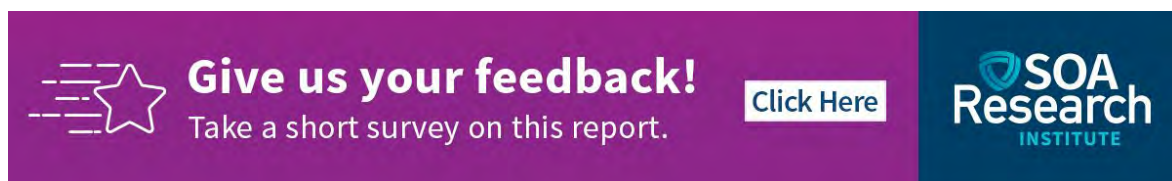
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# MIM-2021-v3 Application Tool User Guide

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**SPONSOR** Mortality and Longevity Strategic  
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Committee

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# MIM-2021-v3 Application Tool User Guide

## Section 1: Introduction

In 2021, the SOA Research Institute released two Excel-based tools (and accompanying user guides) in connection with the publication of the MIM-2021-v2 Report<sup>1</sup>. The MIM-2021-v2 Data Analysis Tool was created to help users compare and analyze various historical U.S. mortality data sets and the MIM-2021-v2 Application Tool enabled users to develop their own sets of mortality improvement rates (or in some cases deterioration) under the MIM-2021-v2 framework. Based on feedback received from the membership, the Advisory Group has incorporated a number of enhancements into this latest version of the Application Tool. This document describes those enhancements and provides a step-by-step guide for the updated Application Tool. Changes from the previous MIM-2021-v2 version are summarized below:

- A more straightforward user interface and the inclusion of a high-level process schematic, both designed to facilitate the entry of model parameters.
- A clearer distinction has been made between “required” parameters (i.e., those necessary for the spreadsheet to produce results) and “optional” parameters that can be selected to produce modified results dealing with projected mortality rates<sup>2</sup>.
- In addition to the ability to load the parameter sets that will reproduce the results of the MP-2021 or O2-2021 mortality improvement scales previously released by the Retirement Plans Experience Committee (RPEC), users will now have the ability to load one additional set of preselected required parameters that could be used as a starting point for other mortality improvement scales.
- The table of optional mortality rate adjustment factors introduced in the prior version of the Application Tool (to adjust for mortality “shocks” such as COVID-19) has been expanded to accommodate an additional three years of factors.

Note that the historical mortality tables underpinning MIM-2021-v3 are exactly the same as those used in the previous model. Specifically, both models include historical SSA and NCHS mortality data through 2019 only. Section 4 of the MIM-2021-v3 Report<sup>3</sup> describes the rationale for not including any 2020 mortality data.

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<sup>1</sup> Society of Actuaries Research Institute. 2021. “Developing a Consistent Framework for Mortality Improvement: MIM-2021-v2”.

<https://www.soa.org/resources/research-reports/2021/mortality-improvement-model/>

<sup>2</sup> Users can enter required parameters in one of two different ways: (1) by selecting one of the preselected parameter sets or (2) by entering each parameter individually. Independent of which method is selected for entry of the required parameters, any optional parameters need to be entered individually.

<sup>3</sup> Society of Actuaries Research Institute. 2022. “Mortality Improvement Model, MIM-2021-v3”

<https://www.soa.org/resources/research-reports/2022/mortality-improvement-model/>

As was the case in the prior versions of the Application Tool, users will need to populate all required parameter cells before the spreadsheet will produce results. This is accomplished by either choosing one of the three preselected parameter sets or by entering each required parameter individually. The required parameters include:

- The desired set of historical mortality rates upon which to base the projection and the appropriate order of two-dimensional graduation;
- The overall shape of and key years associated with long-term (and if desired, intermediate-term) mortality improvement rates;
- The degree of blending between the Tool's horizontal projection along individual ages and its diagonal projection along individual year-of-birth cohorts;
- The historical period used to determine the mortality improvement rates and associated slopes immediately preceding the first year of the projection; and
- The magnitude of long-term (and if desired, intermediate-term) mortality improvement rates.

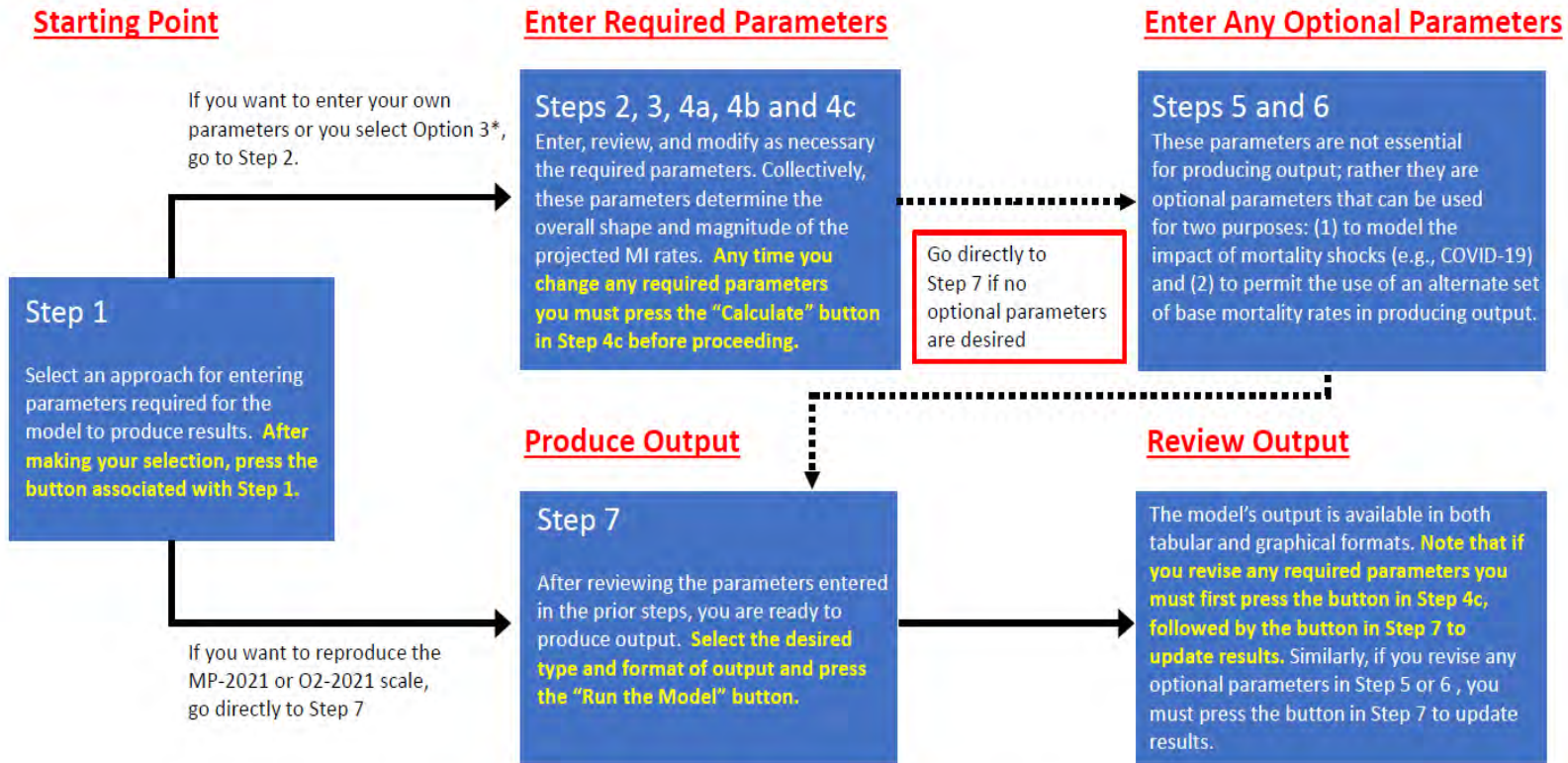
There are two types of optional parameters:

- Adjustment factors that can be used to reflect the anticipated near-term effects of mortality rate shocks, such as the impact of COVID-19; and
- The ability to select a mortality table (different from the historical database used to develop the underlying mortality improvement rates) from which all output dealing with projected mortality rates and life expectancies is based.

Note that the cells corresponding to optional parameters are blacked out until the user indicates that these parameters are to be reflected in the Tool's output.

All users are encouraged to first familiarize themselves with the information in the Disclaimer, Contents, and Readme tabs of the spreadsheet. Given the changes made to the Application Tool's interface since the previous version, the Advisory Group encourages all users to review the following high-level "process flow" summary (Figure 1) included in the Schematic tab before proceeding to the Model tab.

Figure 1  
MIM-2021-v3 PROCESS FLOW SCHEMATIC



\* Selection of Option 3 in Step 1 populates the model's required parameters with a new preselected assumption set designed primarily as a starting point for individual life and individual/group annuity applications. Users who select Option 3 should review all of the preselected parameters in Steps 2 through 4c and modify as necessary.

## Section 2: The “1. Model” Tab

### STEP 1: SELECT METHOD FOR POPULATING REQUIRED PARAMETER SET

Figure 2 shows the four options users have to populate the model’s required parameters. Selecting any of the first three options results in all appropriate cells to be populated with a certain set of preselected parameter sets, while selecting the fourth option requires the user to enter parameters individually in Steps 2 through 4.

Figure 2

MIM-2021-v3 APPLICATION TOOL STEP 1 INPUT CELLS

#### Step 1

#### Select Methodology for Entering the Required Parameters

Options 1 and 2 below reproduce the two RPEC mortality improvement scales, MP-2021 and O2-2021, respectively. Option 3 is a new set of preselected required parameters that could be used as a starting point for subsequent review and modification. Option 4 requires the user to enter each required parameter individually. Enter your selection in cell B17 and then click the blue button.

- 4** Select the desired methodology from the list below and then press the button (below the list)
- 1 = populate with the MP-2021 assumption set
  - 2 = populate with the O2-2021 assumption set
  - 3 = populate with Individual life and individual/group annuity
  - 4 = I would like to start with a blank slate – that is, I will fill in all of the parameters myself

[Click Here After You Have Made Your Selection](#)

Users who wish to replicate the MP-2021 (option 1) or the O2-2021 (option 2) mortality improvement scales will typically move either directly to Step 7 (or to Steps 5 and 6, if any optional parameters are desired) after clicking the blue button. A new third set of preselected required parameters, which was designed to be potentially more appropriate than scales MP-2021 or O2-2021 for certain life insurance and annuity applications, should be regarded as a convenient starting point that users are expected to review carefully and modify as necessary. In all three preselected parameter sets, any of the cells automatically populated can be overwritten as desired in Steps 2 through 4.

After selecting any one of the four options, users must click the blue button before proceeding. For those who have opted for one of the preselected assumption sets (i.e., options 1, 2, or 3), clicking the blue button automatically populates all required parameters into the appropriate remaining worksheet cells. For those who select option 4, clicking the blue button prepares the worksheet for the entry of user-selected parameters<sup>4</sup> in the yellow-shaded cells in Steps 2 through 4.

<sup>4</sup> Note that even after selecting option 4 in Step 1, certain suggested parameters dealing with the starting years of the projection have been prepopulated into a small number of cells in Steps 3 and 4a. These suggested values can be overwritten if desired.

## STEP 2: SELECT THE APPROPRIATE HISTORICAL DATA SET

The sets of historical U.S. mortality rates preloaded in the MIM-2021-v3 Application Tool are exactly the same as those in the prior version (i.e., historical data sets for SSA and NCHS currently do not include data for 2020 as explained in the Executive Summary of the MIM-2021-v3 Report<sup>5</sup>):

- Population mortality rates published by the Social Security Administration (SSA) going back to 1982.
- Population mortality rates developed from National Center for Health Statistics (NCHS) death counts starting in 1982 and U.S. census data going back to 1980.
- A variety of subsets of the NCHS national population data set, split into ranges (quintiles and deciles) based on estimated socioeconomic categories<sup>6</sup>. These subsets can be selected individually, or blended in combination with other subsets to more closely approximate the anticipated mortality experience of the covered population to which the resulting mortality improvement rates are to be applied.
- An additional group of “static” NCHS quintile and decile data subsets. These quintiles and deciles have been based on socioeconomic categories fixed as of 2000<sup>7</sup>, as contrasted to the subsets described in the immediately preceding bullet, which reflect changes in socioeconomic deciles as they varied over time.

Socioeconomic category 1 represents individuals living in the lowest socioeconomic scored quintile/decile counties in the U.S., and categories 5 (for quintile) and 10 (for decile) represent individuals living in the highest socioeconomic scored counties in the U.S. Although there is no option for combining quintile data sets with decile data sets, such a combination can still be accomplished by selecting the desired combination of decile subsets.

Figure 3 displays the opening input cells<sup>8</sup> for Step 2 when one of the two national-level population data sets (options 1 or 2) has been selected. In these cases, the quintile/decile “weight” cells will remain blacked out.

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<sup>5</sup> Society of Actuaries Research Institute. 2022. “Mortality Improvement Model, MIM-2021-v3” <https://www.soa.org/resources/research-reports/2022/mortality-improvement-model/>

<sup>6</sup> 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/>.

<sup>7</sup> Since official U.S. census data was not available as of 1982, the decennial census as of 1980 was used to establish socioeconomic categories for this group of static NCHS data sets.

<sup>8</sup> Throughout the MIM-2021-v3 Application Tool, input/parameter cells are identified with a yellow background.



Figure 3  
MIM-2021-v3 APPLICATION TOOL STEP 2 INPUT CELLS

## Step 2

Select the dataset from which improvement rates will be calculated

- 1** Dataset for determining rates of mortality improvement
- 1 = SSA (national-level)
  - 2 = NCHS, national-level (no quintiles or deciles; rather, all data merged together)
  - 3 = NCHS, quintiles
  - 4 = NCHS, deciles
  - 5 = NCHS, static quintiles based on 2000 socioeconomic data
  - 6 = NCHS, static deciles based on 2000 socioeconomic data

Weight Placed on Each Quintile or Decile of NCHS Data (for options 3 through 6 above)

1	2	3	4	5	6	7	8	9	10	Total

1 = lowest socioeconomic decile; 10 = highest decile (5 = highest quintile)

If the user opts for one of the quintile or decile data sets (options 3 through 6), the appropriate number of slots become open for weighting percentages. Figures 4 and 5 show examples for Option 3 (NCHS quintiles) and Option 4 (NCHS deciles), respectively:

Figure 4  
MIM-2021-v3 APPLICATION TOOL STEP 2 INPUT CELLS – QUINTILE EXAMPLE

## Step 2

Select the dataset from which improvement rates will be calculated

- 3** Dataset for determining rates of mortality improvement
- 1 = SSA (national-level)
  - 2 = NCHS, national-level (no quintiles or deciles; rather, all data merged together)
  - 3 = NCHS, quintiles
  - 4 = NCHS, deciles
  - 5 = NCHS, static quintiles based on 2000 socioeconomic data
  - 6 = NCHS, static deciles based on 2000 socioeconomic data

Weight Placed on Each Quintile or Decile of NCHS Data (for options 3 through 6 above)

1	2	3	4	5	6	7	8	9	10	Total
										0%

1 = lowest socioeconomic decile; 10 = highest decile (5 = highest quintile)

Figure 5  
MIM-2021-v3 APPLICATION TOOL STEP 2 INPUT CELLS – DECILE EXAMPLE

## Step 2

Select the dataset from which improvement rates will be calculated

- 4 Dataset for determining rates of mortality improvement**
- 1 = SSA (national-level)
  - 2 = NCHS, national-level (no quintiles or deciles; rather, all data merged together)
  - 3 = NCHS, quintiles
  - 4 = NCHS, deciles
  - 5 = NCHS, static quintiles based on 2000 socioeconomic data
  - 6 = NCHS, static deciles based on 2000 socioeconomic data

Weight Placed on Each Quintile or Decile of NCHS Data (for options 3 through 6 above)

1	2	3	4	5	6	7	8	9	10	Total
										0%

1 = lowest socioeconomic decile; 10 = highest decile (5 = highest quintile)

Note in each of the options 3 through 6, the “Total” cell must equal exactly 100% before proceeding to subsequent steps.

In addition to the dataset for determining rates of mortality improvement, the user must enter in cell E27 either the order-2 or order-3 Whittaker-Henderson graduation method used to smooth the two-dimensional historical mortality data. Order-2 and order-3 refers to the degree of the finite difference operators used in the smoothness components of the two-dimensional Whittaker-Henderson objective function.

### Select order of Whittaker-Henderson smoothing

WH smoothing is applied to logged mortality rates. The resulting smoothed rates are then anti-logged, thereby producing smoothed mortality rates which, in turn, are used to calculate rates of mortality improvement.

As discussed in SOA’s Retirement Plans Experience Committee (RPEC’s Mortality Improvement Scale MP-2021 report<sup>9</sup>, Scale MP-2021 and its predecessors have been based on historical U.S. population mortality rates that have been graduated with the order-3 Whittaker-Henderson smoothing. Scale O2-2021 is based on order-2 Whittaker-Henderson smoothing. In 2018, RPEC began producing an alternative version of the RPEC\_2014 model, denoted the RPEC\_O2 model, that is based on order-2 rather than order-3 Whittaker-Henderson graduation. RPEC’s research indicated that, relative to the order-3 model, the order-2 model tends to yield greater year-over-year stability in retirement program liability calculations. However, the

<sup>9</sup> See Society of Actuaries. 2021. “Mortality Improvement Scale MP-2021”, <https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/>

order-2 methodology will likely be less sensitive to emerging changes in U.S. mortality patterns and generally produces a weaker fit when compared to ungraduated historical mortality improvement rates.

### STEP 3: SPECIFY THE INTERPOLATION STRUCTURE

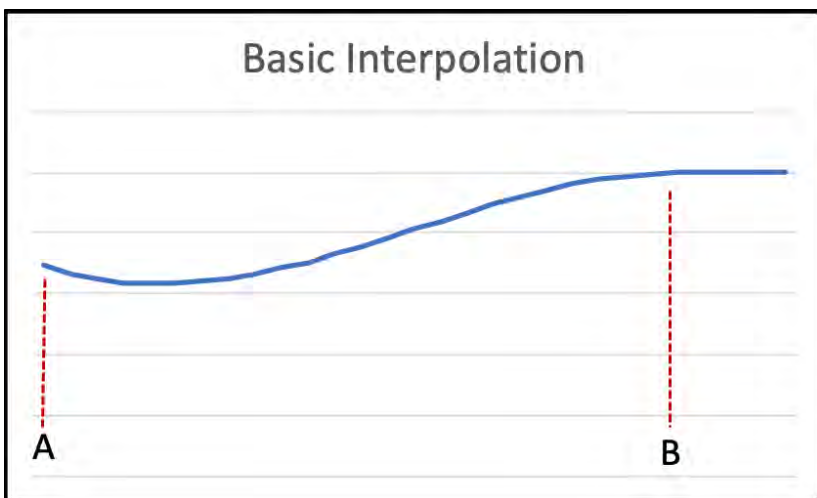
#### TYPES OF INTERPOLATION STRUCTURES

There are two types of interpolation structures for the transition periods<sup>10</sup>: Basic and Advanced.

##### *Basic Interpolation*

The Basic Interpolation structures requires the input of two years (separately for each of the horizontal and diagonal projections):

- Year A: The year from the selected historical data set from which the future mortality improvement rates are generated (also referred to as the “jumping-off” point); and
- Year B: The first year in which the assumed long-term mortality improvement rates are attained.



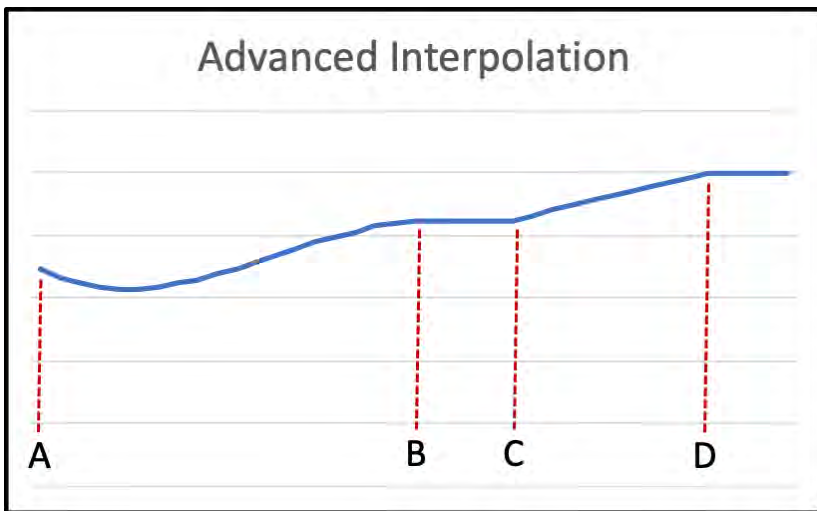
The Basic Interpolation curve is a cubic polynomial passing through two MI rates (at years A and B) and matching two specified slopes at those times. Additional information about these cubic polynomials, including their underlying formulae, can be found in Appendix A of the MIM-2021-v2 Report.

##### *Advanced Interpolation*

The Advanced Interpolation structures allow the user to include a set of intermediate-term MI rates at some time between year A and the first year in which assumed long-term mortality improvement rates are attained. Four points in time (separately for each of the period and cohort projections) are required under this structure:

<sup>10</sup> A “transition period” starts in the first year of projection and ends in the year in which the assumed long-term rates are first attained.

- Year A: Same as Year A above;
- Year B: The year in which the assumed intermediate-term improvement rates are first attained;
- Year C: The year (on or after Year B) through which the intermediate-term improvement rates remain constant before converging linearly to the assumed long-term rates in Year D; and
- Year D: The first year in which the assumed long-term mortality improvement rates are attained.



Between years A and B, the Advanced Interpolation curve uses the same type of cubic polynomials employed in the Basic Interpolation structure. The interpolation curve remains flat for the period between B and C, where it starts a linear convergence to the assumed long-term rates in year D. If no flat period is desired, the user should set year C equal to year B.

**INPUTS TO STEP 3**

The user must first select either the Basic or Advanced interpolation structure in cell Q17. If the Basic structure is selected, the user must enter two “year B” values, one each determining the duration of the interpolation periods of the horizontal and diagonal projections.<sup>11</sup>

Figure 6 displays an illustrative example of inputs for the first part of Step 3 when the Basic interpolation structure has been selected. Note that the cells corresponding to years C and D, which are not part of the Basic structure, have been blacked out.

**Figure 6**  
**MIM-2021-v3 APPLICATION TOOL STEP 3 INPUT CELLS – BASIC INTERPOLATION ENTRIES**

Specify the time points between which MIM will interpolate				
Time Point	A	B	C	D
By Age	2017	2027		
By Cohort		2037		

<sup>11</sup> The two “year B” assumptions for the horizontal and diagonal projections can be the same.

The Basic Interpolation entries in the preceding display can be interpreted as follows:

- The jumping-off year for the projection is 2017. This year must be selected from the historical data set and must be the same for both the age and cohort projections.
- The first year the assumed long-term MI rates are attained is 2027 for the age (horizontal) projection and 2037 for the cohort (diagonal) projection.
- Two sets of interpolated MI rates are generated by means of two families of cubic polynomials, one set in the horizontal direction (between 2017 and 2027) and a second set in the diagonal direction (between 2017 and 2037).
- All MI rates after 2037 are equal to the corresponding MI rate in 2037.

Figure 7 displays an illustrative example of a projection using the Advanced Interpolation structure:

Figure 7

MIM-2021-v3 APPLICATION TOOL STEP 3 INPUT CELLS – ADVANCED INTERPOLATION ENTRIES

Specify the time points between which MIM will interpolate				
Time Point	A	B	C	D
By Age	2017	2027	2040	2060
By Cohort	2017	2037	2050	2060

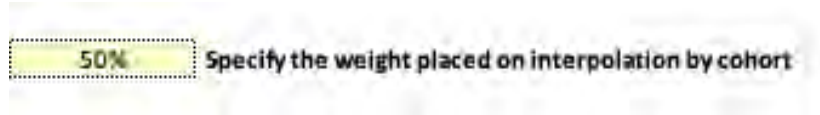
Note: ascending order required: year A < year B < year C < year D

The Advanced Interpolation entries in Figure 7 can be interpreted as follows:

- The jumping-off year for the projection is 2017.
- The MI rates in the age-based projection attain the assumed intermediate-term values in 2027 (by means of a family of cubic polynomials) and remain fixed at that level until 2040, at which point they converge linearly to the assumed long-term rates in 2060.
- The MI rates in the cohort-based projection attain the assumed intermediate-term values in 2037 (by means of a family of cubic polynomials) and remain fixed at that level until 2050, at which point they immediately start to converge linearly to the assumed long-term rates in 2060.
- All MI rates after 2060 are equal to the corresponding MI rate in 2060.

The years entered from left to right in Step 3 must be strictly increasing, with the possible exception that years B and C can be the same if no interim flat period is desired.

The final required parameter in Step 3 determines the relative weighting of the individual horizontal and diagonal projections in the final results. The user can enter any value from 0% to 100% in cell Q38.



Note that entering 0% produces a horizontal-only projection that could deemphasize any future “cohort” effects and entering 100% produces a diagonal-only projection that could deemphasize any future “period” effects.

#### STEP 4A: SET MORTALITY IMPROVEMENT RATES AT “YEAR A”

In Step 4a the user selects assumptions about:

1. The years of the historical mortality data set from which the starting values of the MIM-2021-v3 projection are calculated;
2. The years of the historical mortality data set from which the starting slopes of the MIM-2021-v3 interpolating cubic polynomials are calculated; and
3. Constraints on how large the initial slopes are allowed to be in absolute value.

Before delving into the details of the Step 4a entries, it is important to keep in mind that all of the historical mortality improvement experience referenced in this Step has been previously smoothed using the 2D Whittaker-Henderson methodology described in Appendix A of the MIM-2021-v2 Report. So, for example, an assumption based on a single year of experience does not reflect two “raw” values, but rather two values that have been smoothed in both the age and calendar year directions.

Figure 8 displays the first section of the input cells for Step 4a.

**Figure 8**

#### MIM-2021-v3 APPLICATION TOOL STEP 4A INPUT CELLS: PERIOD FOR JUMPING-OFF VALUES AND SLOPES

Historical Period Across Which to Compute Improvement Rates and Slopes at Time Point A		
	Start	End
For setting improvement rates at time point A	2016	2017
For setting slopes of improvement rates at time point A	2016	2017

The first row of inputs determines the years of smoothed experience used to calculate the starting gender-/age-specific MI rates at the beginning of the projection period. Since short-term mortality improvement rates should be based on recent experience, these years should be close to, but not beyond, year A selected in Step 3<sup>12</sup>. The opening values of 2016 and 2017, for example, mean the MI values at point A will be based on the change in smoothed mortality rates between those two years. If the two selected years are further than one year apart, mortality changes are calculated using geometric averages. These inputs determine the opening MI values for both the horizontal and diagonal projections.

The second row of inputs deal with the initial slope of the interpolating cubic polynomial at point A. For example, the values of 2016 and 2017 in the second row mean the initial slope of the interpolating cubic is calculated based on the change in MI values between those two years. (This is in contrast to the entries in the first row of Step 4a, which are calculated based on the change of smoothed mortality rates.)

The next set of inputs allows the user to add constraints on how steep the jumping-off slopes of the interpolating cubic polynomials can get in absolute value. The illustrative example shown in Figure 9 below limits the initial slopes in the horizontal projection to 0.3% in absolute value, and forces all slopes in the diagonal projection to be 0.0%.

<sup>12</sup> The potential implications of selecting years further away from year A can be found in Considerations For Selection Certain Model Assumptions section of this document.

Figure 9

## MIM-2021-v3 APPLICATION TOOL STEP 4A INPUT CELLS: JUMPING-OFF SLOPE CONSTRAINTS

Constraints on Improvement Rate Slopes at Time Point A	
Maximum absolute value of horizontal (period) slope	0.30%
Maximum absolute value of diagonal (cohort) slope	0.00%

Although there is some logic in attempting to pick up some of the recent trend in near-term MI rates by reflecting some or all of the historical slope at point A, analysis performed by RPEC<sup>13</sup> indicated that year-over-year volatility of the MI rates tends to be mitigated by assuming a jumping-off slope of zero for both the horizontal and diagonal projections. This can be achieved by entering the value of zero in cells Y30 and Y31. Alternatively, users can reflect some limited degree of initial MI slope by entering some small, non-zero value in those cells<sup>14</sup>.

**STEP 4B: LONG-TERM MORTALITY RATE ASSUMPTIONS**

Users who have selected the Basic interpolation structure must include assumed long-term rates at year B, and users who have selected the Advanced interpolation structure must include assumed intermediate-term rates at year B and assumed long-term rates at year D. In both cases, users have two options for selecting those required gender-/age-specific mortality improvement rates:

- By selecting option 1 in cell AC17, the user is required to enter the assumed MI rates in the darker yellow-shaded cells in columns AN and AO (under the Basic structure) or columns AN through AQ (under the Advanced structure) in Step 4c.
- The required MI rates can be calculated as the geometric average across a selected period of time from the historical mortality data set selected in Step 2.

Since long-term rates are conceptually expected to be based on “expert opinion,” it is anticipated many users will decide to opt for the first approach above and enter those rates manually, rather than being over-reliant on some period of past mortality experience.

If the user decides to enter these assumed values manually (Option 1 in cell AC17), the remaining four input cells in Step 4b will be blacked out. Figure 10 shows an illustrative example of inputs under the Advanced interpolation structure.

Figure 10

## MIM-2021-v3 APPLICATION TOOL STEP 4B INPUT CELLS

Historical Period Across Which to Compute Improvement Rates at Times B and D		
	Start	End
For setting improvement rates at time point B	1995	2015
For setting improvement rates at time point D	1985	2017

<sup>13</sup> See Society of Actuaries. 2016. “Mortality Improvement Scale MP-2016”, Section 4.2  
<https://www.soa.org/globalassets/assets/files/research/exp-study/mortality-improvement-scale-mp-2016.pdf>

<sup>14</sup> A warning message will be pop up if the user selects values greater than 0.01 in these cells.



Using these parameters, the assumed gender-/age-specific mortality improvement rates at years B and D will be set equal to the geometric average of those rates over the period 1995 through 2015, and the period 1985 through 2017, respectively. Given the volatility of MI rates, it is suggested that users who choose this option select averaging periods of at least 20 years.

#### STEP 4C: CALCULATION OF MORTALITY IMPROVEMENT RATES AT KEY POINTS IN TIME

Step 4c serves a number of important functions within the Application Tool:

- Clicking the blue button (see Figure 11) initiates the calculation of mortality improvement rates at certain key points in time based on the parameters (either prepopulated or entered individually) in Steps 2 through 4b. If any of those parameters are subsequently modified, the user will need to recalculate these mortality improvement values by clicking the blue button again before proceeding.
- For users who have selected manual entry for one or more assumed long-term mortality improvement rates in Step 4b, darker yellow-shaded cells will appear in columns AN and AO under the Basic structure and -- depending on the selection made in cell AC17 -- in certain columns AN through AQ under the Advanced structure. Each of the darker yellow-shaded cells must be filled in, even those the user wants to set equal to zero.
- The two-dimensional array of gender-/age-specific values starting in cell AL24 and ending in cell AU124, summarize the calculated mortality improvement rates and slopes in the jumping-off year A, and the assumed mortality improvement at year B (under the Basic structure) and at years B and D (under the Advanced structure.) All of the values in this array should be carefully reviewed and modified, if necessary, before proceeding to the next steps.

Figure 11

MIM-2021-v3 APPLICATION TOOL STEP 4C CALCULATION MACRO

**Calculate the Light Yellow Cells Below**  
(dark yellow cells must be entered manually as indicated by your selection in cell AC17)

#### STEP 5: OPTIONAL FACTORS FOR MODELLING MORTALITY SHOCKS

Step 5 allows the user to input adjustment factors in columns AX through BO to mortality rates to model the anticipated effects of near-term mortality shocks, such as the COVID-19 pandemic. Users who wish to include these adjustment factors need to first select “Yes” in cell AX17.

It is important to note that in contrast to the ability to modify mortality improvement rates in Step 4c, the factors described in this Step 5 are applied to the underlying mortality rates themselves. These factors, which can be positive as well as negative, should be entered on a select-and-ultimate basis, with individual values specified by gender and age (20 through 120) for each individual calendar year from 2020 through 2027. Any non-zero factors entered in the 2028+ columns will be applied to mortality rates in all calendar years 2028 and beyond.

Figure 12 shows a sample (females age 20-35) of input columns for the entry of “mortality shock” factors where the user has included a flat 15% load (for all ages) in calendar year 2020, a flat 10% load for 2021

and a flat 5% load for 2022. These entries mean that mortality rates are assumed to be 15%, 10% and 5% higher than what they would have been without the impact of COVID-19 in 2020, 2021 and 2022, respectively, and that mortality rates in all years starting with 2023 will revert to what they would have been without any adjustment. As a result, in this example, year-over-year mortality improvement rates become very negative in 2020, and then recover strongly in years 2021, 2022, and 2023. The mortality improvement rates starting in 2024 return to a more normal pattern.

**Figure 12**  
MIM-2021-v2 APPLICATION TOOL STEP 5: ILLUSTRATIVE EXAMPLE

		Female								
		2020	2021	2022	2023	2024	2025	2026	2027	2028+
<b>20</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>21</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>22</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>23</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>24</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>25</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>26</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>27</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>28</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>29</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>30</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>31</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>32</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>33</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>34</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<b>35</b>		15.00%	10.00%	5.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Any non-zero adjustment factors included in the 2028+ columns will be applied to all projected mortality rates for that gender/age combination in 2028 and beyond. Note that mortality improvement rates for 2029 and beyond will not change even though the underlying projected mortality rates have changed. The reason is because each gender-/age-specific adjustment factor is a constant multiplier to mortality rates for all years 2028 and after, which does not affect the year-over-year ratio of those adjusted rates.

## STEP 6: OPTIONAL BASE YEAR MORTALITY TABLE

Users have the option in Step 6 to enter a set of base mortality rates<sup>15</sup> different than the historical rates selected in Step 2. It is important to note that these user-supplied mortality rates will not be used to generate any historical or future mortality improvement rates. Rather, they will be used (in lieu of the rates selected in Step 2) in the calculation of projected mortality rate and life expectancy output described in Step 7.

Users who wish to reflect these optional mortality rates in their output must (1) select “Yes” in cell BS17, (2) enter the base year of the table they want to use, and (3) enter the desired set of gender-/age-specific mortality rates in columns BR and BS. Figure 13 shows an illustrative portion of those entries.

Figure 13

### MIM-2021-v3 APPLICATION TOOL STEP 6: ILLUSTRATIVE SAMPLE ENTRIES

Use the table below?	Yes	
Base year	2012	
	Mortality Table For the Base Year	
	Female	Male
20	0.00014	0.00043
21	0.00014	0.00044
22	0.00015	0.00043
23	0.00017	0.00043
24	0.00018	0.00043
25	0.00018	0.00042
26	0.00018	0.00042
27	0.00018	0.00042
28	0.00018	0.00042
29	0.00019	0.00042
30	0.00019	0.00042

All output dealing with historical/projected mortality rates and life expectancy values (described in the following Step 7) will reflect this alternate set of base mortality rates, but still projected using the mortality improvement rates calculated using the historical mortality dataset selected in step 2.

For example, assume that (1) the historical SSA mortality rate database (option = 1) was selected in Step 1 and (2) the Pri-2012 mortality table was entered in Step 6. The annual rates of mortality improvement generated by selecting option “1” in cell BV18 would be based solely on the historical SSA mortality rates, but all of the other output options available in Step 7 would be calculated using the Pri-2012 base mortality rates projected into the future with the (SSA-based) MI rates.

<sup>15</sup> 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.

## STEP 7: SELECT AND PRODUCE OUTPUT

Step 7 is where the user selects and produces the desired type and form of output; see Figure 14 for illustrative input values.

Figure 14

MIM-2021-v2 APPLICATION TOOL STEP 7 INPUTS

### Step 7 Select and Produce Outputs

Use the parameters below to specify the type of output you wish to produce.  
After setting the parameters, press "Run the Model"

1983	Enter the first year for which you wish to produce output
2037	Enter the last year for which you wish to produce output
4	Round outputs to this many decimals
1	Select form of output: 1 = annual rates of mortality improvement 2 = historical and projected mortality rates 3 = mortality rate in a particular year, divided by mortality rate in the "jumping off" year in cell R27 4 = period life expectancy by year (i.e. applying no mortality improvement rates after the year of calculation) 5 = cohort life expectancy by year (i.e. applying mortality improvement rates after the year of calculation) 6 = like metric 4, but the change in life expectancy measured against the first year of output 7 = like metric 5, but the change in life expectancy measured against the first year of output

**Run the Model**

The first three entries are self-explanatory. In the fourth entry, the user specifies which gender-specific set of results (two-dimensional, age and calendar year) should be displayed in the results section of the Tool:

1. Annual mortality improvement rates
2. Historical and projected mortality rates
3. The ratio of calculated mortality rates to the corresponding rates in the year in cell R27
4. Period life expectancies; i.e., applying no mortality improvement rates after the year of calculation
5. Cohort life expectancies; i.e., applying mortality improvement rates after the year of calculation
6. The change in period life expectancies measured against the first year of output
7. The change in cohort life expectancies measured against the first year of output

The MIM-2021-v3 Application Tool results are then generated by pressing the "Run the Model" button.

## SUMMARY OF RESULTS

The selected gender-/age-/year-specific values produced by the Tool start in column BY of the “1. Model” tab. The summary section also includes two buttons that generate graphics designed to help the user analyze the results (Figure 15).

**Figure 15**

### MIM-2021-v3 APPLICATION TOOL SUMMARY OF RESULTS BUTTONS



By clicking either of these buttons, the user is sent to the appropriate tab, either “2. Heat Map” or “3. Graph.” More discussion of these two tabs is included in the next section.

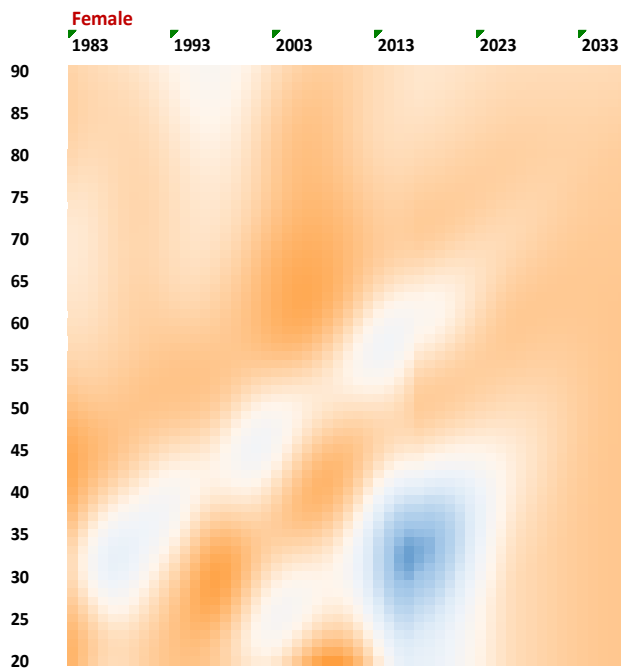
## Section 3: Tabs 2 through 5

### TAB 2: HEAT MAP

Heat maps can be generated for all of the result options described in Step 5 except for options 4 and 5, the two arrays of life expectancies. Heat maps can be generated for options 6 and 7, the arrays of changes in life expectancies. An example of a heat map showing female mortality improvement rates with order-3 graduation for ages 20 through 90 covering the period 1983 through 2037 is shown in Figure 16.

Figure 16

#### MIM-2021-v3 APPLICATION TOOL HEAT MAP EXAMPLE



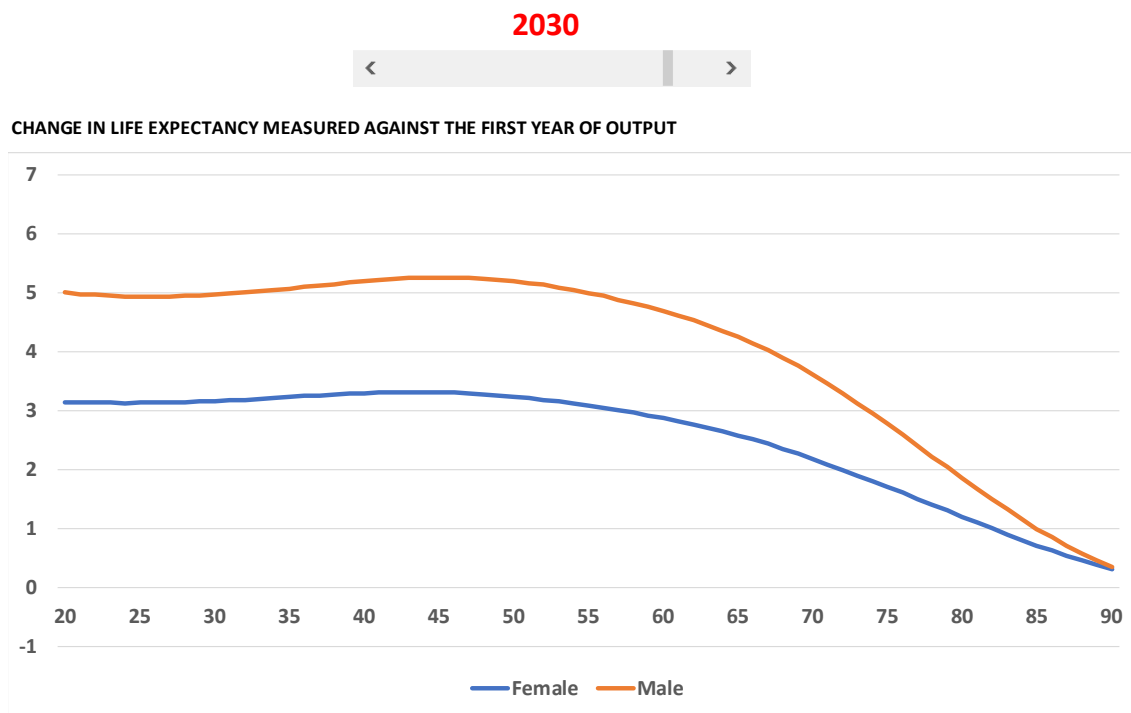
A table with the color-coded legends for each of the possible heat map results is included in the upper left portion of Tab 2. Certain ranges of values and associated colors<sup>16</sup> have been pre-entered into the heat map legend, but the user can modify these if desired. Users who wish to change the color palette must first select “User-Specified” in cell I13. Next, the user must enter their desired color scheme in range C11:R11 by adjusting the background color of each cell (for each cell, press “format” on the Excel menu, followed by “fill,” and then select the desired color). Additionally, with the parameters in C7:R10, a user may adjust the numerical ranges that are mapped to each color. Note that each value in C7:R10 is the upper boundary of a numerical “bucket,” and these boundaries must be entered in ascending order from left to right. All model outputs that exceed the boundary values shown in the final bucket (in range R7:R10) will be mapped to the color of cell R11. Any time the color scheme is changed, or the numerical buckets are changed, the user must re-run the model on Tab 1 for the new colors to take effect on the heat map(s).

<sup>16</sup> The default heat map color palette is the same as that used in the Scale MP-2021 Report.

**TAB 3: GRAPH**

A dynamic graph can be generated for all of the result options described in Step 5. When “Run Dynamic Graph” is pressed, the graph loops dynamically from the first year of output to the final year of output. For each year, the data is briefly displayed on the graph; then the graph cycles onward to the next year. Figure 17 displays the format of the graphs on Tab 3, in this case showing an example of the projected increase in period life expectancies between 2000 and 2030 for ages 20 through 90.

**Figure 17**  
MIM-2021-v3 APPLICATION TOOL TAB 3 GRAPH FORMAT



The speed of this dynamic process can be adjusted using the parameter in cell B11 that represents the number of seconds between “slides” or years. Increasing this parameter will slow the graph down, while decreasing the parameter has the opposite effect. The permissible range of values for B11 is from 0 to 5 (seconds between slides).

Alternatively, a user may step through the data manually using the slider positioned just above the graph. Slide to the right to increase the year displayed on the graph, and slide to the left to decrease the year.

**TABS 4, 5 AND 6**

Tab 4 contains the unsmoothed mortality rate data for each of the six data sets described earlier (see the six data options shown in Step 1 of the modeling process). Tab 5 and Tab 6 contain the corresponding mortality rates in its smoothed form with Tab 5 reflecting order-2 Whittaker-Henderson graduation and Tab 6 order – 3 Whittaker Henderson smoothing. On each of these three tabs, columns B and C indicate the data set, column D indicates the year of data, and column E indicates the gender (“m” = male, “f” = female). Columns G through DM show mortality rates by age. The data set acronyms in column B are defined on the Contents tab in range C21:E26.

While the unsmoothed data runs from ages 0 to 110, the smoothed data runs only from 15 to 97. This asymmetry arises because the smoothing process [described in Appendix A of the MIM-2021-v2 Report] was restricted to ages 15 to 97.

In the case of the SSA data set, “unsmoothed” is not an entirely accurate description of the data. In fact, the data was smoothed by the Social Security Administration using a one-dimensional process in which each year of data was smoothed separately. This data, in turn, was smoothed by the Advisory Group using a two-dimensional smoothing process (by calendar year and age), thus creating the “smoothed” SSA data shown on Tab 4.



## Section 4: Considerations For Selecting Certain Model Assumptions

Much of the flexibility of MIM-2021-v3 derives from the user's ability to select various parameters in connection with the interpolating curves. This section of the User Guide provides insights in connection with these important model assumptions.

### ASSUMPTIONS REGARDING THE YEARS SELECTED FOR THE JUMPING-OFF M RATES

In Step 4a of Tab 1, it is recommended the end year for selecting the historical period used to generate the jumping-off MI rates and slopes (cells Z20 and Z21, respectively) be the same as year A. The rationale for this recommendation is, otherwise, significant MI rate discontinuities can occur at the jumping-off year.

As an illustration, Figure 18 is a heat map showing the MP-2021 MI rates for males, which has a jumping-off year of 2017 (highlighted) and which has jumping-off values based on the smoothed mortality rates between 2016 and 2017. Figure 19 is the heat map showing how the projected rates would change if the jumping-off values were based on the smoothed mortality rates between 2005 and 2006.

Figure 18

#### MP-2021 MI MALE RATES

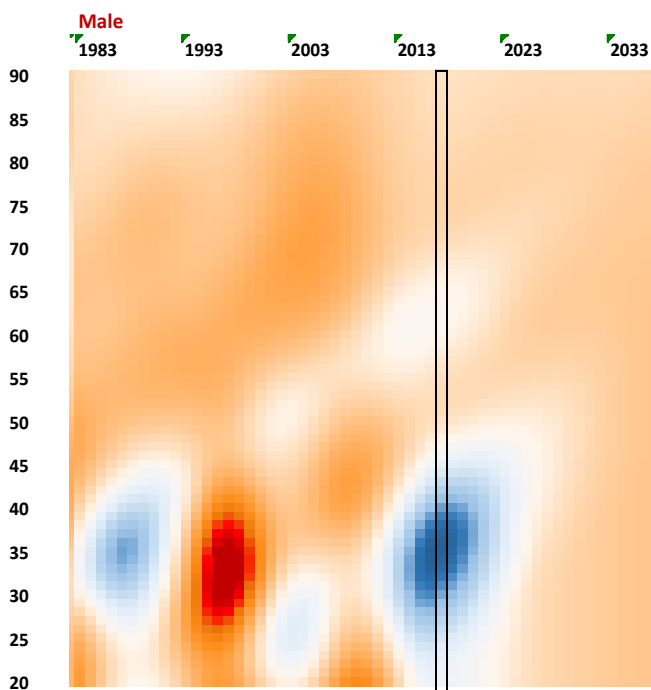
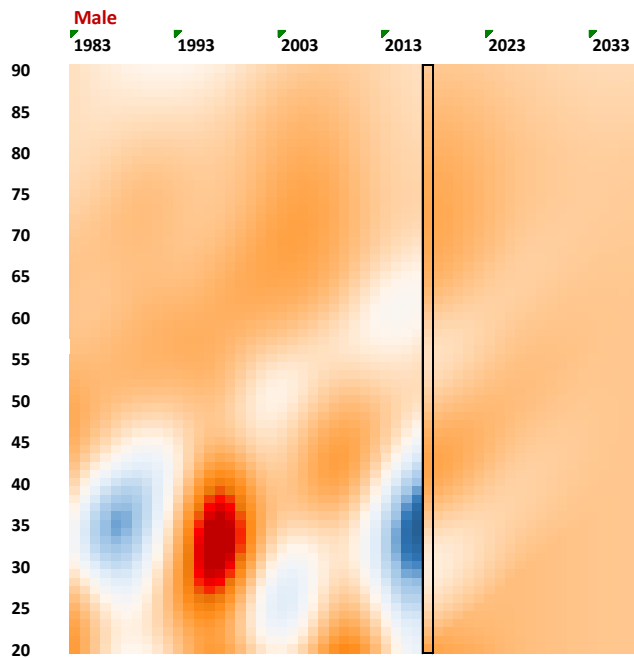


Figure 19

## PROJECTED MI MALE RATES BASED ON THE SMOOTHED MORTALITY RATES BETWEEN 2006 AND 2007

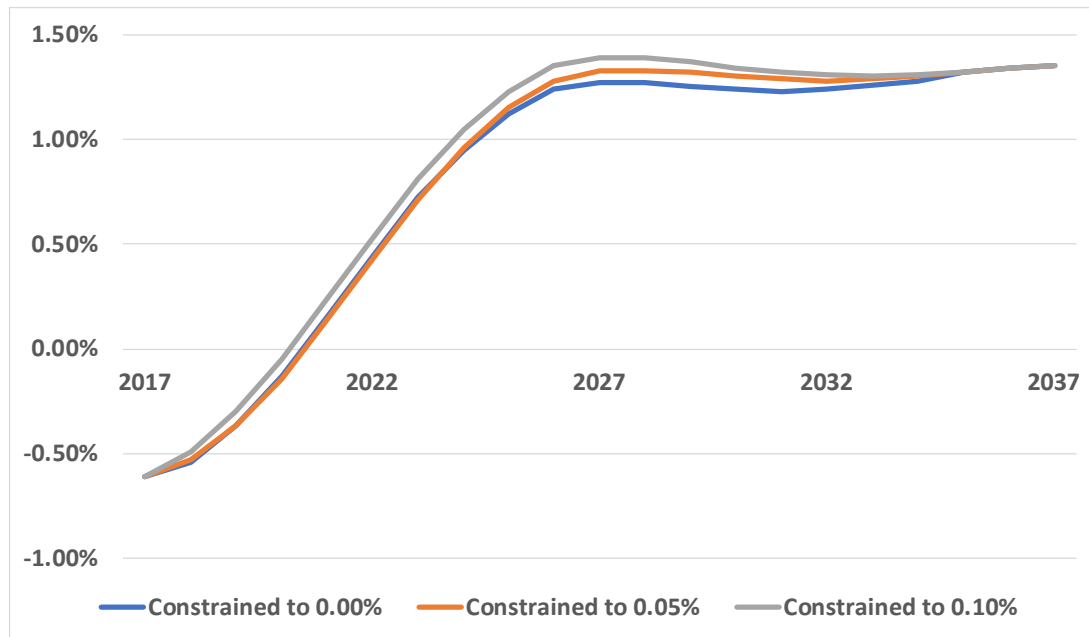


Notice how the 2017 rates in Figure 18 mirror the mortality improvement rates from ten years prior, and how that creates a discontinuity starting in the jumping-off year.

#### ASSUMPTIONS REGARDING THE JUMPING-OFF SLOPE CONSTRAINTS

The parameters in Step 4a of Tab 1 also include constraints on the absolute value of the slopes of the interpolating cubic polynomials at year A. Although it might seem logical to anticipate that some degree of the most recent historical MI slope would continue into the near-term future, back-testing analysis performed by RPEC indicated reflecting those slopes tends to increase year-over-year volatility in the MP scales. Figure 20 illustrates an example of the impact of limiting the absolute values of the slopes in 2017 to 0.00%, 0.05%, and 0.10%, respectively, on projected age-60 MI rates for females.

**Figure 20**  
**IMPACT OF LIMITING THE ABSOLUTE VALUES OF THE SLOPES IN 2017**



As can be seen in this example, the decision of whether or not to limit the slopes at the jumping-off year can have significant implications throughout for the entire cubic polynomial convergence period, which could influence the year-over-year stability of MIM-2021-v3 results.

### ASSUMPTION REGARDING WEIGHT PLACED ON COHORT PROJECTION

In Step 3 of Tab 1, the user must enter in cell Q38 the desired balance between the horizontal projection along individual ages and the diagonal projection along individual year-of-birth cohorts. An entry of 0% means the set of MI rates generated by the spreadsheet will be based entirely on the horizontal projection, whereas an entry of 100% will produce MI rates based entirely on the diagonal projection.

The following illustrates of the impact this weighting assumption has on projected MI rates, based on the following example:

- Historical mortality data set: National-level NCHS for females, with order-3 graduation
- Jumping-off year: 2017 (highlighted in the heat maps that follow)
- Jumping-off values: Determined between years 2016 and 2017
- Jumping-off slopes: 0.0%
- Interpolation Structure: Advanced
  - Intermediate MI rates: 1.75% for all ages; attained 2037 and continuing through 2042
  - Long-term MI rates: 1.00% for all ages; attained 2052

The only differences in the three MI heat maps shown in Figures 21, 22, and 23 are the assumptions selected for weighting the cohort projection; 0%, 50%, and 100%, respectively.

Figure 21  
WEIGHT PLACED ON COHORT PROJECTION = 0%

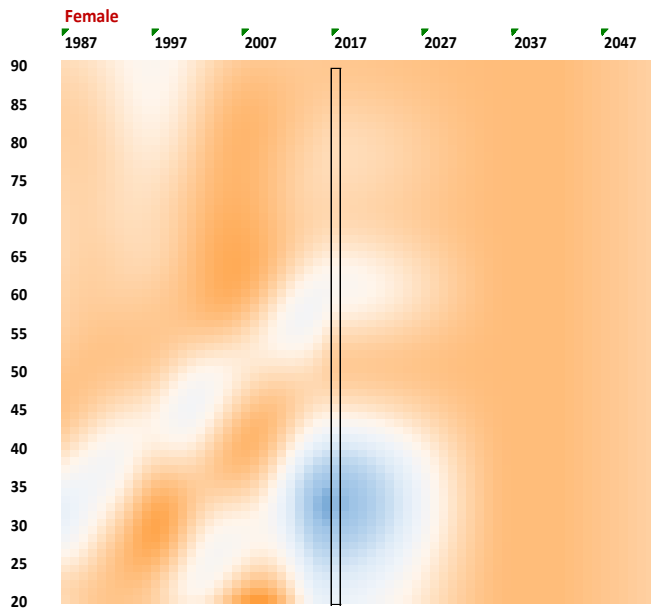
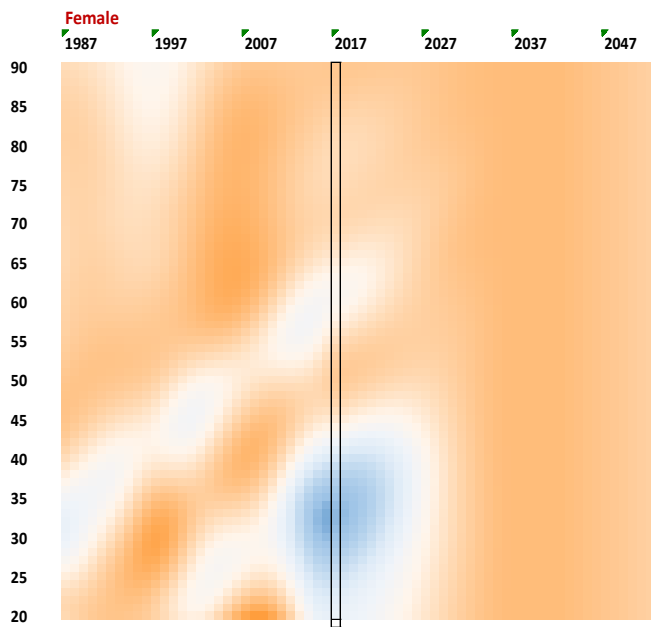
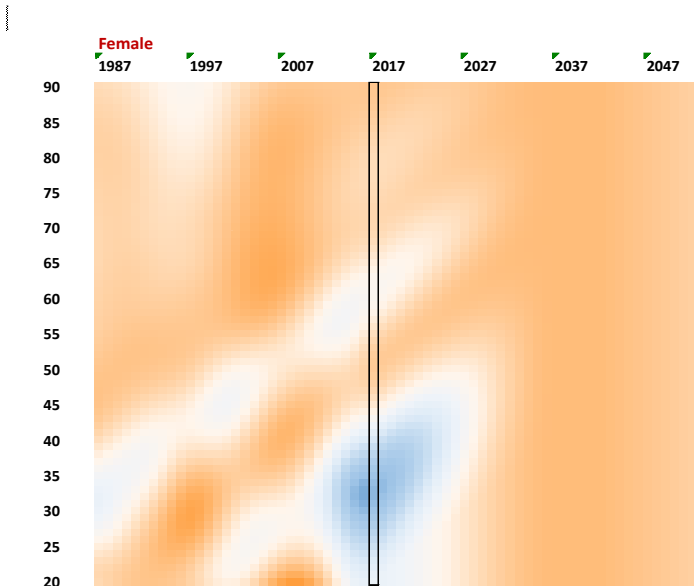


Figure 22  
WEIGHT PLACED ON COHORT PROJECTION = 50%



**Figure 23**  
WEIGHT PLACED ON COHORT PROJECTION = 100%



Section 4.4 of the MP-2014 Report<sup>17</sup> describes the reasoning RPEC used in arriving at its decision to base all of its MP scales to date (2014 through 2021) on a 50%/50% blend of the horizontal and diagonal projections. In particular, the RPEC highlighted the fact that year-of-birth effects for certain age cohorts have persisted in the U.S. population for many decades, and hence not reflecting some continuation of those into the future would be inappropriate.

On the other hand, it was RPEC's opinion the heat maps based on the 100% diagonal interpolations could potentially overemphasize future cohort effects. After reviewing a number of weighting combinations, RPEC concluded a model based on the simple average of the 100% horizontal and the 100% diagonal interpolations produced an appropriate balance of anticipated age/period and cohort effects for many retirement-related applications.

Since other mortality data sets could produce historical horizontal and diagonal MI patterns different from those produced by the national-level SSA data set used by RPEC, users should not necessarily assume any single blending percentage (e.g., 50%/50%) will be appropriate for all applications.

<sup>17</sup> See Society of Actuaries. 2014. "Mortality Improvement Scale MP-2014", Section 4.4  
<https://www.soa.org/493805/globalassets/assets/files/research/exp-study/research-2014-mp-report.pdf>

## ASSUMPTIONS REGARDING THE LENGTH OF THE HORIZONTAL AND DIAGONAL TRANSITION PERIODS

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.

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.



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## Section 5: Acknowledgments

The Society of Actuaries would like to thank the MIM Advisory Group, for their support, guidance, direction and feedback throughout the project.

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