



Mortality
and Longevity

MIM-2021-v2 Application Tool User Guide

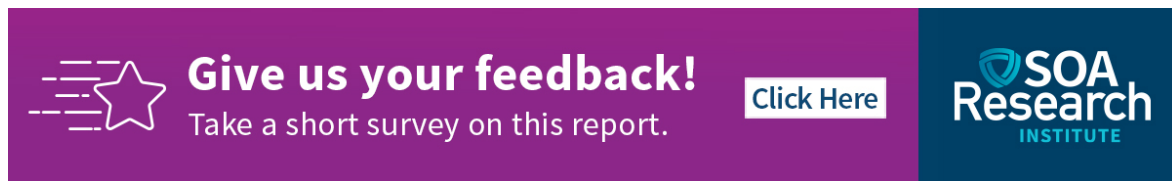






MIM-2021-v2 Application Tool User Guide

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MIM-2021-v2 Application Tool User Guide

Section 1: Introduction

Two Excel-based tools (and accompanying user guides) were released in connection with the MIM-2021-v2 Report¹. The MIM-2021-v2 Data Analysis Tool was created to help users compare and analyze various historical U.S. mortality data sets. The MIM-2021-v2 Application Tool enables users to develop their own set of mortality improvement rates (or in some cases deterioration) under the MIM-2021-v2 framework. This document is a step-by-step guide for the MIM-2021-v2 Application Tool.

This is the second version of the Application Tool released in 2021. 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.

The MIM-2021-v2 Application Tool first requires the user to select (1) a set of mortality rates as the historical basis for the projection and (2) the desired degree of smoothing to be used on those raw rates. The graduated historical mortality rates are used to develop a pattern of mortality improvement prior to the projection period, as well as establishing the starting values for short-term mortality improvement rates.

Then the user must enter a number of inputs into the underlying model related to the assumed long-term level of mortality improvement:

- Certain key dates in the future, including the overall time horizon for the projection,
- Assumptions for the long-term – and, if desired, the intermediate-term – levels of mortality improvement, and
- The type of results desired, e.g., the calculated mortality improvement rates or life expectancies produced by applying those rates to a set of base mortality rates.

The smooth blending of mortality improvement rates from recent experience to the assumed long-term rates is performed by the MIM-2021-v2 Application Tool, and is based on a set of interpolating curves described in more detail in the “Step 2” subsection of Section 2.

As described in Section IV of the MIM-2021-v2 Report², the MIM-2021-v2 Application Tool always produces two sets of gender-specific mortality improvement arrays – one in which the rates are projected horizontally along individual ages and a second in which the rates are projected diagonally along individual year-of-birth cohorts. The final array of MI rates is based on a user-specified linear combination of the two projections.

Section 2: Tab 1

STEP 1: SELECT THE APPROPRIATE HISTORICAL DATA SET

The MIM-2021-v2 Application Tool comes preloaded with a number of sets of historical U.S. mortality rates, including:

- 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 categories³. 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 2000⁴, as contrasted to the subsets described in the immediately preceding bullet, which reflect changes in socioeconomic deciles as they varied over time.

With respect to the last two bullets, 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.

Note that 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, making sure the total allocation adds up to 100%.

Figure 1 displays the opening input cells⁵ for Step 1.

Figure 1
MIM-2021-v2 APPLICATION TOOL STEP 1 INPUT CELLS

Step 1. Select the Appropriate Historical Dataset

1 Dataset for determining rates of mortality improvement

- 1 = SSA
- 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

Order 3 Data smoothing option

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)

In addition to the dataset for determining rates of mortality improvement, the user selects the two-dimensional order-2 Whittaker-Henderson graduation method or the two-dimensional order-3 Whittaker-Henderson method to smooth the 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.

As discussed in SOA's Retirement Plans Experience Committee (RPEC' Mortality Improvement Scale MP-2021 report⁶, 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. In this context, order-3 refers to the degree of the finite difference operators used in the smoothness components of the two-dimensional Whittaker-Henderson objective function.

Scale O2_2021 has been 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 uses order-2 rather than order-3 Whittaker-Henderson graduation. 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 yield greater year-over-year stability in pension liability calculations. However, the order-2 model will 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.

The two national-level population data sets (options 1 and 2) do not require any further inputs in Step 1. 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 2 and 3 show examples for Option 3 (NCHS quintiles) and Option 4 (NCHS deciles), respectively:

Figure 2
MIM-2021-v2 APPLICATION TOOL STEP 1 INPUT CELLS – OPTION 3 EXAMPLE

Step 1. Select the Appropriate Historical Dataset

- 3 Dataset for determining rates of mortality improvement**
- 1 = SSA
 - 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

Order 3 Data smoothing option

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%	0%	0%	0%	0%						0%

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

Figure 3
MIM-2021-v2 APPLICATION TOOL STEP 1 INPUT CELLS – OPTION 4 EXAMPLE

Step 1. Select the Appropriate Historical Dataset

- 4 Dataset for determining rates of mortality improvement**
- 1 = SSA
 - 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

Order 3 Data smoothing option

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%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%

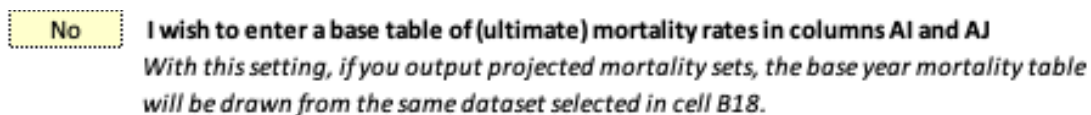
1 = lowest socioeconomic decile; 10 = highest decile (5 = highest quintile)

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

Step 1 also includes two optional inputs. By entering “Yes” in cell B40, the user can enter a set of gender-/age-specific base mortality rates⁷. These user-supplied mortality rates will not be used to generate any historical or future MI rates. Rather, they will be used (in lieu of the base rates in the selected historical mortality table) in the calculation of certain results described in the “Step 5” section.

Figure 4

MIM-2021-v2 APPLICATION TOOL STEP 1 INPUT CELLS – CELL B40



The user can also load the parameter set that will reproduce the results of the MP-2021 or O2-2021 mortality improvement scales previously released by RPEC using the “Reproduction of the MP-2021 Mortality Improvement Scale” Button or “Create Scale with RPEC’s Committee-Selected Assumptions for MP-2021 using Order-2 Smoothed Data” Button (Figure5)

Figure 5

MIM-2021-v2 APPLICATION TOOL STEP 1 INPUT CELLS – REPRODUCE MP-2021 MORTALITY IMPROVEMENT SCALE BUTTON AND O2-2021 MORTALITY IMPROVEMENT SCALE BUTTON

Reproduce the MP-2021 Projection Scale

If you wish to reproduce the MP-2021 projection scale, or if you wish to examine the parameters and assumptions used to produce MP-2021, press the button below.

Load Parameters to Produce MP-2021

Reproduce the O2-2021 Projection Scale

If you wish to produce the O2-2021 scale -- which is similar to MP-2021, but based on order-2 graduation as opposed to order-3 graduation -- then press the button below.

Load Parameters to Produce O2-2021

STEP 2: SPECIFY OVERALL STRUCTURE AND TIMEFRAME FOR THE PROJECTION

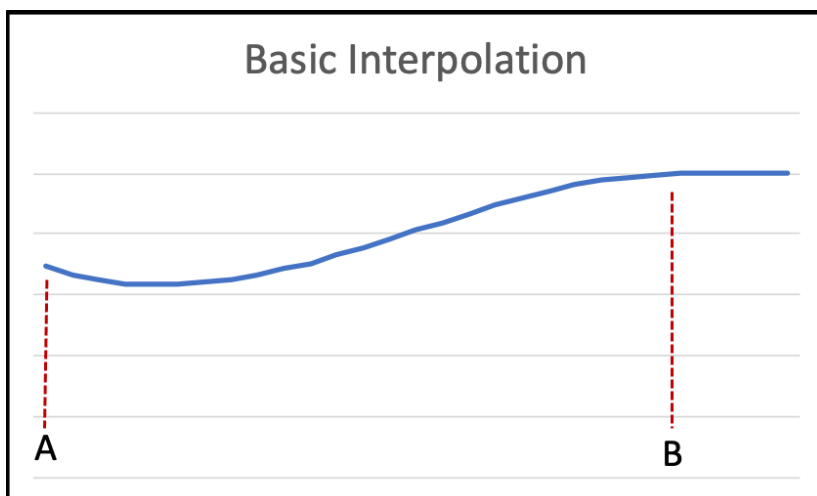
Four key years (labeled A, B, C, and D) can be input starting in cell B9 of the MIM-2021-v2 Application Tool. These dates relate to the overall structure and timing of the transition period from the beginning of the projection period to the point at which the assumed long-term rates begin to apply. Each calculated gender-/age-specific mortality improvement rate in years subsequent to the year in which the long-term rate structure is first attained is set equal to the corresponding assumed long-term rate.

There are two types of interpolation structures for the transition periods⁸: 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.

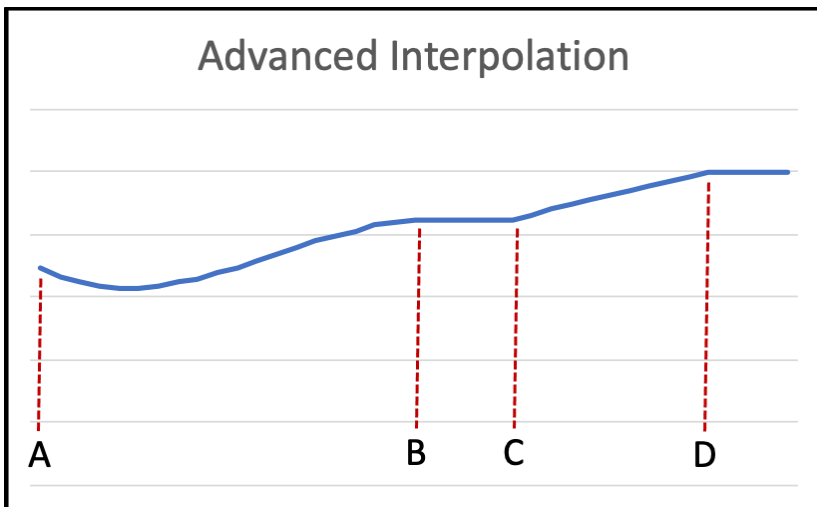


The Basic Interpolation curve is a cubic polynomial passing through two MI rates (at years A and B) and matching two specified slopes at those times. Additional information about these cubic polynomials, including their underlying formulae, can be found in Appendix A of the MIM-2021-v2 Report.

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 years (separately for each of the period and cohort projections) are required under this structure:

- 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 constant for the period between B and C, where it starts a linear convergence to the assumed long-term rates in year D.

2.1.1.1 INPUTS TO STEP 2

Figure 6 displays the opening input cells for Step 2.

Figure 6
MIM-2021-v2 APPLICATION TOOL STEP 2 INPUT CELLS

Step 2. Specify Projection Structure and Time Horizon

Through which point in time do you wish to project?	B
Weight Placed on Cohort Projection	50%

Specify the transition periods between sets of improvement rates

Time Point	A	B	C	D
By Age	2017	2027		
By Cohort		2037		

The first input cell in Step 2 (cell R18) determines which of the two interpolation structures will be used. A selection of "B" or "C"⁹ indicates the Basic Interpolation will be used, while a selection of "D" indicates the Advanced Interpolation methodology is desired.

The second input cell (R19) determines the user's desired balance between the horizontal and diagonal projections. It is acceptable for the user to enter values of either 0%, which would produce a horizontal-only projection (thereby deemphasizing any "cohort" effects), or 100%, which would produce a diagonal-only projection deemphasizing any "period" effects.

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).
- The final set of MI rates are calculated as a 50%/50% blend of the two sets of projected values.
- All MI rates after 2037 are equal to the corresponding MI rate in 2037.
- The mortality-related results specified in Step 5 and displayed in Step 6 will be calculated through 2037.

The Basic Interpolation entries in Figure 7 (with year C selected) can be interpreted in the same way, except that the mortality-related results in the final bullet point above will be calculated through 2050, not 2037.

Figure 7

MIM-2021-V2 APPLICATION TOOL STEP 2 INPUT CELLS – BASIC INTERPOLATION ENTRIES

Step 2. Specify Projection Structure and Time Horizon

Through which point in time do you wish to project?	C
Weight Placed on Cohort Projection	50%

Specify the transition periods between sets of improvement rates

Time Point	A	B	C	D
By Age	2017	2027	2040	
By Cohort		2037	2050	

The following displays an illustrative example of a projection using the Advanced Interpolation structure:

Figure 8

MIM-2021-v2 APPLICATION TOOL STEP 2 INPUT CELLS – ADVANCED INTERPOLATION ENTRIES

Step 2. Specify Projection Structure and Time Horizon

Through which point in time do you wish to project?	D
Weight Placed on Cohort Projection	75%

Specify the transition periods between sets of improvement rates

Time Point	A	B	C	D
By Age	2017	2027	2040	2060
By Cohort		2037	2050	2060

The Advanced Interpolation entries in Figure 8 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.
- The final set of MI rates is calculated as a 25%/75% blend of the horizontal and diagonal projections, respectively.
- All MI rates after 2060 are equal to the corresponding MI rate in 2060.
- The mortality-related results specified in Step 5 and displayed in Step 6 will be calculated through 2060.

STEP 3: SELECT PROJECTION ASSUMPTIONS

In Step 3 the user selects assumptions about:

1. The years of the historical mortality data set from which the starting values of the MIM-2021-v2 projection are calculated;
2. The years of the historical mortality data set from which the starting slopes of the MIM-2021-v2 interpolating cubic polynomials are calculated, including constraints on how large those initial slopes can be in absolute value;
3. The gender-/age-specific long-term MI rates; and
4. If the Advanced Interpolation structure has been selected, the gender-/age-specific intermediate-term MI rates.

Before delving into the details of the Step 3 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 9 displays the first section of the input cells for Step 3.

Figure 9

MIM-2021-v2 APPLICATION TOOL STEP 3 INPUT CELLS

Historical Period Across Which to Compute Improvement Rates 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

Note: it is recommended that cell V30 be set equal to cell O23.

Constraints on Improvement Rate Slopes at Time Point A

Maximum absolute value of horizontal (period) slope	0.0000
Maximum absolute value of diagonal (cohort) slope	0.0000

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 2¹⁰. 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 opening values of 2016 and 2017 in the fourth 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 3, 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. 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 RPEC¹¹ has indicated 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 U35 and U36. Alternatively, users can reflect some limited degree of initial MI slope by restricting its maximum absolute value in cells U35 and U36¹².

Users have two options for selecting long-term, and if desired intermediate-term, gender-/age-specific mortality improvement rates:

- The assumed MI rates can be entered directly in columns AA through AD of Tab 1 as appropriate, based on the selected Interpolation Structure, or
- The rates can be calculated as the geometric average across a selected period of time from the historical mortality data set.

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, the remaining four input cells in Step 3, shown below, should all be left blank.

Figure 10

MIM-2021-v2 APPLICATION TOOL STEP 3 INPUT CELLS – MANUALLY INPUT ASSUMED VALUES

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

Users who wish to base their assumed long-term MI rates on some period of the historical database should enter values based on their selected Interpolation Structure:

- Basic Interpolation: Enter the selected beginning and ending years for the long-term rates in the first row of cells (relating to point B) and leave the second row of cells blank;
- Advanced Interpolation: Enter the selected beginning and ending years for the intermediate-term rates in the first row of cells (relating to point B) and enter the selected beginning and ending years for the long-term rates in the second row of cells (relating to point D).

After entering all of the Step 3 inputs, the user must press the “Calculate Mortality Improvement Rates from Historical Data” button (Figure 11) to run the macro that generates the final sets of MI rates:

Figure 11
MIM-2021-v2 APPLICATION TOOL STEP 3 RUNNING MACRO

Calculate Mortality Improvement Rates from Historical Data

STEP 4a: REVIEW AND REFINE THE ASSUMPTION SET

Step 4a provides the user an opportunity to review and, if necessary, refine the assumptions generated after pressing the final button in Step 3. The gender-specific information summarized for ages 20 through 120 differs based on the interpolation structure selected in Step 2.

- If the Basic Interpolation structure was selected:
 - Columns Y and Z: The initial mortality improvement rates at Year A
 - Columns AA and AB: The assumed long-term mortality improvement rates at Year B
 - Columns AC and AD: Intentionally blank
 - Columns AE through AH: The initial slopes of the cubic polynomials, reflecting any assumed restrictions in absolute value

- If the Advanced Interpolation structure was selected:
 - Columns Y and Z: The initial mortality improvement rates at Year A
 - Columns AA and AB: The assumed intermediate-term MI rates starting at Year B and continuing unchanged until Year C
 - Columns AC and AD: The assumed long-term mortality improvement rates at Year D
 - Columns AE through AH: The initial slopes of cubic polynomials, reflecting any assumed restrictions in absolute value

If the user opts to input a set of base mortality rates different from the historical base rates (by selecting “Yes” in cell B40 of Step 1), those rates should be entered in Columns AI and AJ, and identified in cell AJ20 with the appropriate “Table Year”.

STEP 4b: COVID-19 LOADS

Step 4b allows the user to input loads in columns AM through AX to mortality rates for the effects of the ongoing COVID-19 pandemic. It is important to note that in contrast to the ability to modify mortality improvement rates in Step 4a, the loads described in this Step 4b are applied to the underlying mortality rates themselves. These loads, if any, should be entered on a select-and-ultimate basis, with individual loads specified by age (20 through 120) and gender 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.

Figure 12 shows the input columns for this COVID-19 section where the user has included a load for the individual year 2020. Only ages 20-35 are shown in the figure. 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.

Figure 12
MIM-2021-v2 APPLICATION TOOL STEP 4B INPUT CELLS (2020 ONLY)

Step 4b. COVID-19 Loads

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

	Female						Male					
	2020	2021	2022	2023	2024	2025+	2020	2021	2022	2023	2024	2025+
20	15.00%						15.00%					
21	15.00%						15.00%					
22	15.00%						15.00%					
23	15.00%						15.00%					
24	15.00%						15.00%					
25	15.00%						15.00%					
26	15.00%						15.00%					
27	15.00%						15.00%					
28	15.00%						15.00%					
29	15.00%						15.00%					
30	15.00%						15.00%					
31	15.00%						15.00%					
32	15.00%						15.00%					
33	15.00%						15.00%					
34	15.00%						15.00%					
35	15.00%						15.00%					

Figure 13 shows the input columns for this COVID-19 section where the user has included a load for all years but it is gradually decreasing to a smaller load for long term COVID-19 effects. Only ages 20-35 are shown in Figure 13. 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 2020 improvement rates will be negative and 2021 improvement rate is high and positive. Similar logic applies for the other years of the wear-off, albeit to a smaller degree. Note that improvement rates for 2026 and beyond will not change 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.

Figure 13
MIM-2021-v2 APPLICATION TOOL STEP 4B INPUT CELLS (GRADUAL DECREASE)

Step 4b. COVID-19 Loads

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

	Female						Male					
	2020	2021	2022	2023	2024	2025+	2020	2021	2022	2023	2024	2025+
20	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
21	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
22	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
23	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
24	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
25	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
26	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
27	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
28	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
29	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
30	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
31	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
32	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
33	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
34	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%
35	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%	15.00%	10.00%	8.00%	5.00%	3.00%	2.00%

STEP 5: SELECT AND PRODUCE OUTPUTS

Figure 12 displays the opening input cells for Step 5:

Figure 12
MIM-2021-v2 APPLICATION TOOL STEP 5 INPUT CELLS

Step 5. Select and Produce Outputs

Yes	Show some or all of the historical period, in addition to the projection period?
1983	If answer to prior question is "Yes", then enter first historical year to show in outputs (must be greater than 1983)
5	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 Q23 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

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

1. Annual mortality improvement rates
2. Mortality rates
3. The ratio of calculated mortality rates to the corresponding rates in the year in cell O23
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

Other than the mortality improvement rates (option 1), all generated values are determined from the user-selected set of base rates, if any, entered in columns AI and AJ of Step 4.

The MIM-2021-v2 Application Tool results are then generated by pressing the “Run the Model” button (Figure 13).

Figure 13

MIM-2021-v2 APPLICATION TOOL STEP 5 RUN THE MODEL BUTTON



SUMMARY OF RESULTS

The selected gender-/age-/year-specific values produced by the Tool start on column BD of Tab 1. The summary section also includes two buttons that generate graphics designed to help the user analyze the results (Figure 14).

Figure 14

MIM-2021-v2 APPLICATION TOOL SUMMARY OF RESULTS BUTTONS



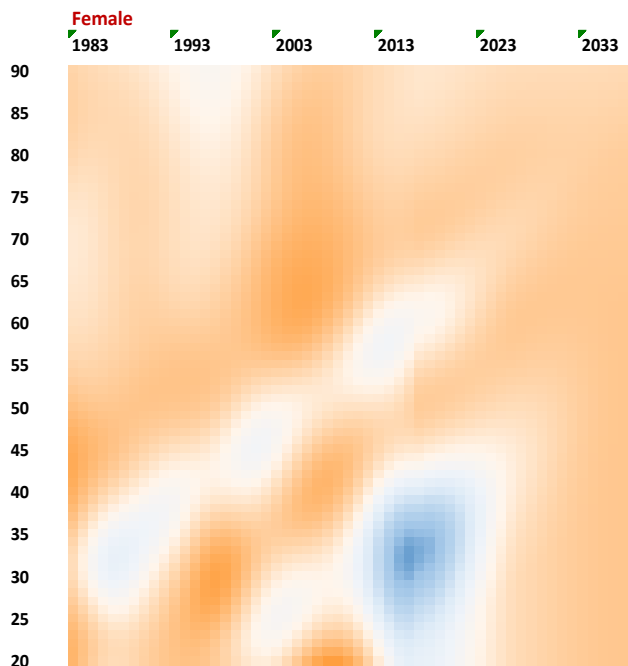
The heat maps are displayed on Tab 2, and the graphs are displayed on Tab 3. More discussion of these tabs is included in the next section.

Section 3: Tabs 2-5

TAB 2

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 MI rates with order-3 graduation for ages 20 through 90 covering the period 1983 through 2037 is shown in Figure 15.

Figure 15
MIM-2021-v2 APPLICATION TOOL HEAT MAP EXAMPLE



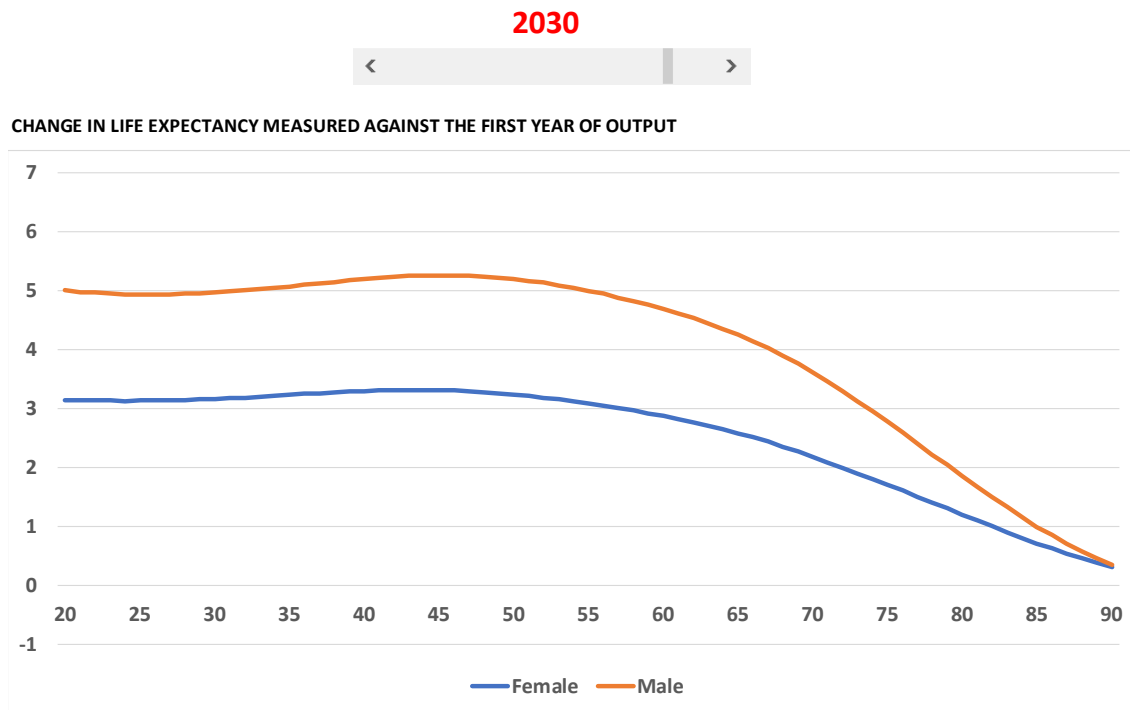
A table with the color-coded legends for each of the possible heat map results is included in the upper left portion of Tab 2. Certain ranges of values and associated colors¹³ have been pre-entered into the heat map legend, but the user can modify these if desired. Users who wish to change the color 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).

TAB 3

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 16 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 16
MIM-2021-v2 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-v2 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 MI RATES

In Step 3 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 V30 and V31, 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 17 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 18 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 17

MP-2021 MI MALE RATES

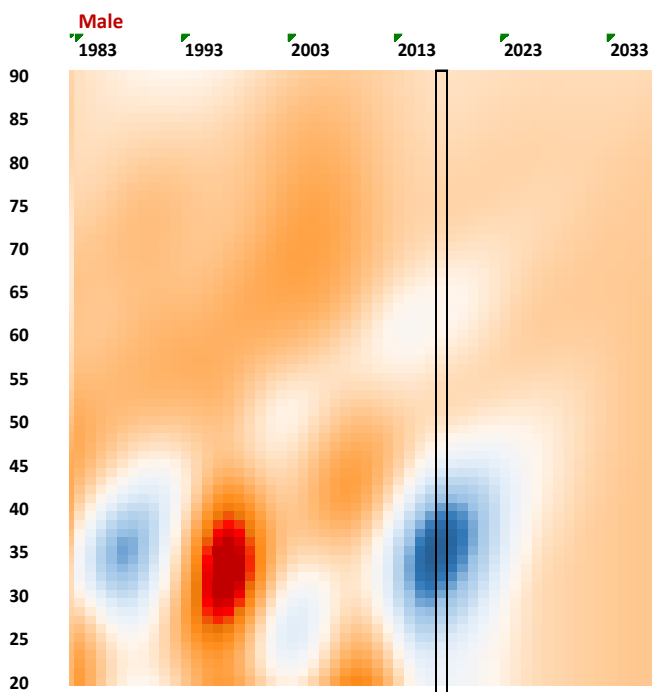
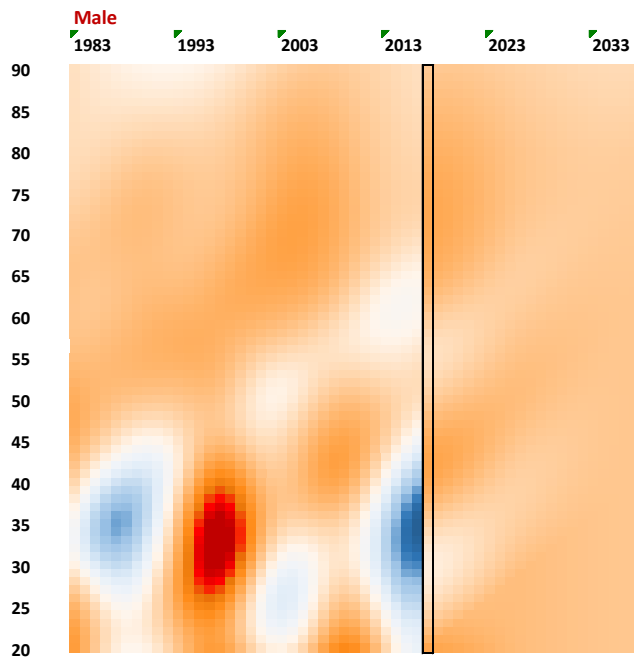


Figure 18

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

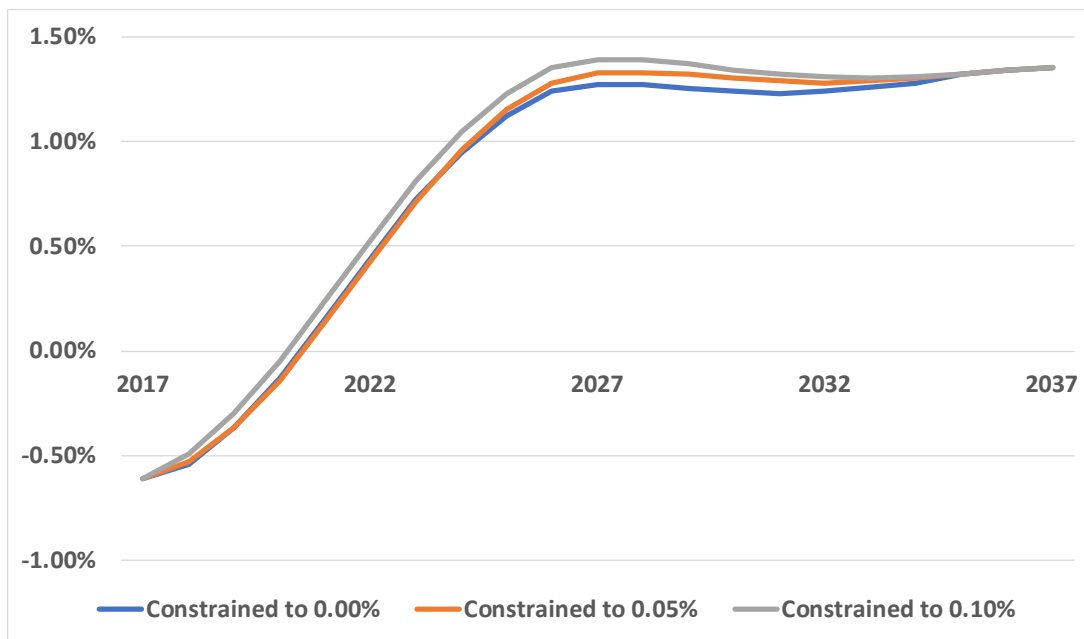


Notice how the 2017 rates in Figure 18 mirror the mortality improvement rates from ten years prior, and how that creates a discontinuity starting in the jumping-off year.

ASSUMPTIONS REGARDING THE JUMPING-OFF SLOPE CONSTRAINTS

The parameters in Step 3 of Tab 1 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 19 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 19
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-v2 results.

ASSUMPTION REGARDING WEIGHT PLACED ON COHORT PROJECTION

In Step 2 of Tab 1, the user must enter in cell R19 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 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

Figure 20
WEIGHT PLACED ON COHORT PROJECTION = 0%

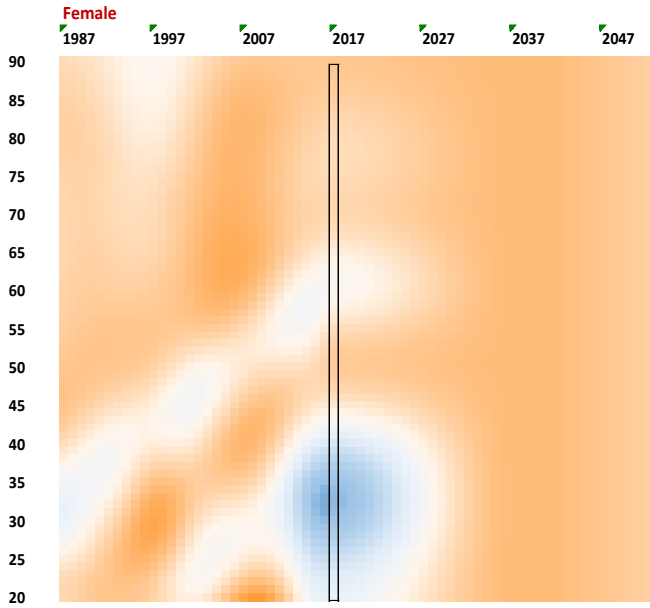


Figure 21
WEIGHT PLACED ON COHORT PROJECTION = 50%

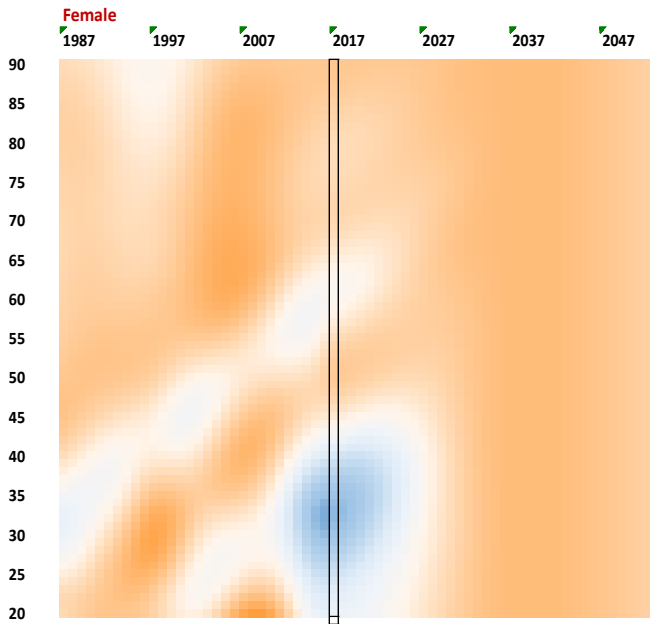
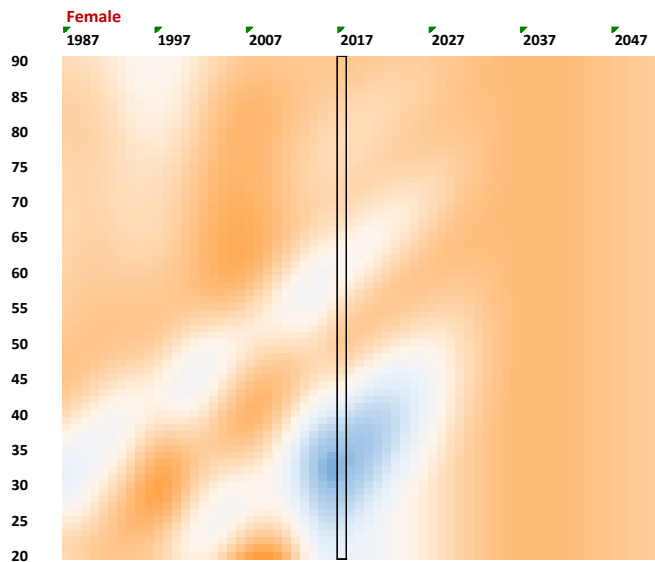


Figure 22

WEIGHT PLACED ON COHORT PROJECTION = 100%



Section 4.4 of the MP-2014 Report 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.

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

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Endnotes

¹ Society of Actuaries. 2021. “Developing a Consistency Framework for Mortality Improvement”.

<https://www.soa.org/resources/research-reports/2021/developing-consistency-framework/>.

² For additional details, see Society of Actuaries. 2014. “Mortality Improvement Scale MP-2014 Report”, Section 3.

<https://www.soa.org/globalassets/assets/files/research/exp-study/research-2014-mp-report.pdf>.

³ 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/>.

⁴ 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.

⁵ Throughout the MIM-2021-v2 Application Tool, input/parameter cells are identified with a yellow background.

⁶ See Society of Actuaries. 2021. “Mortality Improvement Scale MP-2021”,

<https://www.soa.org/resources/experience-studies/2021/mortality-improvement-scale-mp-2021/>

⁷ 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.

⁸ 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.

⁹ Although the mortality improvement rates produced under option “C” are identical to those produced under option “B”, its selection can be used to produce more years of mortality-related information than can option “B”; this is discussed further in the Step 5 section.

¹⁰ 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.

¹¹ 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>

¹² A warning message will be pop up if the user selects values greater than 0.01 in these cells.

¹³ The default heat map color palette is the same as that used in the Scale MP-2021 Report.

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