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Mortality and Longevity

Mortality Improvement Scale MP-2020

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CONTENTS

Mortality Improvement Scale MP-2020

Section 1: Executive Summary

This report presents Scale MP-2020, the latest iteration of the mortality improvement scales developed annually by the Retirement Plans Experience Committee (RPEC, or "the Committee") of the Society of Actuaries (SOA). Scale MP-2020 is based on the same underlying methodology used to develop Scale MP-2019 (SOA 2019). This report reflects one additional year of historical population data for 2018 and a change to the committee-selected assumption for the long-term rate of mortality improvement.

The Scale MP-2020 mortality improvement rates can be found on the SOA website at the following link: https://www.soa.org/resources/experience-studies/2020/mortality-improvement-scale-mp-2020/.

The Scale MP-2020 mortality improvement rates presented in this report are slightly lower than the corresponding Scale MP-2019 rates. Table 1.1 of deferred-to-62 annuity values shows that, starting with Pri-2012 base mortality rates, most 2020 pension obligations calculated using Scale MP-2020 (with a discount rate of 4.0%) are anticipated to be 0.3% to 0.8% lower relative to their Scale MP-2019 counterparts. Section 4 illustrates that the annuity factor changes using other base mortality tables are similar.

Table 1.1

MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020
PRI-2012 PROJECTED GENERATIONALLY

	Age	MP-2019	MP-2020	% Change
Females	25	3.7377	3.7230	*-0.39%*
	35	5.4383	5.4194	*-0.35%*
	45	7.9269	7.8991	*-0.35%*
	55	11.6000	11.5527	*-0.41%*
	65	14.2620	14.1905	*-0.50%*
	75	10.2686	10.1844	*-0.82%*
	85	6.2192	6.1558	*-1.02%*
	95	3.3633	3.3411	*-0.66%*
Males	25	3.4993	3.4928	*-0.19%*
	35	5.0962	5.0834	*-0.25%*
	45	7.4374	7.4121	*-0.34%*
	55	10.9006	10.8503	*-0.46%*
	65	13.4012	13.3238	*-0.58%*
	75	9.4693	9.3941	*-0.79%*
	85	5.5054	5.4519	*-0.97%*
	95	2.9006	2.8746	*-0.90%*

The changes illustrated in Table 1.1 are due to two factors:

1. The annual update to the RPEC_2014 model incorporating a new year of historical data (2018)
2. A change to the committee-selected assumption for the long-term rate of mortality improvement described in Section 3 and discussed at length in Section 5

Section 4 illustrates the separate contribution of these two factors to the changes shown in Table 1.1.

In 2018, RPEC began producing an additional model, denoted “RPEC_O2,” that utilizes a smoother, order-2 Whittaker-Henderson graduation of historical data with the goal of decreasing year-over-year volatility in the measurement of pension obligations. Results for this model are discussed in Section 4.

RPEC believes that Scale MP-2020 produces a reasonable mortality improvement assumption for measuring obligations for most retirement programs in the United States within the context of the “assumption universe” as described in Actuarial Standard of Practice No. 35 (ASOP No. 35) (ASB 2014). However, RPEC also believes that other mortality improvement scales, including those created with an assumption set different from that selected by RPEC or those based on an underlying model other than RPEC_2014 (such as the “order-2” model discussed in subsection 4.3 and introduced in the Scale MP-2018 report), could fall within the ASOP No. 35 assumption universe. It is the responsibility of the actuary to determine which mortality improvement assumption is appropriate to use for a given purpose.

Section 2: Data Sources, Underlying Model and Recent U.S. Mortality Experience

2.1 DATA SOURCES

The historical mortality information published by the Social Security Administration (SSA) in conjunction with the 2020 Trustees' Report included rates that are smoothed across ages for each individual year through calendar year 2017 (SSA 2020a). The data for calendar years 1950 through 2015 used in the MP-2020 study were taken directly from these SSA-published mortality rates. Rates for 2016 through 2018 were calculated using the most recent data developed by the Centers for Disease Control and Prevention (CDC), the U.S. Census Bureau and the Centers for Medicare and Medicaid Services (CMS). The process used to develop the 2016 through 2018 rates follows the SSA's graduation methodology. See Appendix B for additional information.

2.2 MORTALITY IMPROVEMENT MODEL

The 2020 version of the RPEC mortality improvement model, denoted RPEC_2014_v2020, is based on the original RPEC_2014 model updated to reflect the historical mortality data through calendar year 2018 as described in subsection 2.1. As in all prior MP scales, historical rates were calculated using a two-dimensional Whittaker-Henderson graduation of the natural logarithm of U.S. population mortality rates with smoothness components based on the sum of the squares of third finite differences. Scale MP-2020 rates were developed from this RPEC_2014_v2020 model.

Subsection 3.1 describes a change to the committee-selected long-term rate of improvement included in Scale MP-2020. Subsection 3.2 describes a change to the RPEC_2014 model for 2020 that results in minor differences to the improvement rates at the oldest ages for Scale MP-2020. Aside from these changes, Scale MP-2020 was constructed using the same model infrastructure and committee-selected assumption set used to develop Scale MP-2019. The specific committee-selected assumptions used are as follows:

- Long-term rate of mortality improvement: flat 1.35% rate to age 62, decreasing linearly to 1.10% at age 80, further decreasing linearly to 0.40% at age 95, and then decreasing linearly to 0.00% at age 115
- Horizontal convergence period (along fixed ages): 10 years
- Diagonal convergence period (along fixed year-of-birth cohorts): 20 years
- Horizontal/diagonal blending percentages: 50%/50%
- Initial slope constraint: 0

Applying a two-year step-back[1] from 2018 (the most recent year of mortality data), along with a 20-year diagonal convergence period, results in Scale MP-2020 long-term rates that are fully attained in calendar year 2036.

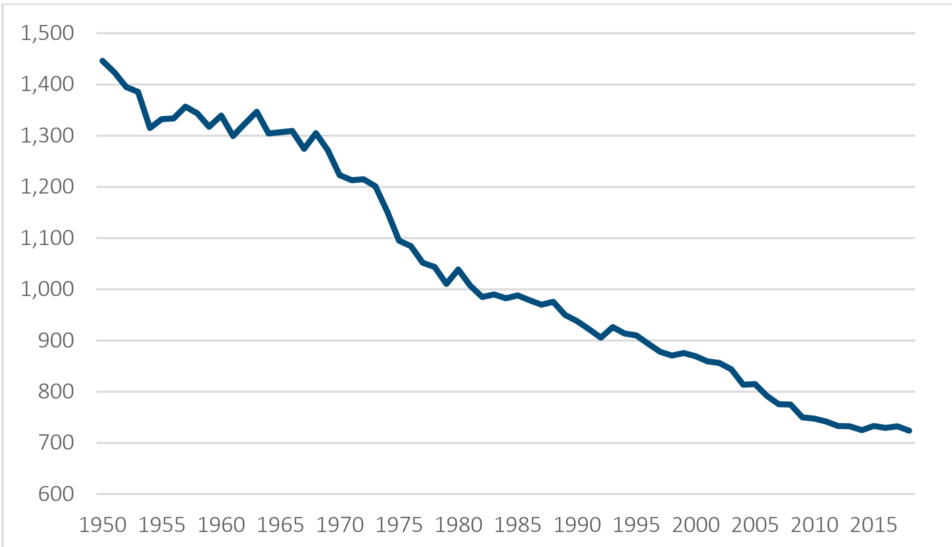
[1] See the Scale MP-2014 Report (SOA 2014) for more information.

2.3 RECENT U.S. POPULATION MORTALITY EXPERIENCE

The age-adjusted mortality rate for 2018 was 723.6 (per 100,000), a decrease of 1.1% from the 731.9 rate for 2017 (NCHS 2020a). Figure 2.1 shows the total (males and females combined) age-adjusted mortality rates in the United States for calendar years 1950 through 2018.

Figure 2.1

U.S. AGE-ADJUSTED MORTALITY RATES PER 100,000, CALENDAR YEARS 1950–2018



Mortality rates in calendar year 2018 were lower for all but two of the 10 leading causes of death in the United States, which included the three leading causes of death—heart disease (−0.8%), cancer (−2.2%) and unintentional injuries (−2.8%). Mortality rates were higher for influenza and pneumonia (+4.2%) and suicide (+1.4%) (NCHS 2020b). Based on the CDC's age-adjusted death rates (NCHS 2020a), the age-adjusted mortality improvement rate averaged approximately 0.4% per year over the period 2010 to 2018, compared to an average of approximately 1.5% per year from 2000 through 2009.

Preliminary analysis by the National Vital Statistics System (NVSS 2020) indicates that the average age-adjusted death rate in the United States (per 100,000 of population) was 708.5 for the 12 months ending with Q3 of 2019, which was 2.7% lower than the corresponding value of 728.1 for the 12 months ending with Q3 of 2018. It should be noted that this preliminary information for calendar year 2019 was not reflected in any of the mortality improvement scales presented in this report.

These mortality improvement statistics illustrate age-adjusted mortality improvement rates for the U.S. population as a whole. The trends of mortality improvement vary significantly by gender and age group.

Section 3: Updates to the RPEC_2014 Model and Scale MP-2020

3.1 UPDATE TO COMMITTEE-SELECTED LONG-TERM MORTALITY IMPROVEMENT RATE STRUCTURE

As described in subsection 2.2, each iteration of the RPEC_2014 model produces the corresponding "MP" mortality improvement scale from its year of publication when it is run with the committee-selected assumption set in effect for that year. In previous years, the committee-selected long-term rate of mortality improvement was as follows:

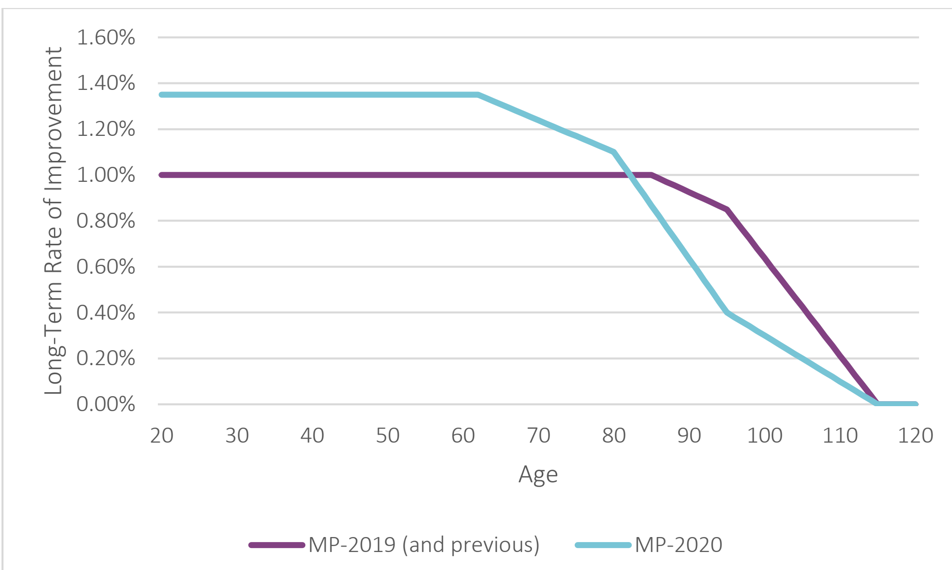
- 1.00% for ages 85 and younger, decreasing linearly to 0.85% at age 95, further decreasing linearly to 0.0% at ages 115 (and thereafter)

For Scale MP-2020, the committee-selected long-term rate of improvement has been changed to the following assumption:

- 1.35% rate for ages 62 and younger, decreasing linearly to 1.10% at age 80, further decreasing linearly to 0.40% at age 95, and then decreasing linearly to 0.00% at age 115 (and thereafter)

Figure 3.1 shows a graphical comparison of these two long-term rate structures.

Figure 3.1
COMMITTEE-SELECTED LONG-TERM RATE OF IMPROVEMENT COMPARISON



The rationale for the Committee's change in this assumption is described at length in Section 5.

3.2 EXTENSION OF CUBIC POLYNOMIAL TRANSITION TO OLDEST AGES

In the RPEC_2014 model, the improvement rates in the convergence period smoothly transition to the ultimate rates via a user-selected blend of horizontal and diagonal interpolation polynomials for ages below 95. Previous iterations of the RPEC_2014 model would grade the mortality improvement rates linearly down to zero between ages 95 and 115 for years throughout the convergence period. In the committee-selected assumption set for Scale MP-2019 (and prior MP scales), the ultimate rates also decreased linearly to zero from ages 95 to 115, so the transition to the ultimate rates was smooth at all ages despite the computational change at age 95.

In previous versions of the model, if a user were to change the long-term rate structure such that the pattern does not linearly grade to zero between ages 95 and 115, the transition to the ultimate would not necessarily be smooth for ages above 95. This is because the linear grade-down to zero between ages 95 to 115 in the last year of the convergence period would not necessarily follow a similar pattern as the user-selected long-term rate structure.

In the RPEC_2014_v2020 model, RPEC has removed the linear grade-down to zero from ages 95 to 115 during the convergence period and extended the polynomial interpolation to these advanced ages to remedy this disconnect at the year in which the ultimate rates are achieved. This new version of the model keeps the transitions to the ultimate rates smooth when the structure is changed. As a byproduct of this update, some of the improvement rates at ages 115 and above in Scale MP-2020 are non-zero (but small in absolute value) in the convergence period due to the extension of the diagonal cohort polynomials. The impact of this change on pension liability calculations is negligible.

Section 4: Impact of Scale MP-2020

4.1 COMPARISON OF 2020 ANNUITY VALUES

Table 4.1 presents a comparison of monthly deferred-to-62 annuity-due values using various SOA mortality tables, all calculated generationally as of 2020 ("Generational @ 2020") using Scale MP-2020. In Table 4.1, and each of the subsequent tables in this Section that uses Pri-2012 as a base table, the "total dataset" version of Pri-2012 is used. These annuity values were computed using the following specifications:

- Employee rates for ages below 62 and Retiree rates for ages 62 and older
- A discount rate of 4.0%

Table 4.1
MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020
SOA MORTALITY TABLES PROJECTED WITH SCALE MP-2020

	Age	Pri-2012	PubG-2010	PubT-2010	PubS-2010
Females	25	3.7230	3.8478	3.9543	3.7595
	35	5.4194	5.6126	5.7816	5.4815
	45	7.8991	8.1995	8.4639	8.0031
	55	11.5527	12.0133	12.4234	11.7073
	65	14.1905	14.7697	15.3286	14.3214
	75	10.1844	10.7360	11.2450	10.3479
	85	6.1558	6.5006	6.8639	6.3573
	95	3.3411	3.4711	3.5215	3.4628
Males	25	3.4928	3.5864	3.7606	3.5785
	35	5.0834	5.2166	5.4840	5.2120
	45	7.4121	7.6132	8.0146	7.6036
	55	10.8503	11.1659	11.7646	11.1243
	65	13.3238	13.6985	14.4549	13.5406
	75	9.3941	9.6934	10.3180	9.4615
	85	5.4519	5.7022	6.0609	5.4928
	95	2.8746	3.0543	3.0848	3.0017

Table 4.2 shows how these annuity factors compare to those calculated using Scale MP-2019. The values in the tables indicate that, generally, updating from Scale MP-2019 to Scale MP-2020 will result in a decrease in pension obligations between 0.3% and 0.8%. This impact is relatively consistent for all the base tables shown.

Table 4.2

IMPACT OF UPDATING FROM SCALE MP-2019 TO MP-2020 USING VARIOUS BASE MORTALITY TABLES
COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020

	Age	Pri-2012	PubG-2010	PubT-2010	PubS-2010
Females	25	-0.39%	-0.65%	-0.83%	-0.48%
	35	-0.35%	-0.57%	-0.72%	-0.43%
	45	-0.35%	-0.52%	-0.64%	-0.41%
	55	-0.41%	-0.51%	-0.59%	-0.44%
	65	-0.50%	-0.56%	-0.60%	-0.52%
	75	-0.82%	-0.86%	-0.87%	-0.84%
	85	-1.02%	-1.02%	-1.00%	-1.02%
	95	-0.66%	-0.65%	-0.64%	-0.65%
Males	25	-0.19%	-0.38%	-0.68%	-0.40%
	35	-0.25%	-0.41%	-0.64%	-0.41%
	45	-0.34%	-0.45%	-0.61%	-0.44%
	55	-0.46%	-0.52%	-0.60%	-0.50%
	65	-0.58%	-0.61%	-0.64%	-0.60%
	75	-0.79%	-0.83%	-0.85%	-0.82%
	85	-0.97%	-1.00%	-0.99%	-0.99%
	95	-0.90%	-0.92%	-0.91%	-0.93%

For comparison purposes, versions of Tables 4.1 and 4.2 with factors computed using a discount rate of 7.0% can be found in Appendix D.

The percentages in Table 4.2 represent the combined effects of 1) the addition of one year of historical data (2018) to the model and 2) the change to the committee-selected assumed long-term rate of mortality improvement described in subsection 3.1. Table 4.3 below breaks down the above combined effects into the component causes using Pri-2012 as a base table (impacts using other current SOA base tables, including the Pub-2010 tables, are similar). The annuity factors in the column labeled “2020 – Prior LTR” reflect the update for 2018 historical data but assume the previous long-term rate structure used in Scale MP-2019 and its predecessors.

Table 4.3

IMPACT OF 2018 DATA AND CHANGE IN LONG-TERM RATE OF IMPROVEMENT USING PRI-2012
COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020

	Age	MP-2019	2020 – Prior LTR	MP-2020	% Change Data	% Change LTR	% Change Total
Females	25	3.7377	3.7366	3.7230	-0.03%	-0.36%	*-0.39%*
	35	5.4383	5.4378	5.4194	-0.01%	-0.34%	*-0.35%*
	45	7.9269	7.9275	7.8991	0.01%	-0.36%	*-0.35%*
	55	11.6000	11.5997	11.5527	0.00%	-0.41%	*-0.41%*
	65	14.2620	14.2608	14.1905	-0.01%	-0.49%	*-0.50%*
	75	10.2686	10.2546	10.1844	-0.14%	-0.68%	*-0.82%*
	85	6.2192	6.1937	6.1558	-0.41%	-0.61%	*-1.02%*
	95	3.3633	3.3538	3.3411	-0.28%	-0.38%	*-0.66%*
Males	25	3.4993	3.4895	3.4928	-0.28%	0.09%	*-0.19%*
	35	5.0962	5.0822	5.0834	-0.27%	0.02%	*-0.25%*
	45	7.4374	7.4198	7.4121	-0.24%	-0.10%	*-0.34%*
	55	10.9006	10.8779	10.8503	-0.21%	-0.25%	*-0.46%*
	65	13.4012	13.3786	13.3238	-0.17%	-0.41%	*-0.58%*
	75	9.4693	9.4525	9.3941	-0.18%	-0.62%	*-0.79%*
	85	5.5054	5.4829	5.4519	-0.41%	-0.57%	*-0.97%*
	95	2.9006	2.8849	2.8746	-0.54%	-0.36%	*-0.90%*

4.2 COMPARISON OF 2020 COHORT LIFE EXPECTANCIES

Table 4.4 presents a comparison of 2020 cohort life expectancy values at the indicated ages, all calculated assuming:

- Base mortality rates equal to headcount-weighted Pri.H-2012 Employee rates for ages below 62 and headcount-weighted Pri.H-2012 Retiree rates for ages 62 and older
- Mortality projection starting in 2012 using Scale MP-2019 for the first column of life expectancies and using Scale MP-2020 for the second column

Table 4.4

COHORT LIFE EXPECTANCIES AS OF JANUARY 1, 2020

PRI.H-2012 PROJECTED GENERATIONALLY

	Age	MP-2019	MP-2020	% Change
Females	25	63.77	63.26	*-0.80%*
	35	53.08	52.67	*-0.77%*
	45	42.50	42.15	*-0.82%*
	55	32.03	31.73	*-0.94%*
	65	22.32	22.06	*-1.16%*
	75	14.00	13.81	*-1.36%*
	85	7.52	7.42	*-1.33%*
	95	3.72	3.70	*-0.54%*
Males	25	60.21	59.91	*-0.50%*
	35	49.73	49.45	*-0.56%*
	45	39.35	39.10	*-0.64%*
	55	29.05	28.80	*-0.86%*
	65	19.68	19.46	*-1.12%*
	75	12.10	11.94	*-1.32%*
	85	6.32	6.24	*-1.27%*
	95	3.15	3.11	*-1.27%*

4.3 ALTERNATIVE ORDER-2 MODEL

Scale MP-2020 and its predecessors have been based on historical U.S. population mortality rates that have been graduated with a two-dimensional “order-3” Whittaker-Henderson method. 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.

In 2018, RPEC began producing a different version of the RPEC_2014 model, denoted the RPEC_O2 model, that uses order-2 rather than order-3 Whittaker-Henderson graduation. 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.

For purposes of this report, “O2-2019” is used to designate the scale produced using the order-2 model (RPEC_O2_v2019) released in October 2019 and the committee-selected assumption set in effect for Scale MP-2019. “O2-2020” is used to designate the corresponding scale produced with this year’s RPEC_O2 model (RPEC_O2_v2020) and committee-selected assumption set used to produce Scale MP-2020 (including the update to the assumed long-term rate of improvement). Table 4.5 shows a comparison of annuity values produced by the O2-2019 and O2-2020 scales as of January 1, 2020, using Pri-2012 as a base table and a discount rate of 4.0%.

Table 4.5
MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020
PRI-2012 PROJECTED GENERATIONALLY

	Age	O2-2019	O2-2020	% Change
Females	25	3.7688	3.7476	*-0.56%*
	35	5.4843	5.4556	*-0.52%*
	45	7.9934	7.9515	*-0.52%*
	55	11.7018	11.6357	*-0.56%*
	65	14.3812	14.2879	*-0.65%*
	75	10.4172	10.3202	*-0.93%*
	85	6.3307	6.2674	*-1.00%*
	95	3.3768	3.3512	*-0.76%*
Males	25	3.5445	3.5317	*-0.36%*
	35	5.1600	5.1391	*-0.41%*
	45	7.5239	7.4877	*-0.48%*
	55	11.0278	10.9630	*-0.59%*
	65	13.5604	13.4650	*-0.70%*
	75	9.6459	9.5545	*-0.95%*
	85	5.6506	5.5985	*-0.92%*
	95	2.9220	2.9039	*-0.62%*

The order-2 model shows slightly greater changes when updating from the 2019 to 2020 versions than the order-3 RPEC_2014 model, though this observation is not uniform across all ages and genders. This is primarily because the order-3 RPEC_2014 model is more sensitive to emerging mortality data than the order-2 model. The years 2015-2017 involved low or negative mortality improvement and the RPEC_2014 model reflected this lower improvement more quickly than the order-2 model[2]. This year, there is a greater decrease in annuity factors using the order-2 model because it is phasing in the downturn in improvement that was already largely reflected in the order-3 model.

[2] Note that, while the order-2 model was first created in 2018, Appendix C of the MP-2018 report (SOA 2018) contains charts and tables of annuity factors with hypothetical order-2 scales dating back to 2014. The charts show that the order-2 model reacted less to the recent downturn in mortality improvement than the order-3 model used to produce the MP scales.

Table 4.6 shows a comparison of the annuity values produced by the 2020 versions of the order-2 model and the order-3 RPEC_2014 model using Pri-2012 as the base table. The order-3 RPEC_2014 model produces lower annuity values. It is worth noting, however, that the spread between the annuity factors resulting from the two scales has narrowed compared to those produced using the 2019 versions of each model (see Table 3.4 of the Scale MP-2019 Report).

Table 4.6
MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 4.0% AS OF JANUARY 1, 2020
PRI-2012 PROJECTED GENERATIONALLY

	Age	MP-2020	O2-2020	% Change
Females	25	3.7230	3.7476	*0.66%*
	35	5.4194	5.4556	*0.67%*
	45	7.8991	7.9515	*0.66%*
	55	11.5527	11.6357	*0.72%*
	65	14.1905	14.2879	*0.69%*
	75	10.1844	10.3202	*1.33%*
	85	6.1558	6.2674	*1.81%*
	95	3.3411	3.3512	*0.30%*
Males	25	3.4928	3.5317	*1.11%*
	35	5.0834	5.1391	*1.10%*
	45	7.4121	7.4877	*1.02%*
	55	10.8503	10.9630	*1.04%*
	65	13.3238	13.4650	*1.06%*
	75	9.3941	9.5545	*1.71%*
	85	5.4519	5.5985	*2.69%*
	95	2.8746	2.9039	*1.02%*

4.4 HISTORY OF IMPACT OF UPDATES TO SCALE MP-2014

Scale MP-2020 is the sixth annual update to Scale MP-2014 that has been produced by the SOA. Table 4.7 shows the history of changes in annuity factors by age and gender for each of these annual updates. These percentage changes were computed on the following basis:

- Employee rates for ages below 62 and Retiree[3] rates for ages 62 and older
- A discount rate of 4%
- RP-2006 as the base table for all columns, except MP-2019 and MP-2020, which use Pri-2012 as the base table

Table 4.7
HISTORY OF IMPACT OF ANNUAL UPDATES TO SCALE MP-2014

	Age	MP-2015	MP-2016	MP-2017	MP-2018	MP-2019	MP-2020
Females	25	-1.4%	-1.3%	-0.7%	-0.4%	-0.4%	-0.4%
	35	-1.4%	-1.4%	-0.7%	-0.4%	-0.3%	-0.3%
	45	-1.5%	-1.5%	-0.7%	-0.4%	-0.3%	-0.4%
	55	-1.5%	-1.5%	-0.7%	-0.3%	-0.3%	-0.4%
	65	-1.7%	-1.3%	-0.6%	-0.2%	-0.3%	-0.5%
	75	-3.0%	-1.8%	-1.0%	-0.3%	-0.5%	-0.8%
	85	-4.5%	-3.2%	-1.5%	-0.2%	-0.8%	-1.0%
Males	25	-0.9%	-1.7%	-0.9%	-0.7%	-0.6%	-0.2%
	35	-1.0%	-1.8%	-0.8%	-0.7%	-0.5%	-0.3%
	45	-1.1%	-1.7%	-0.8%	-0.6%	-0.4%	-0.3%
	55	-1.2%	-1.6%	-0.8%	-0.5%	-0.3%	-0.5%
	65	-1.4%	-1.5%	-0.7%	-0.4%	-0.2%	-0.6%
	75	-2.7%	-1.7%	-1.0%	-0.3%	-0.6%	-0.8%
	85	-3.4%	-2.9%	-1.4%	-0.3%	-1.0%	-1.0%

Scale MP-2014 included historical mortality data through calendar year 2009. As can be seen in the heat maps in the Appendix, mortality improvement for retirement-aged individuals was relatively high through around the end of the 2000-2009 decade. Since then, there has been a trend of lower mortality improvement, including negative improvement in certain age groups.

The effects shown for Scale MP-2015 were due to the addition of two new years of historical data for 2010 and 2011. Scale MP-2016 added three new years of historical mortality information (2012−2014), as well as some changes to the committee-selected assumption set[4]. The updates for Scale MP-2017, Scale MP-2018 and Scale MP-2019 include the addition of only one new year of historical data, with no changes to the underlying model or committee-selected assumption set. Finally, as described in this report, the effects shown for Scale MP-2020 are due to the change in the committee-selected long-term rate of mortality improvement along with the addition of data for calendar year 2018.

[3] For RP-2006, Healthy Annuitant rates were used for ages 62 and older.
[4] Scale MP-2016 also introduced two changes to the committee-selected assumption set. First, the length of the age-period (horizontal) convergence period used to transition from near-term improvement rates to the long-term improvement rates was shortened from 20 years to 10 years. Second, the initial slope for the cubic polynomials used to transition from near-term improvement rates to the long-term improvement rates was fixed at zero. Previous iterations of the scale based the slope on the most recent two years of historical data, constrained to +/−0.003.

Section 5: Selection of Long-Term Rate Structure

Section 4 of the Scale MP-2019 Report (SOA 2019) included a discussion of the September 2019 report from the 2019 Technical Panel on Assumptions and Methods to the Social Security Advisory Board (SSAB 2019). In particular, the report noted that, for broad cohorts of the population, mortality improvement has been approximately 1% per year on average. However, it also suggested that an age gradient is warranted, as the Technical Panel found that improvement for persons over age 65 had been slightly lower, averaging only about 0.8% in the long term. RPEC decided to further research long-term historical mortality improvement rates to determine if there were any noticeable patterns that might inform a long-term rate assumption.

Along with the 2020 OASDI Trustees Report (SSA 2020b), the SSA published a table of age-sex-adjusted death rates per 100,000 from 1940 through 2019 for ages under 65 and ages 65 and over (SSA 2020c). RPEC fit an exponential curve to these historical rates to determine the best-fit annual rate of mortality improvement over several long-term periods (results shown in Table 5.1 below).

Table 5.1

BEST-FIT ANNUAL MORTALITY IMPROVEMENT SPLIT BY OVER/UNDER AGE 65

Time Period	Under 65	65 and Over
1940 – 2019	1.39%	0.94%
1950 – 2019	1.33%	0.94%
1960 – 2019	1.39%	0.98%
1970 – 2019	1.35%	0.90%
1980 – 2019	1.15%	0.87%
1940 – 1980	1.37%	0.95%
1950 – 1990	1.31%	1.00%
1960 – 2000	1.58%	1.02%
1970 – 2010	1.56%	0.85%

This analysis identified a clear difference in historical mortality improvement over and under the age of 65, regardless of the period included. As mortality rates for retirement-aged individuals are most critical for valuation of retirement and postretirement benefit plan obligations, RPEC further sought to understand the pattern of historical improvement rates by age over age 55.

To do this, RPEC constructed age-sex-adjusted death rates across ten-year age bands using the 2010 census (USC 2020) as a reference population and the SSA's historical probabilities of death (SSA 2020a) through 2017. Similar to the above process, RPEC then fit an exponential curve to these historical rates to determine a best-fit annual improvement rate. Table 5.2 shows a summary of these improvement rates over the same multi-year periods.

Table 5.2
BEST-FIT ANNUAL MORTALITY IMPROVEMENT FOR SELECT TEN-YEAR AGE BANDS

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

There were three important takeaways from the results shown in Table 5.2:

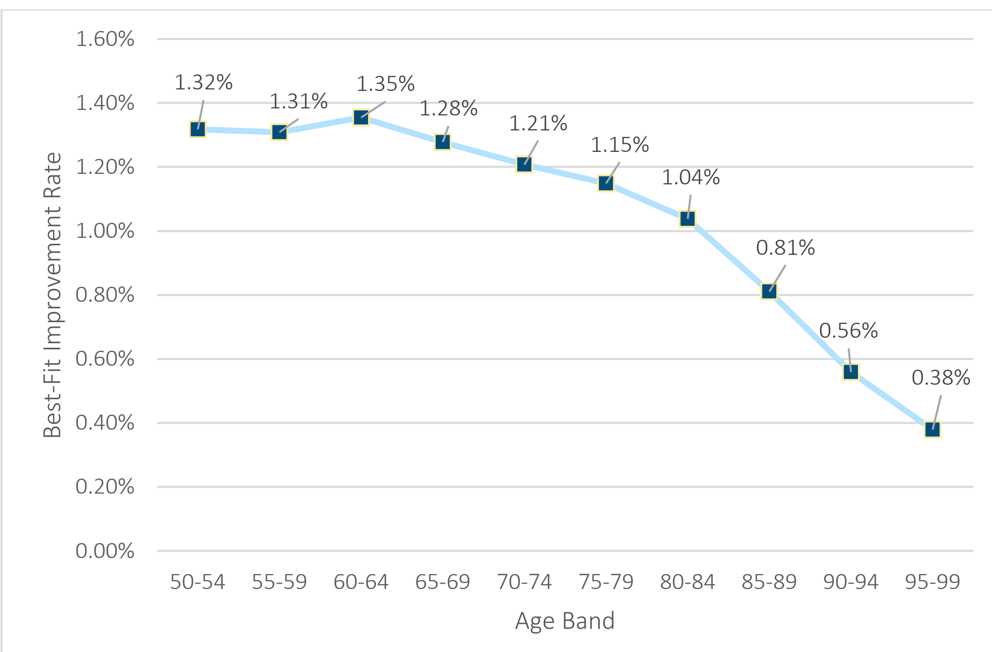
1. Historical mortality improvement has generally decreased as age increases for retirement-aged individuals.

2. Improvement rates for the 55-64 age band were, on average, similar to the improvement rates for the under-65 age group as a whole.

3. The improvement rates observed from 1950-2017 (the range of historical data used in Scale MP-2019) were very close to the average across all time periods studied for each age group.

Using the 1950-2017 time period, RPEC then proceeded to break down mortality improvement into five-year age bands to attempt to construct a long-term assumption using the current RPEC_2014 model framework. Figure 5.1 shows the results of the best-fit exponential annual improvement rate for these five-year groups, including data from ages 50 to 99.

Figure 5.1
BEST-FIT ANNUAL MORTALITY IMPROVEMENT FOR SELECT FIVE-YEAR AGE BANDS, 1950-2017

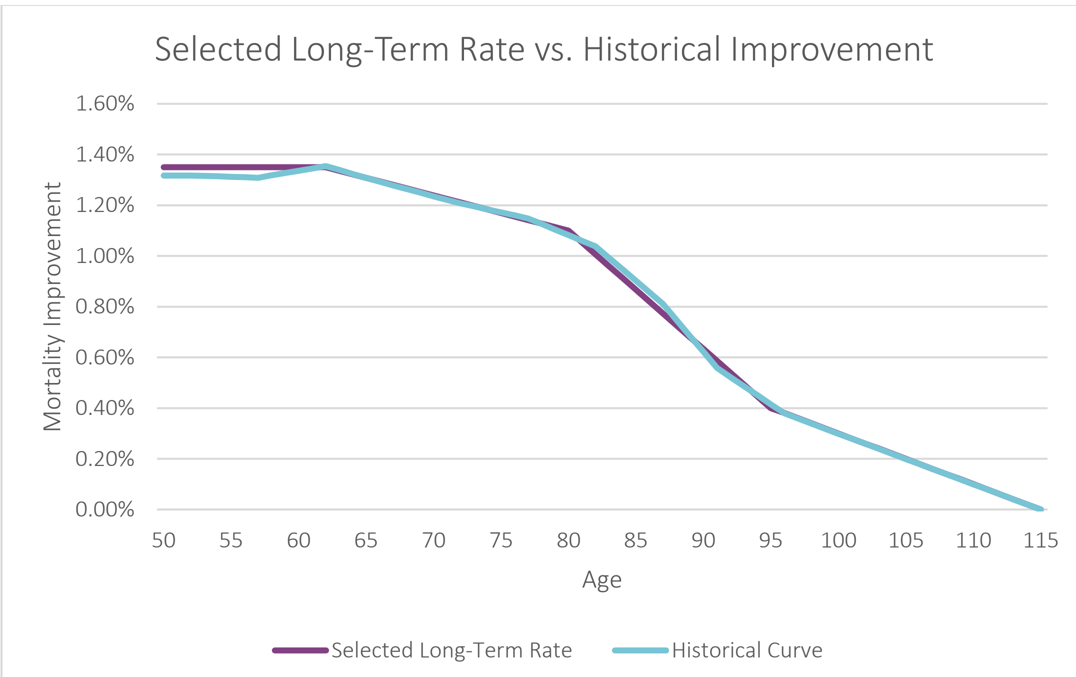


For ages 60 and over, the data shows declining improvement rates by age group, with a more rapid decline after the 80-84 age band. A curve was created by setting the rate at the midpoint age of each five-year age band (e.g. 67 for ages 65-69) equal to the best-fit improvement rate for the five-year age band. For the 90-94 and 95-99 bands, ages 91 and 96 were used as the "midpoint" ages to reflect the significant skew of data toward the younger ages in the band. The rates for ages between successive midpoints were populated via linear interpolation between midpoints. Due to the lack of reliable data above age 100, the historical curve was assumed to grade linearly to zero beginning at the last breakpoint of 96 and ending at age 115.

To reduce the complexity of a proposed long-term rate assumption, RPEC fit a piecewise linear function to the historical data using as few breakpoints as possible without compromising fit. It was found that using a 1.35% rate through age 62, grading down to 1.10% at age 80, grading down to 0.40% at age 95, and finally grading linearly down to 0.00% at age 115 was a close match. This was then chosen by RPEC as the basis for the final MP-2020 long-term rate assumption.

Figure 5.2

REVISED COMMITTEE-SELECTED LONG-TERM RATE VS. BEST-FIT ANNUAL MORTALITY IMPROVEMENT



Section 6: Considerations Related to COVID-19

6.1 COVID-19 AND THE RPEC PROJECTION MODELS AND SCALES

The RPEC projection models and scales published in 2020 do not reflect any adjustment for the impact of COVID-19 on mortality patterns in 2020 and beyond.

According to the Centers for Disease Control and Prevention, over 215,000 deaths due to COVID-19 have occurred in the U.S. as of October 15, 2020. The determination of COVID-19's final toll on 2020 mortality is not yet available, and it is unknown how long the pandemic will last. There has been speculation regarding the net impact of longer-term effects of COVID-19 on population mortality, but there is nothing concrete known at this time. There is also significant uncertainty regarding the timing and effectiveness of potential coronavirus vaccines. Due to a lack of concrete data and the uncertainty regarding how COVID-19 will change public health after 2020, RPEC has not made any changes to its projection models or scales to attempt to reflect COVID-19.

It is unclear at this time how the Committee will decide to use the 2020 mortality data for future mortality projections once it becomes available. As described in subsection 2.2, the RPEC_2014 model smooths historical mortality improvement rates using two-dimensional Whittaker-Henderson graduation. A two-year step-back is performed from the most recent year of historical data. If there are no changes to RPEC's process or the availability of data from the sources described in subsection 2.1, RPEC will first have access to complete 2020 mortality information in early 2022, and the 2022 version of the model would be the first to potentially phase in effects from COVID-19 in the projection of future mortality. As 2021 data emerges, this may help inform the Committee whether the 2020 experience turns out to be a one-year blip or a lasting period effect.

6.2 CONSIDERATIONS FOR PRACTITIONER ADJUSTMENTS FOR COVID-19

Any adjustment for COVID-19 will need to be handled by practitioners, potentially using the parameters available in the RPEC model. Note that the latest data incorporated into the 2020 model was for 2018.

The effects of COVID-19 may depend on plan-specific demographic circumstances and could vary by infection rates within the plan population. Practitioners may want to collect plan mortality experience for 2020 or updated census records as of a current date to assess the actual COVID-19 impact so far and to help inform projection assumptions relevant to the population. An elevated mortality rate in 2020 is not necessarily predictive of future mortality rates. Collection of population data updates will effectively reflect the impact of 2020 mortality on the plan's population.

It is overwhelmingly likely that the year 2020 will ultimately have significant negative mortality improvement over 2019 in the aggregate. Knowing in advance that mortality improvement rates for 2020 will be generally much lower than predicted by the unadjusted RPEC_2014 or RPEC_O2 models, some practitioners may wish to adjust the rates for 2020 in their improvement scales. This should be done with caution, as the mortality improvement rates in the scales produced by the RPEC models are meant to be applied cumulatively across calendar years. Any one-year manual adjustment will, therefore, be effectively used as a multiplicative factor that will affect the assumed mortality rates for all future years.

For example, if the 2020 mortality improvement rate imputed for a given age x is adjusted to be an increase in mortality of 10% (i.e., a negative 10.00% "improvement"), the 2020 mortality rate produced by the scale would be 1.1 times the 2019 mortality rate. Unless the practitioner believes the elevated level of mortality in 2020 will persist in future years, offsetting adjustments will also need to be made for future years' mortality improvement rates. In this example, if the practitioner estimates that the mortality rate at age x in 2021 will be close to what it was in 2019 (due to the advent of a vaccine or improved ability to treat COVID-19), then the mortality rate in 2021 will need to be 90.91% (1 / 1.1) of the 2020 mortality rate. To achieve this, a mortality improvement rate of positive 9.09% (1 – 1 / 1.1) would need to be imputed for 2021. To return to the same 2021 mortality rate that Scale MP-2020 would have produced without adjustment, additional factors will need to be included as well. These examples are shown in more detail in Appendix C.

Section 7: Online Tools

The SOA has made available the following Excel workbooks that users may find helpful:

- Scale MP-2020 rates can be downloaded in an Excel format at https://www.soa.org/globalassets/assets/files/resources/experience-studies/2020/scale-mp-2020-rates.xlsx.

- The RPEC_2014_ v2020 tool can be used to reconstruct Scale MP-2020 or construct alternative scales based on the same underlying order-3 graduated historical mortality data; see the workbook for instructions at https://www.soa.org/globalassets/assets/files/resources/experience-studies/2020/rpec-2014-v2020.xlsm.

- The RPEC_O2_v2020 tool can be used to construct alternative scales based on the order-2 graduated historical mortality data; see the workbook for instructions at https://www.soa.org/globalassets/assets/files/resources/experience-studies/2020/rpec-o2-v2020-model.xlsm.

Section 8: Reliance and Limitations

Mortality Improvement Scale MP-2020, the RPEC_2014_v2020 model, and the RPEC_O2_v2020 model have been developed from U.S. population data for the purpose of valuing U.S. pension and other post-retirement benefit (OPEB) obligations. No assessment has been made concerning the applicability of the models and scale to other purposes.

Section 9: Acknowledgments

The Society of Actuaries would like to thank the Retirement Plans Experience Committee, and especially the Mortality Improvement Subcommittee, for their support, guidance, direction and feedback throughout the project.

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Appendix A: Heat Maps

The next two pages compare the MP-2020 and O2-2020 gender-specific heat maps for calendar years 1951 through 2038[5]. Because of the continued use of a two-year step-back in both sets of rates, 2016 is the final year of graduated historical data included explicitly and 2017 is the first year of the projected rates. The vertical dashed white lines on the heat maps distinguish between the historical and projected rates, and the thin vertical gray lines indicate the 2020 rates.

To cover negative improvement rates with as much detail as positive rates, the color scheme in the RPEC_2014 and RPEC_O2 models have changed compared to the 2019 versions. The range of both positive and negative rates has expanded, and the width of each color band is 0.8% (compared to 0.5% in previous models).

[5] The ultimate rates are achieved in 2036; two additional years are shown to illustrate that the rates level off.

Figure A.1

SCALE MP-2020 HEAT MAP: FEMALES

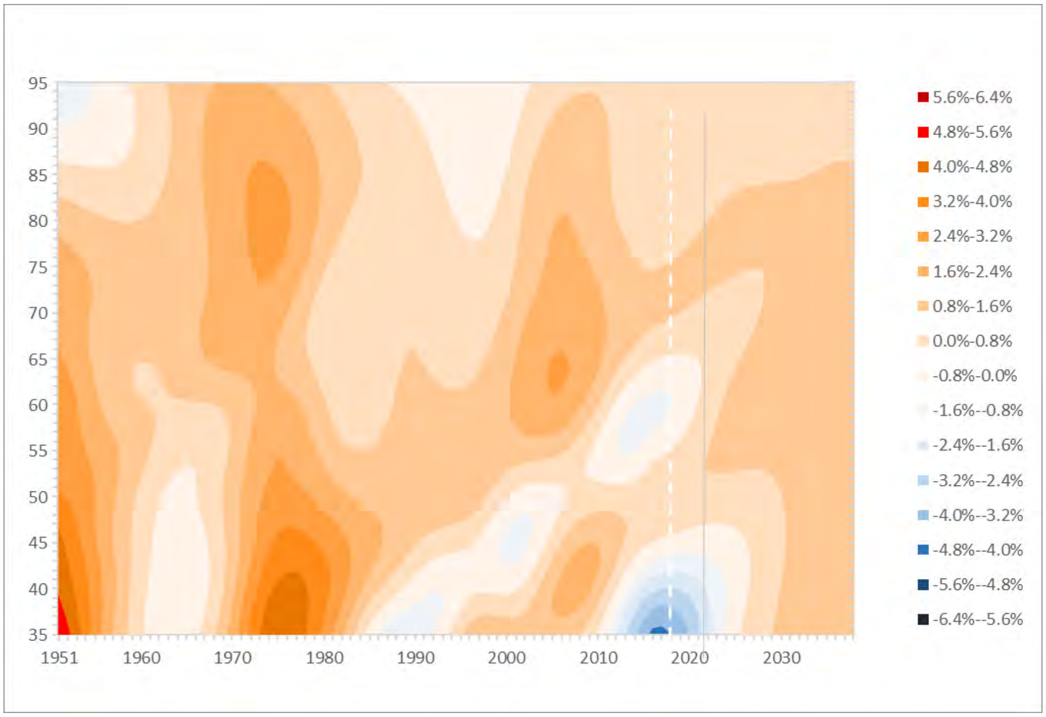


Figure A.2

SCALE MP-2020 HEAT MAP: MALES

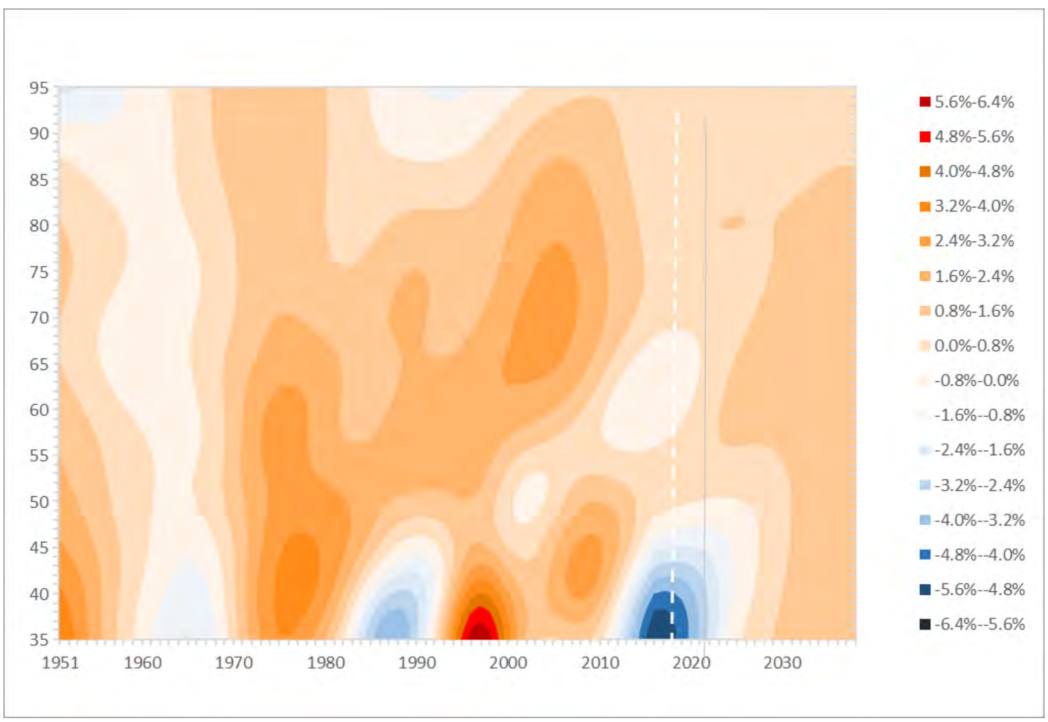


Figure A.3

SCALE O2-2020 HEAT MAP: FEMALES

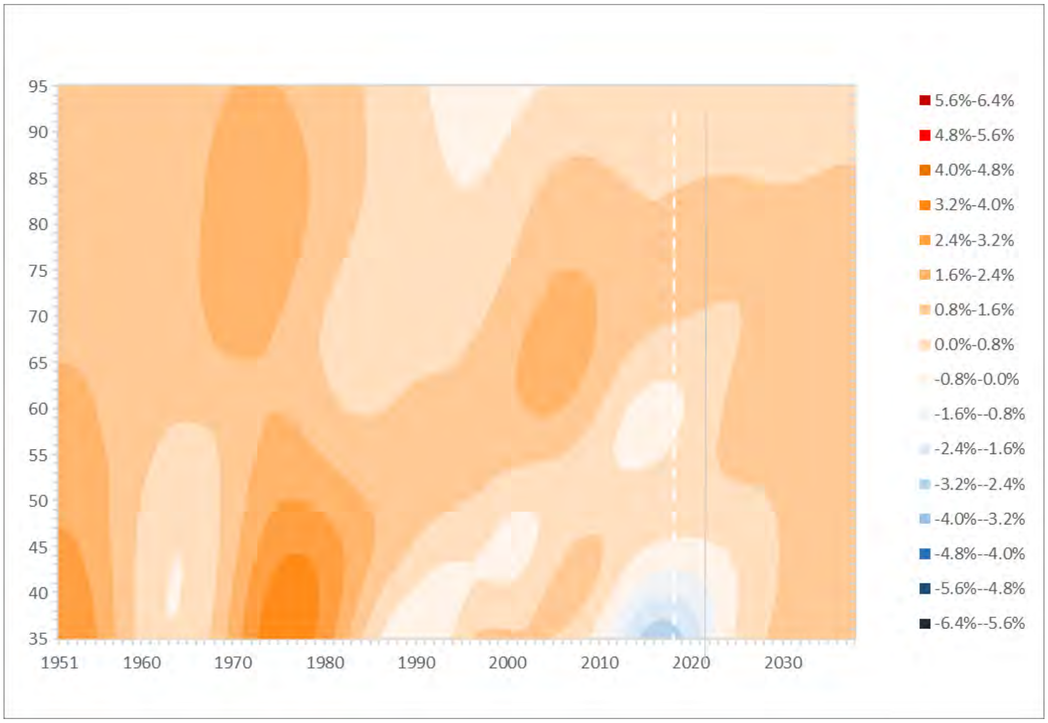
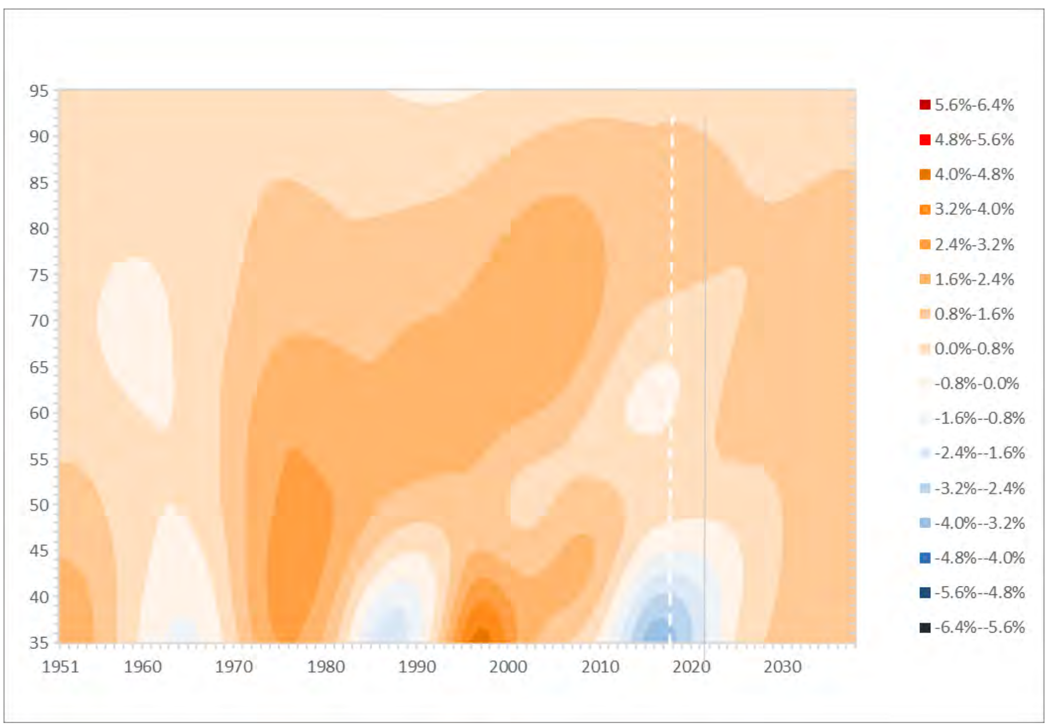


Figure A.4

SCALE O2-2020 HEAT MAP: MALES



Appendix B: Development of SSA-Style Mortality Rates for 2016-2018

RPEC followed the methodology described in the SSA's Actuarial Study No. 120 (SSA 2005) in its development of estimated mortality rates for 2016-2018. The deaths for ages below 65 were taken from the CDC WONDER database (CDC 2020), and the exposures for ages below 65 were taken from the most recent population estimates published by the U.S. Census Bureau (USC 2020). Deaths and exposures for ages 65 and above were made available to RPEC by the CMS.

Appendix B1.3 of the Scale MP-2016 Report (SOA 2016) detailed multiple adjustments made to the Medicare data, including averaging adjacent January 1 populations to approximate a July 1 population count and estimating a forthcoming true-up to preliminary death counts for ages 65 – 69. These adjustments are no longer made due to an update to the manner in which the CMS data has been provided. The CMS exposures are now presented as of mid-year, removing the need for averaging, and there are no longer predictable and significant true-ups of data that take place after the initial release.

Once the raw gender/age-specific death and exposure databases for each calendar year had been developed, RPEC used the iterative process described in Actuarial Study No. 120 to develop graduated "SSA-Style" mortality rates for 2016-2018.

Appendix C: Example of Adjusting RPEC_2014 Model Rates for COVID-19

The RPEC_2014 model produces mortality improvement scales that project mortality rates to future years in the manner described in subsection 6.3 of the Scale MP-2014 report (SOA 2014). Specifically, let $q(x,y)$ represent a specific mortality rate at age x in calendar year y. The projected mortality rate at age x and calendar year $y+1$ under the RPEC_2014 model is calculated as:

$$q(x, y+1) = q(x, y) * (1 - f(x,y+1)),$$

where $f(x, y)$ is the RPEC_2014 mortality improvement rate at age x in calendar year y.

From the above formula, it follows that any adjustment to a mortality improvement rate at age x in a single calendar year to reflect COVID-19 will be applied as a multiplicative factor to determine the mortality rates in all future years.

Adjustments for COVID-19 could vary by age or apply to a range of ages. However, Tables C.1 through C.4 below specifically consider an example of females aged 70. Assume that the 2019 mortality rate for females aged 70 is 0.01000 and the assumed age-70 female mortality improvement rates with no adjustment for COVID-19 are taken from Scale MP-2020. Using the above formula, we can compute the assumed mortality rate for age-70 females in each calendar year[6], as shown below in Table C.1.

Table C.1
SAMPLE UNADJUSTED MORTALITY RATE PROJECTION

Calendar Year	Improvement Rate	Mortality Rate
2019		0.01000
2020	0.0072	0.00993
2021	0.0065	0.00986
2022	0.0059	0.00981
2023	0.0055	0.00975
2024	0.0055	0.00970
2025	0.0058	0.00964

[6] Note that the mortality rates shown in Tables C.1 through C.4 are for females that are 70 years old in the shown calendar year. These are not cohort projections for females aged 70 in 2019, as such persons would be age 71 in 2020, age 72 in 2021, and so forth; separate mortality rates applicable to each successive age would need to be computed for years after 2019 for such a projection.

Suppose it is estimated that mortality for a 70-year old will be approximately 10% higher in 2020 than it was in 2019. This would be an improvement rate of -0.1000. If an actuary were to impute an improvement rate of -0.1000 for 2020 and leave other years unadjusted, the rate projection would be as shown in Table C.2.

Table C.2

SAMPLE ONE-YEAR ADJUSTMENT TO MORTALITY IMPROVEMENT

Calendar Year	Improvement Rate	Mortality Rate
2019		0.01000
2020	-0.1000	0.01100
2021	0.0065	0.01093
2022	0.0059	0.01086
2023	0.0055	0.01080
2024	0.0055	0.01074
2025	0.0058	0.01068

As illustrated by Table C.2, the one-year adjustment to mortality improvement substantially raised the mortality rate not only in 2020, but in all future years. For example, the 2022 mortality rate is approximately 10.7%[7] higher than the unadjusted value shown in Table C.1. This adjustment effectively creates an assumption that leads to mortality rates in short-term future years similar to that experienced in 2020.

If one believes that, due to the advent of a vaccine or a treatment that the 2021 mortality rate for a female age 70 will be approximately the same as the 2019 mortality rate, a corresponding adjustment to the mortality improvement rate in 2021 could be made. Per the example in subsection 6.2, the 2021 improvement rate would be 9.09%(1 – 1 / 1.1). Table C.3 illustrates this progression.

Table C.3

SAMPLE REVERSAL OF ONE-YEAR ADJUSTMENT TO MORTALITY IMPROVEMENT

Calendar Year	Improvement Rate	Mortality Rate
2019		0.01000
2020	-0.1000	0.01100
2021	0.0909	0.01000
2022	0.0059	0.00994
2023	0.0055	0.00989
2024	0.0055	0.00983
2025	0.0058	0.00977

Note that, in Table C.3, the adjusted rates have effectively eliminated the Scale MP-2020 improvement rates for 2020 and 2021 from the calculation of future mortality rates. If the user wishes to continue to reflect those projected MP-2020 improvement rates, another possibility would be to assume that the 2021 mortality rate would be the same as what it would have been had the pandemic never taken place. The

[7] Equals the combined effect of eliminating the 0.72% improvement rate and replacing it with a -10% improvement rate.

improvement rate for 2021 in this case would need to be 10.33%[8]. Table C.4 shows a projection under this assumption.

Table C.4
ALTERNATIVE SAMPLE REVERSAL OF ONE-YEAR ADJUSTMENT TO MORTALITY IMPROVEMENT

Calendar Year	Improvement Rate	Mortality Rate
2019		0.01000
2020	-0.1000	0.01100
2021	0.1033	0.00986
2022	0.0059	0.00981
2023	0.0055	0.00975
2024	0.0055	0.00970
2025	0.0058	0.00964

The purpose of these illustrations is to demonstrate how manual changes to the improvement rates produced by the RPEC_2014 and RPEC_O2 models will impact future assumed mortality rates. None of these hypothetical adjustments are specifically endorsed by RPEC. It is the responsibility of the actuary to determine if and how to adjust mortality projections for the COVID-19 pandemic.

[8] Equals the combined effect of the 9.09% from Table C.3 and the unadjusted Scale MP-2020 improvement rates for 2020 and 2021 (0.72% and 0.65%, respectively). This is calculated as 1 - (0.01 * (1 - 0.0072) * (1 - 0.0065) / 0.011).

Appendix D: Annuity Factors Computed at 7.0%

Table D.1 presents a comparison of monthly deferred-to-62 annuity-due values using various SOA mortality tables, all calculated generationally as of 2020 ("Generational @ 2020") using Scale MP-2020. The "Pri-2012" column of the table uses the "total dataset" version of Pri-2012. These annuity values were computed using the following specifications:

- Employee rates for ages below 62 and Retiree rates for ages 62 and older
- A discount rate of 7.0%

Table D.1

MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 7.0% AS OF JANUARY 1, 2020

SOA MORTALITY TABLES PROJECTED WITH SCALE MP-2020

	Age	Pri-2012	PubG-2010	PubT-2010	PubS-2010
Females	25	0.9560	0.9810	1.0015	0.9630
	35	1.8577	1.9094	1.9531	1.8743
	45	3.6155	3.7228	3.8142	3.6538
	55	7.0624	7.2813	7.4701	7.1384
	65	10.8431	11.1873	11.5155	10.9141
	75	8.3689	8.7531	9.1027	8.4737
	85	5.4221	5.6966	5.9859	5.5788
	95	3.0992	3.2134	3.2587	3.2060
Males	25	0.9080	0.9277	0.9645	0.9284
	35	1.7650	1.8019	1.8770	1.8058
	45	3.4381	3.5124	3.6614	3.5189
	55	6.7255	6.8822	7.1755	6.8785
	65	10.3280	10.5589	11.0247	10.4749
	75	7.8269	8.0352	8.4808	7.8753
	85	4.8654	5.0627	5.3570	4.8946
	95	2.6921	2.8505	2.8781	2.8029

Table D.2 shows how these annuity factors compare to those calculated using Scale MP-2019.

Table D.2

IMPACT OF UPDATING FROM SCALE MP-2019 TO MP-2020 USING VARIOUS BASE MORTALITY TABLES
COMPARISON OF MONTHLY DEFERRED-TO-62 ANNUITY-DUE VALUES AT 7.0% AS OF JANUARY 1, 2020

	Age	Pri-2012 7 pct	PubG-2010 7 pct	PubT-2010 7 pct	PubS-2010 7 pct
Females	25	0.15%	-0.06%	-0.21%	0.06%
	35	0.10%	-0.07%	-0.20%	0.03%
	45	0.01%	-0.12%	-0.21%	-0.04%
	55	-0.12%	-0.19%	-0.25%	-0.14%
	65	-0.24%	-0.29%	-0.32%	-0.26%
	75	-0.56%	-0.58%	-0.59%	-0.57%
	85	-0.84%	-0.84%	-0.82%	-0.84%
	95	-0.60%	-0.59%	-0.58%	-0.59%
Males	25	0.29%	0.13%	-0.11%	0.10%
	35	0.14%	0.02%	-0.16%	0.01%
	45	-0.02%	-0.10%	-0.22%	-0.10%
	55	-0.20%	-0.23%	-0.29%	-0.22%
	65	-0.34%	-0.35%	-0.37%	-0.35%
	75	-0.56%	-0.58%	-0.60%	-0.58%
	85	-0.81%	-0.82%	-0.82%	-0.83%
	95	-0.83%	-0.85%	-0.84%	-0.87%

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About The Society of Actuaries

With roots dating back to 1889, the Society of Actuaries (SOA) is the world's largest actuarial professional organization with more than 31,000 members. Through research and education, the SOA's mission is to advance actuarial knowledge and to enhance the ability of actuaries to provide expert advice and relevant solutions for financial, business and societal challenges. The SOA's vision is for actuaries to be the leading professionals in the measurement and management of risk.

The SOA supports actuaries and advances knowledge through research and education. As part of its work, the SOA seeks to inform public policy development and public understanding through research. The SOA aspires to be a trusted source of objective, data-driven research and analysis with an actuarial perspective for its members, industry, policymakers and the public. This distinct perspective comes from the SOA as an association of actuaries, who have a rigorous formal education and direct experience as practitioners as they perform applied research. The SOA also welcomes the opportunity to partner with other organizations in our work where appropriate.

The SOA has a history of working with public policymakers and regulators in developing historical experience studies and projection techniques as well as individual reports on health care, retirement and other topics. The SOA's research is intended to aid the work of policymakers and regulators and follow certain core principles:

Objectivity: The SOA's research informs and provides analysis that can be relied upon by other individuals or organizations involved in public policy discussions. The SOA does not take advocacy positions or lobby specific policy proposals.

Quality: The SOA aspires to the highest ethical and quality standards in all of its research and analysis. Our research process is overseen by experienced actuaries and nonactuaries from a range of industry sectors and organizations. A rigorous peer-review process ensures the quality and integrity of our work.

Relevance: The SOA provides timely research on public policy issues. Our research advances actuarial knowledge while providing critical insights on key policy issues, and thereby provides value to stakeholders and decision makers.

Quantification: The SOA leverages the diverse skill sets of actuaries to provide research and findings that are driven by the best available data and methods. Actuaries use detailed modeling to analyze financial risk and provide distinct insight and quantification. Further, actuarial standards require transparency and the disclosure of the assumptions and analytic approach underlying the work.

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