Canadian Institute of Actuaries | Institut canadien des actuaires

Research Paper

Research Paper on Mortality Improvement Promulgation

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MEMORANDUM

To: All Fellows, Affiliates, Associates, and Correspondents of the Canadian Institute of Actuaries and other interested parties

From: Pierre Dionne, Chair
Practice Council

Dominic Hains, Chair
Designated Group

Date: May 17, 2017

Subject: **Research Paper on Mortality Improvement Promulgation**

Deadline for Comments: **June 30, 2017**

The Designated Group on Mortality Improvement has prepared this research paper and seeks the comments of CIA members and other interested parties.

Please forward your comments regarding this report to Chris Fievoli, at chris.fievoli@cia-ica.ca and Dominic Hains, Chair, at DHains@rgare.ca.

PD, DH

Table of Contents

1. General Overview

The primary purpose of this research paper is to provide support for an updated promulgation for mortality improvement (a secular trend toward lower mortality rates) with respect to the valuation of insurance and annuity business.

According to subsection 2350 of the current Standards of Practice, for insurance mortality:

.07 The actuary would consider the inclusion of mortality improvement (a secular trend toward lower mortality rates) in the best estimate assumption and associated margin. The margin for adverse deviations related to the mortality improvement assumption is not restricted to the range of 5% to 20% noted in paragraph 2350.01.

.08 If the inclusion of mortality improvement reduces the insurance contract liabilities, then the resulting reduction would be no greater than that developed using prescribed mortality improvement rates as promulgated from time to time by the Actuarial Standards Board. If, at an appropriate level of aggregation, the inclusion of mortality improvement increases the insurance contract liabilities, then the actuary's assumption would include such improvement. The resulting increase in insurance contract liabilities would be at least as great as that developed using prescribed mortality improvement rates as promulgated from time to time by the Actuarial Standards Board.

.09 The low and high margins for adverse deviations for the mortality rates per 1,000 would be respectively an addition or subtraction, as appropriate, of 3.75 and 15, each divided by the curtate expectation of life at the life insured's projected attained age. These margins for adverse deviations are applied after mortality improvement.

For annuitant mortality:

.12 The mortality improvement assumption would include a best estimate assumption and an associated margin. The margin for adverse deviations related to the mortality improvement assumption is not restricted to the range of 5% to 20% noted in paragraph 2350.01. The actuary's assumption would include mortality improvement, the effect of which is to increase insurance contract liabilities, such that the resulting increase would be at least as great as that developed using prescribed mortality improvement rates as promulgated from time to time by the Actuarial Standards Board.

.13 The low and high margins for adverse deviations for the mortality rates would be respectively a subtraction of 2% and 8% of the best estimate.

The promulgated prescribed mortality improvement rates from the 2011 promulgation were supported by a research paper published in 2010, based on Canadian population mortality data from 1921–2002. The intent was to periodically review the prescribed mortality improvement rates described in the promulgation. Canadian population mortality data from different sources is now available for calendar years up to 2015.

Since the promulgation, there have also been many developments worldwide on mortality improvement models, and a number of mortality improvement tables have been published (for example the CPM-B table in Canada and the MP-2016 table in the United States). Many of these models are two-dimensional with mortality improvement rates a function of both

calendar year and attained age, in comparison to the current prescribed mortality improvement rates that are a function of the attained age only.

This document provides updated guidance and background on future expected mortality improvement. It also outlines revised levels of margins for adverse deviations for insurance and annuity policy liabilities.

2. Task Force Report on Mortality Improvement

The base mortality improvement rates presented in section 3 correspond to the mortality improvement scale for the general Canadian population produced by the CIA Task Force on Mortality Improvement (task force). This scale (MI-2017) is described in the task force's research paper published concurrently to this report. This section provides a high-level overview of the data and method used by the task force to develop their mortality improvement scale.

2.1 Data

The task force primarily used the data from the Human Mortality Database (HMD) which includes mortality data for the general population in Canada covering the period from 1921 through 2011. Data is available by attained age and gender. The HMD is based on Canadian vital statistics prepared by Statistics Canada.

The task force was also able to obtain, on a confidential basis, data from Old Age Security (OAS) in Canada from 2005 to 2015 for ages 65 and older. OAS and HMD data are almost identical for years and ages where they are both available.

The task force used both the HMD and OAS data. A statistical technique was used to infer the mortality rates from 2012 to 2015 for ages 64 and younger.

2.2 General Approach

The base mortality improvement rates were developed under the following conceptual framework:

- Past mortality data are graduated to determine initial mortality improvement rates. These rates vary by gender, age, and calendar year.
- Ultimate mortality improvement rates are established based on ultimate average mortality improvement rates and expert opinion. These rates vary by age only.
- Mortality improvement rates are assumed to transition smoothly from the initial mortality improvement rates to the ultimate mortality improvement rates over a certain convergence period.

2.3 Initial Rates

The graduation technique used to smooth the past mortality data is the Whittaker-Henderson (WH) method.

The logarithms of the ratios of the raw mortality rates to the rates of a smooth base table (A/E ratio) were graduated. The weights of the graduation are the expected deaths on the base table.

WH minimizes the following sums:

$$\sum\sum(Wt(Grad-Raw)^2+h\sum\sum({}_{hor}\Delta^m Grad)^2+v\sum\sum({}_{ver}\Delta^n Grad)^2$$

The second term is the sum of squared m[th] finite difference taken in a horizontal direction (across years within each age), and the third is the sum of squared n[th] finite difference taken in a vertical direction (along ages within each year). The variable "Raw" corresponds to the logarithm of A/E ratios and "Wt" to the normalized expected deaths. The order of difference (m and n) is 2 is both cases, and the balancing factors (h and v) are both 300. These parameters were chosen using back testing, striking a balance between stability and predictiveness.

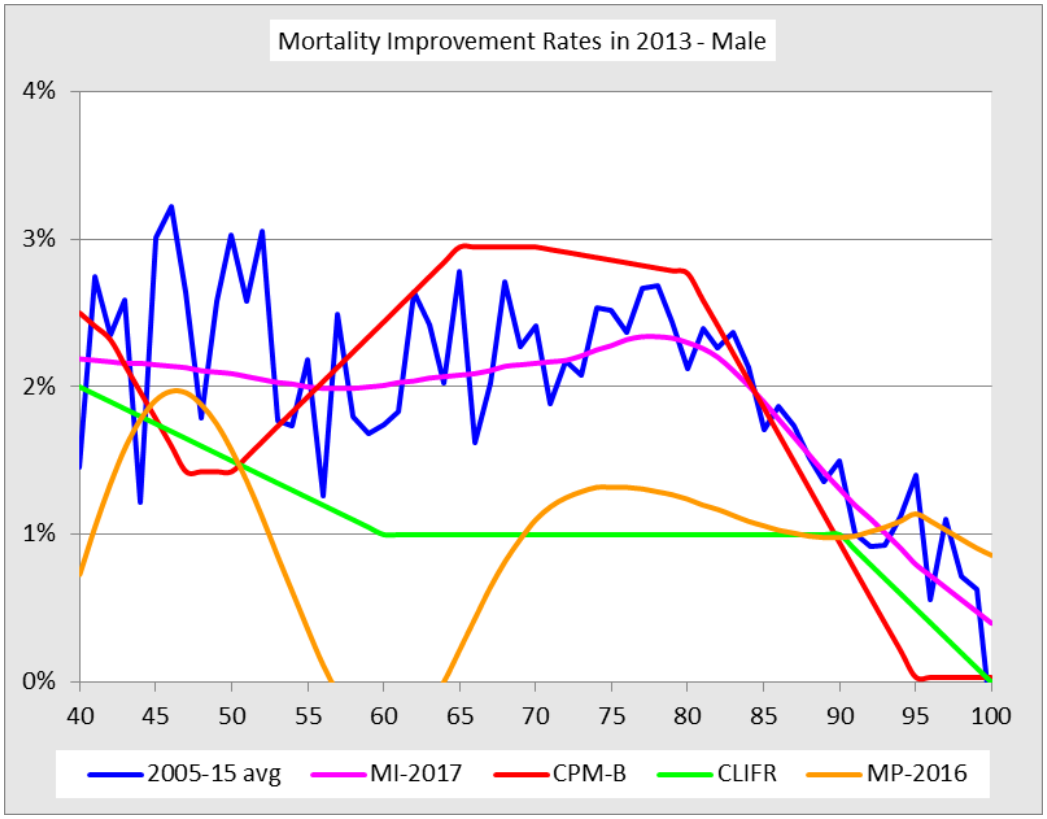
Improvement rates for age *x* and year *y* are calculated directly from the graduated numbers:

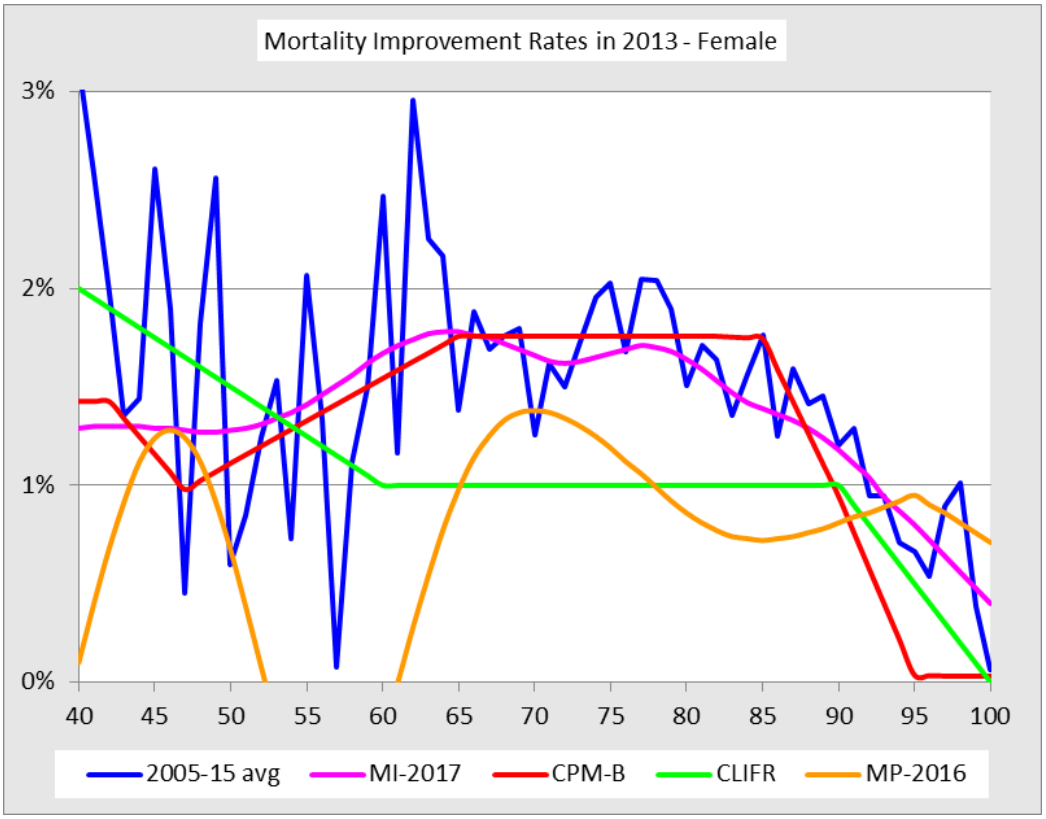
$$\mathrm{Imp}(x,y)=1-\exp(\mathrm{Grad}(x,y)-\mathrm{Grad}(x,y-1))$$

The initial rates for male and female are defined as the age-specific improvement rates covering calendar years 1970 to 2013 resulting from this graduation. The year 2013 corresponds to a step back of two years from 2015, the last year of the available historical data. A step back is used because the graduated rates are less reliable along the edges of the data.

Although improvement rates were calculated to age 100, the rates at the highest ages could not be considered reliable because there is little data at the highest ages. Therefore, the step back was set at five years for high ages. Improvement rates over age 95 are calculated by linear interpolation from the age 95 rate to zero at age 105 and higher.

The following graphs show the resulting rates in 2013 in comparison to the 10-year average improvement rates and to other existing publicly available scales.





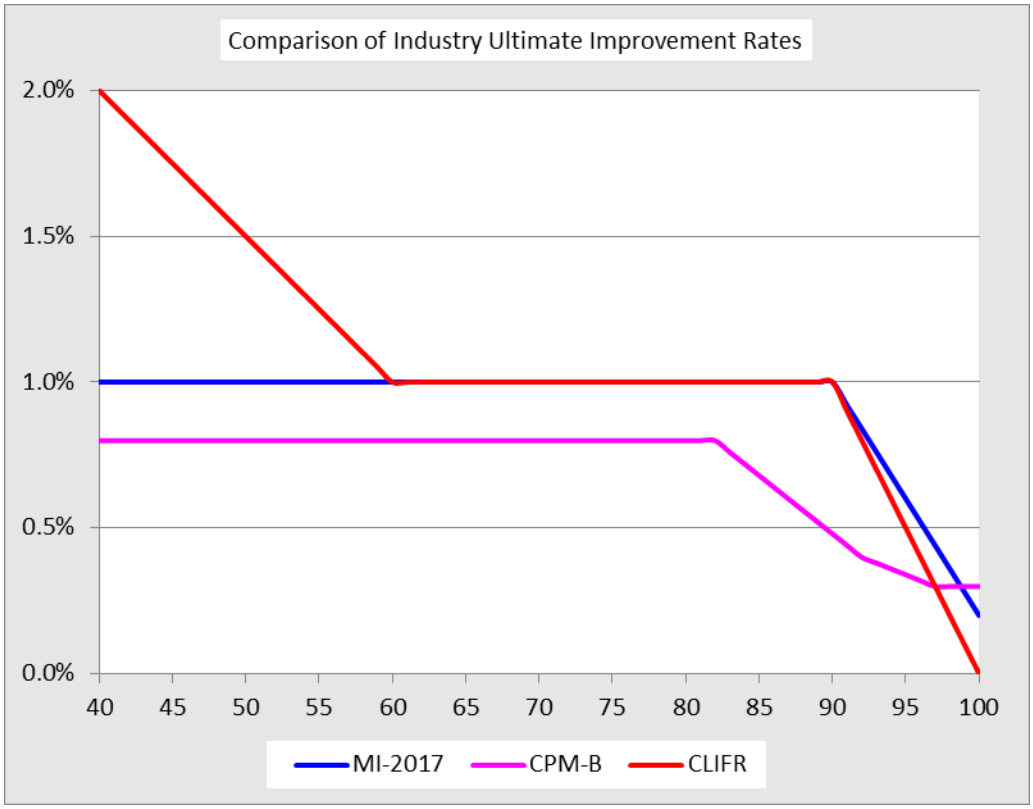
2.4 Ultimate Rates

The task force considered ultimate historical averages of mortality improvement from the HMD data (over periods of the last 20, 50, and 90 years) and considered a large range of opinions from experts in the field to come up with a ultimate-rate mortality improvement assumption.

In reviewing available results and surveys of the mortality projections produced by various organizations in Canada and around the world, the task force found that most of the common range for the ultimate rate assumption is around 0.8% to 1.2%. This range gave the task force a reference point to ensure that their view of future longevity was similar to other experts in the industry.

The task force established the ultimate mortality improvement rates at 1% for ages up to 90. Ultimate mortality improvement rates decrease to 0.2% at age 100 and 0% at age 105.

The following graph shows the proposed ultimate improvement rates compared to the CPM-B and Committee on Life Insurance Financial Reporting (CLIFR) scales.



2.5 Convergence Period and Method

Significant professional judgment is required to select a convergence period in the mortality improvement model. The main consideration for establishing this assumption was the length of the cycles of mortality improvement rates observed in the past. A visual inspection of the historical heat maps provided some insight in this respect.

In the absence of a compelling quantitative analysis, the task force decided to adopt a convergence period similar to that assumed in the building of other mortality improvement scales in recent years throughout the world.

The task force decided to assume a convergence period of 10 years (until 2023) for ages 0–40 and a convergence period of 20 years (until 2033) for ages 60 and up. For ages 41–59 the transition period is interpolated linearly.

To achieve a smooth transition, the task force fitted a cubic equation between 2013 (the last year of the initial rates) and the ultimate rate. This method is similar to that used by the Continuous Mortality Investigation (CMI) and the Society of Actuaries' (SOA's) Retirement Plans Experience Committee (RPEC).

3. Base Mortality Improvement Scales

The designated group has reviewed all aspects of the task force work, including the choice of data and methods, and considers that the task force's proposed mortality improvement scale (MI-2017) is an appropriate basis for the purpose of this promulgation.

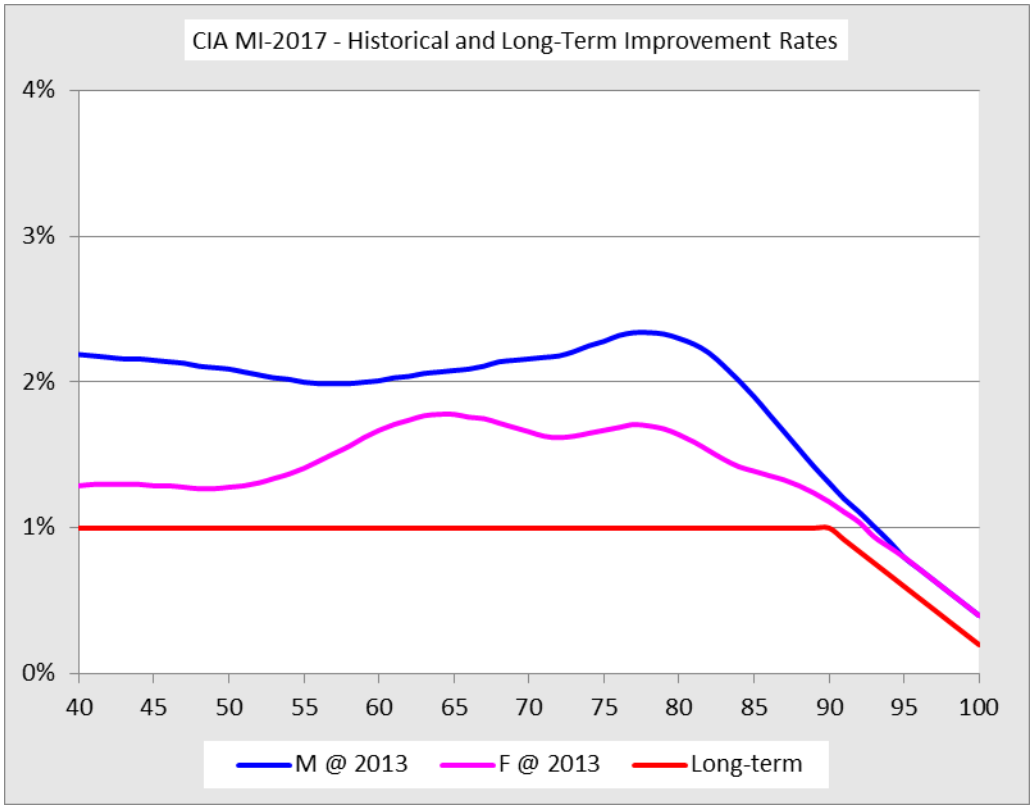
Link to Excel file

The following tables show illustrative rates for key ages:

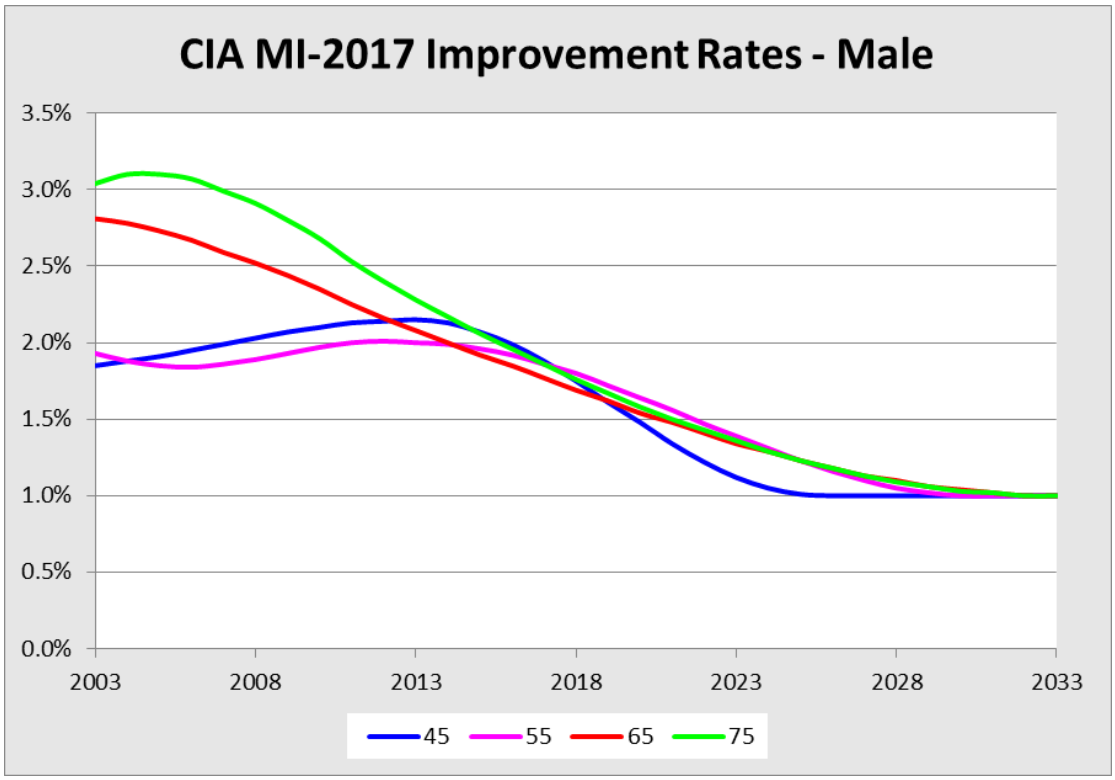
Male					
Attained Age\Calendar Year	**2013**	**2018**	**2023**	**2028**	**2033**
45	2.15%	1.75%	1.12%	1.00%	1.00%
55	2.00%	1.80%	1.39%	1.05%	1.00%
65	2.08%	1.69%	1.34%	1.10%	1.00%
75	2.28%	1.76%	1.35%	1.09%	1.00%
85	1.90%	1.57%	1.29%	1.08%	1.00%

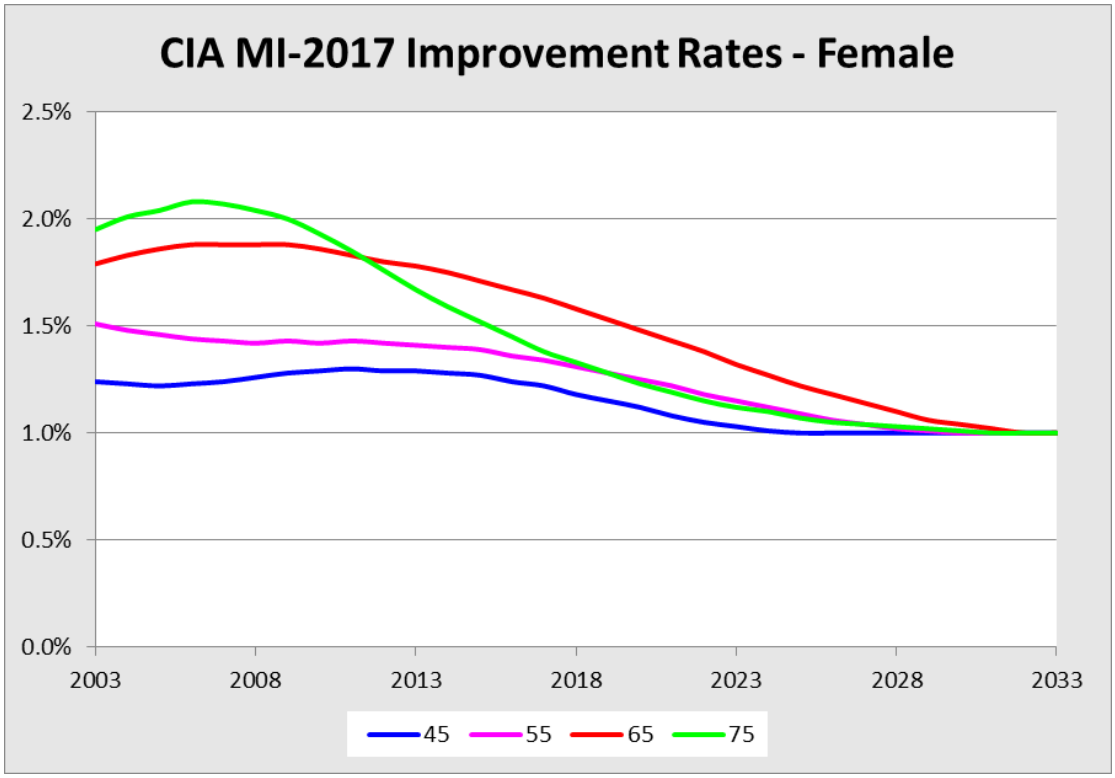
Female					
Attained Age\Calendar Year	**2013**	**2018**	**2023**	**2028**	**2033**
45	1.29%	1.18%	1.03%	1.00%	1.00%
55	1.41%	1.32%	1.15%	1.02%	1.00%
65	1.78%	1.58%	1.32%	1.10%	1.00%
75	1.67%	1.33%	1.12%	1.02%	1.00%
85	1.39%	1.04%	0.94%	0.96%	1.00%

The following graph shows how the initial improvement rates as of 2013 (the last year of historical improvement rate after step back) and ultimate improvement rates compare.



The following graphs present the improvement rates of the MI-2017 scale for key attained ages. One can see the smooth progression from the rates for historical years toward the ultimate rate. The first year of the projection is 2014.





4. Prescribed Mortality Improvement Scales

4.1 Adjustments for Segments of the General Population

The task force did conduct a literature review of what studies exist to determine whether the best estimate assumption for the general population could or should be modified for different segments of the population.

The main observations are the following:

- Several papers concluded that in the U.S., mortality improvement has been higher for the higher socio-economic classes during a period from approximately 1980 to 2000. The inequality has thus been rising during this period in the U.S.
- Some papers concluded that the inequality has diminished in the UK and in Canada during the 2000 to 2010 period.
- Mortality improvement has been lower for smokers than for non-smokers.

The designated group supports the task force view that it may be appropriate for the actuary to establish mortality improvement assumptions that vary by segments of the population, when there is evidence of differences in recently observed data, but that the mortality improvement scale developed by the task force and based on the general population would be in a reasonable range for most actuarial applications in Canada. As a result, the prescribed mortality improvement rates are based on population data and would be used for all segments of the population.

4.2 Prescribed Mortality Improvement Rates

The prescribed mortality improvement rates are a function of the gender, attained age, and calendar year, and are intended to be used to project future mortality improvement after the valuation date (e.g., they are not intended to be a constraint on how the actuary brings forward

the results of a mortality study to the valuation date). The promulgated mortality improvement rates vary by calendar year. Therefore, there would be no reset of the calendar year scale from one valuation to the next.

It is intended that the prescribed mortality improvement rates include a measure of conservatism.

The prescribed rates are developed from a set of base mortality improvement rates and mortality improvement scenarios as described below. The first scenario would be expected to apply in situations where the reflection of mortality improvement decreases liabilities and the second scenario where the effect is to increase liabilities.

1. Mortality improvement would be projected for all future years using the base mortality improvement rates as described above, reduced by a margin for adverse deviations, as described below, adjusted for diversification. The margin for adverse deviations varies by attained age.
2. Mortality improvement would be projected for all future years using the base mortality improvement rates as described above, augmented by a margin for adverse deviations, as described below, adjusted for diversification. The margin for adverse deviations varies by attained age.

Table 1: Margin for Adverse Deviations to Deduct from/Add to Annual Base Mortality Improvement Rates

(applies to both females and males, and to both smokers and non-smokers)

Attained Age	MfAD	Attained Age	MfAD
0 to 40	1.00%	61 to 90	0.500%
41	0.975%	91	0.480%
42	0.950%	92	0.460%
43	0.925%	93	0.440%
44	0.900%	94	0.420%
45	0.875%	95	0.400%
46	0.850%	96	0.380%
47	0.825%	97	0.360%
48	0.800%	98	0.340%
49	0.775%	99	0.320%
50	0.750%	100	0.300%
51	0.725%	101	0.280%
52	0.700%	102	0.260%
53	0.675%	103	0.240%
54	0.650%	104	0.220%
55	0.625%	105 to 115	0.200%
56	0.600%	116+	0.000%
57	0.575%		
58	0.550%		
59	0.525%		
60	0.500%		

As a first step, the prescribed mortality improvement rates would be the rates from the mortality improvement scenario producing the higher liability, determined at an appropriate level of aggregation. For this first step, it would be inappropriate to aggregate annuities with life insurance business.

When considering an appropriate level of aggregation for different insurance products, the actuary would consider different factors, such as

- The plan of insurance and its benefits provided;
- The socioeconomic profile of the insureds;
- The insurer's underwriting practice for the plan of insurance;
- The age distribution;
- The country of issue and residence; and
- The insurer's distribution system and other marketing practice.

The structure and impact of any reinsurance agreement would not be a reason alone to differentiate between products with a similar profile.

Diversification (Death Sensitive and Supported)

As a second step, the actuary would determine whether it is appropriate to include a diversification benefit between 1) all aggregated death-sensitive blocks of business and 2) all aggregated death-supported blocks of business. Mortality improvement reflects a secular trend that impacts populations' mortality in general. It is expected that significant changes in this trend would impact mortality widely and in a similar way across populations, irrespective of whether the individuals possess life insurance policies or annuities. Hence, companies with death-supported and death-sensitive products are expected to have some natural hedging with respect to the uncertainty of future mortality improvement. To better recognize the value of such diversification, the revised promulgation is allowing a reduction up to 50% of margins used in developing the prescribed mortality improvement rates. Capping the reduction to 50% recognizes that the natural hedging between death-supported and death-sensitive portfolios is partial, and that uncertainty of future mortality improvement cannot be fully eliminated. Considerations that impact the level of diversification include the following:

1. Sensitivity of the blocks to mortality improvement.

   This is a key consideration in better understanding the level of potential offset between two blocks of business. Higher diversification may be achieved when sensitivities applied to future mortality improvement impact liabilities similarly in magnitude, but in the opposite direction. For example, a situation where sensitivities of one block are much larger than the other would highlight that there is little diversification benefit with respect to the uncertainty of future mortality improvement.

2. Distribution of exposures by age.

   Historically, we have observed variations in mortality improvement by age. This was caused by different drivers impacting various age groups differently. For example, the reduction in mortality from cardiovascular diseases mainly impacted older ages as this is not a significant cause of death at younger ages.

Similar distribution of exposures by age between the death-supported and the death-sensitive blocks would increase confidence that future mortality improvement impacts liabilities similarly. For example, term insurance policies would likely have very little mortality exposure at advanced ages and provide limited offset against a life annuity at these ages.

3. Duration of blocks.

   Dissimilar durations between the death-supported and the death-sensitive blocks would reduce the benefits from diversification at later durations.

4. Gender, socio-economic profiles, country of issue, and residence; other factors.

   Historically, we have observed variations in mortality improvement among gender, socio-economic profiles, and/or country of issue and residence. Other factors may also exhibit different patterns of mortality improvement, such as smoking status or preferred risk classes. Similar compositions between the death-supported and the death-sensitive blocks would increase confidence that future mortality improvement impacts liabilities similarly.

4.3 Margin for Adverse Deviations

The margin related to the base mortality improvement was developed considering uncertainty with respect to the future improvement assumption due to factors such as the following:

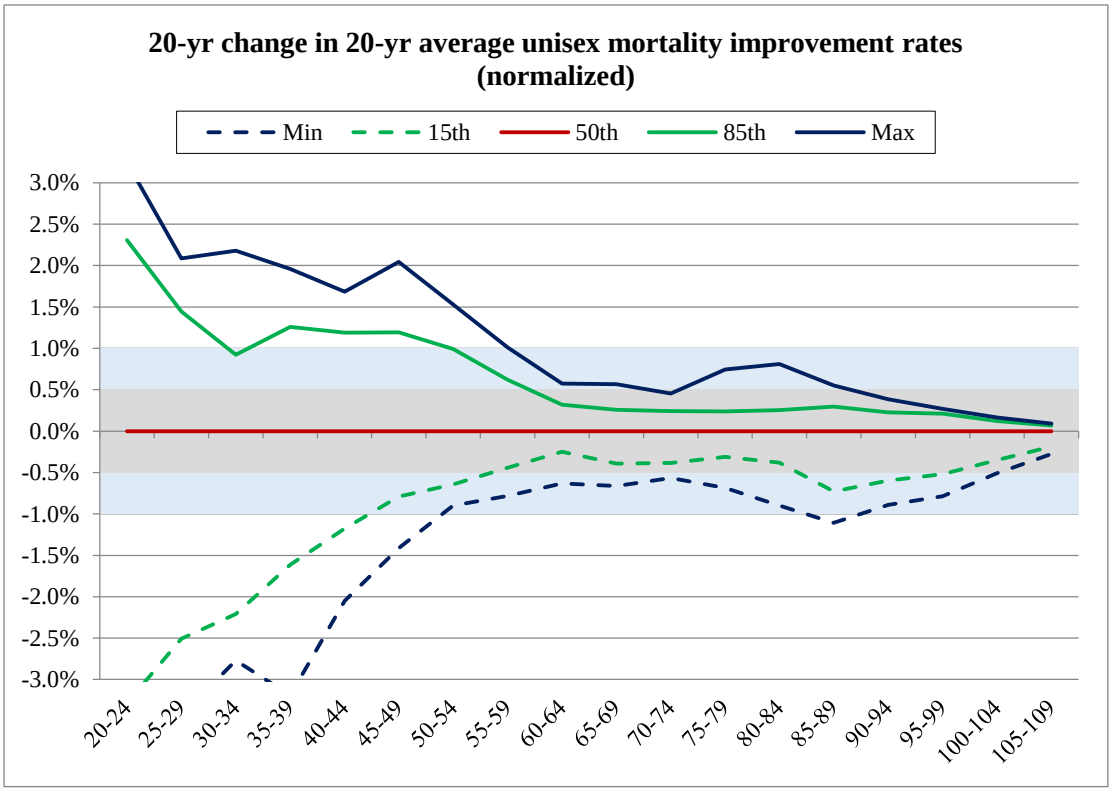
- Past experience not being representative of future experience. Historical improvements due to medical advancements and lifestyle changes may not affect mortality to the same degree in the future.
- Future experience is difficult to estimate. Potential impacts from medical and technological breakthroughs could increase the rate of improvement in the future, while the emergence of new or mutated forms of disease, and resistance to antibiotics, could impede improvement in the future.
- Current lack of smoker/preferred risk splits.
- Use of population rather than insurance/annuity data (for example, the AIDS death rate pattern in the insured population has not been the same as in the general population; target markets are different; genetic testing may affect self-selection).

The following margins for adverse deviations that vary by attained age were developed for both life insurance and annuities:

- 1.0% for ages 0 to 40;
- 0.5% for ages 60 to 90;
- 0.2% for ages 105 to 115;
- 0% for 116+; and
- Decreasing linearly between ages.

The margin for adverse deviations are illustrated in table 1 above and are the same for both females and males, and for both smokers and non-smokers.

The margin was developed based on the analysis around the uncertainty of the mortality improvement assumption to ensure we would cover potential adverse deviations in the future. The following chart summarizes the variability of using the last 20 years of historical mortality improvement rates to predict the next 20 years of mortality improvement. The mortality improvement difference at the 85th (15th) percentile shown on the chart is consistent with the recommended margins for adverse deviations.



It is recommended that the margins for adverse deviations be in the form of a constant scalar to add/deduct from the base mortality improvement rates rather than multiplying the base rate by a factor. This prevents having a very small margin for adverse deviations when the base mortality improvement rate is close to 0.

Using time series theory, one would conclude that the margin required, expressed as a flat addition to or subtraction from the base mortality improvement rates, should decrease as the projection horizon increases. Intuitively, this is because of a diversification effect that applies over time, where periods of higher-than-average mortality improvement follow periods of lower-than-average mortality improvement. This means that in theory, the margin required to cover a certain level of risk would be larger for a 10-year projection than a 40-year projection. For this reason, a decreasing pattern of margins has been considered, but after considering practicality and materiality, a constant margin is recommended.

4.4 Comparison to 2011 Prescribed Mortality Improvement Rates

The 2017 margins for adverse deviations are similar to the 2011 promulgation except for the following:

1. Higher margins for ages 90+ reflecting recent acceleration in mortality improvement rates at older ages in a number of countries around the world. The 2011 promulgation assumed that margins decrease linearly from 0.5% to 0% from age 90 to 100 compared

to the 2017 margins decreasing from 0.5% to 0.2% from ages 90 to 100 and 0.2% to age 115.

2. Application of margins for adverse deviations at all durations. The prescribed mortality improvement rates from the 2011 promulgation had a maximum projection period of 25 years of mortality improvement for life insurance. That 25-year maximum did not apply to annuity business and death-supported life insurance. Continuing to use the same approach was considered, but ultimately not recommended due to the asymmetry in the margin for adverse deviations that it creates in the projected mortality improvement rates (i.e., 100% margin beyond 25 years for life insurance, and 0% margin beyond 25 years for annuity business and death-supported life insurance). A symmetrical approach for the application of the margin for adverse deviations at all durations was preferred. The fact that the base mortality improvement rates are developed using population data also supports that symmetry. As a result, it is recommended to apply the margin for adverse deviations at all durations in determining the minimum valuation assumption for both life insurance and annuity business.

The following table presents illustrative life expectancy factors for key ages as at January 1, 2018, using 100% of the CPM2014 mortality table.

Table 2: Life Expectancy Factors for Key Ages

Gender	Age	2011 Promulgation			2017 Promulgation			% change from 2011		
		Base	PfAD	Total	Base	PfAD	Total	Base	PfAD	Total
Male	40	46.2	1.0	47.2	46.6	1.7	48.2	0.7%	71.7%	2.2%
	50	36.1	0.8	36.9	36.4	1.2	37.7	1.0%	44.8%	2.0%
	60	26.5	0.7	27.2	26.8	0.8	27.6	1.1%	23.3%	1.7%
	70	17.6	0.4	18.0	17.8	0.5	18.3	1.3%	15.0%	1.6%
	80	9.9	0.2	10.1	10.0	0.2	10.2	1.1%	21.2%	1.4%
	90	4.5	0.0	4.5	4.5	0.1	4.6	0.7%	68.7%	1.3%
Female	40	49.7	0.8	50.6	49.9	1.6	51.5	0.4%	92.4%	1.9%
	50	39.4	0.8	40.1	39.5	1.2	40.8	0.4%	59.6%	1.6%
	60	29.3	0.6	30.0	29.5	0.9	30.3	0.5%	33.7%	1.2%
	70	20.0	0.4	20.4	20.1	0.5	20.6	0.4%	22.9%	0.9%
	80	11.7	0.2	11.9	11.7	0.2	12.0	0.3%	30.8%	0.8%
	90	5.5	0.0	5.6	5.5	0.1	5.6	0.5%	92.1%	1.2%

These factors are provided for reference only, to illustrate the potential materiality of applying the 2017 prescribed mortality improvement rates compared to the 2011 promulgation.

5. Accident and Sickness

5.1 Active Lives

It is expected that the trends in mortality improvement for active lives will be generally similar to those used for life insurance and annuity business for the following reasons:

- The prescribed mortality improvement rates to be used for life insurance and annuity business are based on population data; and
- There is no data to support, and no reason to believe, that active lives for accident and sickness insurance would be different than the lives for life insurance and annuity business.

Therefore, the actuary would perform the two scenarios described in section 4.2 for active lives. The scenario that increases the liability would be the minimum valuation assumption. The same considerations for aggregation and diversification would apply to active lives.

5.2 Non-Active Lives

Non-active lives are lives that are currently receiving benefits and the portion of lives that are expected to be in receipt of future benefits as measured in an active life reserve.

The designated group supports the conclusion reached by a CLIFR subcommittee in 2014 that there is no reason to broadly support the application of mortality improvement to non-active lives and that there is no publicly available evidence that clearly supports the view that mortality improvement applies to non-active lives. The actuary would consider mortality improvements for non-active lives only if the actuary has rationale that the population of non-active lives will exhibit mortality improvement.