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Draft Report

Task Force Report on Mortality Improvement

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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

Alexis Gerbeau, Chair
Task Force on Mortality Improvement

Date: April 28, 2017

Subject: **Task Force Report on Mortality Improvement (Draft)**

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

The Task Force on Mortality Improvement has prepared this report 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 Alexis Gerbeau, Chair, at Alexis_Gerbeau@manulife.com.

PD, AG

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1 Executive Summary

The report has been prepared by the Canadian Institute of Actuaries (CIA) Task Force on Mortality Improvement and provides an analysis of the rate of mortality improvement for the Canadian population and the construction of a mortality projection scale for the purpose of reflecting future mortality improvement in Canadian actuarial work.

The results presented in this report are based in part on an examination of the historical rates of mortality improvement up to 2011 in the general Canadian population data recorded in the Human Mortality Database (HMD), supplemented by additional data for the Canadian Old Age Security (OAS) Program plan up to 2015. This analysis included the application of standard actuarial techniques for graduating volatile historical improvement rates to identify underlying trends. In addition, the task force also reviewed commonly used techniques for building future mortality improvement scales that combine historical experience with expert opinion on the prospects for future improvement in population mortality rates.

A two-dimensional mortality improvement scale, MI-2017, is presented in this report. This scale was derived by assuming that observed historical mortality improvement rates will transition smoothly to an assumed long-term mortality improvement rate, with the transition occurring over a 10–20 year period varying by age. The long-term mortality improvement rate was selected to be close to the long-term historical average and in the middle of the range of typical expert opinion. A sample of the mortality improvement rates under MI-2017 are as follows:

Age\ Year	Male					Female				
	2013	**2018**	**2023**	**2028**	**2033**	**2013**	**2018**	**2023**	**2028**	**2033**
45	2.15%	1.75%	1.12%	1.00%	1.00%	1.29%	1.18%	1.03%	1.00%	1.00%
55	2.00%	1.80%	1.3[illegible]%	1.05%	1.00%	1.41%	1.31%	1.15%	1.02%	1.00%
65	2.08%	1.69%	1.34%	1.10%	1.00%	1.78%	1.58%	1.32%	1.10%	1.00%
75	2.28%	1.76%	1.30%	1.09%	1.00%	1.67%	1.33%	1.12%	1.03%	1.00%
85	1.90%	1.5[illegible]%	1.29%	1.08%	1.00%	1.39%	1.04%	0.94%	0.96%	1.00%

We recommend that Canadian actuaries consider the selection of MI-2017 for use in actuarial work in Canada. It might be appropriate for Canadian actuaries to make adjustments to mortality improvement assumptions recommended by this task force to reflect the nature of their work.

This report does not provide alternative assumptions for different segments of the population. The task force view is 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. The task force believes that the mortality improvement scale presented in this report, and based on the general population, would be in a reasonable range for most actuarial applications in Canada.

Notwithstanding the above recommendation, the task force recognizes that the selection of a mortality improvement assumption is inherently subjective, particularly with respect to the long-term improvement scale. Furthermore, short-term mortality improvement rates are volatile, and emerging experience should be regularly monitored.

2 Background

Mortality improvement assumptions are used by actuaries across all areas of practice. Historically, each practice area has developed its own guidance with respect to mortality improvement.

In February 2014, the Pension and Group Annuity Experience Subcommittee of the Research Committee published a report on Canadian pensioners' mortality, including a mortality improvement scale (CPM-B) developed based on the Canada Pension Plan (CPP)/Québec Pension Plan (QPP) experience ending in 2007. Although the mortality improvement scale for Canadian pension plan valuation is not prescribed by the Standards of Practice, the CPM-B scale is commonly used for this purpose by Canadian actuaries and is supported by the CIA Committee on Pension Plan Financial Reporting's (PPFRC) March 2014 *Educational Note on the Selection of Mortality Assumptions for Pension Plan Actuarial Valuations*. For the purpose of determining lump sum commuted values payable to eligible pension plan participants, the mortality assumption is prescribed in the Standards of Practice and the Actuarial Standards Board (ASB) has promulgated the use of the CPM-B improvement scale for this purpose effective October 1, 2015[1].

The ASB promulgated in July 2011 prescribed mortality improvement rates referenced in the Standards of Practice for the valuation of insurance contract liabilities. A research paper released in September 2010 provided the rationale for the promulgation. These prescribed mortality improvement rates were developed based on the general population experience ending in 2002. As almost 15 years of additional data is now available, the Life MI Margins and Aggregation Subcommittee, a subcommittee of the Committee on Life Insurance Financial Reporting (CLIFR), was created in 2014 to update the prescribed mortality improvement rates.

In the course of 2014, several members of the actuarial community suggested that a common guidance for mortality improvement be developed for all practice areas, as it is generally accepted that the mortality improvement experienced by different segments of the population is correlated. An example where the correlation would be very high is between pensioners and group annuitants; both groups coming from the same segment of the population.

The Research Committee therefore established a Task Force on Mortality Improvement, composed of representatives of the different practice areas, with the mandate of developing a common view on mortality improvement. The outcome of this task force could then be used by the various practice areas to develop consistent guidance. Consistent guidance will better serve the public interest by avoiding divergent advice

[1] The ASB promulgation permits the temporary use of a simplifying approximation to the CPM-B scale to ease the transition to a two dimensional mortality improvement scale.

from actuaries in different practice areas. We also believe that combining the knowledge of actuaries across all practice areas has contributed to a better outcome.

Mortality improvement rates cannot be predicted with certainty, as they are driven by numerous drivers which are themselves difficult to predict. Because of this, there is a wide range of opinion about future magnitude, and even direction, of mortality improvement. Examples of drivers include lifestyle changes, medical advances, and access to medical care. The task force has used the most recent information available and considered a large range of expert opinions to come up with one recommendation for mortality improvement rates. However, we must acknowledge that the actual future improvement may be very different from that recommended. We believe that the recommendation of the task force is balanced; it is not at either extreme of the range of opinions.

3 Objectives

The objectives of the task force were to do the following:

- Include appropriate representation from relevant practice areas;
- Develop a best estimate assumption for the mortality improvement rates for the general Canadian population;
- Determine whether the best estimate assumption for the general population needs to be modified for different segments of the population;
- Leverage the work done by the UK actuarial association (Institute and Faculty of Actuaries) and the Society of Actuaries (SOA) where appropriate; and
- Educate members.

The appropriate level of conservatism (margin for adverse deviations), which is specific to each practice area, was out of the scope of our mandate.

Modelling mortality improvement rates is complex. The models for projecting mortality improvement rates have evolved greatly over the last decade and have become increasingly sophisticated. Given its timeline, the objective of the task force was not to develop a new revolutionary model, but to make the best use of modelling tools currently available.

4 Data

To develop a best estimate assumption for the mortality improvement rates for the general Canadian population, the task force naturally selected Canadian population mortality data.

The primary source of general population mortality improvement data for Canada is Statistics Canada, which is required by law to provide statistics for the whole of Canada and each of its provinces.

Statistics Canada provides national data relating to the Canadian population, resources, economy, society, and culture, including the Canada life tables. The life tables are available for experience years 1990 through 2011 on a periodic basis. Splits of population mortality results are available by age, gender, race, and cause of death. CANSIM is an electronic database service provided by Statistics Canada that is updated daily for new information.

Another source for Canadian population data is the Human Mortality Database (HMD) which includes mortality data for Canada covering the entire period from 1921 through 2011. Data to 2013 are expected to become available later in 2017. Data are available by attained age and gender. The HMD is a database created by the Department of Demography at the University of Montréal in collaboration with the Max Planck Institute for Demographic Research in Rostock and the Department of Demography of the University of California at Berkeley, and is based on Canadian vital statistics prepared by Statistics Canada. HMD is an international database which currently holds detailed data for 37 countries or regions.

Statistics Canada and HMD present similar but not totally identical data. For example, Statistics Canada presents data for ages 0 to 99 by single year and then for the open interval 100+, while HMD presents data for ages 0 to 109 and then the age group 110+.

The task force was also able to obtain, on a confidential basis, total deaths and exposure data for OAS for 2005 year-end to 2015 year-end by individual ages for 65–94 and for ages 95 and up combined. The OAS and HMD populations have considerable overlap for years and ages where they are both available. Because the exposures for OAS come from administrative data rather than census data, as used by HMD, OAS mortality rates are expected to be more reliable. OAS has fewer lives exposed at its younger end but a similar number at the older end. OAS mortality rates are higher at younger ages, but similar at older ages.

The task force decided to use both the HMD and OAS data. HMD data are easily accessible, consistent over long periods of time, and consistent for comparison across regions. OAS data allowed the task force to use more recent data.

5 Analysis

5.1 General Approach

The task force considered mortality improvement rates using the general approach summarized below. The task force believes this approach is appropriate for the purpose of this report.

Although past trends in mortality improvement are instructive, the task force does not believe that recent past trends should be assumed to continue indefinitely into the future. In this report, mortality improvement rates are developed under the following conceptual framework:

- Past mortality data are graduated to determine initial mortality improvement. These rates vary by gender, age, and year.

- Long-term (ultimate) mortality improvement rates are established based on long-term 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 long-term mortality improvement rates over an assumed convergence period.

5.1.1 Model for Mortality Improvement Rates

The characteristics and components of the model are as follows:

- Mortality improvement rates are two-dimensional, varying by age and year.
- Observed past rates of mortality improvement are smoothed using standard actuarial graduation techniques.
    - For data in the most recent years to be smoothed, the last year of the smoothed rates precedes the final year of data available (i.e., there is a step-back in the historical mortality improvement rates compared to the final year of available data).
- Mortality improvement rates are interpolated between the graduated recent past experience (initial rates) and the assumed long-term mortality improvement rates by fitting a curve between the recent trend and the long-term rates.

The details of the model (i.e., graduation methodology, step-back, and the specific formulas for interpolation) are set out in the rest of this section.

5.1.2 Assumptions for Mortality Improvement Rates

The assumptions used in the model to derive mortality improvement rates are as follows:

- The long-term mortality improvement rates are themselves an assumption. As noted above, long-term expected mortality improvement trends are largely judgmental. A substantial body of literature on the topic is available.
- The length of time until the assumed long-term mortality improvement rates are attained is also subject to judgment. This convergence period is an assumption in the model.
- Mortality improvement trends have been observed by age (i.e., horizontal trends in mortality tables organized by age and year) and by year of birth (i.e., diagonal trends in mortality tables organized by age and year, also known as cohort trends). The extent to which horizontal and diagonal trends are assumed to continue in the future is an assumption in the model.

Information on how the long-term mortality improvement rates for this report were selected is available in section 5.5. Information on convergence period, and horizontal vs. diagonal trends appears in section 5.6.

The general approach described above is commonly used to establish mortality improvement rates for actuarial purposes. In recent years, this overall approach has been used by several actuarial research entities:

- The UK actuarial profession's Continuous Mortality Investigation (CMI) research organization uses a similar approach to establish mortality improvement assumptions for UK actuarial work[2].
- Research committees for both the SOA and the CIA used a similar approach for the purpose of publishing mortality assumptions for pension plan valuation in the U.S. and Canada, respectively[3].
- The Office of the Chief Actuary uses a similar approach to project the mortality component of the population projections which are in turn used to project the long-term financial status of Canada's OAS Program and the CPP.

As described above, the task force's mandate is to develop information that is relevant to all Canadian actuaries. Different areas of practice in the Canadian actuarial profession have different requirements with respect to the inclusion of margins for adverse deviations in actuarial assumptions. Accordingly, the mortality improvement rates determined in this report are intended to represent a best estimate assumption. Individual actuaries using this information in the preparation of actuarial work are responsible for establishing appropriate margins.

5.2 Materiality Considerations

As discussed earlier, development of mortality improvement rates for each age and gender depends on several parameters: initial rates, long-term rates, length of transition period, convergence method, as well as reflecting cohort effects.

Materiality was one of the factors taken into account in the task force's decisions. Materiality was measured by the impacts of proposed mortality improvement scales on annuity factors as well as on life expectancies at certain ages. Note that the impacts on annuity factors are usually less than those on life expectancies due to the time value of money.

Where impacts of the variation in parameters and/or methods were judged not to be material, the simpler approach was chosen. Reducing the complexity has the advantage of increasing transparency, minimizing the likelihood of errors, as well as improving the understanding of methodology by individuals who have limited knowledge in the development of mortality tables.

Note that the task force's focus was mainly on pension and insurance products as well as on the valuations performed over the next decade or so. However, other programs, especially social security programs such as C/QPP and OAS, may have much longer

[2] For more information, refer to the Continuous Mortality Investigation website.

[3] For more information, refer to the Society of Actuaries Retirement Plans Experience Committee website on mortality improvement scale MP-2014 and MP-2015, and the Canadian Institute of Actuaries 2014 paper on Canadian pensioners' mortality.

projection horizons than the majority of pension and insurance products, and are mostly based on open group projection methodology. Moreover, the main emphasis in assessing the financial sustainability of these programs is put on non-discounted cash flows (time value of money is not taken into account). As a result, the considerations that were judged as immaterial by the task force in the context of its work may be material in the development of mortality improvement rates assumptions for these programs. Therefore, it might be appropriate for Canadian social security actuaries to make adjustments to mortality improvement assumptions recommended by this task force to reflect the nature of their work.

5.3 Extension of the HMD Data Using the OAS Data

HMD data are available only as far as 2011 at this time. The task force was provided with OAS data on a confidential basis. Those data are summarized by sex, by year for 2005–2015, and by age for 65–94, and for 95+. The OAS data were used to extend the HMD data to 2015 for all ages. The extension is only approximate for ages under 65, but it can be considered an improvement in quality for at least ages 66–94. The task force judged the extension to be desirable because of the length of the gap between the current year and the last year for HMD. A detailed description of the extension method is provided in section 8.1.

5.4 Initial Rates

5.4.1 **Graduation Issues**

Typically, raw mortality improvement is a very volatile data set. The purpose of graduation is to smooth out the noise so that the assumed smooth underlying improvement rates can be observed.

Current best practice is to graduate a two-dimensional data set (ages and calendar years) to determine mortality improvement rates. There are a number of techniques that work well in two dimensions. Many actuaries will be familiar with Whittaker-Henderson graduation (WH) from their student days, although it is no longer on the SOA syllabus. In recent years, the CMI in the UK has popularized P-splines as a graduation method. WH is actually a special case of P-spline graduation. The task force chose to use WH because it is better known among Canadian actuaries, efficient software is available, and task force members were more readily able to control the graduation.

Although it is feasible to graduate the raw improvement rates, better results are obtained on most data sets by graduating mortality rates first and then calculating improvement rates from the smooth mortality rates.

The task force decided to graduate the logarithms of the ratios of the raw mortality rates to the rates of a smooth base table (A/E ratio). The weights of the graduation are the expected deaths on the base table. The A/E ratios were chosen because it was not practical to graduate the mortality rates for newborns directly since mortality rates slope downward for the first several years of life. Because mortality improvement can be regarded as a multiplicative process, it is reasonable to work with the logarithm of the mortality rates or mortality ratios.

The base table was developed from HMD data for 2002–2011, the last 10 years available. Ages 0–2 were taken as the raw mortality rates. The remaining rates were obtained from a WH graduation of the logarithm of the average rates with the average exposure as the weights. The WH parameters were 4 for order of difference and 500 for the smoothness factor. The smoothness factor was selected to be larger than normal for such a graduation because it is important to have a smooth base table; the two-dimensional graduation will produce smooth A/E ratios, but the result will not be smooth if the base table is not itself smooth. The goodness of fit for the base table is less important because the two-dimensional graduation also gives attention to goodness of fit.

Any graduation of a two-dimensional data set will have more reliable data in the middle of the data set, less reliable along the edges, and least reliable on the corners. That is so because the graduated value for a particular point is influenced by all of its neighbours, but on the edges and at the corners there are fewer neighbours. Accordingly, it is good practice to drop off from the graduated values those that lie on the edges. This is referred to as a step-back to avoid edge effects. A step-back of two or three years is typically necessary. It is not feasible to step back for the edge representing age zero; some lack of precision will have to be tolerated.

5.4.2 **Graduation Technique**

WH minimizes the sums shown below.

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

The second term is the sum of squared mth finite difference taken in a horizontal direction (across years within each age in our case), and the third is the sum of squared nth finite difference taken in a vertical direction (along ages within each year in our case). There are four parameters that must be chosen for the graduation: the orders of difference *m* and *n*, and the balancing (or smoothing) factors, *h* and *v*.

It is helpful, but not required, that the weights be scaled so that their sum is the number of numbers being graduated. (This is referred to as normalizing the weights.) Doing so simplifies the task of finding good values for *h* and *v*.

The graduation uses the logarithm of A/E ratios for “Raw” and normalized expected deaths for “Wt”. The order of difference (m and n) is 2 is both cases, and the balancing factors (h and v) are both 300. The reasons for these choices are set out in section 8.2.

Improvement rates are calculated directly from the graduated numbers:

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

Initial mortality improvement rates were calculated covering calendar years 1968 to 2015. A step-back of two years was chosen.

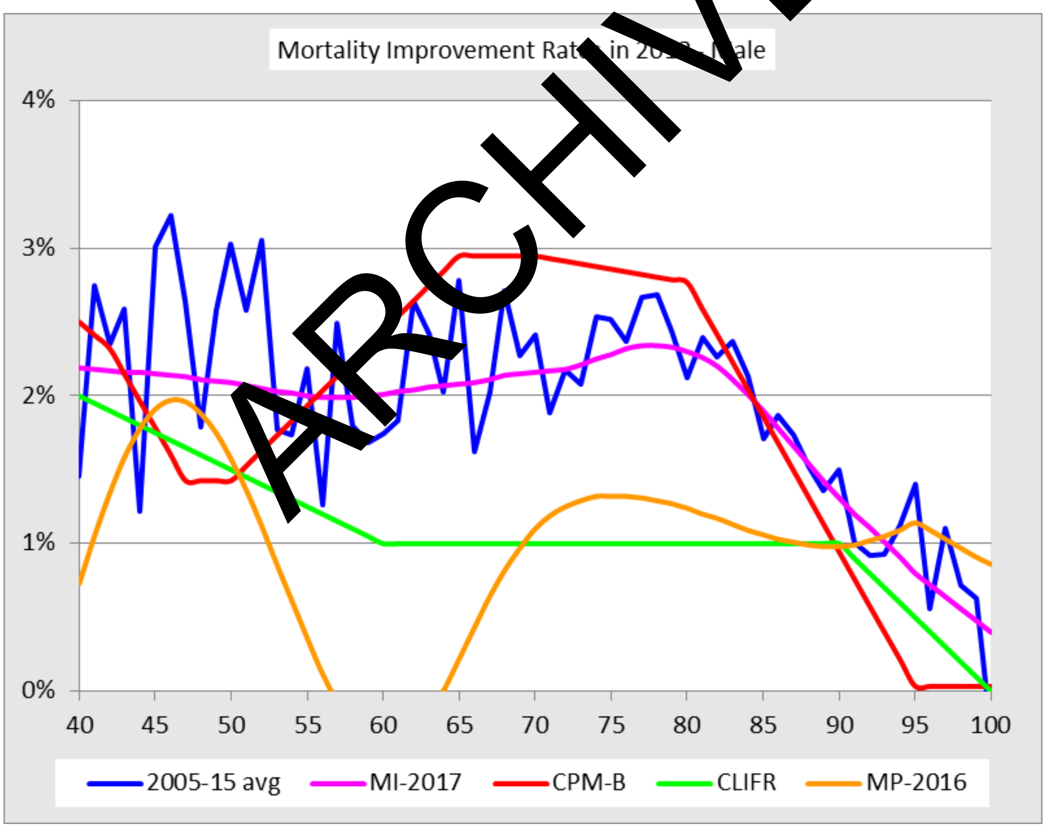
Therefore, the last year of historical improvement rates in the initial rates is 2013, and thus, the first year of projection will be 2014.

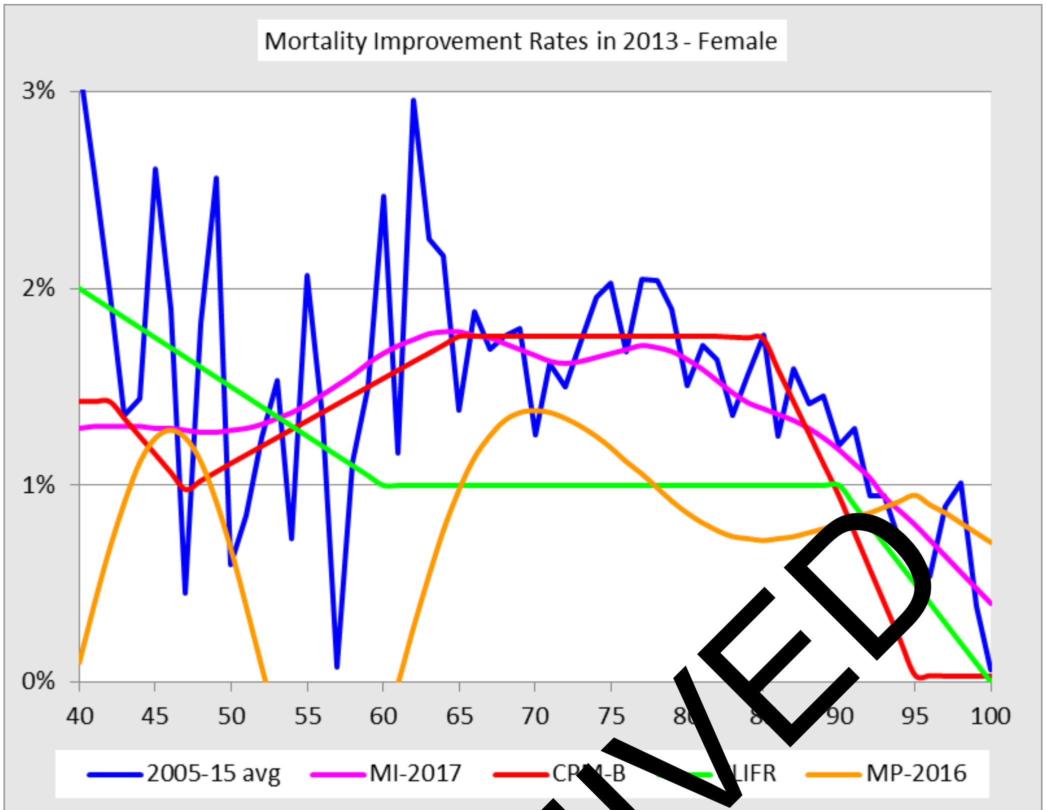
Although improvement rates were calculated to age 100, the rates at the highest ages cannot be considered reliable because there is little data at the highest ages. Therefore, the step-back was set at five years for high ages. Improvement rates over age 95 are calculated by linear interpolation from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

5.4.3 **Initial Rates**

The initial rates for male and female are defined as the age-specific improvement rates covering calendar years 1970 to 2013 and resulting from the graduation described in the previous section. The year 2013 corresponds to the step-back of two, and year 2014 is the first year of projection.

The following graphs show the resulting rates in 2013 (of MI-2017) in comparison to the 10-year average improvement rates and to other existing publicly available scales (the average is calculated by a linear regression of the logarithm of the raw mortality rates for 2005–2015 at each age).





5.5 Long-Term Rates

5.5.1 **Overview**

The long-term mortality improvement rates are a critical assumption of MI-2017 (or any mortality improvement scale). The task force recognizes that the selection of the long-term assumption is also one of the more judgmental and subjective aspects and is as much or more a look into the future as it is a look back. Many factors, each with their own uncertainties, can impact such a far-reaching assumption such as mortality improvement of the Canadian population.

In looking back, mortality has steadily improved through a succession of medical breakthroughs, improved public health awareness, and the general increase in the standard of living in the developed world. There are a number of areas of medical research where huge investments are being made to conquer even more dread diseases. All of this represents the momentum of the past and often carries significant weight in the actuary's deliberations on mortality improvement.

Looking forward is harder. Since the turn of the last century, developed nations have enjoyed an unprecedented period of prolonged economic growth and prosperity. Fueled by cheap energy (oil and natural gas), economies have grown steadily, broad segments of the population experienced steadily increasing standards of living, coupled with technological innovation that progressed at a breathtaking pace.

The task force has analyzed historical trends and considered a large range of opinions from experts in the field to develop a long-term rate mortality improvement assumption of 1.0 percent for ages up to 90, 0.2 percent at age 100, and 0 percent at age 105. The long-term rates between ages 90, 95, and 105 assumes a linear grading.

5.5.2 **What Does History Tell us about Past Mortality Improvements?**

In order to help us better understand the future mortality trends, the task force reviewed and analyzed the historical mortality improvement rates over a period of 1921 to 2011 in Canada using mortality from the HMD.

The following table shows the long-term averages of Canadian males and females for different periods and age groups.

Age Group	**Last 90 years**			**Last 50 years**			**Last 20 years**		
	Male	**Female**	**Both**	**Male**	**Female**	**Both**	**Male**	**Female**	**Both**
20–39	1.67%	2.93%	2.18%	1.68%	1.73%	[illegible]	2.57%	1.30%	2.18%
40–64	1.09%	1.64%	1.32%	2.08%	1.59%	1.90%	2.23%	1.56%	1.98%
65–74	0.85%	1.49%	1.12%	1.73%	1.53%	[illegible]	2.75%	1.69%	2.34%
75–84	0.71%	1.25%	0.97%	1.19%	[illegible]	1.30%	2.38%	1.69%	2.07%
85–94	0.46%	0.77%	0.65%	0.59%	[illegible]	0.77%	1.12%	0.88%	0.97%
95–99	0.04%	0.32%	0.25%	0.20%	0.37%	0.33%	0.45%	0.21%	0.27%
20+	0.82%	1.23%	1.03%	1.43%	1.23%	1.33%	2.14%	1.30%	1.74%
40+	0.78%	1.17%	[illegible]	[illegible]	1.23%	1.33%	2.13%	1.30%	1.73%
65+	0.67%	1.07%	[illegible]	1.18%	1.15%	1.17%	2.09%	1.25%	1.67%
85+	0.43%	0.71%	0.61%	0.56%	0.80%	0.71%	1.06%	0.77%	0.88%

It is important to note that the historical mortality improvement rates for higher age bands shown in the table above are derived from fewer exposures than younger ages, and accordingly the credibility of the past experience is lower.

5.5.3 **What Can We Learn from Other Experts and Organizations?**

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 the most common range for the long-term rate assumption is around 0.8 percent to 1.2 percent. This range gave us a reference point to ensure that our view of future longevity is similar to other experts in the industry.

The best estimate views regarding the long-term rate of mortality improvement assumptions for Canada, the U.S., and the UK general population are presented in the table below. Note that the mortality improvement rates should always be considered in conjunction with the underlying mortality table. As such, one should exercise caution in comparing mortality improvement rates associated with different countries as well as with different subpopulations within the same country.

<table>
<tr><th colspan="11">Assumed Long-Term Rate of Annual Mortality Improvement Assumption</th></tr>
<tr><th rowspan="2">Age</th><th rowspan="2">MI-2017</th><th rowspan="2">2015 Statistics Canada (Males)[1]</th><th rowspan="2">2015 Statistics Canada (Females)[1]</th><th rowspan="2">27th CPP Actuarial Report[2]</th><th rowspan="2">2016 U.S. Trustees Report[3]</th><th rowspan="2">2015 U.S. Technical Panel[4]</th><th colspan="2">QPP Actuarial report as at 31/12/2015 2046–2055[5]</th><th rowspan="2">2014 UK ONS [6]</th></tr>
<tr><th>Male</th><th>Female</th></tr>
<tr><td>20</td><td>1.0%</td><td>1.2%</td><td>1.0%</td><td>0.80%</td><td rowspan="2">1.01%</td><td rowspan="8">1.00%</td><td>0.5%</td><td>0.5%</td><td rowspan="8">1.20%</td></tr>
<tr><td>40</td><td>1.0%</td><td>0.9%</td><td>1.0%</td><td>0.80%</td><td>0.5%</td><td>0.5%</td></tr>
<tr><td>65</td><td>1.0%</td><td>1.3%</td><td>1.1%</td><td>0.80%</td><td rowspan="2">0.74%</td><td>0.9%</td><td>1.1%</td></tr>
<tr><td>75</td><td>1.0%</td><td>1.1%</td><td>1.0%</td><td>0.80%</td><td>1.3%</td><td>1.3%</td></tr>
<tr><td>85</td><td>1.0%</td><td>0.6%</td><td>0.7%</td><td>0.80%</td><td rowspan="4">0.49%</td><td>0.5%</td><td>0.5%</td></tr>
<tr><td>95</td><td>0.6%</td><td>0.1%</td><td>0.1%</td><td>0.45%</td><td>0.5%</td><td>0.5%</td></tr>
<tr><td>100</td><td>0.2%</td><td>0.0%</td><td>0.1%</td><td>0.30%</td><td>0.2%</td><td>0.4%</td></tr>
<tr><td>105</td><td>0.0%</td><td>0.0%</td><td>0.0%</td><td>0.10%</td><td>0.2%</td><td>0.4%</td></tr>
</table>

[1] The 2015 Statistics Canada Population Projections for Canada medium assumption for the period 2031/2032.

[2] The 27th Actuarial Report on the Canada Pension Plan as at 31 December 2015.

[3] The 2016 Trustees ultimate intermediate assumptions are for the period 2040–2090.

[4] The 2015 Technical Panel ultimate assumptions are for the period 2039–2089.

[5] The QPP mortality improvement rates are shown by decades. For ages over 50, mortality-to-incidence ratios (MIRs) in the decade 2036–2045 are slightly higher than shown, and for the decade 2056–2065 are slightly lower than shown (especially for males).

[6] The 2014 Office for National Statistics in the UK principal projection assumptions are for the period 2038+.

5.5.4 **Recommended Long-Term Rates**

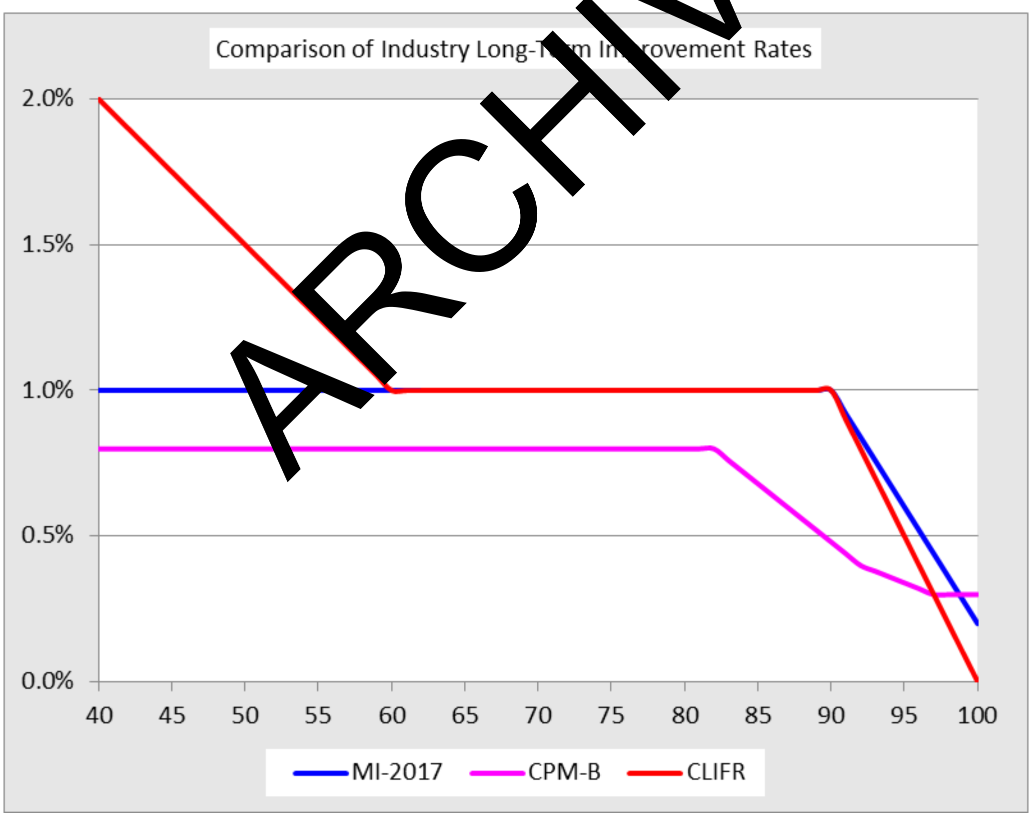
After considering both the historical mortality improvement trends and the expert opinions, the task force believes it is reasonable to assume that the long-term rate of mortality improvement will continue at the historically observed mortality improvement rate of about 1 percent for ages up to 90. Long-term mortality improvement rates would decrease to 0.2 percent at age 100 and 0 percent at age 105. The same annual reduction of the mortality rate is assumed for women and men. Male improvement rates in Canada have been higher than female rates, but the task force observed that male life expectancies have been converging with higher female life expectancies in the past 20 years. Therefore, the task force concluded that the long-term rates for males should be the same as female rates at the end of the convergence period.

The task force built a modest allowance for mortality improvement rates at ages over 100, recognizing the uncertainty about mortality improvement at all ages but especially very high ages. The task force believes that history provides an instructive warning that mortality improvement can happen at ages where there has not yet been credible prior experience.

The following table presents the projected average annualized rates of mortality improvement from the proposed MI-2017 scale starting in year 2016.

Age Group	**Next 90**			**Next 50**			**Next 20**		
	Male	**Female**	**Both**	**Male**	**Female**	**Both**	**Male**	**Female**	**Both**
20+	0.99%	0.94%	0.96%	1.04%	0.95%	0.99%	1.25%	1.02%	1.13%
40+	0.99%	0.93%	0.96%	1.04%	0.95%	0.99%	1.25%	1.02%	1.13%
65+	0.99%	0.92%	0.95%	1.03%	0.94%	0.98%	1.24%	0.99%	1.10%
85+	0.91%	0.84%	0.87%	0.93%	0.85%	0.8[illegible]%	[illegible].03%	0.86%	0.92%

The following graph shows the proposed long-term improvement rates compared to the CPM and CLIFR scales.



5.6 Convergence Period and Method

5.6.1 Convergence Period

Significant professional judgment is required to select the convergence period in our mortality improvement model. The main consideration for establishing this assumption is the length of the cycles of mortality improvement rates observed in the past. The visual inspection of the historical heat maps provides 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. The assumption used by the CMI in the UK is a convergence period of 10 years for ages 20 to 50, 20 years for ages 60 to 80, five years for ages 95 and older, with a linear interpolation for other ages. A convergence period of 20 years for all ages was assumed for the 2014 CPP-26, the 2014 CPM-B, and MP-2014. MP-2016 used a mix of 10 years (horizontal) and 20 years (diagonal). This information is summarized in a table format in section 7.4. Twenty years, therefore, is the most common convergence period assumed in the building of improvement scales in recent years for ages between 60 and 80. The task force believes that this convergence period is reasonable in light of the historical heat maps.

The heat maps reveal that historical improvement rates have tended to be more volatile at younger ages than at older ones. Accordingly, it seemed reasonable to use a shorter convergence period for younger ages, as the CMI assumed.

At very old ages (90 years and up), an argument could be made that high improvement rates have been observed for a shorter period than at younger ages, that the experience is less credible, and that therefore the convergence period should be shorter at old ages, as the CMI assumed. The heat maps, however, reveal that there has been a long-term upward trend in mortality improvement rates at old ages, comparable to those observed at younger ages. Another consideration for not shortening the convergence period at very old ages is that there is a lower differential between initial and long-term mortality improvement rates at older ages compared to ages 60–80. It is thus less material to have a different convergence period. Therefore, the task force believes that the convergence period assumed at very old ages should be the same as for ages 60 to 80.

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 (not rounded).

5.6.2 Convergence Method

The task force believes that improvement rates may be assumed to progress smoothly from recent history to the long-term rates. Of course, the assumption is about the trend rather than the actual improvement rates that emerge over time because the actual is still expected to show volatility from year to year and age to age.

The task force considered the approach used by CMI: a cubic running between the last historical improvement rate and the long-term rate. The slope is set to zero at the ultimate year, and a third point is estimated at the middle year of the transition.

The SOA's Retirement Plans Experience Committee (RPEC) also used cubics for the transition in MP-2016. Rather than estimating a third point, RPEC used as the initial slope of the cubic the slope of the secant between the last two historical improvement rates. The slope was not allowed to exceed 0.003 in absolute value. RPEC used two cubics, one along attained ages and one along birth cohorts, believing that the observed cohort effect would be maintained better.

The task force decided to use an approach similar to that used by RPEC, but testing indicated that little was gained by using the more complicated approach with two cubics. It was believed that the cohort effect was sufficiently recognized by a cubic interpolation along attained ages.

To achieve a smooth transition, the task force decided to fit a cubic equation between 2013 (the last year of historical graduated improvement rate after step-back) and the long-term rate. The slope is assumed to be zero at the ultimate year, and the slope at the start is taken as the slope from 2012 to 2013, to a maximum absolute value of 0.003. There is a separate equation for each age. No attempt was made to link successive equations because there is adequate smoothness in both the historical rates by age and the long-term rates.

The formula for the cubic equation is:

$$\begin{aligned} Imp(x,y) = {} & Imp(x,2013) + m(y-2013) \\ & - \frac{2m(yUlt-2013) - 3\big(Imp(x,yUlt) - Imp(x,2013)\big)}{(yUlt-2013)^2}(y-2013)^2 \\ & + \frac{m(yUlt-2013) - 2\big(Imp(x,yUlt) - Imp(x,2013)\big)}{(yUlt-2013)^3}(y-2013)^3 \end{aligned}$$

where *y* is the year of improvement, *x* is the age, *m* is the slope at 2013, and *yUlt* is the first year that the long-term rate applies.

6 Segments of the General Population

There is little data available to study mortality improvement at a more granular level than the general population and determine whether the best estimate assumption for the general population could or should be modified for different segments of the population. The task force has not produced any new analysis on the matter but has conducted a literature review.

In 2013, the CIA published a document authored by Louis Adam on mortality improvement rates[4]. This study used individual administrative data of Canadian pensioners over the age of 60. It analyzed mortality improvement rates by gender, age, income level, and data source (CPP, QPP, and both plans combined) over various periods ending in 2007. Amongst other findings, the study found differences in mortality improvement rates by income and by data source, especially for males.

A paper published in 2011, produced by Towers Watson and sponsored by the SOA, also provides insight on the segments of the population directly relevant for actuaries, like smokers versus non-smokers and insureds and annuitants. Other references focus on the impact of socio-economic profiles, and use a variety of techniques to measure it.

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 going approximately from 1980 to 2000. The inequality in longevity among socio-economic segments has thus been rising during this period in the U.S.
- Some papers concluded that the inequality in longevity among socio-economic segments 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 task force view is 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. The task force believes that the mortality improvement scale presented in this report and based on the general population would be in a reasonable range for most actuarial applications in Canada.

7 Recommendation

The mortality improvement scale recommended by the task force is called CIA MI-2017 (or simply MI-2017). This section shows rates from the scales and compares it with some other published scales.

7.1 Scales

The CIA MI-2017 recommended improvement rates vary by gender, attained age, and calendar year. They comprise gender-specific initial rates for 1970–2013, converging to unisex long-term rates over a period of up to 20 years (shorter for younger ages) by attained age, along cubic curves.

The full set of rates for CIA MI-2017 are provided in the Excel workbook, available for download from the CIA, called Constructing MI-2017, in the worksheets “MI-2017 Male”

[4] Document 213012, “The Canadian Pensioners Mortality Table, Historical Trends in Mortality Improvement and a Proposed Projection Model Based on CPP/QPP Data as at December 31, 2007”.

and "MI-2017 Female". The workbook also includes VBA code to enable the calculation of a similar scale with a variation in parameters in case that may be needed for some purpose such as sensitivity testing; see the worksheet "Parameters" and follow the instructions.

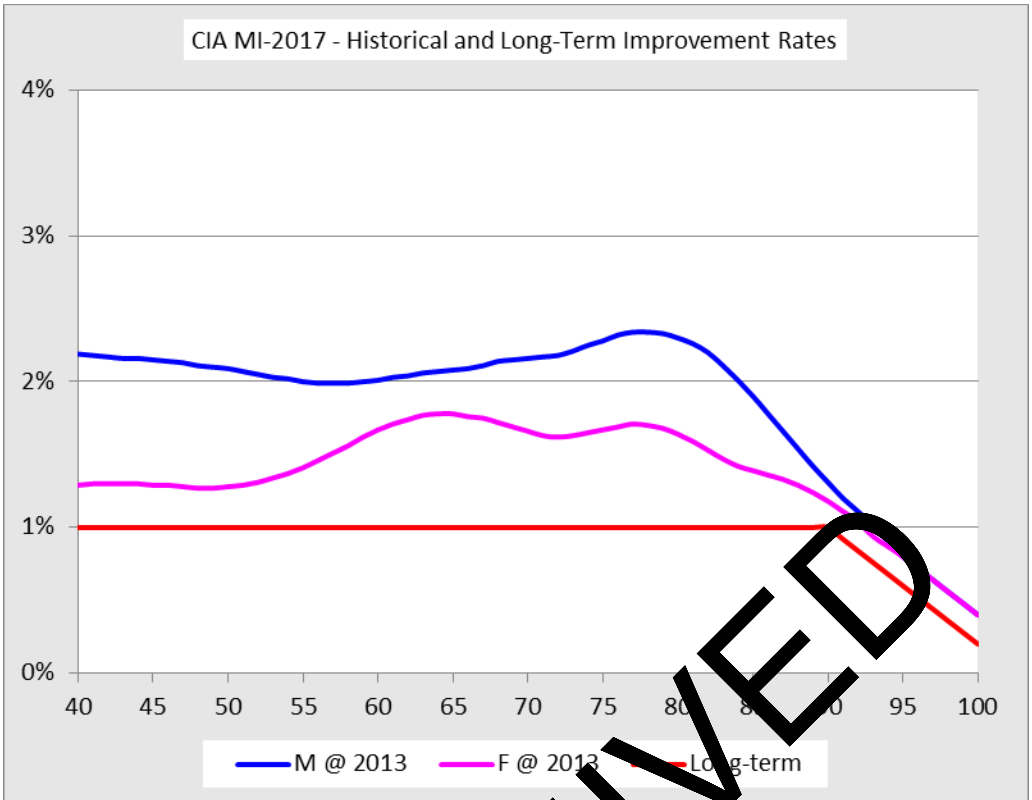
The following tables show illustrative rates for key ages starting in 2013:

Male					
AA\CY	**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%	1.36%	1.09%	1.00%
85	1.90%	1.57%	1.29%	1.08%	1.00%

Female					
AA\CY	**2013**	**2018**	**2023**	**2028**	**2033**
45	1.29%	1.18%	1.03%	1.00%	1.00%
55	1.41%	1.31%	1.15%	1.02%	1.00%
65	1.78%	1.58%	1.32%	1.10%	1.00%
75	1.67%	1.33%	1.12%	1.03%	1.00%
85	[illegible]	1.04%	0.94%	0.96%	1.00%

7.1.1 **Initial and Long-Term Improvement Rates**

The following graph shows how the improvement rates for 2013 (the last year of the initial improvement rates after step-back) and long-term improvement rates compare.

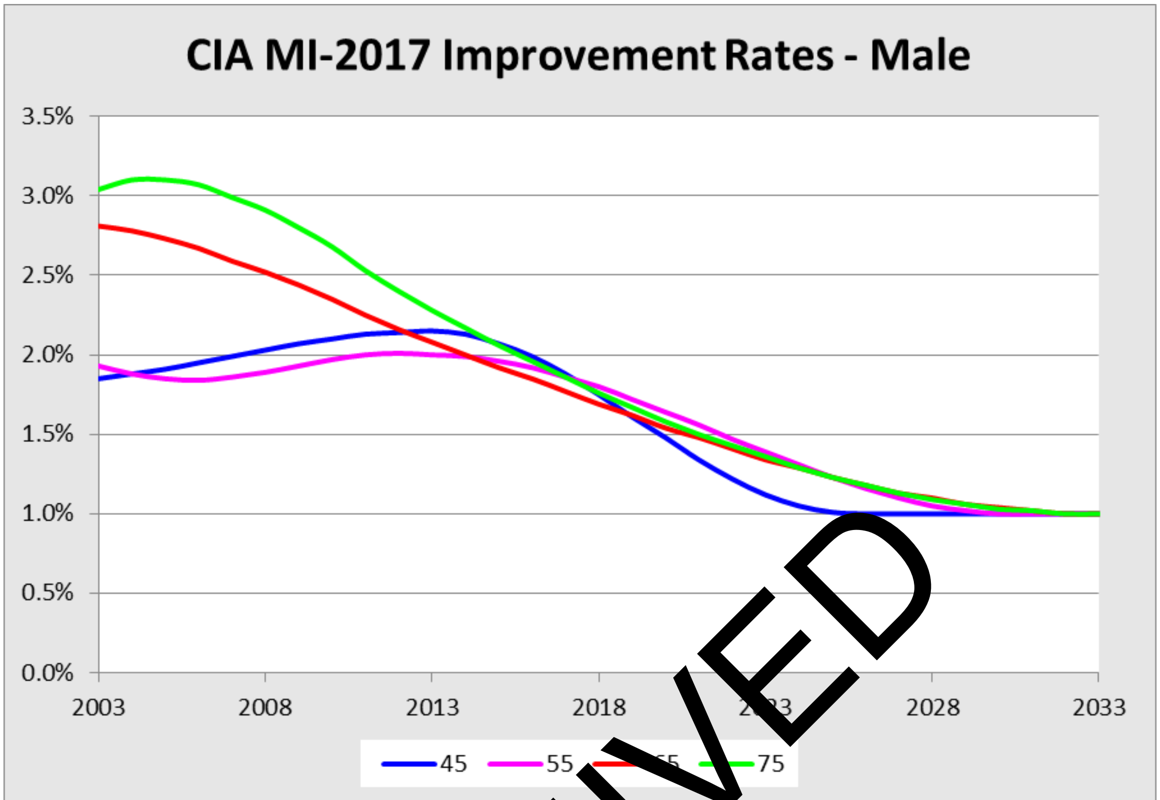


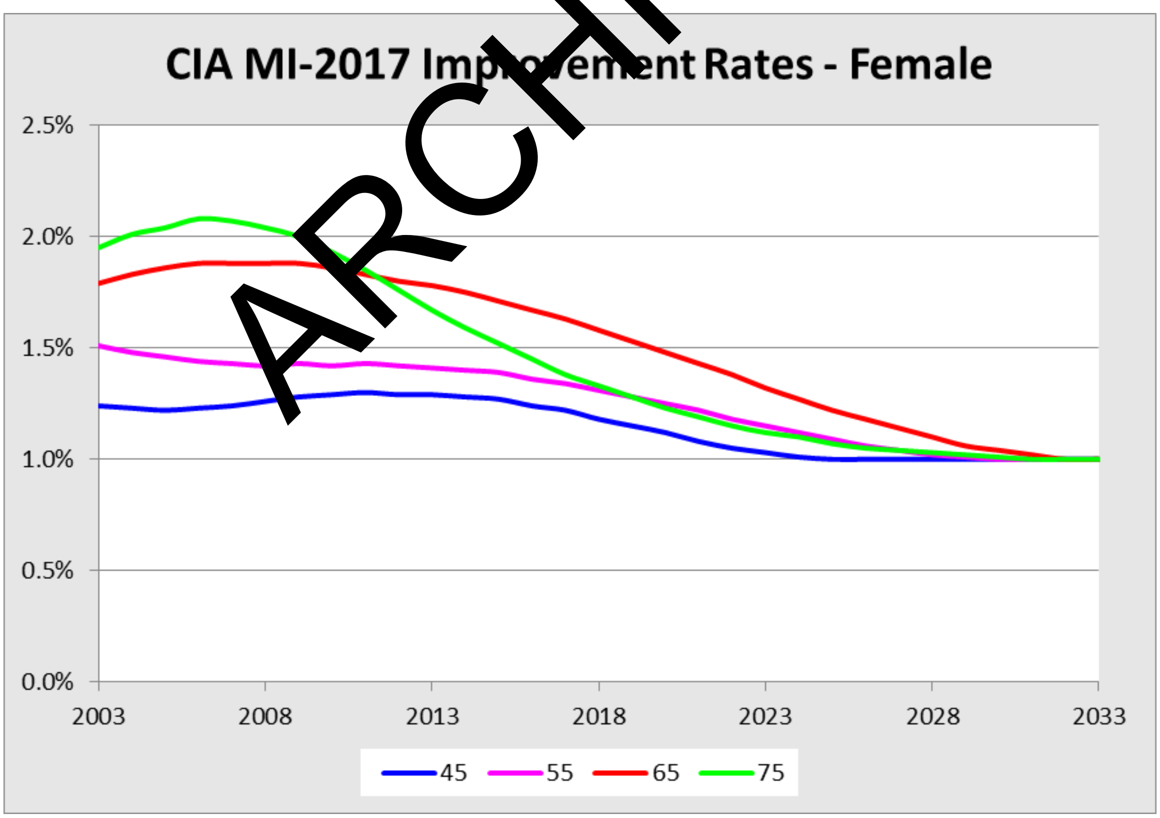
7.1.2 Transition between Historical and Long-Term Rates

The transition period is 10 years for ages 0 to 40, 20 years for 60 and higher, and grading linearly in between (not rounded to the nearest integer). Thus the transition period is 10.5 years for age 41, 11 years for age 42, 11.5 years for age 43, etc.

The improvement rates in the transition are obtained by fitting a cubic equation separately for each age from 0 to 104, as described in section 5.6.

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 towards the ultimate rate. The first year of the projection is 2014.


CIA MI-2017 Improvement Rates - Male
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
2003
2008
2013
2018
2028
2033
45
55
75


CIA MI-2017 Improvement Rates - Female
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
2003
2008
2013
2018
2023
2028
2033
45
55
65
75

7.2 Annuity Factors and Life Expectancy

The following table presents illustrative annuity factors for key ages as at January 1, 2018 on the following basis:

- Annuity-due paid monthly;
- Discount rate of 4 percent;
- Base mortality rates using the CPM2014 mortality table; and
- Alternative mortality improvement scales, including MI-2017 and other industry scales.

These factors are provided for reference only to illustrate the potential materiality of applying the MI-2017 mortality improvement rates. The scope of the task force's work did not include a review of the appropriateness of using the MI-2017 mortality improvement scale in combination with any particular underlying mortality table for any specific purpose.

	Annuity Factors (January 1, 2018)				***% Change from MI-2017***		
	MI-2017	**CPM-B**	**CLIFR**	**AA**	***CPM-B***	***CLIFR***	***AA***
M45	19.94	19.85	19.83	19.85	-0.4%	-0.6%	-0.5%
M55	17.51	17.46	17.35	17.33	-0.3%	-0.9%	-1.0%
M65	14.35	14.31	14.16	14.11	-0.2%	-1.3%	-1.7%
M75	10.27	10.21	10.09	9.98	-0.5%	-1.7%	-2.8%
M85	5.89	5.80	5.82	5.71	-1.4%	-1.2%	-3.0%
F45	20.67	20.56	20.63	20.41	-0.5%	-0.2%	-1.3%
F55	18.40	18.29	18.33	18.09	-0.6%	-0.4%	-1.7%
F65	15.30	15.23	15.23	15.01	-0.5%	-0.5%	-1.9%
F75	11.33	11.28	11.27	11.08	-0.4%	-0.5%	-2.2%
F85	6.84	6.79	6.81	6.68	-0.8%	-0.5%	-2.4%

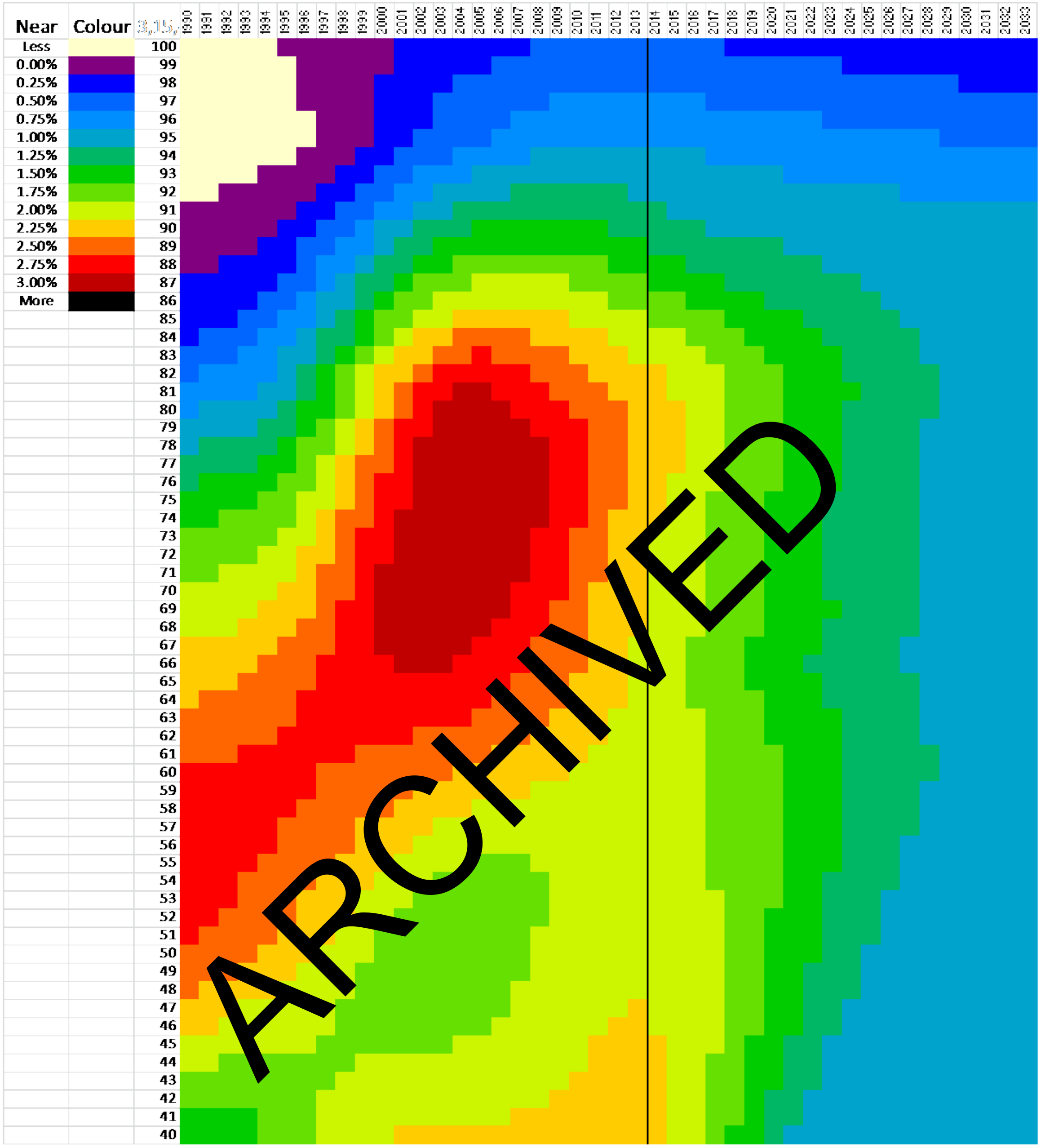
The following table presents the life expectancy as of certain key ages for males and females, calculated under the CIA MI-2017 scale and compared to other industry scales.

Life Expectancy (January 1, 2018)					*% Change from MI-2017*		
	MI-2017	**CPM-B**	**CLIFR**	**AA**	***CPM-B***	***CLIFR***	***AA***
M45	41.88	41.30	41.34	41.15	-1.4%	-1.3%	-1.7%
M55	31.91	31.58	31.40	31.18	-1.0%	-1.6%	-2.3%
M65	22.59	22.40	22.16	21.92	-0.8%	-1.9%	-3.0%
M75	13.97	13.83	13.67	13.44	-1.0%	-2.2%	-3.8%
M85	7.02	6.90	6.92	6.77	-1.8%	-1.5%	-3.6%
F45	44.96	44.30	44.71	43.47	-1.5%	-0.6%	-3.3%
F55	34.70	34.24	34.46	33.52	-1.3%	-0.7%	-3.4%
F65	24.91	24.65	24.73	24.09	-1.0%	-0.7%	-3.3%
F75	15.91	15.78	15.80	15.41	-0.8%	-0.7%	-3.2%
F85	8.39	8.29	8.33	8.14	-1.1%	-0.6%	-3.0%

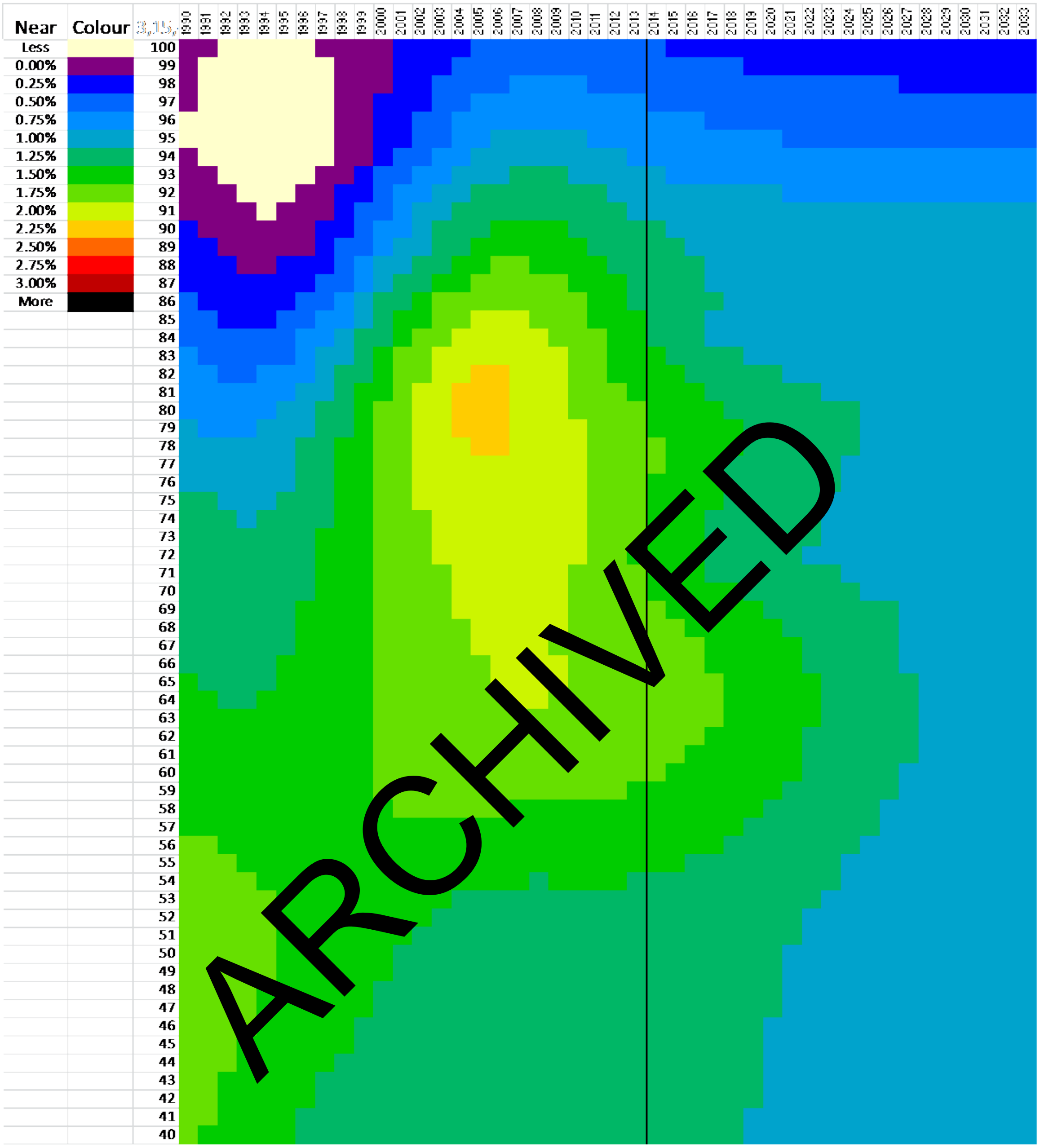
7.3 Heat Maps

The following heat maps present the improvement scale CIA MI-2017 in a graphical format. The vertical black line on the heat maps is after 2013, demarking the initial rates from the projected ones. One can see that CIA MI-2017 produces a smooth and intuitive transition from the initial improvement rates to the projected.

MI-2017 Male


Near
Colour
Less
0.00%
0.25%
0.50%
0.75%
1.00%
1.25%
1.50%
1.75%
2.00%
2.25%
2.50%
2.75%
3.00%
More
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033
100 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40

MI-2017 Female



7.4 Comparison with Other Scales

The following table compares the construction of the CIA MI-2017 improvement rates against other recent two-dimensional improvement scales.

	Assumptions	Canada 2015 CIA Task Force	Canada 2016 CPP-27	Canada 2014 CPM-B	UK CMI 2015 "core model"	US MP-2016
Initial Rates	**Source of Data**	Canadian Population extended with Old Age Security data	Canadian Population extended with Old Age Security data	C/QPP Income Class 4	U.K. Population	Social Security Administration with conjunction of OASDI Trustees' Reports
	Smoothing Method	Whittaker-Henderson	15-year average by age	10-year weighted average	Age-Cohort P-Spline	Whittaker-Henderson
	Calendar Years[5]	1967–2015	1996–2013	1967–2007	Jan 1, 1975 to July 31, 2015	1950–2014
	Ages[1]	0–105	0–100	65–80	18–102	20–95
	Rates at Older Ages	Grade linearly from age 95 to 0% at 105	Step decrease to a rate of 0.0% at age 120	Linear decrease from rate of 3.0% at age 80 to a rate of 0.[illegible]% at age 95	Linear decrease from rate at age 100 to a rate of 0.0% at age 110	Linear decrease from rate at age 95 to 0.0% at age 115
	Recognize Cohort Effect?	No	Male ages 60-74 only maximum rate of 0.5%	No	Age/Period and Cohort (year-of-birth) Component	Age/Period (fixed ages) and Cohort (year-of-birth)
	Last Year of Historical Initial Rates	2013 (Last available data – two years)	2011 – CMHD, 2014 – OAS	2011	2012 (Last available full-year data – two years)	2012 (Last available data – two years)
Long-Term Rates	**Long-Term Rate (Age/Period)**	Ages 0–90: 1.0% Age 100: 0.2% Ages 105+: 0.0% linear interpolation in between	Ages 0–87: 0.8% Age 92: 0.5% Ages 97: 0.26% Ages 110+: 0.0% Linear interpolation in between	Same as 2014 CPP-26 but 0.0% at age 115+	User Defined; Linear decrease from rate at age 90 to a rate of 0.0% at age 120	1% to age 85, linear to 0.85% at age 95, linear to 0.0% at age 115+
	Long-Term Rate (Cohort)	N/A	N/A	N/A	0.0%	0
	Long-Term Rate (Maximum Age of Improvement)	105	110	115	120	115
Convergence Period	**Convergence Period (Age/Period)**	Ages 0–40: 10 years Ages 60+: 20 years Increasing by one every two ages in between	20 years	20 years	Ages 20–50: 10 years Ages 60–80: 20 years Ages 95+: 5 years In/(de)creasing by one in between	10 years

[5] Raw rates used for data smoothing.

	Assumptions	Canada 2015 CIA Task Force	Canada 2016 CPP-27	Canada 2014 CPM-B	UK CMI 2015 "core model"	US MP-2016
	Convergence Period (Cohort)	N/A	N/A	N/A	Ages 20–60: 40 years Ages 95+: 5 years Decreasing by one in between	20 years
	Rates during Convergence Period	N/A	Same as UK CMI methodology, except males ages 30–44 use 25% of initial rate remaining at mid-point of convergence period	N/A	- 50% of initial rate remaining at mid-point of convergence period - Cubic interpolation in-between	N/A
	Convergence Method	Cubic interpolation	Same as UK CMI	Linear grading	Cubic interpolation	Cubic Interpolation both by age and year of birth

8 Appendix

8.1 Extension of the Data to 2015 using OAS Data

The extension was made by distinct methods in each of three age ranges. Each is described below. In-force counts were provided for year-ends 2005–2015, and deaths for each of those years. Therefore, raw mortality rates could be calculated for 2006–2015 and raw improvement rates for 2007–2015.

Definitions

qH(x,y) Mortality rate obtained from HMD for age x, year y, y < 2012.

EH(x,y) The corresponding exposure from HMD for age x, year y.

qO(x,y) Mortality rate obtained from OAS for age x, year y, 2005 < y < 2016.

Raw(x,y) The raw mortality rate to be used in graduation for age x, year y.

Wt(x,y) The weight to be used in graduation for age x, year y.

For All Ages and Years except Those Specified Below

Raw(x,y) = qH(x,y)

Wt(x,y) = EH(x,y)

For 65 < x < 95 and 2006 < y < 2016

OAS data are available for individual ages 65–94. Because there are many new entrants at age 65 and because the implied improvement rates at age 65 seemed inconsistent with age 66, the data for age 65 was not used.

The mortality rates for 2007 to 2015 were developed from the HMD rates in 2006 with the rates of mortality improvement observed in the OAS data from 2007. Note that this is not simply an extension. HMD rates were actually replaced for 2007–2011 to be consistent with mortality improvement rates observed in OAS data; it was believed that the OAS data were of higher quality than the HMD data, particularly at the oldest ages.

Raw(x,y) = Raw(x,y-1) * qO(x,y) / qO(x,y-1)

Wt(x,y) = EH(x,y) for y ≤ 2011 only. Later weights will be described below.

For x > 94 and y > 2011

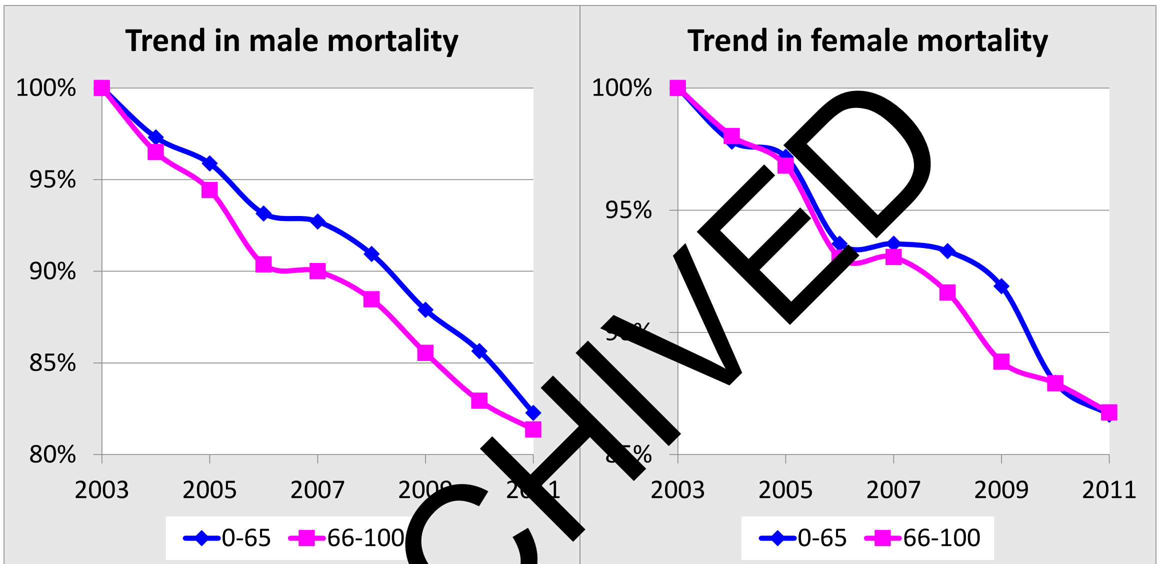
OAS rates are grouped for ages 95 and up. HMD mortality rates were extended for 2012–2015 as the HMD rates for 2011 at ages 95–100 with the rates of improvement observed for OAS for ages 95+. Note that the same improvement rates are used for each of ages 95–100 for this calculation.

Raw(x,y) = Raw(x,y-1) * qO(95+,y) / qO(95+,y-1)

For x < 66 and y > 2011

Because OAS starts at age 65, there is no data for lower ages for the period 2012 to 2015. Nonetheless, the task force was satisfied that a sufficiently reliable extrapolation could be made using the correlation observed in HMD data between the mortality improvement for the two age ranges 0–65 and 66–100, and the improvement for 2012–2015 in the OAS data.

A necessary hypothesis is that mortality improves at about the same rate, by years, for the two age ranges 0–65 or 66–100. To test the hypothesis, the change in age-adjusted mortality rates (which represents the average mortality rates in each age range) for the two age ranges are compared for 2003–2011. The charts below provide an illustration of the results. The trends are very close for females and close enough for males. Essentially, this shows that we can safely use the improvements observed at ages 66+ from 2012 to 2015 to infer the improvement at ages 0 to 65 for the same period.



The calculation for the extension is much more complex than for the other sections. It involves several steps.

Step 1. Calculate two sets of age-adjusted mortality rates.

$$\mathrm{qLo(y)} = \left(\sum_{x=0}^{65} \mathrm{Raw(x,y)Wt(x,2011)}\right) \Big/ \left(\sum_{x=0}^{65} \mathrm{Wt(x,2011)}\right) \text{ for } 2003 \le y \le 2011$$

$$\mathrm{qHi(y)} = \left(\sum_{x=66}^{100} \mathrm{Raw(x,y)Wt(x,2011)}\right) \Big/ \left(\sum_{x=66}^{100} \mathrm{Wt(x,2011)}\right) \text{ for } 2003 \le y \le 2015$$

The choice of weights for age-adjusting is arbitrary; 2011 is a reasonable choice. The start of the calculation in 2003 is also arbitrary. For a later step, we did not want to go too far back into the past; 2003 was chosen for that reason.

The charts above show qLo and qHi scaled to 1 in 2003. Note how similar they are.

Step 2. Calculate a year pattern for 2011–2015.

The cumulative improvement factor over 2003–2011 is 82.3 percent for qLo and 81.4 percent for qHi for males, and 86.6 percent for qLo and 86.7 percent for qHi for females.

The cumulative improvement is very close for females, and it is sufficiently close for males.

The closeness of the improvement factors justifies applying the pattern of improvement for 2011–2015 of qHi to extend mortality rates for 0–65 to 2015. The term year pattern (YP) is used to refer to the cumulative improvement in the age-adjusted mortality rates over those years.

Note that YP is based on qHi only because qLo is not available to 2015.

$$\mathrm{YP(y)} = \frac{\mathrm{qHi(y)}}{\mathrm{qHi(2011)}} \text{ for } 2012 \leq \mathrm{y} \leq 2015$$

Step 3. Remove the year pattern from mortality rates for 2003–2011.

The goal is to estimate an age pattern (AP) using data for 2003–2011. To see the impact of age, as distinct from year, the year pattern has to be removed from each mortality rate. The calculation is done to age 75, but ultimately ages over 65 will not be used.

$$\mathrm{q(x,y)} = \mathrm{Raw(x,y)}\frac{\mathrm{qLo(2011)}}{\mathrm{qLo(y)}} \text{ for } 2003 \leq \mathrm{y} \leq 2011$$

Step 4. Calculate an age pattern from 2003–2011.

This step calculates the average improvement rate for each age, 0 to 75, using a linear least squares regression on the logarithm of the adjusted mortality rates in the previous step. The least squares regression of all the mortality is used rather than just the end points because the end points have too much inherent volatility. The result is a better estimate of the average. Logarithms are used because improvement is essentially a multiplicative rather than additive process.

$$\mathrm{AP(x)} = 1 - \exp(\text{slope of log regression line of } \mathrm{q(x,y)})$$

Step 5. Graduate age pattern.

The graduation is done with Whittaker-Henderson, order of difference 2, smoothing factor 50, with Wt(x,2011) as the weights. Graduated rates are used only to age 65. They replace AP(x) calculated above.

This step was not absolutely essential. We applied graduation to avoid too much influence on the extension from the fluctuation by age.

Step 6. Estimate mortality rates for 0–65 for 2012–2015.

$$\mathrm{Raw(x,y)} = \mathrm{Raw(x,2011)YP(y)}(1 - \mathrm{AP(x)})^{\mathrm{y}-2011}$$

This has mortality rates improving at the same year pattern and also according to the age pattern.

Exposures for Years 2012 to 2015

Because the exposures will be used later as weights in the graduation, it is necessary to estimate exposures for 2012–2015 for each age. Weights are calculated by the recursive formulas below.

$$\mathrm{Wt}(0,\mathrm{y}) = \mathrm{Wt}(0,\mathrm{y}-1)$$

$$\mathrm{Wt}(\mathrm{x},\mathrm{y}) = \mathrm{Wt}(\mathrm{x}-1,\mathrm{y}-1)\left(1-\frac{\mathrm{Raw}(\mathrm{x}-1,\mathrm{y})+\mathrm{Raw}(\mathrm{x},\mathrm{y})}{2}\right)$$

$$\text{for } \mathrm{x} > 0 \text{ and } \mathrm{y} > 2011$$

Because the approximation is less precise other than for ages 66–94, in the graduation, 50 percent of the above weights is used for ages 0–65 and 75 percent of the above weights for ages 95+.

8.2 Choice of Method and Parameters in Construction

There are four metrics that can be considered in choosing the method and parameters for constructing CIA MI-2017:

1. Stability;
2. Fit;
3. Predictiveness; and
4. Smoothness.

The four metrics are calculated by doing backtesting on the method. A scale is calculated for each of 15 consecutive years using the HMD data that is assumed to have been available at that time. The metrics are calculated on that scale or by a comparison between scales. For the purpose of the backtesting, it is assumed that there is a gap of three years between the last year of history available from HMD and the year of publication of the scale.

The idea of stability is to determine how close valuations are when using successively developed scales with the same method and graduation parameters. Stability has been looked at using backtesting over a moving three-year range (assuming a new scale is developed every three years). The task force believes that a method which exhibits more stability is to be preferred over one that exhibits less because there would be less fluctuation in actuarial values.

The idea of fit is to determine how close the calculated improvement rates are to the actual. Of course, the actual cannot be known; the actual is estimated by the average improvement rate over the last several years of historical data. The average of the scale is calculated in the same manner. A method that produces a better fit would normally be considered a better method; however, because the actual data are so noisy, there is a danger that an extremely good fit would show fluctuations in the data rather than the underlying trend.

The idea of predictiveness is to determine how good the prediction of the next several improvement rates is compared to the actual improvement rates that are seen to emerge over time. A strongly predictive method is desirable, but it may not be attainable. There seems to be little variation in the predictive metric over a range of reasonable methods and parameters.

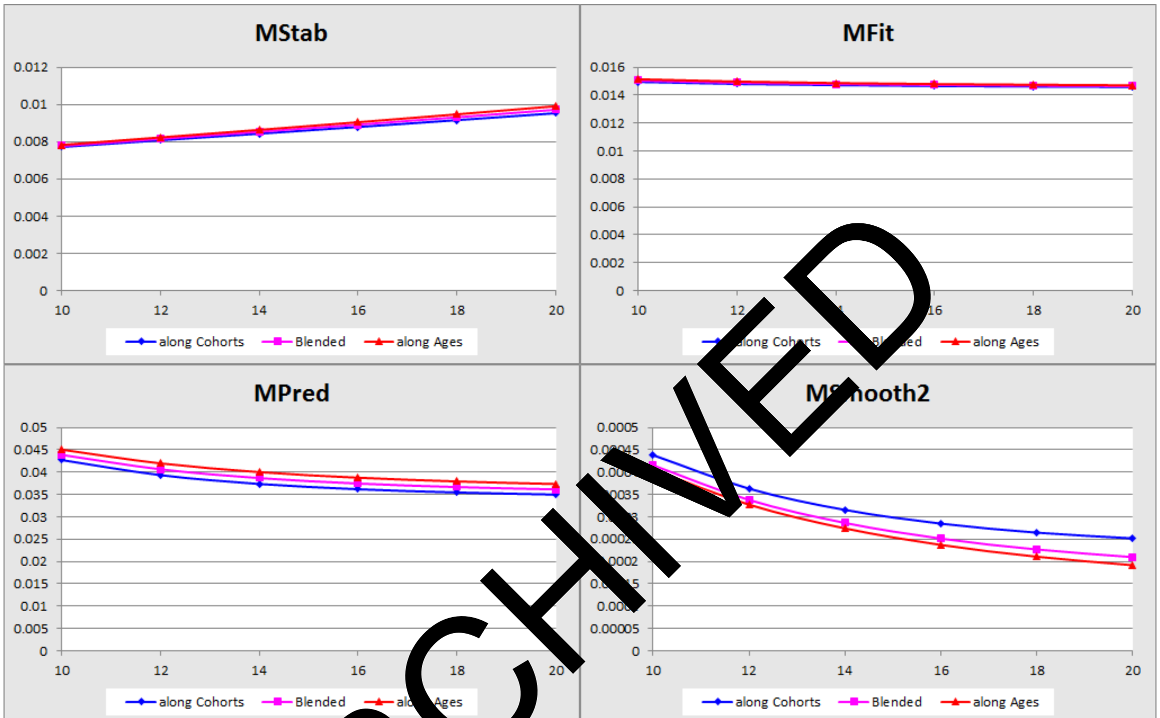
The idea of smoothness is to verify that the improvement rates are progressing smoothly from year to year for each age within a scale. In the real world, the progression will not appear smooth, a lot because of fluctuation, but some because the drivers of mortality improvement may not be smooth themselves. However, we cannot hope to predict accurately an unsmooth trend. Therefore, our scale should be a smooth approximation to the impact of many drivers.

A good method will have generally low values for each of the four metrics. Within a method, parameters which produce generally lower values will likely be preferable. We found no method which simultaneously minimizes all metrics. Judgment is still required. The optimal improvement scale is not necessarily the one that has the lowest combined value for the four criteria.

For example, the charts below show how the four metrics varied for males when trying order of difference 2 and 3 in the graduation and a number of different balancing factors.

Our analysis reveals that stability is much better for order 2 than order 3, but the opposite is true of fit. Smoothness is consistently better for order 2. Predictiveness is not materially different for order 2 and 3. Because order 2 provides better stability with no deterioration in predictiveness, the choice of order 2 is quite clear. The choice of balancing factor is less obvious. A value in the range of 100–300 seems to strike a good balance. The decision was to use 300 because there were some anomalies around age 65 for a balancing factor at the lower end of that range which disappeared at the upper end.

Another aspect of the construction which the task force considered was whether to interpolate between the graduated historical rates and the long-term rates by age, by cohort, or a combination of the two. The task force also considered how long the interpolation period should be. The charts below, also for males, show the metrics for the three directions of interpolation and various lengths of interpolation. (The charts assume the same length for all ages, although the final decision was to use a shorter period at younger ages.)



It seems evident that the direction of interpolation is not important. Predictiveness is slightly better along cohorts and smoothness is better along ages. (Because smoothness is always calculated along ages, that result is not surprising.) The task force decided to interpolate along ages because the method was simpler.

Stability is better with a shorter interpolation period, but predictiveness and smoothness are better with a longer period. Although the task force generally emphasized stability, it may not be reasonable to improve stability by shortening the interpolation period. The extreme case is to use no interpolation at all but use the long-term rates immediately after the initial; then stability is zero. But the result is not acceptable because it implies that recent history is irrelevant for future improvement rates in the near term.

The four metrics are defined below.

8.3 Definition of Metric for Stability

Suppose a new improvement scale is developed and implemented every three years. It would not be desirable, for example, for one scale to produce a 4 percent increase in liability followed by a 4 percent decrease three years later. Unless there were compelling evidence to support the increase and decrease, it would not be considered in the public interest to have this type of oscillation in liabilities. A method which produced an increase of 1 percent followed by a decrease of 1 percent would be viewed as better. The point is that it is normally better to have small changes than large ones unless there is strong evidence that a large change is warranted. A method that results in more stable improvement scales would be considered preferable. Stability is calculated by examining the magnitude of changes in liability due to the change in improvement scale.

The formula for stability in year of publication y is given below.

$$Stab(y) = \frac{Val(y, q_{base}, MI(y))}{Val(y, q_{base}, MI(y-3))} - 1$$

$$Stability = \sqrt{\sum_{y=2000}^{2014} Stab(y)^2}$$

where $Val(y, q_{base}, MI(y))$ is the valuation of a representative set of exposure effective in year y, using the specified base mortality table, and mortality improvement scale. The representative exposure is the exposure underlying the construction of CPM2014, and the valuation is done at 4 percent interest.

q_{base} is the base table. In fact, CPM2014 is used in all cases, but it is taken as if it were a base table appropriate for the years *y – 7*.

MI(y) is the mortality improvement scale published in year *y*, and developed using data to *y – 3*.

8.4 Definition of Metric for Fit

The improvement scale should fit well with recent history, but it is not a simple matter to assess how good that fit is. The graduation should ensure a reasonably good fit overall unless the balancing factor is unreasonably high. However, for the current purpose it is better to focus on the most recent years of data.

Ideally the improvement of the scale would be compared with the true improvement rates revealed by the history. Unfortunately, the true rates are unknown and can only be estimated. To minimize the impact of fluctuation in the actual data and to avoid the bias of using a metric similar to that used in the graduation, the method chosen for the fit metric is to compare the average improvement rate over the most recent five years of history with the average for the same years in the scale. The average is calculated at each age using a least squares regression on the logarithm of the mortality rates over six years. The averages are weighted by the deaths at each age in 2011.

The formula for fit in year of publication y is given below.

$$Ft(y) = \frac{\sum_{x=50}^{95} D_x (1 - AVa(x, y-7, y-3))^5}{\sum_{x=50}^{95} D_x (1 - AVp(y, x, y-7, y-3))^5} - 1$$

$$Fit = \sqrt{\sum_{y=2000}^{2014} Ft(y)^2}$$

where D_x is the number of deaths at age x in 2011.

$AVa(x, yLo, yHi)$ is the average actual improvement rate for age x over yLo to yHi.

$AVp(yPub, x, yLo, yHi)$ is the average improvement rate for age x of the scale published in yPub with the calculation done over years yLo to yHi.

8.5 Definition of Metric for Predictiveness

Because an improvement scale includes assumed rates of mortality improvement into the future, ideally the improvement rates for at least the first several years of the transition would be close to the improvement rates that emerge as additional years of actual experience are added over time. The calculation is functionally equivalent to that for fit, but it looks forward, where fit looks backward. In this case, the calculation considers the last five years of actual and compares to what was predicted for those same years by the scale published when the last year of history was five years earlier.

The formula for predictiveness in year of publication y is given below.

$$Pred(y) = \frac{\sum_{x=50}^{95} D_x(1 - AVa(x, y-7, y-3))^5}{\sum_{x=50}^{95} D_x(1 - AVp(y-5, x, y-7, y-3))^5} - 1$$

$$Predictiveness = \sqrt{\sum_{y=2000}^{2014} Pred(y)^2}$$

8.6 Definition of Metric for Smoothness

WH graduation automatically balances fit and smoothness, but both are calculated over all data being graduated. The concern for a method of constructing an improvement scale is concerned not just with the initial years, but all years of the scale, and especially in the early years of transition from historical towards the long-term rates. The metric is based on differences of order 2 calculated along ages. The metric would then be zero if the surface of improvement rates were planar. Because we expect mortality rates to decrease about exponentially, second differences are reasonable.

The formula for smoothness in year of publication y is given below.

$$Sm2(y) = \sqrt{\frac{\sum_{t=y-7}^{y} \sum_{x=50}^{95} (\Delta^2 Imp(x,t))^2}{8 \times 46}}$$

$$Smoothness = \sqrt{\sum_{y=2000}^{2014} Sm2(y)^2}$$

where $Imp(x,t)$ is the improvement rate for age x, year t, of the scale published in y.

$\Delta^2 Imp(x,t)$ is the second difference in improvement rates along age x.

Thus, $\Delta^2 Imp(x,t) = Imp(x,t) - 2Imp(x,t-1) + Imp(x,t-2)$.