SOCIETY OF ACTUARIES

Society of Actuaries Cause of Deaths Forecasting Tool

User Guide

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This tool provides a framework to build mortality forecasts by cause. The model specification is detailed in the Society of Actuaries (SOA) report. This model is intended to provide short-term forecasts (10–15 years ahead) and cannot be used for longer-term projections.

To launch the forecast, the user must fill an initial and maximal projection date in the Tab “Main” and update the calculation. The results can be seen on tab “Graphs” and “Graphscomparison” and on tabs “Life Expectancy” to “Forecasts Aggregate.” Other options for the forecast are explained below.

The initial death rates represent the 2016 mortality, but the user has the possibility to change these values.

The following parameters cannot be modified:

- Age groups
- Causes of death
- Lee-Carter parameter (tab “LC parameters”), but the trend can be calibrated using expert judgment.

Additionally, the death rates given in this tool are the death rates in the sense of force of mortality (not the probability of death).

Color scheme

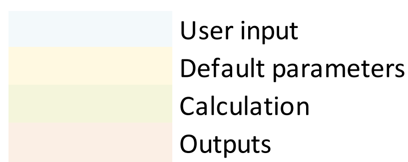


Figure: Colors used in the tool

Tab “Contents”

Use this to access directly the chosen tab.

Tab “Main”

The mandatory parameters are the initial date—which cannot be superior to the maturity max and may be entered manually—and the maturity max, which cannot be superior to the initial date plus 30 years. Moreover, limit the horizon to 10 or 15 years. The initial date can be different for the baseline population (the national population) and the cluster population. However, the user cannot enter an initial date for the cluster population earlier than the initial date of the baseline population because the death rates of the cluster population are based on the death rates of the baseline population.

Optionally, the user may modify some parameters for the baseline population. First is the type of trend. Design the trend parameter of the time component of the Lee-Carter model, by cause and gender. The user has three options:

- Historical1, the trend calibrated over the 1999–2016 historical period.

- Historical2 (default), trend calibrated on the historical data until the last trend change (using breakpoint detection) in the 1999–2016 window.

- Manual, where the user can change the trend by defining the target improvement, the relative variation of the mortality rate; the reference horizon, at which this variation is reached; and the reference age for which this variation is reached. The calibration of the trend in the case the manual option is activated is performed in tab “Expert opinion”.

The second parameter is adjustment (default = no), which is the manual adjustment applied to the mortality rate by period *x* age. If yes, please fill the corresponding tab(s). Note that if the adjustment is used, the future evolution of the rates as configured in type of trend will not be taken into account. The evolution will only depend on the rate at the first date and on the adjustment. Thus, the Calibrated Lee-Carter model will not be used.

The adjustment can be used similarly to the manual change of the trend in the case where the user believes that the historical trends calibrated by the model do not represent the vision the user has about evolution of the death rates for a specific cause. The main difference is that for the manual change of the trend, the user must specify a target for a specific age group, and the overall forecasted death rates are deduced for the other age groups. For the adjustment, the user must specify the entire evolution of the future deaths, and the Lee-Carter model is not used.

The final parameters are variables alpha and beta, the basis risk parameters (spread between the cluster population and the baseline population) that the user has chosen with the formula: $\ln(\tilde{\mu}_{k,a,g,y}) = \alpha \ln(\mu_{k,a,g,y}) + \beta$ with $\mu_{k,a,g,y}$ the death rate in Tab “Mortality rates at t0” and $\tilde{\mu}_{k,a,g,y}$ the initial value of the forecasted death rate. This adjustment could be performed to adjust the national death rate by cause of mortality for an insured (cluster) portfolio. For example, if the relational model is expressed for each cause k, age group a, gender g and year y, then the mortality rate of the cluster population $\mu_{k,a,g,y}^{cluster}$ writes as a function of the mortality rate of the national population $\mu_{k,a,g,y}^{nat}$ as follows:

$$log(\mu_{k,a,g,y}^{cluster}) \approx \alpha_{k,g} \times log(\mu_{k,a,g,y}^{nat}) + \beta_{k,g}$$

In such case, $\alpha = \alpha_{k,g}$ and $\beta = \beta_{k,g}$ for the cause k and gender g.

In practice, the parameter $\beta = \beta_{k,g}$ is not necessary because the formula used in the tool is:

$$\mu_{k,a,g,y}^{cluster} = \mu_{k,a,g,y-1}^{cluster} \left(\frac{\mu_{k,a,g,y}^{nat}}{\mu_{k,a,g,y-1}^{nat}} \right)^{\alpha_{k,g}}$$

Tab “mortality rates at t0”

This is the initial death rate (in the sense of force of mortality) for each age and gender and for each cause, for both the baseline and the cluster population.

Tab “Mortality trends”

This tab presents the mortality trends output of the model for each cause of death. The deviations of mortality rates between the first date of projection and the last date of projection are displayed for each age group, gender and cause of death for both the baseline and the cluster population.

Tab "Graphs"

For output, the user enters the desired cause, the gender and the age group (dropdown lists) to get the graph of the forecast for both the baseline and the cluster population. The forecast of all causes is also available (condition: entering the age group and the gender). The user can also get the forecast of life expectancy at birth calculated automatically (condition: entering the gender). And the user can get the forecast of life expectancy at some age calculated automatically (condition: entering the gender and the exact age. This exact age is entered separately in another cell). The partial life expectancy until 85 is also calculated for both the baseline and the cluster population. Some graphs show the comparison between the two populations in terms of death forecasts.

The user can also launch a comparison of the results obtained for several trend calibrations of the baseline population (all historical1, all historical2 or manual), using the "Comparison (trend)" button (for a given gender, age group and cause of death).

Tab "Graphscomparison" (for the baseline population)

The user can get the forecasted death rate, the aggregated death rate, life expectancy at birth and life expectancy at some age for the baseline population and for several trend parameters (all historical1, all historical2, or actual—user choice, that is, the set of parameters, manual or historical, that the user has entered in tab "Main"). The cause of death, gender and age group considered are those set in tab "Graphs."

Tab "Life expectancy"

The user cannot modify this tab**.** It contains formula (survival probabilities and life expectancy) allowing the user to get the results and the graphs shown in tab "Graphs – results," depending on the inputs the user enters (purple tabs).

The formula used are:

- $\mu_{a,g,y} = \sum_{k=1}^{n} \mu_{k,a,g,y}$
- ${}_a p_0 = \exp\left(-\int_0^a \mu_{s,g,y} ds\right) = \exp\left(-\sum_{s=0}^{a-1} \mu_{s,g,y}\right)$
- $e_0^{total} = \sum_{i=1}^{a_{max}-1} \ {}_i p_0 + 1 - \frac{1}{2}\sum_{i=0}^{a_{max}-1} \ {}_i p_0 q_i = \sum_{i=1}^{a_{max}-1} \ {}_i p_0 + \frac{1}{2}$ for the life expectancy at birth
- $e_a^{total} = \sum_{i=1}^{a_{max}-a-1} \ {}_i p_a + 1 - \frac{1}{2}\sum_{i=0}^{a_{max}-a-1} \ {}_i p_a q_{a+i} = \sum_{i=1}^{a_{max}-a-1} \ {}_i p_a + \frac{1}{2}$ for the life expectancy at age a
- $e_{a/b}^{partial} = \sum_{i=1}^{b-a-1} \ {}_i p_a + 1 - \frac{1}{2}\sum_{i=0}^{b-a-1} \ {}_i p_a q_{a+i}$ for the partial life expectancy at age a until b

  With:

  ${}_y p_a = P(T > a + y \mid T \geq a) = \frac{P(Y>a+y)}{P(Y\geq a)} = \frac{{}_{a+y}p_0}{{}_a p_0}$; $q_{a+i} = P(Y < a + i + 1 \mid Y \geq a + i) = \frac{{}_i p_a - {}_{i+1} p_a}{{}_i p_a}$;

  and $q_{a_{max}-1} = 1$
- $e_{0/b}^{partial} = \sum_{i=1}^{b-1} \ {}_i p_0 + 1 - \frac{1}{2}\sum_{i=0}^{b-1} \ {}_i p_0 q_i$ for the partial life expectancy at birth (until b)

Tabs "Forecasts Cardiovascular" to "Forecasts Other"

The user cannot modify this tab. It contains mortality rates outputs (for the baseline population, formula: $\mu_{k,a,g,y} = \mu_{k,a,g,0} e^{\beta_{k,a,g}(\kappa_{k,g,y} - \kappa_{k,g,0})}$ with $\kappa_{k,g,y} - \kappa_{k,g,0} = \Delta_{k,g} \times y$, where $\Delta_{k,g}$ is the trend parameter). The formula depends on the inputs (purple tabs) and of the choice of an adjustment or not and of historical1, historical2 and manual trends (tab "Main") that specify $\Delta_{k,g}$.

For the cluster population, the formula used is:

$$\mu_{k,a,g,y}^{cluster} = \mu_{k,a,g,y-1}^{cluster} \left(\frac{\mu_{k,a,g,y}^{nat}}{\mu_{k,a,g,y-1}^{nat}} \right)^{\alpha_{k,g}}$$ for each cause k, age group a, gender g and year y.

$\mu_{k,a,g,y}^{nat}$ is the death rate of the baseline population.

$\alpha_{k,g,y} = \alpha_{k,g}$ is the parameter of the following regression: $log(\mu_{k,a,g,y}^{cluster}) \approx \alpha_{k,g,y} \times log(\mu_{k,a,g,y}^{nat}) + \beta_{k,g,y}$ as α is supposed not to be time-dependent.

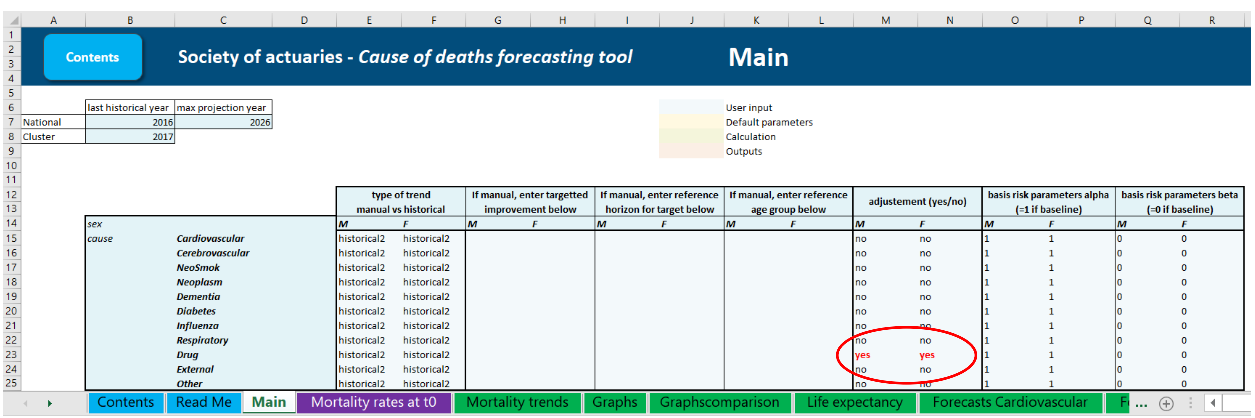
Tab "Forecasts Aggregate"

The user cannot modify this tab. It contains mortality rates of the 11 causes aggregated (sum of the mortality rates) for both the baseline and the cluster population.

Tab "adjustment Cardiovascular" to "adjustment Other" (for the baseline population)

The user must change these tabs if the user decides in tab "Main" to get an adjustment of the mortality rates outputs (for the baseline population only). The adjustment rates are relative to the adjustment in the first year of projection that may be changed. For example, a user wishes to forecast the death rates adjusting the cause drug because he believes that the historical trend does not represent what will happen in the future. In that case, the user must first activate the option on tab "Main":

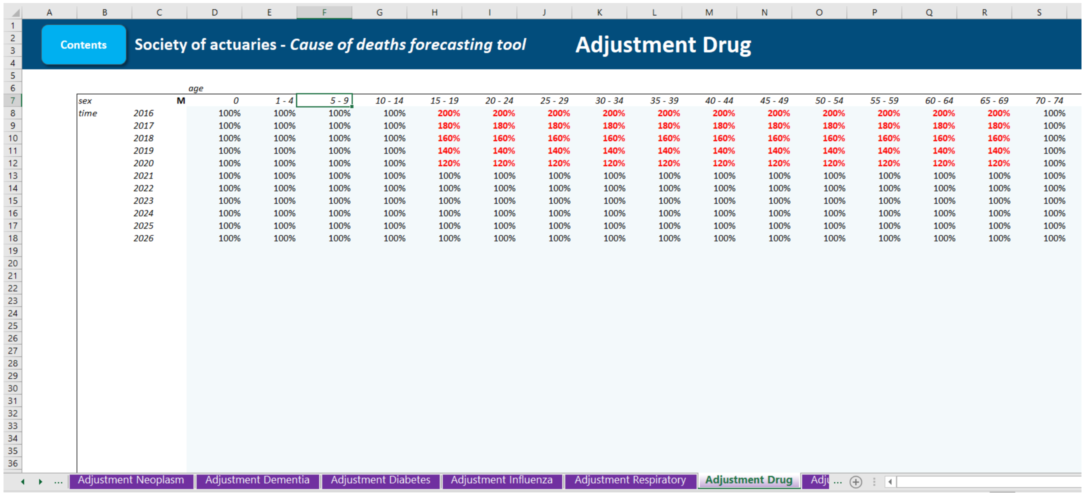
Figure 2
ADJUSTMENT USE EXAMPLE



Then, the user must fill the "Adjustment Drug" tab with his hypothesis. For the example, the hypothesis is that there is an unusual high mortality in year 2016 for ages between 15 and 69 and that the death rate progressively returns to the normal within the next five years.

Figure 3

ADJUSTMENT USE EXAMPLE

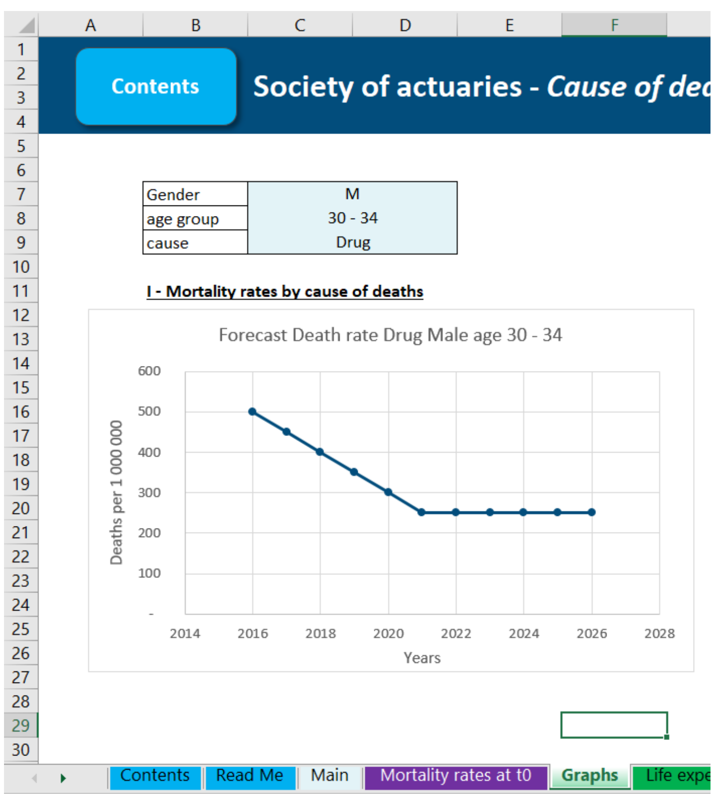


		age															
sex	M	0	1 - 4	5 - 9	10 - 14	15 - 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	65 - 69	70 - 74
time	2016	100%	100%	100%	100%	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%	100%
	2017	100%	100%	100%	100%	180%	180%	180%	180%	180%	180%	180%	180%	180%	180%	180%	100%
	2018	100%	100%	100%	100%	160%	160%	160%	160%	160%	160%	160%	160%	160%	160%	160%	100%
	2019	100%	100%	100%	100%	140%	140%	140%	140%	140%	140%	140%	140%	140%	140%	140%	100%
	2020	100%	100%	100%	100%	120%	120%	120%	120%	120%	120%	120%	120%	120%	120%	120%	100%
	2021	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	2022	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	2023	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	2024	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	2025	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	2026	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

The initial "200%" means that the user believes the mortality is in 2016 twice what it should normally be for this cause. More precisely, the adjustment factors will not change the value of the death rates of the year 2016, but the future forecasts will take into account that the death rates of the year 2016 were higher than what they should be. Finally, on tab "Graphs," the result of the adjustment shows that the death rate is only driven by the adjustment factor (for cause drug only).

Figure 4

ADJUSTMENT USE EXAMPLE

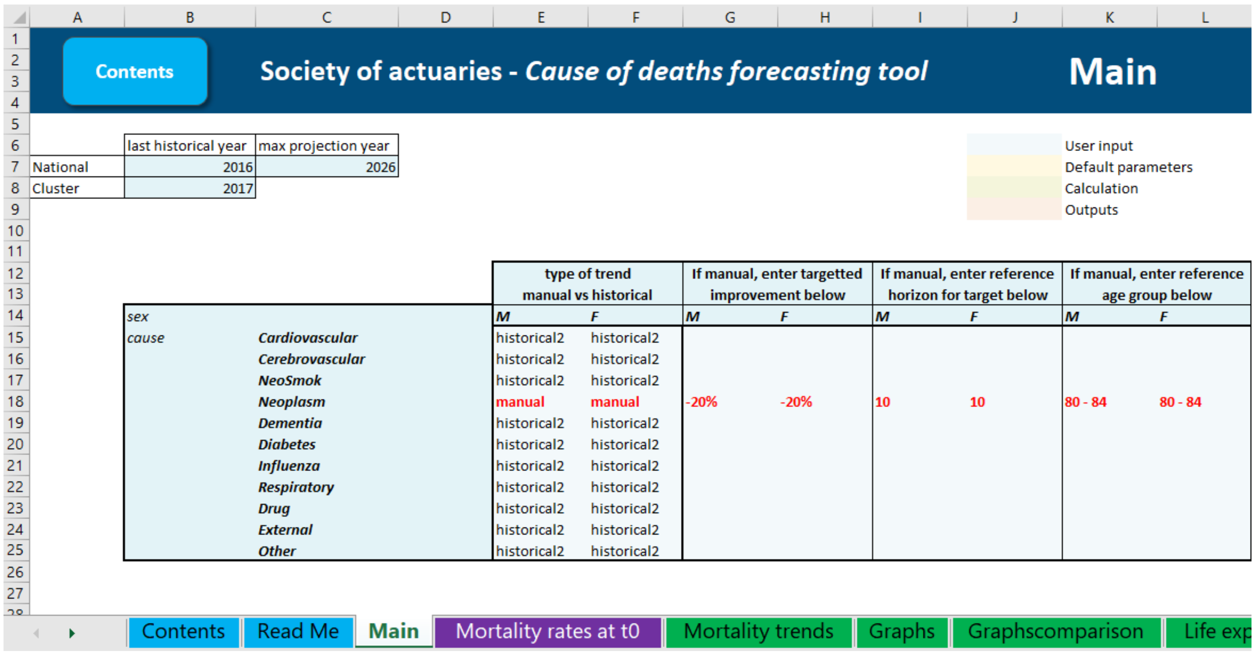


Tab “expert opinion” (hidden; for the baseline population)

The user has the possibility to modify the results if the user has an opinion on the evolution of the death rates of the baseline population. In such cases, the user enters in the tab “Main” a target of improvement rate for the cause, which reflects the evolution of future mortality, a reference age at which that target should be applied and a period over which that target should be reached. In the following example, the user chooses for the cause “Neoplasm” to have a −20% evolution over the next 10 years at ages 80–84.

Figure 5

EXPERT JUDGEMENT USE EXAMPLE



Finally, on tab “Graphs,” the result of the expert judgement is shown. The trend is calibrated to replicate with target for one age group but will affect all the groups.

Figure 6
EXPERT JUDGEMENT USE EXAMPLE

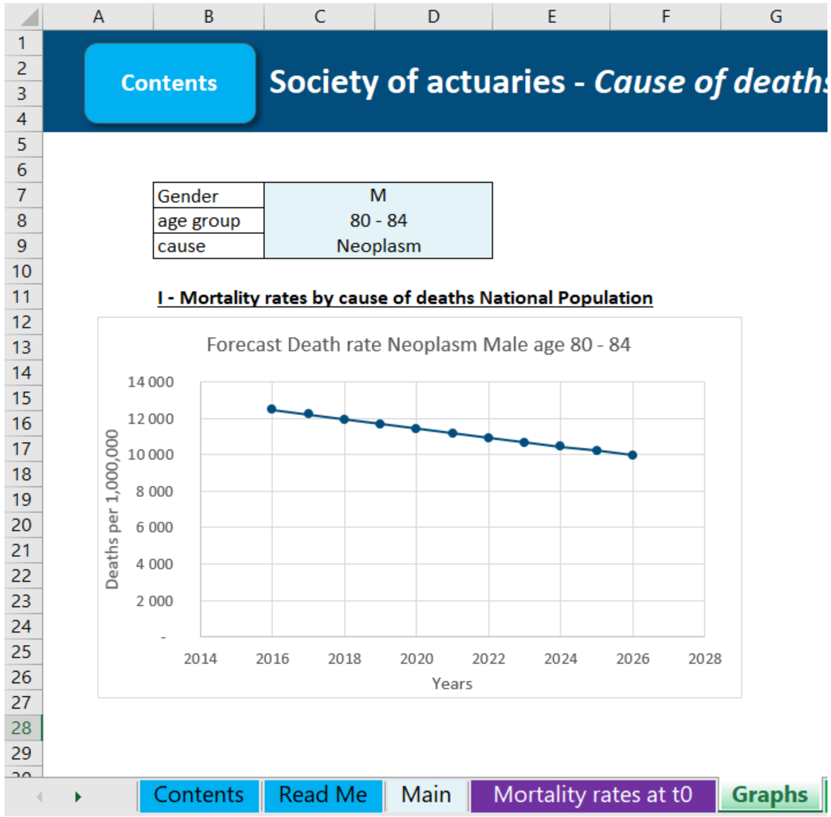


Figure: Expert judgement use example (2)

The trend is changed for all age groups. To assess the impact of the trend change for the other age group, it is possible to use the tab "Mortality trends." Below are the trends implied by the previous target (above 40 years old).

Figure 7
EXPERT JUDGEMENT USE EXAMPLE

mortality rate deviation over the next 10 years
National Population

sex	***M***	***40 - 44***	***45 - 49***	***50 - 54***	***55 - 59***	***60 - 64***	***65 - 69***	***70 - 74***	***75 - 79***	***80 - 84***	***85 - 89***	***90 - 94***	***95+***
cause	***Cardiovascular***	-5,7%	-6,2%	-5,6%	-6,5%	-8,0%	-9,9%	-11,2%	-11,2%	-11,3%	-10,6%	-8,1%	-6,0%
	Cerebrovascular	-5,21%	-5,6%	-4,5%	-4,5%	-7,1%	-9,9%	-11,5%	-12,6%	-14,4%	-15,9%	-14,3%	-11,4%
	NeoSmok	-41,5%	-29,4%	-18,7%	-19,6%	-24,8%	-23,4%	-20,8%	-17,2%	-13,3%	-11,7%	-9,3%	-7,8%
	Neoplasm	**-20,9%**	**-20,6%**	**-12,2%**	**-7,5%**	**-10,8%**	**-17,4%**	**-18,9%**	**-18,4%**	**-20,0%**	**-21,9%**	**-17,4%**	**-15,4%**
	Dementia	3,8%	9,0%	13,9%	15,7%	17,4%	14,1%	14,4%	15,1%	14,8%	15,4%	19,4%	24,6%
	Diabetes	2,5%	1,9%	2,0%	1,7%	0,7%	-1,3%	-2,2%	-2,5%	-2,9%	-3,2%	-0,9%	1,5%
	Influenza	-1,9%	-1,7%	-0,1%	1,6%	-0,8%	-2,4%	-4,0%	-5,32%	-6,8%	-7,4%	-7,3%	-6,5%
	Respiratory	-12,0%	-7,2%	9,3%	0,4%	-7,9%	-13,1%	-12,6%	-12,3%	-13,5%	-14,7%	-10,8%	-4,6%
	Drug	16,1%	18,8%	44,0%	63,9%	53,5%	19,0%	5,8%	5,3%	-3,4%	-6,9%	-25,2%	-45,5%
	External	3,5%	1,7%	-1,4%	-2,7%	-1,5%	-0,5%	0,4%	1,1%	0,8%	1,0%	0,0%	-2,0%
	Other	-28,1%	-18,8%	-3,8%	12,3%	13,1%	2,5%	-2,6%	-4,9%	-9,0%	-12,4%	-12,1%	-11,5%

The target trend is replicated for the age group 80–84. However, note that the trends forecasted for some other age groups are quite different; for instance, the trend leads to a −15.14% deviation of the mortality rates for the age group 95+.

Tab "LC parameters" (for the baseline population)

The user cannot change this tab. These are the Lee-Carter parameters calibrated for this model.

Tab "variables" (hidden)

This tab has been only used to create the dropdown lists.

About The Society of Actuaries

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

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

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

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

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

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

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

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