SOCIETY OF ACTUARIES

# Society of Actuaries Cause of Deaths Forecasting Tool

## User Guide

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**Caveat and Disclaimer**

The opinions expressed and conclusions reached by the authors are their own and do not represent any official position or opinion of the Society of Actuaries or its members. The Society of Actuaries makes no representation or warranty to the accuracy of the information

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 drift 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

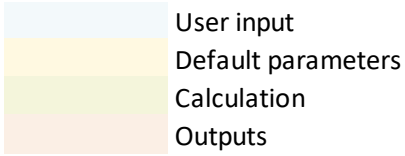



*Figure: Colors used in the tool*

## 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.

Optionally, the user may modify some parameters. First is the type of trend. Design the drift 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 drift 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 drift 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 drift, 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 k1 and k2, the basis risk parameters (spread between the model and the baseline) that the user has chosen with the formula: $\ln(\tilde{\mu}_{xt}) = k_1 \ln(\mu_{xt}) + k_2$ with $\mu_{xt}$ the death rate in Tab "Mortality rates at t0" and $\tilde{\mu}_{xt}$ 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 portfolio.

### 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.

### 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.

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

### Tab "Graphscomparison"

The user can get the forecasted death rate, the aggregated death rate, life expectancy at birth and life expectancy at some age for several drift 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 a 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 :

- $\mu_{xt} = \sum_{i=1}^{n} \mu_{xt}^{i}$
- $S_t(0,x) = \exp\left(-\int_0^x \mu_{st} ds\right) = \exp\left(-\sum_{s=0}^{x-1} \mu_{st}\right)$
- $LE_t = \int_0^{x_{max}} S_t(0,x)dx = \frac{1}{2} + \sum_{x=1}^{x_{max}} S_t(0,x)$

## Tabs "Forecasts Cardiovascular" to "Forecasts Other"

The user cannot modify this tab. It contains mortality rates outputs (formula: $\mu_{xt} = \mu_{x0} e^{\beta_x(\kappa_t - \kappa_0)}$ with $\kappa_t - \kappa_0 = \Delta \times t$, where $\Delta$ is the drift parameter). The formula depends on the inputs (purple tabs) and of the choice of an adjustment or not and of historical1, historical2 and manual drifts (tab "Main") that specify $\Delta$.

## Tab "Forecasts Aggregate"

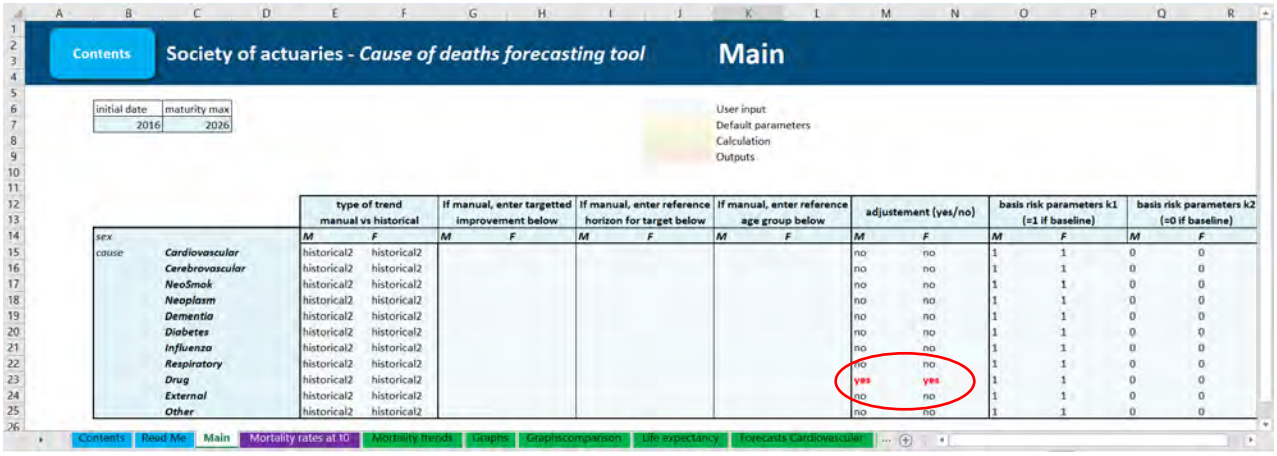
The user cannot modify this tab. It contains mortality rates of the 11 causes aggregated (sum of the mortality rates).

## Tab "adjustment Cardiovascular" to "adjustment Other"

The user must change these tabs if the user decides in tab "Main" to get an adjustment of the mortality rates outputs. 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":

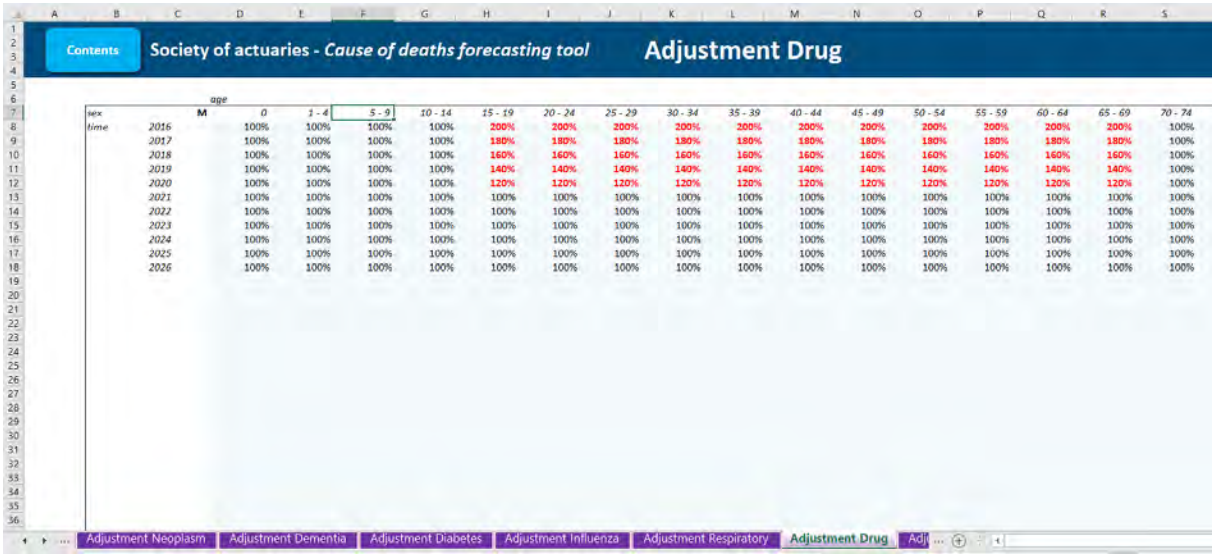
**Figure 2**

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.

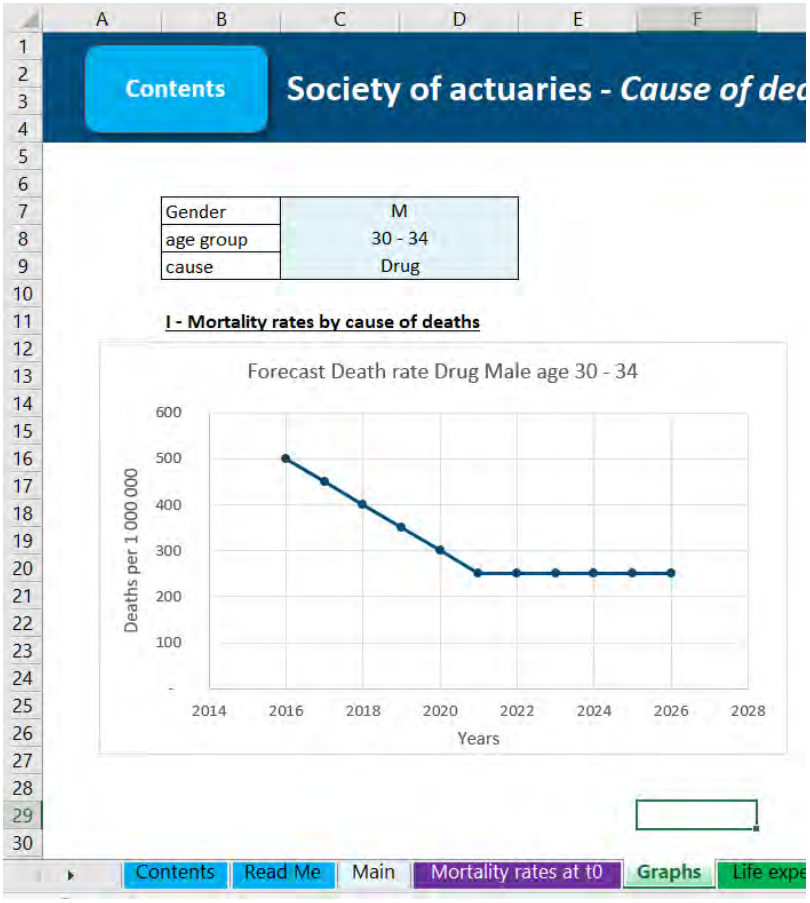
**Figure 3**
ADJUSTMENT USE EXAMPLE




| sex | | age | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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).

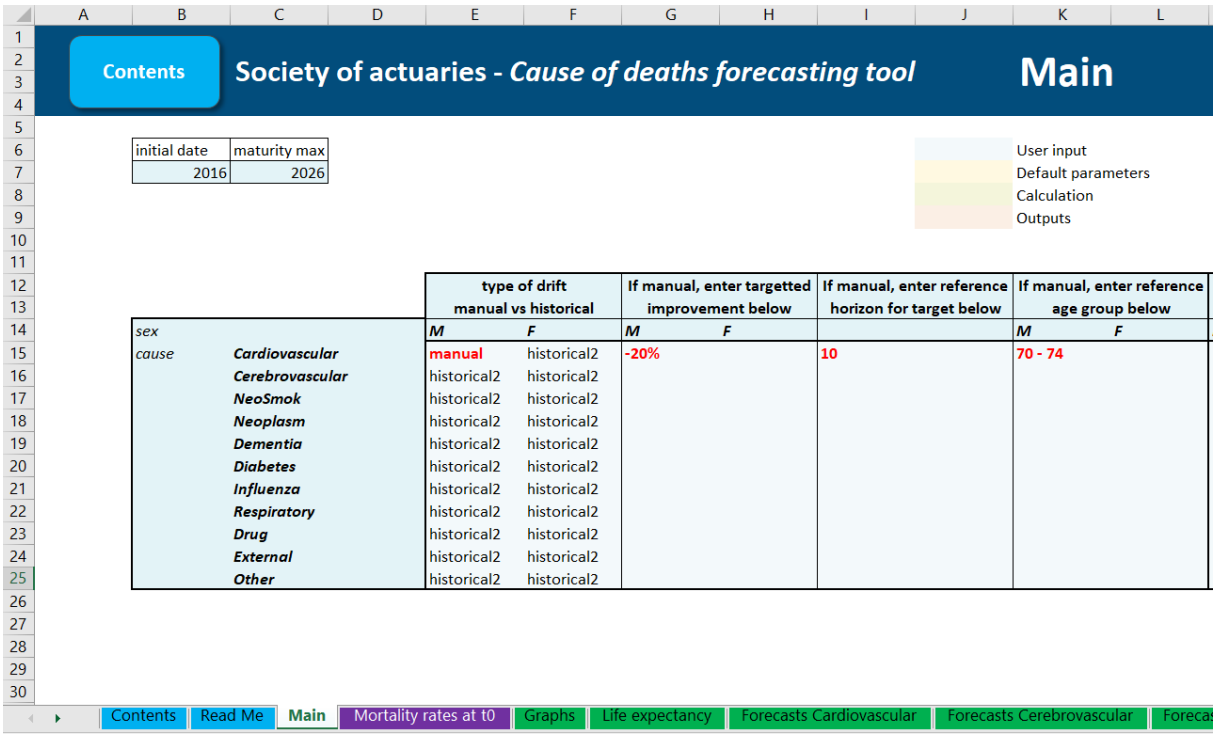
**Figure 4**
ADJUSTMENT USE EXAMPLE




## Tab "expert opinion" (hidden)

The user has the possibility to modify the results if the user has an opinion on the evolution of the death rates. In such cases, the user enters 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 cardiovascular cause to have a −20% evolution over the next 10 years at ages 70–74.

**Figure 5**
EXPERT JUDGEMENT USE EXAMPLE




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

**Figure 6**
EXPERT JUDGEMENT USE EXAMPLE

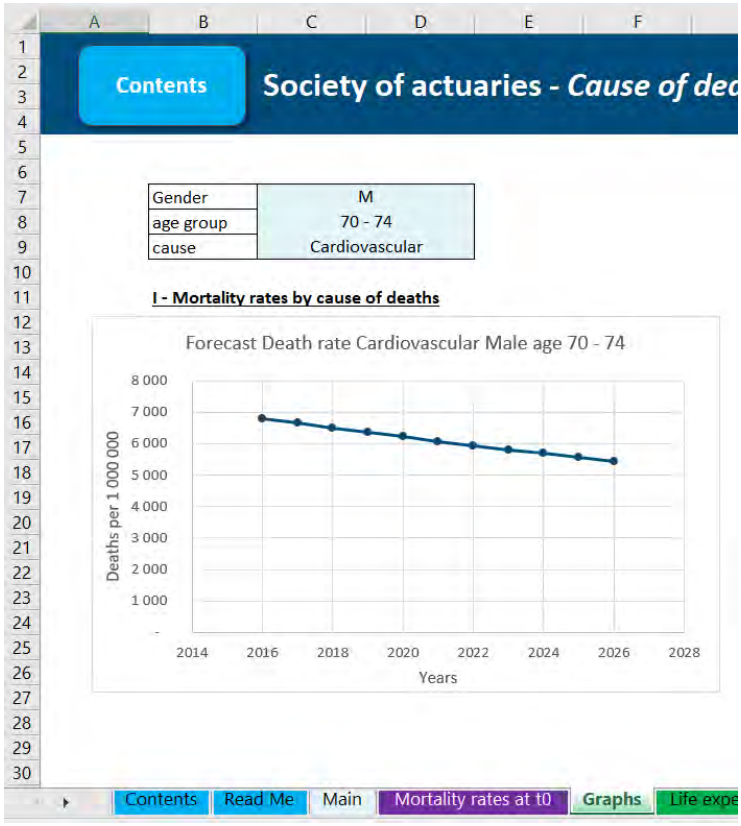



*Figure: Expert judgement use example (2)*

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

| 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 | -10.4% | -11.3% | -10.3% | -11.9% | -14.5% | -17.9% | -20.0% | -20.0% | -20.2% | -18.9% | -14.7% | -11.1% |
| | 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 | -7.7% | -7.6% | -4.4% | -2.6% | -3.8% | -6.4% | -6.9% | -6.8% | -7.4% | -8.1% | -6.4% | -5.6% |
| | 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 70–74. However, note that the trends forecasted for some other age groups are quite different; for instance, the trend leads to a −11.1% deviation of the mortality rates for the age group 95+.

### Tab “LC parameters”

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.