SCOR Chair on Mortality Research

Progress report – February 2025

Objectives

The aim of the SCOR Chair on Mortality Research is three-fold (1) to conduct groundbreaking demographic research in the fields of mortality and longevity, (2) to train the next generation of researchers through supervision of PhD students, and (3) to advance an ongoing discussion between academic and actuarial institutions.

Objective 1: To initiate research actions in the fields of demography and actuarial science applied to the analysis of mortality and longevity with a focus on three research topics: (1) multi-morbidities and causes of death, (2) forecasting mortality, and (3) formal demographic models in the field of mortality analysis.

Objective 2: To offer co-supervision of graduate students between SCOR and CPop/SDU.

Objective 3: To disseminate knowledge via (1) active participation at scientific conferences and (2) organizing seminars with SCOR.

People

The Chair comprises the collaborative efforts of five active members: Associate professor and principal investigator (PI) Marie-Pier Bergeron-Boucher (MPBB), Associate Professor Silvia Rizzi (SR), Associate Professor Trifon Missov (TM), Postdoc Cosmo Strozza (CS) and PhD student Elizaveta Ukolova (EU). Other collaborators, not funded by the Chair, also play an important role, including Julien Tomas (JT) from SCOR and other colleagues from CPop and from our international network.

Research: Progress on Objective 1

In the proposal, we committed to producing at least nine research articles over the duration of the Chair related to (A) reliability of multiple causes of death (MCoD) data, (B) diversity of multiple causes of death, (C) association between causes, (D) probability to die from one cause before another (competing risk), (E) multi-morbidities and (F) mortality forecasting. However, once the Chair began, we adjusted our plan to 11 papers, as some applications of new models by socioeconomic status were better suited to be addressed in separate publications. As of the writing of this report, three articles have been published, four have been submitted, and eight are currently in progress. Over the next year and a half, we aim to initiate five additional papers. The table below summarizes the paper prepared and planned, with a summary of the progress on each topic following.

Topics	Proposed papers	Produced/planned papers	Who	Planned submission	Status	Notes: Submission, delays and presentations
A. Reliability	A1. Reliability of multiple causes of death data	A1 Understanding end-of-life multimorbidity: An analysis of multiple causes of death in Denmark	CS, EU, MPBB	2025 Q2	In progress	The results will be presented at the Population Association of America (PAA) 2025 Annual Meeting in April
		A2 A comparative analysis of regional mortality differences using underlying and multiple causes of death: A case study of Czechia	EU	2024 Q3	Published	Published in *Spatial Demography*: https://link.springer.com/article/10.1007/s40980-024-00130-2
		A3 Hidden Mortality Dynamics in Surface Plots: A Contrasting View with Underlying vs. Multiple Causes of Death in the U.S., 1960–2022	EU	2026 Q1	In progress	Results presented at the Young Demographer Conference (YDC) in February 2025.
B. Diversity	B1 Diversification in causes of death and multi-morbidities	B1 Diversity in causes of death: A new approach using multiple causes of death life tables	MPBB and others	2025 Q2	In progress	The results were presented at a SCOR meeting and will be presented at the PAA 2025 Annual Meeting in April.
	B2 Causes diversification and differences between socioeconomic groups	B2 Causes diversification and differences between socioeconomic groups	MPBB, CS	2025 Q4	Awaiting start	
C. Association	C1 Association between causes of death	C1 What if dependent causes of death were independent?	EU, TM	2024 Q3	Submitted	Under review in *Discover Public Health*. Presented at the YDC in 2024, European Population Conference (EPC) 2024, Czech Demographic Society Conference 2024 and at a SCOR meeting
		C2 Multiple-cause mortality in the U.S., 2000–2021: Insights from pattern-of-failure life tables	EU, MPBB	2025 Q1	In progress	
		C3 An attempt to model interactions between multiple causes of death using causal pies	EU	2025 Q1	Submitted	Under review in *Population Health Metrics*. Will be presented at International Population Conference in Australia, in July 2025.
D. Competing risk	D1 Probability to die from cause A rather than B	D1 Probability to die from one cause before another.	MPBB, EU	2025 Q3	In progress	
		D2 Makeham mortality models as mixtures: Advancing mortality estimations through competing risks frameworks	TM and others	2024 Q3	Published	Published in *Demographic Research*: https://www.demographic-research.org/articles/volume/51/18 Results presented at the EPC 2024 and at a SCOR meeting
E. Multi-morbidities	E1 Years of life lived with multiple morbidities and associated lifetimes – Disease 1	E1 Years of life lived with multiple morbidities and associated lifetimes – Hospitalization Data (Danish and Swedish comparison)	MPBB, CS	2026 Q2	Awaiting start	

	E2 Years of life lived with multiple morbidities and associated lifetimes – Disease 2	E2 Years of life lived with multiple morbidities and associated lifetimes – Chronic diseases in Denmark	CS, MPBB	2026 Q3	Awaiting start	
		E3 Bridging Morbidity and Mortality: Analysis of Mortality by Disability and Interrelated Causes of death using Czech administrative data	EU, CS	2025 Q4	In progress	Presented at a SCOR meeting
		E4 Risk of death of individuals with different comorbidity profiles during the COVID-19 pandemic	SR, CS and others	2025 Q1	Submitted	Submitted to *Annals of Epidemiology* Results presented at the EPC 2024
F. Forecast	F1 Harvesting: Recovery after mortality shocks	F1 Harvesting: Recovery after mortality shocks	TM	2025 Q1	In progress	Delayed submission by a few months. The results will be presented at the PAA 2025 Annual Meeting in April
	F2 Harvesting by subpopulations	F2 Harvesting by subpopulations	TM	2025 Q3	Awaiting start	
	F3 Cohort life expectancy after COVID-19	F3 Cohort life expectancy after COVID-19	SR	2025 Q1	In progress	
	F4 Cohort life expectancy after COVID-19 by subpopulation	F4 Cohort life expectancy after COVID-19 by subpopulation	SR	2026 Q1	Awaiting start	
		F5 Month-to-month all-cause mortality forecasting: a method allowing for changes in seasonal patterns	SR and others	2024 Q2	Published	Published in the *American Journal of Epidemiology*: https://academic.oup.com/aje/article/193/6/898/7603305
		F6 Modelling and short-term forecasting of seasonal mortality	SR and others	2024 Q4	Submitted	Submitted to the *International Journal on Forecasting* Results presented at the EPC 2024 and at a SCOR meeting

A. Reliability of MCoD data

The validity of cause-of-death reporting has frequently been questioned. Often, a single cause of death is analyzed, being the cause which initiated the chain of events leading to death, labelled the underlying cause of death (UCD). However, since individuals can have multiple simultaneous health conditions, and death often results from the interplay between these conditions, determining the underlying cause can be complex. Would analyzing all causes listed on the death certificate provide a more reliable portrayal of end-of-life conditions?

In our proposal, we outlined plans to use Danish registry data to track disease histories at the end of life and evaluate if MCoD data are representative of these. This study (A1) is currently underway, with results expected in the Spring of 2025. Additionally, we obtained access to Czech data on chronic diseases and MCoD data, which has led to another paper examining potential regional disparities in cause-of-death reporting (A2). The latter paper was recently published and is summarized below. A third paper (A3) uses Lexis surface to reveals changes in coding practice and reporting of leading causes of death in the U.S.

Some key outcomes from this research area are still pending, but our initial results indicate that cause-of-death reporting can vary even within the same country, regardless of whether the underlying or multiple causes of death approach is used. In Czechia, some regions tend to identify more specific causes as the underlying cause, while others classify them as contributing factors. This variation may contribute to cause-specific mortality differences between regions in Czechia. This finding highlights the lack of a uniform practice in reporting causes of death, even within the same country, making regional comparison difficult.

Stay tuned for our upcoming results on the reliability of MCoD data (A1 and A3)

CS, EU and MPBB are currently working on a paper assessing the reliability of MCoD data in reflecting health conditions near death. Using Danish registers, we trace diagnoses of cancer, chronic obstructive pulmonary disease, and dementia, examining (1) the time between diagnosis and death, (2) the frequency of these causes in MCoD data by years since diagnosis, and (3) their roles as underlying, immediate, intermediate, or contributory causes. The analysis is stratified by age, sex, and spans the full range of available data. Our findings will improve understanding of end-of-life multimorbidity patterns and assess the quality of Danish MCoD data.

EU is also working a paper showing how our understanding of cause specific mortality shift when all conditions recorded on the death certificate are considered. This contribution presents cause-specific mortality dynamics in a Lexis surface for the U.S. from 1960 to 2022, focusing on current leading causes of death and offering an "alternative perspective" on mortality trends by cause. This perspective reveals several novel findings: for example, an increase in dementia-related mortality was evident much earlier than observed through UCD data. Moreover, a phenotype, that today is called “dementia”, was most likely previously recorded as unspecific nervous disease. Similar surprising results are obtained in other diseases as well, demonstrating that UCD represents only the "tip of the iceberg" of disease burden in the population.

A2 - A Comparative Analysis of Regional Mortality Differences Using Underlying and Multiple Causes of Death: A Case Study of Czechia, by Elizaveta Ukolova

In this paper, we analyzed spatial patterns of cause-specific mortality from leading causes, comparing the underlying cause of death approach with the multiple causes of death approach. Results showed, that for conditions such as heart failure and chronic obstructive pulmonary disease, regional mortality patterns differ substantially depending on whether the underlying or multiple causes are considered. The Jihočeský and Vysočina regions exhibit the greatest disparities between the two approaches, whereas the Plzeňský and Olomoucký regions show consistent patterns under both approaches. In some districts of Czechia, applying standardized age-specific probabilities of recording causes of death as underlying conditions can result in more than a twofold increase or decrease in death rates (e.g., in Havlíčkův Brod, Kolín, Český Krumlov, Rychnov 5nd Kněžnou). The inconsistency between the underlying and multiple approaches is highly homogeneous across districts within the same regions. Our findings suggest that variations in death certification practices across regions could exacerbate regional differences in mortality in Czechia.

Published in *Spatial Demography*: https://link.springer.com/article/10.1007/s40980-024-00130-2

B. Diversity of MCoD

Studies showed that, in recent years, the causes of death became more varied, where we shift from a causes of death structure dominated by a few leading causes – cardiovascular diseases and cancers, especially - to a structure where deaths are more equally distributed across various, smaller causes. These studies did not, however, consider multiple causes of death. In our proposal, we suggested to deepen our understanding of the diversity of causes of death by leveraging MCoD data, examining both the number of contributing causes and the complexity of causes of death profiles. This ongoing research (B1) propose using various measures of diversity, to study causes diversity in Denmark, France, Spain and the US. We anticipate completing the final paper in the Spring of 2025. Once the methods are finalized, we also plan to examine socio-economic differences in the diversity of causes of death, utilizing available data for Denmark and the United States (B2). This analysis is scheduled to begin in mid-2025.

Stay tuned for our upcoming results on the diversity of MCoD (B1)

MPBB and colleagues are introducing a MCoD life table to study two key dimensions of cause diversity: richness and evenness. Richness relates to the number of causes contributing to death and evenness to the relative abundance of the causes in a population. These two dimensions of diversity are applied to Danish, French, Spanish and US data. The results show that causes of death have become more diversify over time, due to both an increase in the number of contributing causes and a more complex causes of death distribution. Using MCoD data reveals greater cause diversity than analyzing the underlying cause alone. We also introduce decomposition approaches to understand why the number and the diversity of causes of death have changed over time.

C. Association between causes

In a third research area, we suggested assessing the associations between causes of death based on MCoD data. How are specific causes of death more often associated with one another? Can we evaluate the dependence between causes? In our proposal, we initially proposed using machine learning to identify clusters of causes contributing to death. However, this approach yielded limited new insights, leading us to adopt a new methodology that has produced compelling results (C1). Instead of examining the dependence between causes, we evaluated what would happen if we broke down the association between pairs of causes. Using U.S. data, we revealed that the dependencies between causes are more complex than previously understood. Many causes are often interconnected, meaning that if the dependency between two specific causes were altered, it would impact dependencies across other causes as well. This paper is currently under review and summarized below.

Two additional papers were also considered to further investigate associations between causes of death. In the first paper, we study mortality for sets of diseases using a pattern-of-failure life table in the U.S. (C2). Instead of assuming that each cause acts independently, we assume that a set of specific diseases are dependent and lead to a specific mortality risk. We show that a pattern-of-failure life table can shed light on the significance of specific diseases in particular roles and their overall impact on life expectancy

The last paper analyzes interactions between causes of death and proposes a model to identify the most likely causal relationships within a set of causes (C3). We move beyond the more "standard" approach of studying associations between causes and focus on the mechanisms of interaction among these causes, showing the role of contributing causes as mediators in the chain of events leading to death. This last paper has also been submitted.

Stay tuned for our upcoming results on association between causes (C2)
EU and MPBB are using pattern-of-failure life tables to study mortality risks for a set of diseases, rather than for individual causes. The selected model explicitly model disease interdependence unlike traditional multiple decrement tables. We apply cause-elimination strategies in pattern-of-failure life tables by "turning off" the risk of death from distinct sets of diseases. We eliminate individual causes of death, but our approach allows us to extend the effect of such elimination to deaths where the eliminated disease appeared as a dependent cause, not just as the underlying cause. This allows for a more accurate representation of the burden of individual diseases, as deaths in countries that have undergone the epidemiological transition are often the result of multiple causes. Our results reveal: (i) distortions in death recording during the COVID-19 pandemic, (ii) cohort-specific impacts of digestive and infectious diseases, (iii) evolving classifications of dementia-related deaths, (iv) a decline in the role of cerebrovascular diseases in the chain of morbid events, and (v) the growing significance of residual diseases, especially in younger populations.

C1 - What if Dependent Causes of Death Were Independent? By Elizaveta Ukolova and Trifon Missov

In this paper, we explored the effects of disrupting the dependencies between leading cause-of-death pairs in the US. The aim was to assess how these disruptions would impact the overall structure of cause-of-death relationships. Disrupting associations between leading cause-of-death pairs would generally lead to decreases in the strength of relations these diseases have with others outside the disrupted pair. The most pronounced effects are observed in the loss of association between mental and behavioral disorders with other respiratory diseases, heart diseases with endocrine, nutritional, and metabolic disorders, and heart diseases with mental and behavioral disorders. Changes in dependencies between leading cause-of-death pairs do not occur in isolation from other diseases.

Under review in *Discover Public Health*.

C3 - Are contributory causes of death mediators of chains of morbid events leading to death? By Elizaveta Ukolova

This study uses causal pie models to examine how contributory causes of death influence the chain of events leading to death, using U.S. Multiple Cause of Death Microdata. While previous studies have explored associations between causes of death, none have yet focused on the mechanisms of interaction among these causes. The findings underpin the importance of contributory causes in the lethal process by showing (i) variations in life expectancy between individuals with and without these contributory causes, even when controlling for underlying causes of death, and (ii) how contributory causes affect the sequence of morbid events leading to death. The impact on life expectancy was particularly pronounced for contributory diabetes and Alzheimer's disease, while the influence of contributory causes on morbid event sequences was especially evident in younger age groups, as well as in triads involving contributory chronic pulmonary disease and diabetes. Our study demonstrates that contributory causes of death act as mediators in the progression of morbid events leading to death, particularly in individuals under 80 years of age, highlighting their crucial role in transitions to terminal morbid states.

Under review in *Population Health Metrics*.

D. Competing-risk between causes

There are two broad perspectives on how multiple diseases can lead to death: they can interact (Section C), but they can also compete. If individuals are exposed to multiple risks, where the occurrence of one can prevent the others, this is referred to as a competing risk. In this research focus, we aim to model and estimate competing risks between causes. In the proposal, we suggested using the probability of superiority to measure the probability to die from one cause before another competing causes. An ongoing paper uses the probability of superiority to assess the probability of dying from Cause A before Cause B, considering both cases where A and B are underlying causes and cases where both are listed on the death certificate using MCoD data (D1). A multi-country comparison is also included, focusing on Denmark and the US, with ongoing discussions to incorporate additional countries.

Additionally, we established a new relationship for assessing competing risks, resulting in an additional paper that demonstrates how competing risks can be represented as a mixture of distributions (D2). This paper has been published and is summarized below.

Stay tuned for our upcoming results on competing risk between causes (D1)

MPBB and CS are conducting pairwise comparisons among the 10 leading causes of death in the U.S. and Denmark to assess the probability that one cause leads to death before another. Using outsurvival statistics, we estimate this probability under the assumption of independence between causes. This method is then compared to the cumulative incidence function, which accounts for dependence among causes. Furthermore, we evaluate both methods using two data types: deaths where diseases are listed solely as the underlying cause of death (UCD) and deaths where both causes being compared appear on the death certificate, utilizing multiple causes of death data (MCD). Our results reveal that, when using UCD and assuming independence, there is a higher probability of dying from diseases of the circulatory system compared to other causes, highlighting their significant population burden. However, this probability decreases when accounting for dependence among causes and further decreases when analyzing MCD data. Analysis of MCD data highlights that individuals with neoplasms or diseases of the nervous system at the end of life are more likely to have these conditions as their underlying causes of death compared to other co-morbidities present on the death certificate.

D2 - Makeham mortality models as mixtures: Advancing mortality estimations through competing risks frameworks, by Silvio C. Patricio and Trifon I. Missov

The study presents a formal relationship that represents competing risk models as a mixture of distributions, where each cause of death corresponds to a component distribution, and an individual's lifespan is a mixture of these component distributions. The weights in this mixture correspond to the probabilities of each cause of death being the first to occur among all competing causes. This representation allows for a clear understanding of how (not necessarily independent) competing risks influence overall mortality and provides a framework for modeling complex mortality patterns. The mixture-model specification aids in representing the distribution of deaths as a convex combination of distributions for risk-specific subpopulations. This facilitates calculating various mortality and longevity measures for each subpopulation, as well as assessing the overall and age-specific prevalence of each cause of death.

Published in *Demographic Research*: https://www.demographic-research.org/articles/volume/51/18

E. Multi-morbidities

In the proposal, we suggested analyzing multi-morbidity patterns and their relation to the age at death and cause of death, leveraging Danish registry data. This involves examining the number of years lived with multiple morbidities, associated lifetimes, and changes over time (E1 and E2). Originally scheduled for a later phase, this research is on track to begin in mid-2025. Meanwhile, two additional papers have been initiated.

The first paper utilizes Czech administrative data to quantify the years lived with specific diseases and with specific number of comorbidities (E3). Preliminary results indicate that as the number of comorbidities increase, life expectancy tend to decrease.

The second paper analyzes the risk of COVID-19 mortality among individuals with varying morbidities (E4), which is currently under review. The study reveals several important findings regarding the interplay between comorbidities, sociodemographic factors (such as sex and socioeconomic status), and COVID-19 mortality risk. For non-COVID deaths during the pandemic, we observe a largely similar comorbidity-mortality pattern as in the pre-pandemic period; for COVID related deaths, on the contrary, individuals with any degree of comorbidities are more equally at risk of mortality.

Stay tuned for our upcoming results on multi-morbidities (E3)

EU and CS are using population-wide administrative health data to measure burden of chronic diseases and multimorbidity in Czechia, as well as its impact on life expectancy between 2014 and 2023. We use prevalences and life table analysis. Since 2014, the proportion of individuals with complex multimorbidity (3+ conditions) has declined, with the decline accelerating following the COVID-19 pandemic. Individuals with diabetes or COPD, without additional comorbidities, have a remarkably long lifespan of nearly 90 years. As the number of comorbidities increases, life expectancy declines sharply—on average by 8 years per additional condition. These effects vary depending on which diseases cooccur. In general, the life expectancy among multimorbid individuals has stagnated or even declined during 2014-2023, except for neoplasms.

E4 - Risk of death of individuals with different comorbidity profiles during the COVID-19 pandemic, by Virginia Zarulli, Cosmo Strozza and Silvia Rizzi

We here investigate how comorbidities diagnosed prior to the pandemic interacted with COVID-19 and whether the mortality risk for individuals with comorbidities changed during the pandemic. We examine COVID-19-specific and non-COVID-19-related mortality during 2020 and 2021 to assess the direct and indirect effects of the pandemic on the mortality risk of individuals with and without comorbidities. We utilize comprehensive, nationwide Danish registry data, and employ survival analysis techniques. Kaplan-Meier curves show a clear gradient in the risk of death based on comorbidity levels, with women exhibiting more pronounced differences. During the pandemic, the relationship between comorbidity and non-COVID related deaths appears similar, while with COVID-related deaths appears less distinct, especially among men, indicating intriguing gender-health-status-specific patterns.

Submitted to *Annals of Epidemiology*

F. Mortality forecasting

In this last research area, we are particularly focused on forecasting mortality trends following the COVID-19 pandemic. The COVID-19 pandemic brought new challenges for forecasters. Specifically, we proposed evaluating the pandemic's impact on mortality across different cohorts (F1) and examining how pandemic-related mortality shocks may influence future life

expectancy through harvesting effects (F3). Both papers are currently underway and are providing crucial methodological development to forecast the sort and long-term effect of the COVID-19 pandemic on mortality trends. Applications of these models by socio-economic status are also planned (F2 and F4) and will commence once methods are fully developed in the initial papers.

Two additional papers are being produced to better quantify and understand the death toll caused by the COVID-19 pandemic, assessed by quantifying excess mortality. This is done by measuring the difference between expected mortality, established through forecasting, and observed mortality. In the first paper (F5), we introduce a new model to forecast month-to-month mortality, which more accurately predicts mortality from the second wave of the COVID-19 pandemic onward. This paper has been published and is summarized below. In the second paper (F6), we evaluate which specification of one of the most used models for estimating excess mortality yields the most accurate forecast. The paper has been submitted.

Stay tuned for our upcoming results on mortality forecasting (F1 and F3)

SR is working on estimating the changes in cohort life expectancy associated with the COVID-19 pandemic. During the COVID-19 pandemic, period life expectancy at birth declined from 2019 to 2020 in most of the Western countries. However, it is not clear how the pandemic will impact the life expectancy of cohorts. A novel forecasting method to forecast cohort mortality and the cohort life expectancy of non-extinct cohorts is applied to data pre- and post- the COVID-19 pandemic. Prediction intervals are computed via a bootstrapping procedure. Changes in cohort life expectancy due to the COVID-19 pandemic are estimated as the difference between expected cohort life expectancy using data up to and including 2019 and expected cohort life expectancy using data from 2022 onwards.

In addition, TM is currently working on the harvesting approach. “Harvesting” denotes a specific type of mortality displacement when a sudden shock eliminates imminently a higher than anticipated number of individuals, especially those that are expected to die soon. The outcome, in terms of death counts or death rates, is a curve with a sharp peak, corresponding to the excess deaths caused by the shock, followed by a trough, reflecting the lack of deaths because the expected individuals at risk have already been eliminated. The COVID-19 pandemic provides a unique setup to study harvesting in that the epidemic struck every country not just once, but in several waves. The study develops a harvesting model reflecting the immunity profiles of the population during each of the waves to address the following research questions: What subgroups (by age, disease history, etc.) were more prone to withstand the mortality shock in the first wave? How did this change in each subsequent wave, given the acquired immunity (through recovery or vaccines) after the previous one? How many waves did harvesting affect, i.e., at what stage did acquired immunity eliminate harvesting? The developed dynamic model not only detects, but also quantifies the magnitude of the harvesting effect. The model also serves as a basis for short- and mid-term mortality forecasts that can inform policy makers how many pensioners, and in what health, to expect in the years to come, as well as what causes of death have been affected by the pandemic, i.e., what diseases must the health system pay attention to.

F5 - Month-to-month all-cause mortality forecasting: a method allowing for changes in seasonal patterns, by Ainhoa-Elena Léger and Silvia Rizzi

Real-time mortality forecasts are needed during severe winter spikes and/or pandemic waves to guide policy-making and public health decisions. In this study, we propose a method to forecast all-cause mortality one month ahead considering short-term changes in seasonal patterns within an epidemiological year. The method forecasts the deaths one-month-ahead, based on their expected ratio to the next month. Prediction intervals are obtained via bootstrapping. The forecasts accurately predict the winter peaks before COVID-19. Although the method predicts mortality less accurately during the first wave of the COVID-19 pandemic, it captures the aspects of later waves better than other traditional methods. The method is attractive for health researchers and governmental offices to aid public health responses because it uses minimal input data, makes simple and intuitive assumptions, and provides accurate forecasts during seasonal influenza epidemics and during virus pandemics.

Published in *American Journal of Epidemiology*:
https://academic.oup.com/aje/article/193/6/898/7603305

F6 - Modelling and short-term forecasting of seasonal mortality, by Ainhoa-Elena Léger, Silvia Rizzi and Ugofilippo Basellini

Excess mortality, i.e., the difference between expected and observed mortality, is used to quantify the death toll of mortality shocks, such as epidemics and pandemics of infectious diseases. However, predictions of expected mortality are sensitive to model assumptions. We analyse which specification of a Poisson regression for seasonal mortality yields more accurate predictions. We compare the Poisson Serfling model with 1) parametric effect for the trend and seasonality, 2) non-parametric effect for the trend and parametric effect for the seasonality, and 3) non-parametric effect for the trend and seasonality, also known as modulation model. Forecasting is achieved with P-splines smoothing. Model 2) resulted in more accurate historical forecasts on the series of monthly deaths from national statistical offices in 25 European countries. An application to the COVID-19 pandemic years illustrates how excess death can be used to evaluate the vulnerability of populations and aid public health planning.

Submitted to the *International Journal on Forecasting*

Supervision: Progress on Objective 2

Elizaveta Ukolova, PhD student, has been hired under the Chair, supervised by MPBB, TM and JT. Her PhD, started on September 1, 2023, is entitled *Multi-morbidities, dependencies and mortality risk*.

She will do a research stay in Stockholm to work with JT in the Fall of 2025. They will work on diseases trajectory using networks.

Dissemination: Progress on Objective 3

The Chair members have been participating and presenting at scientific conferences. The table below provides an overview.

Title of presentation	Paper no.	Authors	Conference	Session	Date	Place	Link to program
What if causes of death were independent?	C1	**Elizaveta Ukolova** and **Trifon Missov**	Young Demographers Conference	Poster session 4	February 7-9, 2024	Prague, Czechia	https://docs.google.com/document/u/1/d/e/2PACX-1vRtlZqjerrRXeGDkniVXepCo8g-OR8LjcImrGV0oHZ5dhYuyvEbTzhZvVxuyMFDS10n_74IvQh2auBe/pub
Smoothing trends and seasonality in short-term mortality forecasting	F6	Ainhoa Elena Léger, **Silvia Rizzi**, Ugofilippo Basellini	European Population Conference	Flash session Morbidity (presentation and poster)	June 12-15, 2024	Edinburgh, Scotland	https://www.eaps.nl/files/EPC2024-FinalProgram.pdf
Cause of death dependencies: structure and impact of hypothetical disruptions	C1	**Elizaveta Ukolova** and **Trifon Missov**	European Population Conference	Modelling and Forecasting Mortality (presentation)	June 12-15, 2024	Edinburgh, Scotland	https://www.eaps.nl/files/EPC2024-FinalProgram.pdf
Risk of death of individuals with different comorbidity profiles during the COVID-19 pandemic.	E4	Virginia Zarulli, **Cosmo Strozza** and **Silvia Rizzi**	European Population Conference	Excess Mortality and Life Expectancy Changes during the COVID-19 pandemic (presentation)	June 12-15, 2024	Edinburgh, Scotland	https://www.eaps.nl/files/EPC2024-FinalProgram.pdf
A three-component model for adult mortality	D2	**Trifon I. Missov** and Silvio C. Patricio	European Population Conference	Mortality Modelling (presentation)	June 12-15, 2024	Edinburgh, Scotland	https://www.eaps.nl/files/EPC2024-FinalProgram.pdf
ÚMRTNOST PODLE NEZÁVISLÝCH A ZÁVISLÝCH PŘÍČIN SMRTI (Mortality by Independent and Dependent Causes of Death)	C1	**Elizaveta Ukolova** and **Trifon Missov**	Czech Demographic Society Conference	Mortality, Disease (presentation)	May 23-25, 2024	Olomouc, Czechia	https://www.czechdemography.cz/akce/konference/konference-cds-2024/prispevky-z-konference/
Hidden Mortality Dynamics in Surface Plots: A Contrasting View with Underlying vs. Multiple Causes of Death in the U.S., 1960–2022	A3	**Elizaveta Ukolova**	Young Demographers Conference	Poster session 1	February 5-7, 2025	Prague, Czechia	https://docs.google.com/document/d/1ANk2xr69Wri5kJlZzGuKN76NcHg9PGTSFB_7FkvQs_w/edit?tab=t.0

We have upcoming conferences for the Spring of 2025:

Population Association of America, 2025 Annual Meeting in Washington DC, 10-13 April 2025.

- "Assessing and Predicting the Impact of Mortality Shocks on Population Trends" by Trifon I. Missov was accepted for an oral presentation in the session *Epidemic and Pandemic Mortality and Morbidity*. (paper F1)
- *"*Understanding end-of-life multimorbidity: An analysis of Multiple Causes of Death in Denmark*"* by Cosmo Strozza, Elizaveta Ukolova and Marie-Pier Bergeron Boucher was accepted for an oral presentation in the session *Chronic Disease and Multimorbidity Burden across High-Income Countries*. (paper A1)
- "Diversity in Causes of Death: A New Approach Using Multiple Causes of Death Life Tables", by Marie-Pier Bergeron-Boucher, Sergi Trias-Llimós and Aline Désesquelles was accepted for a poster session. (paper B1)

International Population Conference in Brisbane Australia, 13-18 July 2025.

- Modelling Interactions between Multiple Causes of Death Using Causal Pies, by Elizaveta Ukolova has been accepted for an oral presentation in the session *Chronic Diseases and Multimorbidity* (paper C3)

Many members of the team have also submitted an abstract to the Nordic Demographic Symposium, which will be held in Middelfart, Denmark in June 2025.

By the time this report was finalized, two workshops had been organized in collaboration with SCOR: one on April 4-5, 2024 and another on November 7-8, 2024. Colleagues from CPop, SCOR, and external institutions participated in these events. We here list the presentations given by member of the Chair during these workshops.

1rst SCOR seminar, Paris, April 4-5, 2024

- Elizaveta Ukolova presented her work on "Cause of death dependencies: effect on length of life and impact of their hypothetical disruption". (paper C1)
- Trifon Missov presented his research "Mortality regularities in a dependent competing-risk setting", done in collaboration with Silvio Cabral. (paper D2)

2nd SCOR seminar, Paris, 7-8 November 2024

- Elizaveta Ukolova presented her ongoing work on "Bridging Morbidity and Mortality. Analysis of (mortality by) disability using Czech administrative data". (paper E3)
- Silvia Rizzi presented her work in collaboration with Ainhoa-Elena Leger and Ugofilippo Basellini, titled "Smoothing trends and seasonality in short-term mortality forecasting". (paper F6)
- Marie-Pier Bergeron Boucher presented her research "Diversity in Causes of Death: A New Approach Using Multiple Causes of Death Life Tables", done in collaboration with Sergi Trias-Llimós and Aline Désesquelles. (paper B1)

A third meeting with SCOR will take place on 3-4 April 2025, at the University of Southern Denmark, in Odense, Denmark.

Practicalities

We received Danish registry data in October 2024, following an approximate eight-month delay. These delays were primarily due to the setup and subsequent update of a new data infrastructure for CPop and other departments at the University of Southern Denmark. This upgraded infrastructure will allow us to access a wider range of data faster and at a reduced cost. This will be particularly advantageous should we need to request updated data covering the most recent periods later in the project.

The PI was on maternity leave from October 2023 to August 2024. To accommodate this, the project schedule was adjusted prior to the start of the Chair, shifting from the original period of April 2023 - March 2026 to the revised timeline of July 2023 - November 2026. MPBB has resumed her work from the Chair. During her absence, the rest of the team remained highly productive, ensuring that most of the planned papers are on track, with several additional papers also being produced.