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CALCULATING FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR SLOVAKIA USING HOLT'S LINEAR METHOD

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Abstract
This study uses annual time series data on MMR for Slovakia from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes Holt's double exponential smoothing model. The optimal values of smoothing constants α and β are 0.5 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain very low over the out of sample period. Therefore, we encourage authorities to continuously address local causes of maternal deaths.

Keyword(s): - Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality ratio (MMR) is an indicator of the level and quality of medical care in all countries. Factors associated with maternal mortality include access to quality health care, age, education, socio-economic factors and the stage of development of the country (Oliveira et al. 2023). High maternal mortality rates in certain countries highlights differences in access to quality healthcare service during pregnancy, childbirth or the postpartum period (WHO, 2024). According to the World Health Organization (WHO), the number of maternal deaths worldwide fell by 43.3%, from 447 000 in 2000 to 287 000 in 2020, and the maternal mortality ratio (MMR) decreased from 339 to 233 per 100 000 live births. A decline in MMR during this period was also recorded in European countries – from 26 to 13 per 100 000 live births (WHO, 2023). The aim of this paper is to forecast MMR for Slovakia using the double exponential smoothing technique. The study results will inform allocation of resources to the health sector so that preventable deaths are eradicated.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Camarinha et al. (2026)	to estimate Severe Maternal Morbidity (SMM) rates and trends among public hospital deliveries in Portugal, 2010-2018, and identify associated factors	A register-based observational cross-sectional study was conducted using public hospital admission delivery episodes	Trends in SMM between 2010 and 2018 in Portugal show an increase, particularly for blood transfusion. Risk factors included age,

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			hospitalization length, intensity of diagnoses and procedures, and ICD-10-CM/PCS coding
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic review	Positive aPLs significantly increased the risk of miscarriage rate in assisted reproductive technology (ART) and were also associated with total fetal loss, PE, intrauterine growth retardation and placental abruption
Kotríková et al. (2025)	Analysis of maternal mortality and identification of risk factors for maternal deaths in Slovakia in the years 2007–2023	Retrospective population-based descriptive analysis of maternal mortality from 2007 to 2023 based on the International Classification of Diseases—Maternal Mortality 10th edition (ICD-MM). Selected demographic characteristics were analyzed, and statistical data from official sources and the enhanced surveillance system were compared	he most common causes of death were cardiovascular diseases (22.0%), amniotic fluid embolism (11.0%), viral infections (10.1%), obstetrics hemorrhage (8.3%) and hypertensive disorders of pregnancy, childbirth and puerperium (8.3%)
Kotríková et al. (2025)	Analysis of coincidental maternal mortality in Slovakia	Retrospective population analysis of maternal	The study highlighted the problem of under-

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	in the years 2007–2024 from the database of the Slovak Gynecological and Obstetric Society (enhanced surveillance system)	mortality from 2007 to 2024 focused on coincidental maternal deaths	recognition of coincidental maternal deaths, despite its significant impact on public health
Vargová et al. (2025)	Analysis of life-threatening maternal morbidities and their subsequent treatment in intensive care units in Slovakia during the years 2012–2021	A descriptive, population-based study of 747 cases of mothers admitted to intensive care units (ICU)	Severe postpartum hemorrhage, hypertensive disorders and sepsis remain the leading cause of ICU admissions
Nunn et al. (2025)	To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait Islander women contributed to reduced perinatal death rates	Retrospective population-based cohort study of all births in Victoria from 2000–2019	Changes in key maternal characteristics may have contributed to improved perinatal death rates among babies of Victorian Aboriginal and/or Torres Strait Islander women
Haninger-Vacariu et al. (2024)	To describe pregnancy and delivery outcomes in women with Fabry disease	Retrospective cohort-study of women with Fabry disease in Austria using a specific questionnaire and the Austrian Mother–Child Health Passport	The cohort-study in women with Fabry disease showed an increase of pain burden during pregnancies and clearly points to an increased risk for preeclampsia, prematurity, and neonates small for gestational age. With a substantial number of high-risk pregnancies, neonatal outcomes are somewhat worse in Fabry

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			disease than in the general public
Kornyicki & Fedor (2024)	to publish findings on the lifestyle factors of pregnant women in Hungary and their impact on early childhood health status by examining changes over time and regional/geographical disparities	Secondary analysis of raw indicators reported by health visitors as per mandatory annual report data for the period of 1997–2019 in Hungary	Interventions to improve early childhood health in some counties of Hungary are urgently needed to reduce regional disparities
Wilhelm et al. (2024)	To describe the contribution of CA to NMR in Malta, investigating possible associations with known maternal risk factors of maternal age, nationality, and education	-Anonymous data for births and neonatal deaths were obtained for 2006 2020 from the National Obstetrics Information System (NOIS) in Malta -applied regression analysis	Between 2006 and 2020, Malta's NMR remained stable. Maternal Nationality, from non- EU low-income countries, was associated with higher neonatal mortality
Pintassilgo et al. (2023)	(1) to describe the characteristics of childbirth in Portugal according to the place of birth, and (2) to analyze the association between homebirth assistance and perinatal, neonatal, and infant mortality rates	Researchers performed a descriptive, correlational analysis of the official datasets of live births in Portugal (census-based) produced by the National Institute of Statistics.	In 2020, home births had more similarities with hospital births than to births occurring in any "other place". Furthermore, considering the 1995–2020 timeframe, home births with specialized assistance were negatively correlated with perinatal, neonatal, and infant mortality, and home births with non-

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			specialized professional assistance or those that were unassisted showed a positive correlation with these mortality rates
Diguisto et al. (2022)	To compare maternal mortality in eight countries with enhanced surveillance systems	Descriptive multi-country population-based study	Variations in maternal mortality ratios exist between high income European countries with enhanced surveillance systems
Wami et al. (2022)	To explore both real maternal and feto-neonatal characteristics associated with Hungarian homebirths	Retrospective cohort study	Aggregated maternal complications (primary uterine inertia, prolonged second stage labor, and third stage hemorrhage) were prevalent among homebirth cases (1.29% vs. 0.72%, $p < 0.05$) and were associated with an average of 11.77% rate of transfer to a health care institution. On the other hand, the rate of operative (vaginal or caesarean) delivery was 26.31% among institutionalized births
Lameijer et al. (2019)	to present an extensive overview concerning the specific	Researchers assessed all cases of maternal death due to	The maternal cardiovascular mortality ratio is low in the

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	cardiovascular causes of ma ternal death and to identify avoidable contributing care factors related to these deaths	cardiovascular disorders collected by a systematic national confidential enquiry of maternal deaths published by the Dutch Maternal Mortality and Morbidity Committee on behalf of the Netherlands Society of Obstetrics and Gynecology over a 21-year period (1993–2013) in the Netherlands	Netherlands and the main causes of maternal cardiovascular mortality are in line with other European reports

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Slovakia. In exponential smoothing forecasts are generated from the smoothed original series with the most recent historical values having more influence than those in the more distant past as more recent values are allocated more weights than those in the distant past. This study uses the Holt's linear method (Double exponential smoothing) because it is an appropriate technique for modeling linear data.

Holt's linear method is specified as follows:

Model equation

$A_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t$

Smoothing equation

$S_t = \alpha A_t + (1-\alpha)(S_{t-1} + b_{t-1})$

$0 < \alpha < 1$

Trend estimation equation

$b_t = \beta (S_t - S_{t-1}) + (1-\beta) b_{t-1}$

$0 < \beta < 1$

Forecasting equation

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$f_{t+h} = S_t + hb_t$

A_t is the actual value of MMR at time t

ε_t is the time varying **error term**

μ_t is the time varying mean (**level**) term

ρ_t is the time varying **slope term**

t is the trend component of the time series

S_t is the exponentially smoothed value of MMR at time t

α is the exponential smoothing constant for the data

β is the smoothing constant for trend

f_{t+h} is the h step ahead forecast

b_t is the trend estimate (slope of the trend) at time t

b_{t-1} is the trend estimate at time t-1

Data Issues

This study is based on annual MMR in Slovakia for the period 1985– 2023. The out-of-sample forecast covers the period 2024 – 2035. All the data employed in this research paper was gathered from the World Bank online database.

Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.500
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.098632
Sum Square Error (SSE)	117.918586
Mean Square Error (MSE)	3.023553

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Mean Percentage Error (MPE)	0.835921
Mean Absolute Percentage Error (MAPE)	13.476792

Residual Analysis for the Applied Model

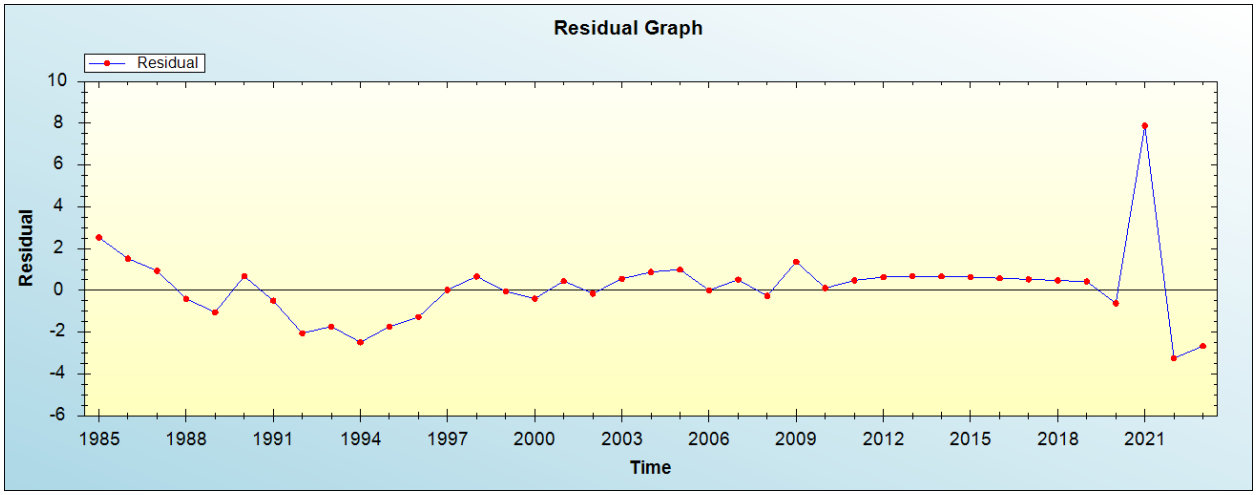


Figure 1: Residual analysis

In-sample Forecast for A

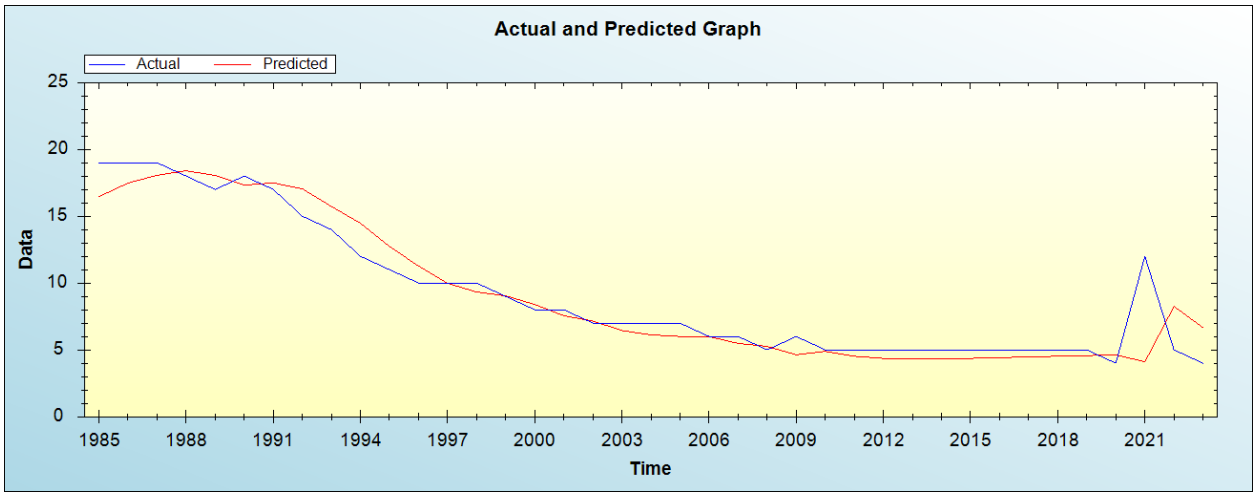


Figure 2: In-sample forecast for the A series

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Actual and Smoothed graph for A series

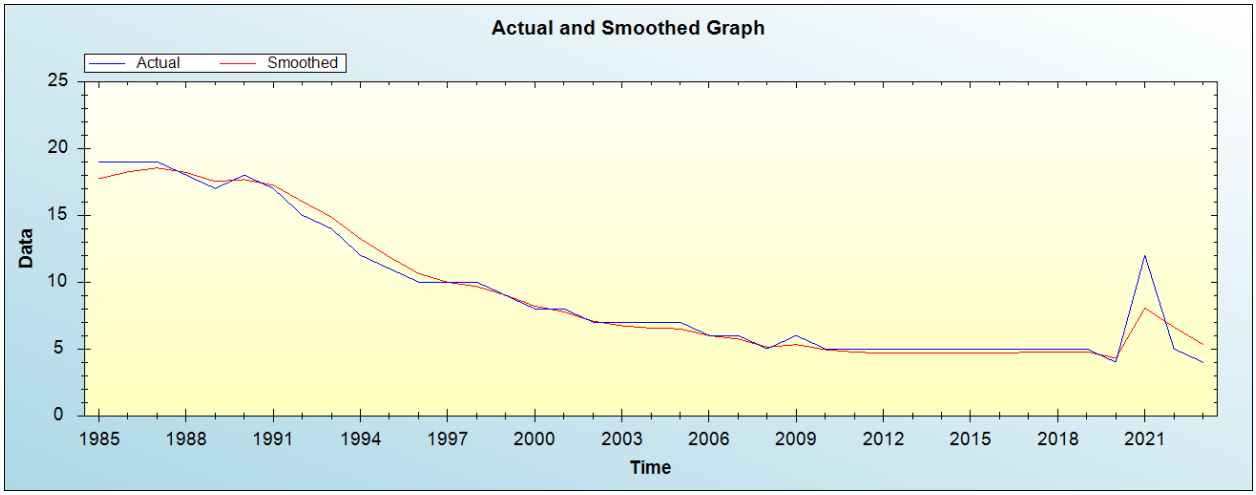


Figure 3: Actual and smoothed graph for A series

Out-of-Sample Forecast for A: Actual and Forecasted Graph

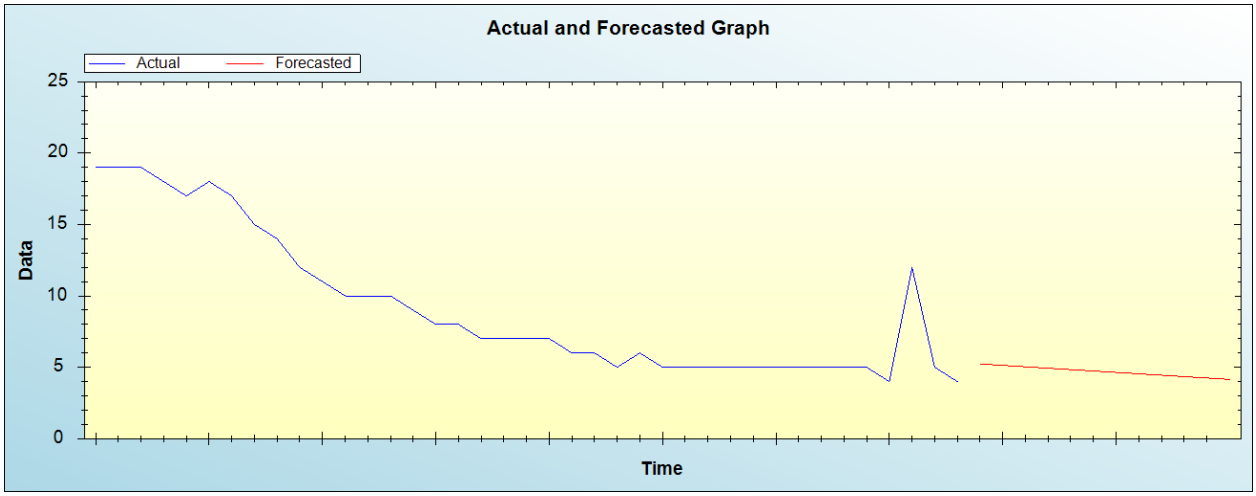


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	5.2324
2025	5.1340

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2026	5.0355
2027	4.9370
2028	4.8386
2029	4.7401
2030	4.6417
2031	4.5432
2032	4.4448
2033	4.3463
2034	4.2478
2035	4.1494

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that annual MMR will remain very low over the out of sample period.

Conclusion

This study applied the double exponential smoothing technique to model and forecast MMR for Slovakia and findings indicate that MMR will remain very low in the forecast period. Hence, we implore authorities to address local causes of maternal deaths.

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