



TRACKING THE FUTURE PATH OF MATERNAL MORTALITY RATE FOR SERBIA USING HOLT'S LINEAR METHOD

Smartson. P. NYONI 1

Thabani NYONI 2

1Independent Researcher & Medical Doctor, Harare, Zimbabwe

2Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract

This study uses annual time series data on MMR for Serbia 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 0.4 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will hover around 15 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage authorities to tirelessly address major drivers of preventable maternal deaths.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality refers to deaths of women from complications of pregnancy, childbirth, and puerperium. The most common complications that lead to maternal deaths are sepsis, excessive hemorrhage after childbirth or abortion, and hypertensive disorders (Mhyre (2012)). Worldwide, above 350,000 women die every year from complications during pregnancy and childbirth, 99% occurring in developing countries (Cristina Rossi & Mullin, 2012). Since 1990, the maternal mortality ratio has been nearly cut in half, and most of the reduction has happened since 2000. More than 71% of births were assisted by skilled health personnel globally in 2014, an increase from 59% in 1990. In the developing regions, only 56% of births in rural areas are attended by skilled health personnel, compared with 87% in urban areas. Only half of pregnant women in the developing regions receive the recommended minimum of four antenatal care visits (Petronijevic et



al. 2019). Serbia has successfully met the United Nations maternal mortality ratio (MMR) target, and this value has remained nearly unchanged since 1990 (Petronijevic et al. 2019). The impressive MMR statistics are as a result of a high proportion of childbirths in healthcare facilities. According to the United Nations Children's Fund and data from the 2019 Mixed Indicators Cluster Survey, only a small number of childbirths happened outside healthcare facilities and were recorded among the vulnerable Roma population (UNICEF, 2020). In 2023, the MMR stood at 9.8 per 100,000 live births, which remains higher than many European Union member states (Petronijevic et al. 2019). This paper projects MMR for Serbia using Holt's linear method. The study findings will assist in policy making, planning and allocation of adequate resources to the health sector so that there can be further reduction of preventable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Markovic et al. (2025)	to identify factors associated with extreme hospital childbirth costs in a tertiary-level hospital in Belgrade, Serbia	cross-sectional study	Mothers with extreme costs had a median hospital stay of 23 days compared to 5 days for those with expected costs ($p < 0.001$). The median total cost of maternity healthcare was 604.3 USD. Women undergoing cesarean delivery had four times higher odds of incurring extreme costs compared to those with spontaneous vaginal delivery
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
Nunn et al. (2025)	To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait	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



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 6, June 2026

Website: usajournals.org

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

	Islander women contributed to reduced perinatal death rates		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 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
Tran et al. (2023)	To analyze of the state of maternal healthcare in Bayan-Ölgii, Mongolia including its strengths, weaknesses, and future considerations	descriptive single-case study	many potential interventions seem to lie at the community level in order to ensure the health and well-being of women in Bayan-Ölgii before and up to the time that they become pregnant
Chimed-Ochir et al. (2022)	to describe the leading causes of death and disabling conditions and their trends between 1990 and 2019 in the Mongolian population	used the data from the Global Burden of Disease (GBD) 2019 study	Although Mongolia saw substantial improvements across many communicable diseases, maternal and neonatal disorders, and under-5 mortality between 1990 and 2019, non-communicable diseases remained leading causes of mortality



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 6, June 2026

Website: usajournals.org

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

Kabakchieva et al. (2022)	To investigate access-related barriers (availability, appropriateness, affordability, approachability, and acceptability) to maternity care in Romania, Bulgaria, and Moldova	cross- country study	Results show high rates of cesarean births (CB) and a low number of antenatal and postnatal care visits. Informal payments and use of personal connections are common practices
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 fetoneonatal 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
Lazarević et al. (2020)	To perform a trend analysis of neonatal mortality in Serbia	Join point regression was used to analyze neonatal mortality data for the years 1997 to 2016 that were obtained from the Statistical Office of Serbia	The neonatal mortality rate in Serbia decreased between 1997 and 2016, excluding deaths due to short gestation and low birth weight
Petronijevic et al. (2018)	to analyze maternal mortality in Republic of Serbia	Maternal mortality in Republic of Serbia was analyzed in two periods, 2007-2011 and 2012-2016	Maternal mortality ratio in Serbia, although relatively high, in the last six years shows a declining trend (from 14.9 in 2012 to 10.8 per 100,000 live births in 2016)
Schildberger et al. (2017)	-To investigate the personal meanings and experiences of	Conducted semi-structured interviews	Participants reported limited acceptance of their life decisions and experienced an



	women with disabilities in regard to pregnancy, childbirth and the puerperium		environment of discriminatory attitudes. They experienced a lack of support and lack of confidence in their parenting abilities, which negatively influenced their self-efficacy and self-awareness. Violations of personal borders and a feeling of being watched and controlled were reported
--	---	--	---

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Serbia. 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

$$A_t = \mu_t + \rho_t t + \varepsilon_t$$

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

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

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 Serbia 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	0.400
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.501816
Sum Square Error (SSE)	276.043593
Mean Square Error (MSE)	7.078041
Mean Percentage Error (MPE)	-1.100109
Mean Absolute Percentage Error (MAPE)	9.759618



Residual Analysis for the Applied Model

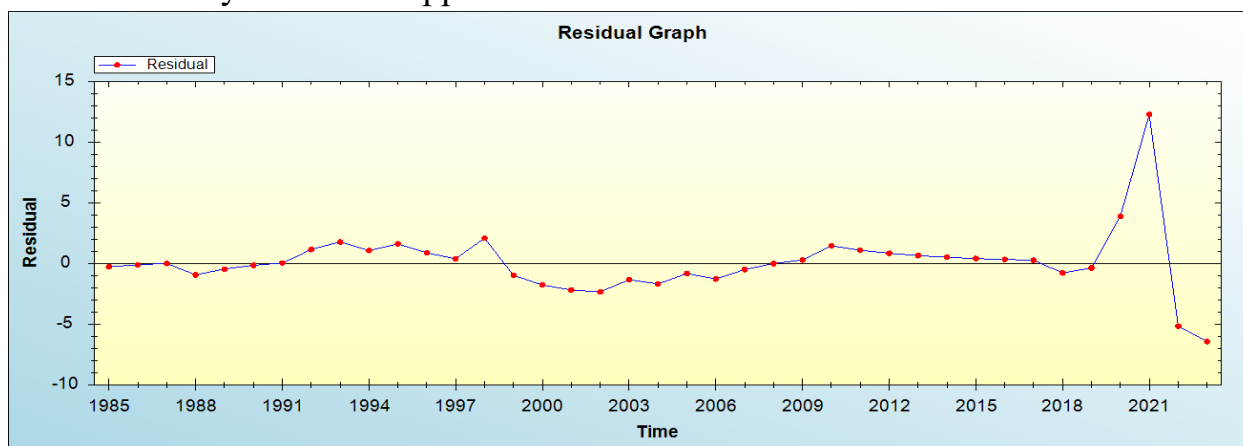


Figure 1: Residual analysis

In-sample Forecast for A

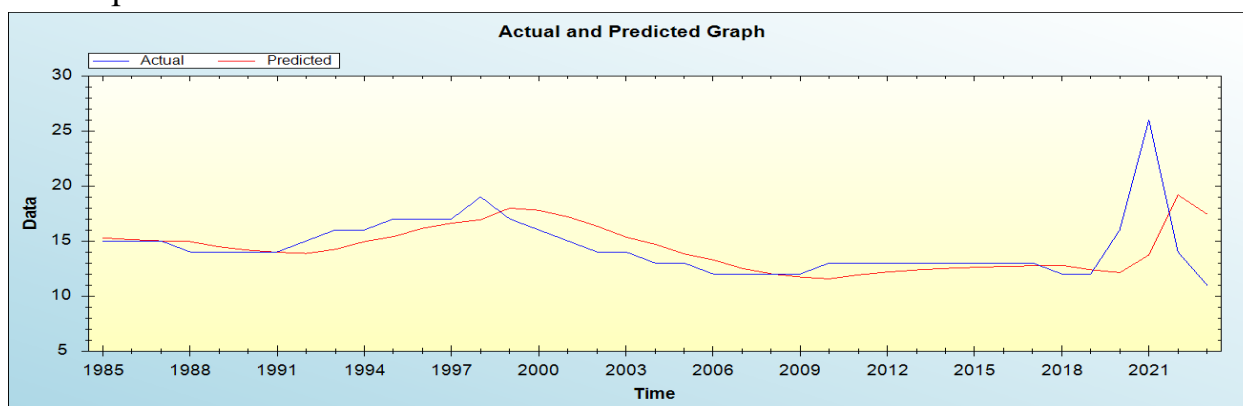


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

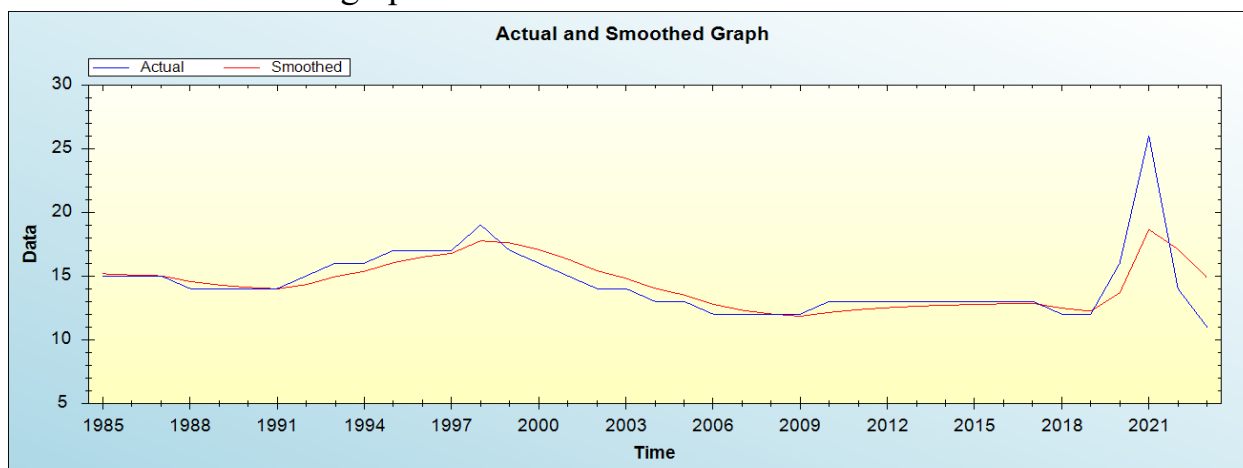


Figure 3: Actual and smoothed graph for A series

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

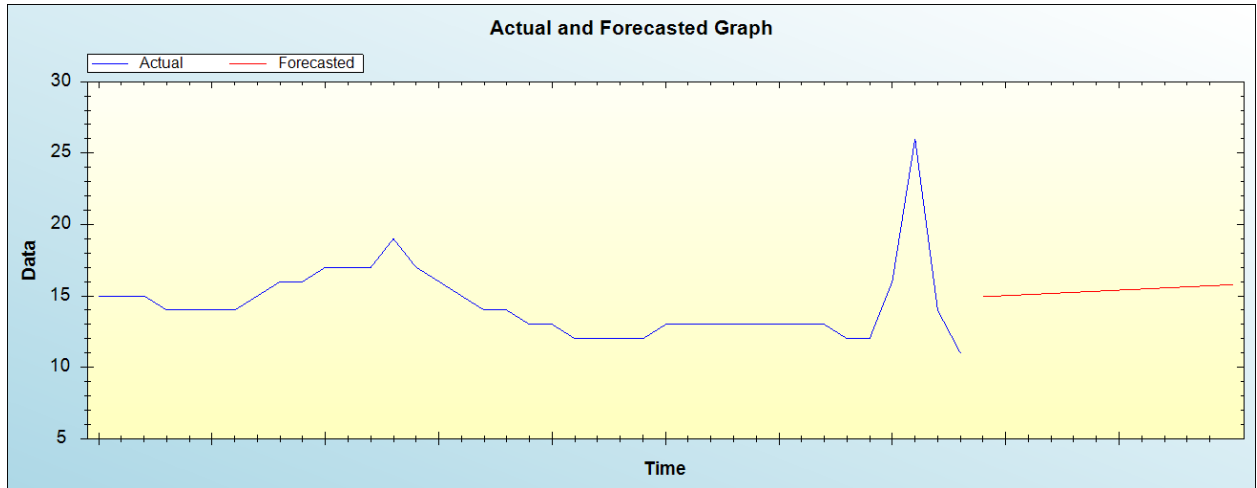


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	14.9410
2025	15.0178
2026	15.0946
2027	15.1713
2028	15.2481
2029	15.3249
2030	15.4016
2031	15.4784
2032	15.5552
2033	15.6319
2034	15.7087
2035	15.7854

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 hover around 15 deaths per 100 000 live births throughout the out of sample period.



Conclusion

Serbia has made significant progress in the reduction of maternal mortality as evidenced by MMRs below 30 per 100 000 live births. Low MMRs indicate high quality of maternal health services being offered during the antenatal, childbirth and puerperium periods. In this study we applied the double exponential smoothing technique to model and forecast MMR and results indicate that MMR will hover around 15 deaths per 100 000 live births throughout the out of sample period. Hence, authorities are encouraged to address local drivers of maternal mortality.

References

1. Cristina Rossi A and Mullin P (2012). “The etiology of maternal mortality in developed countries: a systematic review of literature”. Arch. Gy necol. Obstet., 2012, 285, 1499
2. M. Petronijevic., S. V. Petronijevic., I. Ivan K. Maja., and D. Bratic (2019). Maternal mortality in Serbia – revisited, Clin. Exp. Obstet. Gynecol. - ISSN: 0390-6663 XLVI, n. 6, 2019 doi: 10.12891/ceog4869.
3. Mhyre J.M (2012). “Maternal mortality”. Curr. Opin. Anaesthesiol., 2012, 25, 277.
4. UNICEF (2020). Statistical Office of the Republic of Serbia, UNICEF. Serbia multiple Indicator cluster survey and Serbia Roma settlements multiple Indicator cluster survey, 2019, survey findings report. Serbia: Belgrade.