



APPROXIMATION OF ANNUAL MATERNAL MORTALITY RATE FOR SRI LANKA USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Sri Lanka 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 0.6 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall and reach levels around 12 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to relentlessly address main drivers of maternal deaths and direct some of the resources towards quality improvement activities.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal health is the health status of women during pregnancy, childbirth, and the post-partum period, which incorporates the health care dimension of family planning, preconception, and prenatal and postnatal care to reduce maternal morbidity and mortality (WHO, 2015). Then maternal death refers to death of a woman whilst pregnant or within 6 weeks of termination of pregnancy, regardless of the duration and the site of the pregnancy, from any causes related to or aggravated by the pregnancy or its management but not from accidental or incidental causes according to the World Health Organization (WHO, 2015). Most maternal deaths are recorded in low-middle countries. Approximately 830 women die every day globally as result of pregnancy-related causes, which can be avoided. The World Health Organization estimated that 303,000 women



worldwide will have died by the end of 2015 during and following pregnancy and childbirth. A recent World Health Organization report highlighted that maternal mortality has declined by 43% worldwide; however, maternal death is still high in sub-Saharan Africa and South Asia. Sri Lanka's Maternal and child health program is a success story among low-middle income countries (Malitha & Asanka, 2022; Senanayake et al. 2011). The MMR for Sri Lanka stood at 29.2 per 100,000 live births in 2019 (Family Health Bureau, 2020). The percentage of Sri Lankan mothers receiving the care of skilled birth attendance at delivery is over 99.5% and the percentage of institutional deliveries is over 99% with 85% taking place in institutions that have the services of a specialist obstetrician (Family Health Bureau, 2017; Senanayake et al. 2011). This study models and projects MMR for Sri Lanka using the double exponential smoothing technique. The study findings are expected to inform policy making and allocation of adequate resources to the health sector so that preventable maternal deaths are further reduced.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Kurvinen et al. (2026)	To examine the social determinants and timing of maternal deaths in Nepal to identify high-risk groups and inform targeted interventions	cross-sectional descriptive study	Maternal deaths were most frequent in Lumbini province, peri-urban and rural areas, and the Tarai region. Socioeconomic disparities were evident, with nearly half of maternal deaths occurring among women from poor households
Feng et al. (2025)	-to analyze trends (1990–2021) and projected (to 2050) MMR in Southeast Asia using the Global Burden of Disease (GBD) 2021 database and addressing gaps in regional granularity	-Data GBD 2021, covering MMR and age-standardized MMR (ASMR) for 1990–2021, stratified by country, age group, and cause -Trend assessment was conducted using the estimated annual percentage change (EAPC), while 30-year	The ASMR in Southeast Asia fell by 59%, dropping from 255.88 in 1990 to 104.56 per 100,000 live births by 2021. This decline was primarily driven by reduced rates of maternal hemorrhage and hypertensive disorders. Progress slowed during the 1997 Asian financial crisis yet picked up pace after 2000



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		projections were generated via an autoregressive integrated moving average (ARIMA) model	
Rai et al. (2025)	to examine the current burden of maternal and neonatal disorders in Nepal and to assess any changes over time	Researchers examined the annual Global Burden of Disease Study data on prevalence, deaths, Years Lived with Disability, and Disability-Adjusted Life Years for maternal and neonatal disorders in Nepal for the 1990-2019 period. Estimated annual percentage changes were also calculated to assess the trends of the age-standardized rates of these burden metrics	the prevalence of overall maternal disorder in Nepal decreased by 37% from 128,176 in 1990 to 80,724 in 2019 with Age-Standardized Ratio of 432.07 per 100,000 in 2019 and Estimated Annual Percentage Change of -4.34 (CI 95%: -4.49 to -4.18)
Shrestha et al. (2025)	to estimate the maternal mortality ratio and identify the causes of maternal deaths using the WHO International Classification of Disease – Maternal Mortality (ICD-MM) tool	retrospective study	The maternal mortality ratio in the study was low in comparison to the national data
Kwee et al. (2024)	To evaluate the impact of healthcare access on maternal and child mortality rates in the rural region of Kayin State, Myanmar, where disparities in healthcare services significantly affect vulnerable populations	cross-sectional study design	The findings reveal alarming maternal mortality rates of 250 per 100,000 live births and child mortality rates of 80 per 1,000 live births in rural areas, compared to urban counterparts. Major barriers identified include geographic isolation, economic challenges, and cultural factors limiting healthcare utilization
Phan et al. (2024)	To examine the association between health insurance coverage and antenatal care (ANC) visits during pregnancy	The study 19 utilized data from the 2021-22 Cambodia Demographic and Health Surveys (CDHS). A total of 20 3,162 weighted women who gave birth within two years were included in the analysis. Multiple logistic	Having health insurance coverage was significantly associated with four or more 31 ANC visits



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		regression analysis assessed the association between health insurance coverage and pregnant women who attended at least four antenatal care visits during pregnancy	
Win et al. (2024)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Low utilization rates were due to several supply-side constraints
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-seeking practices, timing, and place of deaths	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative sample of 298 284 households -adapted the World Health Organization's 2014 verbal autopsy (VA) questionnaire. Trained physicians reviewed the responses and assigned the cause of death based on the International Classification of Diseases (ICD-10)	Nineteen per cent of the maternal deaths occurred at home, another 19% in-transit, almost half (49%) in a public facility, and 13% in a private hospital. Hemorrhage contributed to 31% and eclampsia to 23% of the maternal deaths. Twenty-one per cent of the maternal deaths occurred due to indirect causes
Jabeen et al. (2023)	To examine the current levels, trends, time of death, and care-seeking practices for hemorrhage-related maternal deaths in Bangladesh	-conducted a secondary analysis with data from the nationally representative 2001, 2010, and 2016 Bangladesh Maternal Mortality Surveys (BMMS) -The cause of death information was collected through verbal autopsy (VA) interviews using a country-adapted version of the standard World Health Organization VA questionnaire	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh
Win et al. (2023)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Poor family income, illiteracy, low education levels, living in poor households, and agricultural and unskilled



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			manual job types of mothers contributed to insufficient antenatal care
Irangani et al. (2022)	To report complex patterns in which social determinants act towards paving the path to maternal deaths in a rural Sri Lankan setting	Qualitative study	Social autopsies of maternal deaths revealed complex social issues and social determinants of health leading to maternal deaths in Sri Lanka, indicating the need for a socially sensitive health system
Lwin et al. (2022)	To examine factors influencing institutional maternity service utilization and identified the need for improved maternal health outcomes	cross-sectional study design	A greater number of ANC visits and level of the couple's education had a positive association with institutional delivery
Patabendige & Jayawardane (2022)	To summarize the current status of respectful maternity care (RMC) in Sri Lanka and the way forward with the pandemic	Systematic review	The impact of COVID-19 pandemic has implications, especially in allowing a labor companion. However, promoting of RMC could be performed in micro, meso/intermediate, and macro/national levels
Singh et al. (2022)	to inform on potential options for measuring maternal mortality	Applied a case study approach to compare methodologies and estimates of pregnancy-related mortality ratio (PRMR)/maternal mortality ratio (MMR) obtained from four different data sources from similar time periods in Bangladesh, Mozambique, and Bolivia—national population census; post-census mortality survey; household sample survey; and sample vital registration system (SVRS)	For Bangladesh, PRMR from the 2011 census falls closely in line with the 2010 household survey and SVRS estimates, while SVRS' MMR estimates are closer to the PRMR estimates obtained from the household survey. Mozambique's PRMR from household survey method is comparable and shows an upward trend between 1994 and 2011, whereas the post-census mortality survey estimated a higher MMR for 2007. Bolivia's DHS and post-census mortality survey also estimated comparable MMR during 1998–2003



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Chham et al. (2021)	to explore the coverage level of the Optimal CoC by (1) measuring the continuity of optimal antenatal care (ANC), skilled birth attendance (SBA) and optimal post-natal care (PNC), (2) identifying the determinants of drop ping out from one service to another and (3) of not achieving the complete CoC	The study employed data from the Cambodia Demographic Health Survey 2014. We restricted our analysis to married women who had a live birth in the five years preceding the survey (n = 5678). Bi-variate and multivariate logistic regression were performed using STATA version 14	Household wealth was found to be the most influential factor, yet the study discovered also other barriers to optimal maternal health care which need to be addressed
Sitaula et al. (2021)	to determine the MMR and identify the various risk factors and causes of maternal mortality	retrospective study	Despite the availability of comprehensive emergency obstetric care at our center, maternal mortality is still high and almost 75% of deaths were avoidable. The leading contributory factors of maternal mortality are delay in seeking care and delayed referral from other health facilities
Akhter, & Alam. (2019)	-to present the trends of maternal and neonatal mortality - to explain the maternal and neonatal mortality rate by background characteristics and the causes of maternal and neonatal deaths in Bangladesh on the basis of South Asian perspective	The main source of data collection and analysis was the secondary sources, from different journals and project reports published between the years 2001 to May 2018	In Bangladesh, 35% maternal deaths occurred as indirect causes and 9% causes of deaths are still remaining unidentified. hemorrhage (31%) and pre-eclampsia-eclampsia (20%) are found two vital causes of maternal deaths with two more causes which are due to obstructed labor (7%), and termination of pregnancy (1%)
Akhter et al. (2018)	to present, analyze and interrelate recent data to find barriers to achieving set MDG 5 targets by 2015	literature review has been done as a main method of data collection from Elsevier, Lancet, WHO, UNICEF, BBMS, NIPORT published from 2001 to May 2018	approximately 80% of maternal deaths could be averted if women had access to essential maternity and basic health care services
Kabir et al. (2018)	to identify the relationship between socio-demographic characteristics of Myanmar women and utilization of antenatal care services	This was a descriptive cross-sectional study utilizing the Myanmar Demographic and Health Survey Data 2015-16. A	The study found that women with no education, poorer socioeconomic status, less access to mass media, living in rural areas and with more



		total of 13,454 women aged between 15-49 years were surveyed. This study sampled married women only (n=7870).	children were not utilizing ANC services adequately
Mahara et al. (2016)	to critically evaluate and explore the situation of maternal health in Nepal based on published or unpublished governmental or nongovernmental organization's scientific reports regarding maternal health	The study was based on published or unpublished governmental or nongovernmental organization's scientific reports regarding maternal health	Women have been facing different consequences during pregnancy and delivery, attributed to lack of proper knowledge or less available and affordable health facilities in rural communities

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

X_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 Sri Lanka 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	X
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.600
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.852521
Sum Square Error (SSE)	379.073790
Mean Square Error (MSE)	9.719841
Mean Percentage Error (MPE)	0.536063
Mean Absolute Percentage Error (MAPE)	5.973043



Residual Analysis for the Applied Model

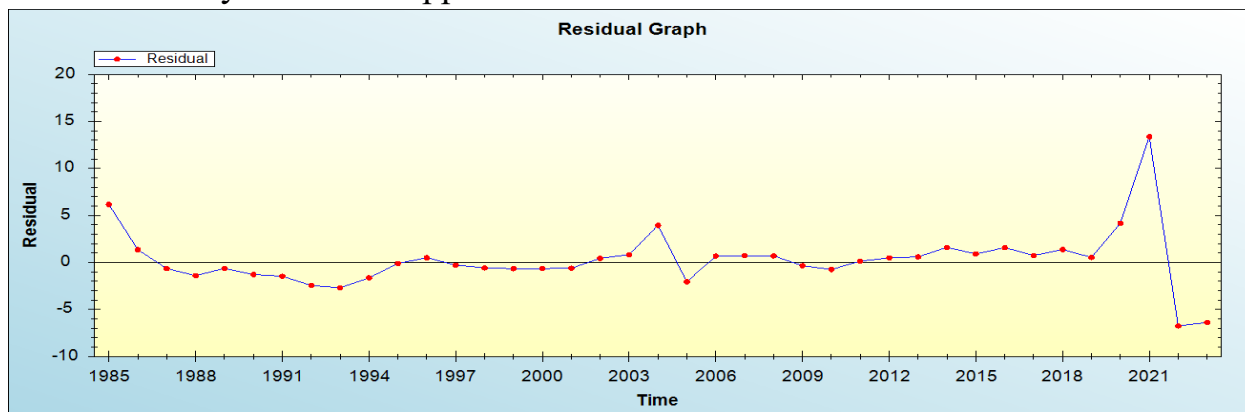


Figure 1: Residual analysis

In-sample Forecast for X

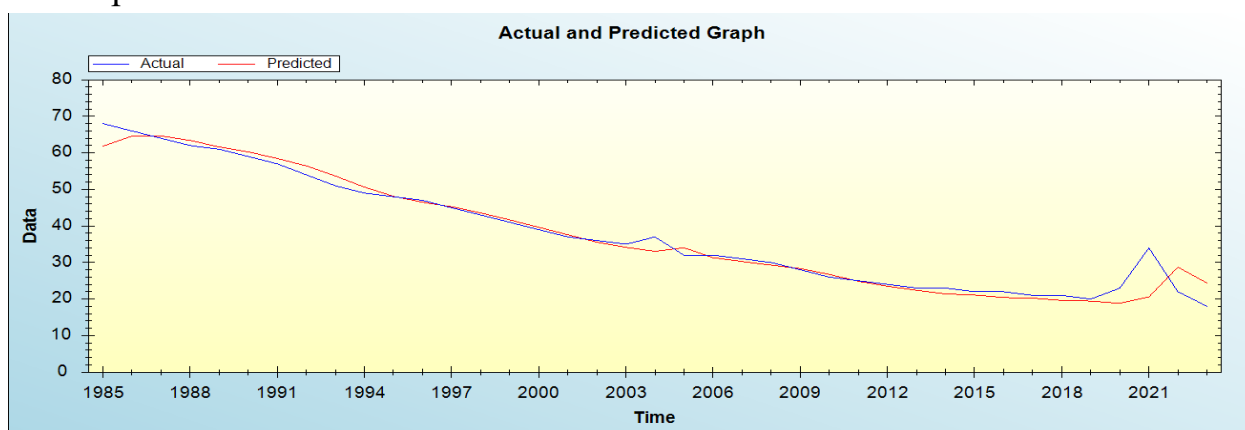


Figure 2: In-sample forecast for the X series

Actual and Smoothed graph for X series

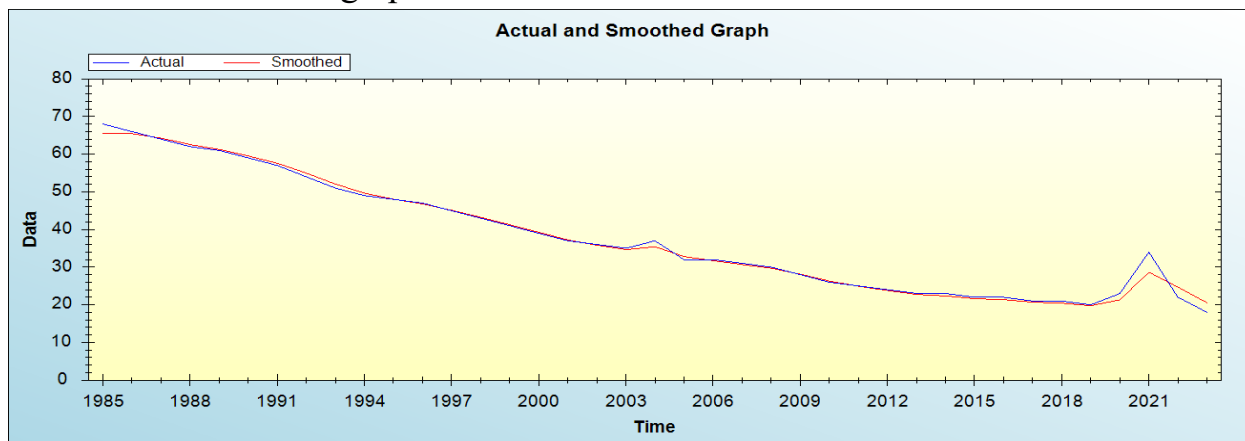


Figure 3: Actual and smoothed graph for X series



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

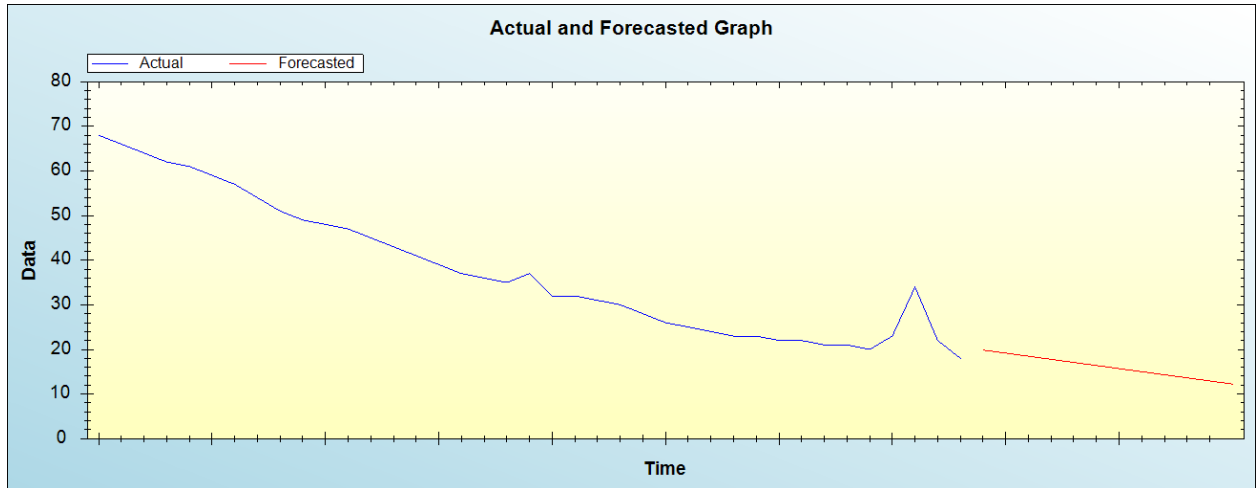


Figure 4: Out-of-sample forecast for X: actual and forecasted graph

Out-of-Sample Forecast for X: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	19.8618
2025	19.1686
2026	18.4754
2027	17.7822
2028	17.0891
2029	16.3959
2030	15.7027
2031	15.0095
2032	14.3163
2033	13.6231
2034	12.9299
2035	12.2367

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 continue to fall and reach levels around 12 deaths per 100 000 live births by 2035.



Conclusion

The maternal and child health program in Sri Lanka is one of the success stories to talk about in the region. The government has managed to lower maternal mortality to levels below 30 maternal deaths per 100 000 live births. In this study we applied the double exponential smoothing technique to model and forecast MMR and findings indicate that MMR will continue to fall and reach levels around 12 deaths per 100 000 live births by 2035. Hence, health authorities are encouraged to relentlessly address local drivers of maternal deaths and direct some of the resources towards implementation of quality improvement strategies.

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