

ESTIMATION OF FUTURE VALUES OF ANNUAL MATERNAL MORTALITY FOR INDONESIA USING HOLT'S LINEAR TECHNIQUE

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ABSTRACT

This study uses annual time series data on MMR for Indonesia 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 0.7 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall to reach levels around 60 deaths per 100 000 live births by 2035. Therefore, we encourage health authorities to adopt the suggested 4-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is an important indicator of the quality of health care. All signatories to the United Nations outcome document of 2015, "The Agenda 2030 for Sustainable development", agreed to reduce global maternal mortality ratio to levels below 70 deaths per 100 000 live births (WHO, 2015). The MMR in South East Asia stood at 134 women per 100,000 live births in 2020. Indonesia has the fourth highest MMR (173/100,000 LB) in the region, following Timor-Leste, Cambodia, and Myanmar (WHO, 2023). In the 2020 population census, Indonesia's MMR had dropped to 189 maternal deaths per 100,000 livebirths (Mahmood et al. 2018), which was still high compared to other middle-income countries in South East Asia (Wiseman et al. 2018; ASEAN, 2017). A high MMR is usually linked to disparities of maternal health care access (Ahmed, 2019; WHO, 2017). Indonesia's maternal and child health program has many challenges which include problems in accessing healthcare and shortage of healthcare workers especially in rural areas (Wenang et al. 2021; Kwane et al. 2017). The national physician to-population ratio of 1:2294 and the availability of close to 5 000 gynecologists/obstetricians countrywide are associated with a high MMR of 177/100,000 live births (Ministry of Health, 2021). In 2020, the reported WHO UHC Index achieved via JKN stood at 60%, with high variability of the coverage values throughout the country (Ambarriani, 2024; Noya et al. 2021).

The objective of this paper is to model and forecast MMR for Indonesia using Holt's linear method. The study results are expected to inform policy, planning and allocation of resources to the maternal and child health program.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Ara et al. (2025)	to summarize the frequencies of sociodemographic characteristics, parity distribution, antenatal care patterns, and causes of death among maternal mortality	Conducted a retrospective study which analyzed maternal mortality at Rangpur Medical College Hospital, Bangladesh, in 2024, reviewing 4,741 birth records with 83 maternal deaths.	-Among 83 maternal deaths, majority of deaths occurred among women aged 16–25 (41%) and those from low socioeconomic backgrounds (72.2%). -Parity distribution showed 49.39% had 1–2 children, while 73.4% received no antenatal care (ANC), highlighting gaps in healthcare access. - Eclampsia (37.35%) and obstetric hemorrhage (26.50%) were the predominant cause of maternal deaths.
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 projections were generated via an autoregressive integrated moving average (ARIMA) model	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
Singh & Swain (2025)	to explore the factors influencing CDMR and its effect on maternal and fetal outcomes	Prospective cohort study	The prevalence of CDMR was 21.35%, which was relatively higher than the World Health Organization's recommended guidelines
Syairaji et al. (2024)	to describe trends in the MMR and causes of maternal deaths in Indonesia over the past decades, regionally and nationally	Systematic review	Despite the steady decline of maternal deaths in Indonesia, it remains one of the highest in Southeast Asia, with enormous disparities within the country. Hypertensive disorders and non-communicable diseases make up a growing share of maternal deaths, making maternal death reduction strategies increasingly challenging
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-seeking	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative	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.

	practices, timing, and place of deaths	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)	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
Wenang et al. (2023)	To analyze outcome and maternal health care utilization, as well as differences related to demographic and economic subgroups in Indonesia	For univariate group comparison ANOVA method was applied and combined with Scheffe' procedure and Bonferoni correction for post-hoc tests.	-Specialized hospital facilities (type A/B) for advanced care covered a large part of uncomplicated cases (~35%) - MMR and stillbirth rates can be predicted by availability of human resources and C-section rates explaining 49.0% of variance
Aryastami & Mubasyiroh (2022)	To analyze the optimal utilization of maternal health services in Indonesia from 2015 to 2018.	Cross-sectional study	The optimal utilization of MHS is independent of the free services delivery, but having health insurance and less parity brought about a better optimal score for MHS. Mothers in rural areas were more protective of optimal utilization
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	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

	basis of South Asian perspective		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

METHODOLOGY

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

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

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 Indonesia 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	0.700
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	11.363909
Sum Square Error (SSE)	13216.238785
Mean Square Error (MSE)	338.877918
Mean Percentage Error (MPE)	-0.368293
Mean Absolute Percentage Error (MAPE)	4.613974

Residual Analysis for the Applied Model

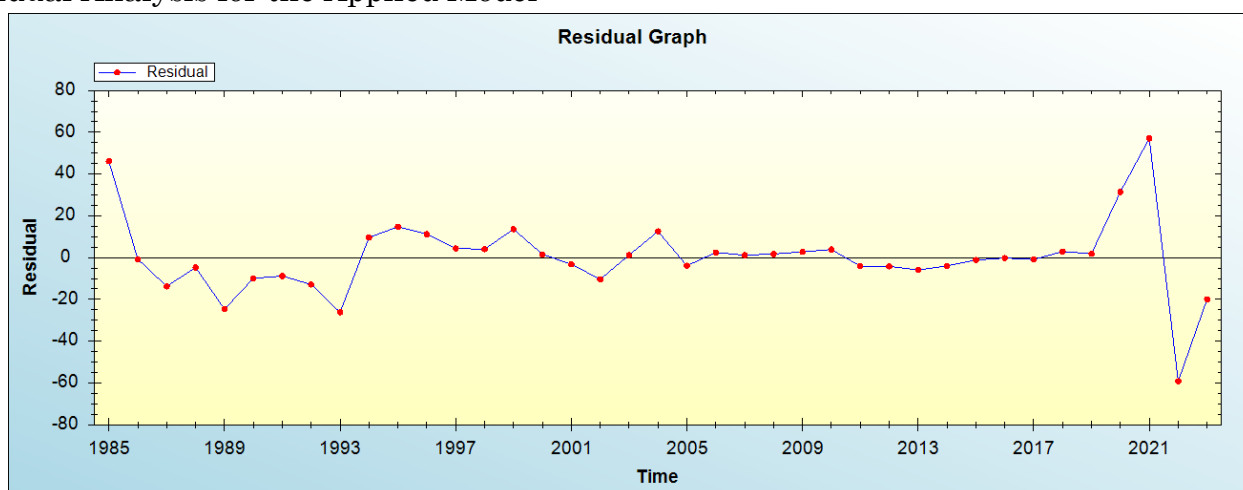


Figure 1: Residual analysis

In-sample Forecast for A

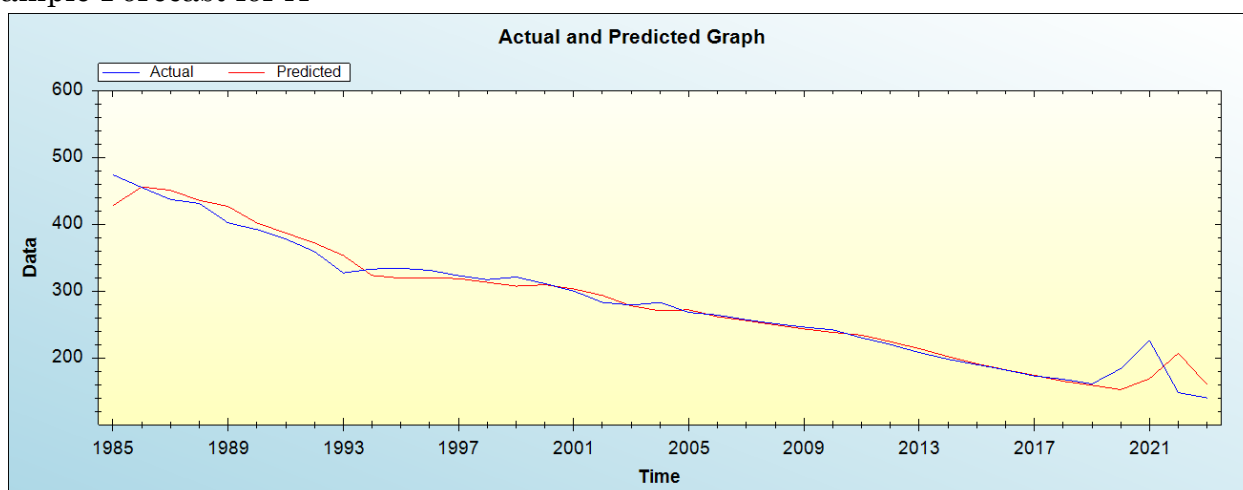


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

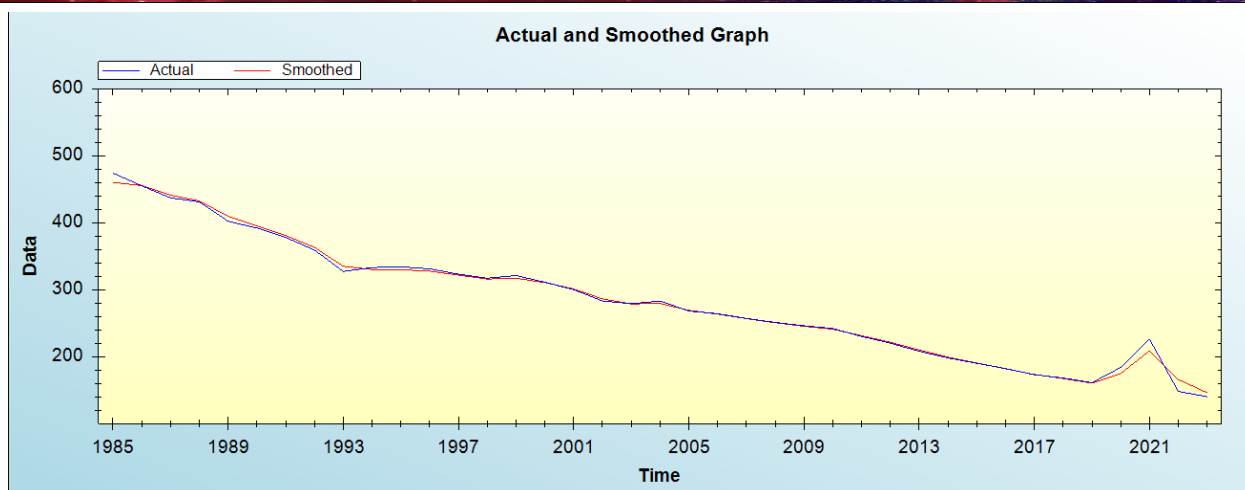


Figure 3: Actual and smoothed graph for A series

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

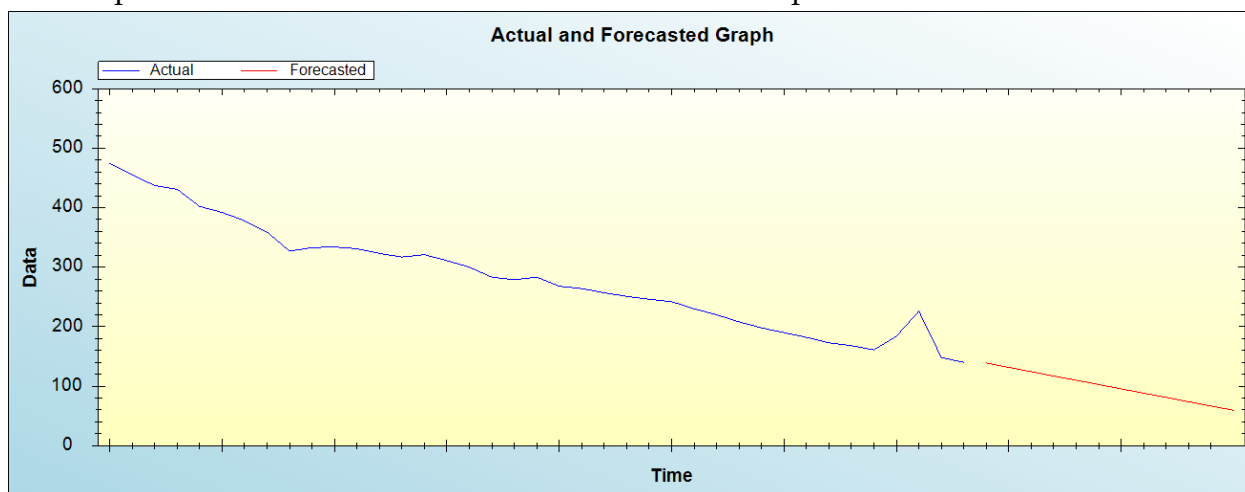


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	138.7698
2025	131.5570
2026	124.3442
2027	117.1314
2028	109.9186
2029	102.7058
2030	95.4930
2031	88.2802
2032	81.0674
2033	73.8546
2034	66.6418
2035	59.4290

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 to reach levels around 60 deaths per 100 000 live births by 2035.

RECOMMENDATIONS & CONCLUSION

High maternal mortality rates in Indonesia suggest huge gaps in the continuum of care. Shortage of medical staff and commodities as well as challenges in accessing maternal healthcare services are the main factors associated with maternal mortality. In this study, we applied the double exponential smoothing model to forecast MMR for Indonesia and the findings suggest that MMR will continue to fall to reach levels around 60 deaths per 100 000 live births by 2035. Hence, we encourage Indonesian authorities to adopt the following policy prescription: (1) end adolescent pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) improve quality of maternity services and (4) ensure availability of adequate medical supplies and medical staff in all medical facilities.

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