



PREDICTION OF ANNUAL MATERNAL MORTALITY RATE FOR SINGAPORE USING THE SINGLE EXPONENTIAL SMOOTHING MODEL

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Abstract

This study uses annual time series data on MMR for Singapore from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes single exponential smoothing model. The optimal value of the smoothing constants α is 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 relentlessly address local drivers of maternal mortality.

Keywords: 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. Maternal mortality in Singapore fell from 49.4 to 8.0 cases per 100,000 live births from 1966 to 2017 (World Bank, 2019; Ratnam, 2000), while infant mortality rate fell from 27.4 to 2.1 cases per 1000 live births from 1965 to 2019 (World Bank, 2021). Maternal deaths in this country are due to indirect causes particularly non-communicable diseases which seem to be on the rise (GBD, 2015; Lopez et al. 2006). This paper focuses on forecasting MMR for Singapore using single exponential smoothing technique. The study findings will assist in policy drafting and allocation of resources to the health sector so that maternal mortality is kept under control.

Literature Review

Author (s)	Objective(s)	Methodology	Main finding(s)
Mackin et al. (2026)	to understand how levels of MNH care are organized in different country contexts	Scoping review	Three or four levels of MNH facility care were most commonly reported. Linking maternal and newborn facility care to community connections is an important consideration to ensure equitable access to routine and emergency care
Al-Taïar et al. (2025)	to assess the prevalence of anemia in pregnant women and its associated factors in the Kuwait Birth Cohort study	Prospective cohort study	-The prevalence of anemia was 28.16% (95% CI:25.53–30.91%), with 8.75% of women experiencing moderate anemia and 19.40% mild anemia. No cases of severe anemia were observed -Multivariable analysis identified current iron supplement use, (Adjusted Odds Ratio [AOR] 0.52, 95%CI:0.28–0.99; p = 0.049), vitamin D status (sufficient vs. insufficient/deficient), (AOR 0.63, 95%CI:0.43–0.92; p =



			0.018), iron levels ($p < 0.001$), and ferritin levels ($p < 0.001$) as factors significantly associated with anemia
Cresswell et al. (2025)	To obtain updated evidence on causes of maternal death to accelerate SDG progress	conducted a multi-strategy systematic review to identify causes of maternal deaths occurring in 2009–20	Hemorrhage remains the leading cause of death, despite the existence of effective clinical interventions, emphasizing the need for improved access to quality health care
Hamdan et al. (2025)	To describe postpartum Hemorrhage Burden, Management and Challenges in Malaysia	Scoping review	the review identified critical gaps in blood loss estimation methods, with visual estimation being unreliable and leading to underdiagnosis, while patient intrinsic factors such as uterine atony, retained placenta, and placenta accreta spectrum disorders contribute to treatment complexity.
Kama et al. (2025)	to establish the period prevalence of MNM and mortality index, and to compare near-miss cases with maternal mortality and to identify their risk factors and causes	Cross-sectional study	The leading causes of MNM were eclampsia (47.8%), abruptio placentae (19.7%) and postpartum hemorrhage (8.3%), and the leading causes of maternal death were eclampsia (29.2%), puerperal sepsis (25%) and postpartum hemorrhage (12.5%)
Bhalotra & Clarke (2024)	to investigate the association of women's education with maternal and child mortality	Panel regression	moving an additional 1 percentage point of women into primary education reduces rates of maternal death by 4.6%, and reduces the rate of infant deaths by 1.9%
Duka et al. (2024)	to quantify the inequalities in the distribution of nurses in Albania, analyzing the nurse-to-population	Descriptive analytic study	The average nurse-to-population ratio in Albania is 28 nurses per 10,000 inhabitants, with significant variations between regions.



	ratio and its impact on the quality of healthcare		Tirana has the highest ratio (60 nurses per 10,000 in habitants), while Kukës and Dibër have the lowest values (10 per 10,000 inhabitants)
Chin et al. (2023)	to understand the demography, case characteristics and causes of maternal mortality in Sabah from 2015 through 2020	Retrospective study	Majority of deceased women, 56.7%, never attended antenatal visits prior to their death in the latest pregnancy. Overall, 63.88% deaths were due to direct obstetric causes, postpartum hemorrhage was the leading direct cause of death (24.53%), and most of the maternal deaths (65.5%) were preventable
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. In-depth analyses of differences in the quality of care and health system performance at national levels are needed to reduce maternal mortality further by learning from best practices and each other
Pouyanfar et al. (2022)	to investigate the factors affecting the maternal mortality ratio (MMR) in different regions of Iran	Systematic review	The leading causes of maternal death were hemorrhage (43.7%), preeclampsia/eclampsia (24.5%), other hypertensive disorders (24%), and embolism (22.8%)
Gabrani et al. (2020)	to identify key factors influencing the utilization of governmental and private primary	cross- sectional health facility survey using a 4- point Likert scale questionnaire to rank the importance of	The use of primary healthcare is strongly influenced by geographical and financial access for public facility users and availability of equipment for private users. This study



	healthcare services in Albania	factors driving services utilization.	found that aspects of acceptability and adequacy of services are equally valued
Norhayati et al. (2016)	to study severe maternal morbidity and maternal near miss among women in two tertiary hospitals in Kota Bharu, Kelantan, Malaysia	A cross-sectional study with record review was conducted in 2014. Severe maternal morbidity and maternal near miss were classified using the new World Health Organization criteria. Health indicators for obstetric care were calculated and descriptive analyses were performed using SPSS version 22.0	The maternal near miss mortality ratio was 23.5 and the mortality index was 4.1 %. The process indicators for essential interventions were almost 100.0 %. Hemorrhagic disorders were the most common event for severe maternal morbidity (68.6 %) and maternal near miss (80.9 %) and management-based criteria accounted for 85.1 %

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Singapore. 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 single exponential smoothing technique because it is an appropriate technique for modeling data without a trend and seasonal pattern

The single exponential smoothing model is specified as follows;

$$Y(t) = \beta(t) + \varepsilon(t)$$

Where $\beta(t)$ is a constant at time t , $\varepsilon(t)$ is a stochastic error term

$Y(t)$ is the actual value of the time series variable at time t

The forecast equation is then expressed as follows:

$$F_{t+1} = \alpha Y_t + (1-\alpha) F_t$$

Where F_t is the forecast value of variable Y at time t

F_{t+1} is the forecast value of variable Y at time $t+1$

α is the smoothing constant



Data Issues

This study is based on annual MMR in Singapore 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	Y
Included Observations	39
Smoothing constant	
Alpha (α)	0.300
Forecast performance measures	
Mean Absolute Error (MAE)	2.232789
Sum Square Error (SSE)	822.202491
Mean Square Error (MSE)	21.082115
Mean Percentage Error (MPE)	-9.491025
Mean Absolute Percentage Error (MAPE)	18.032196

Residual Analysis for the Applied Model

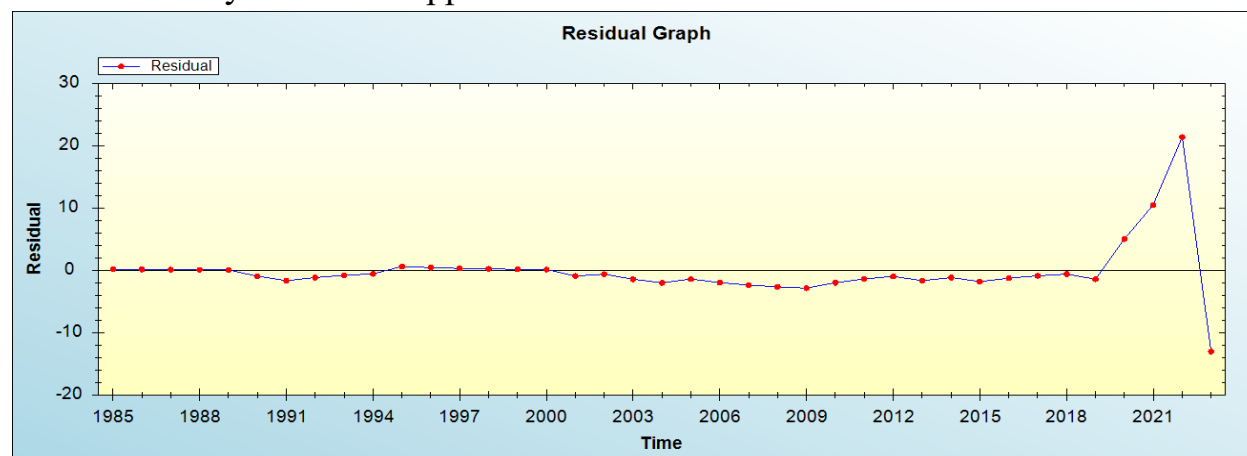


Figure 1: Residual analysis



In-sample Forecast for Y

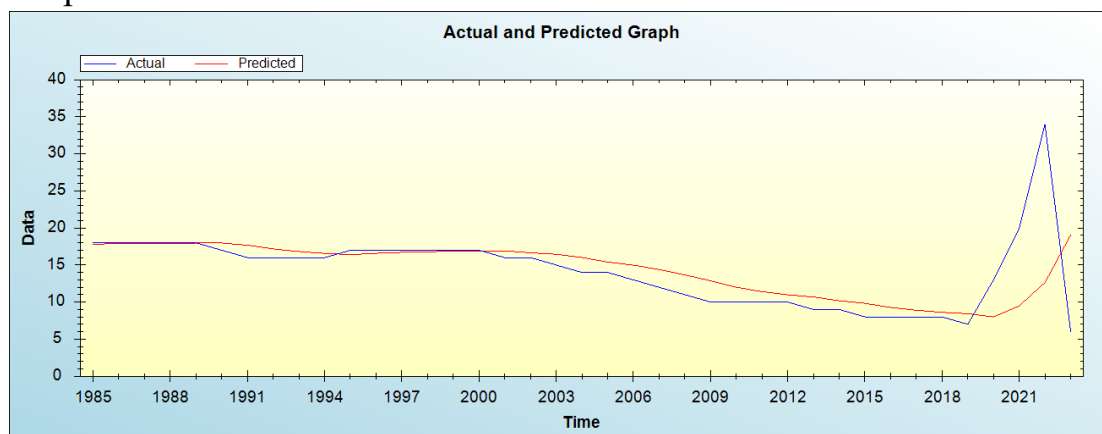


Figure 2: In-sample forecast for the Y series

Actual and Smoothed graph for Y series

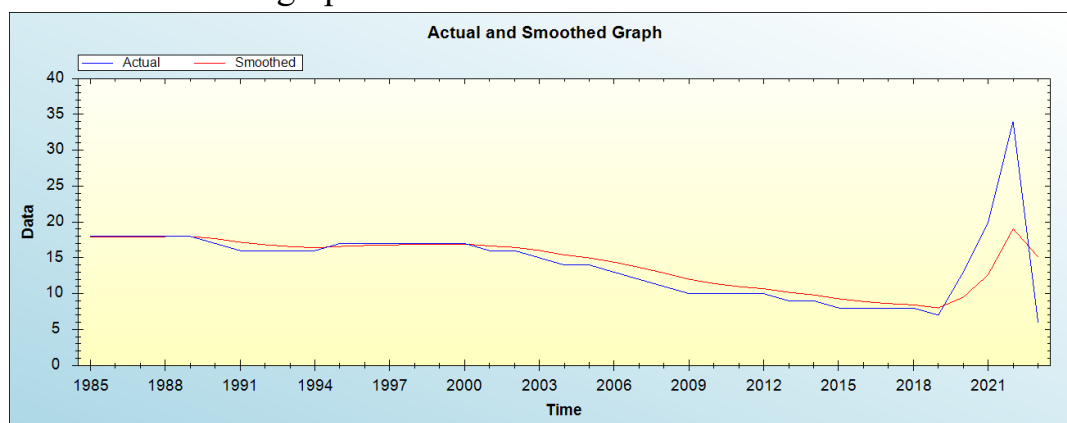


Figure 3: Actual and smoothed graph for Y series

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

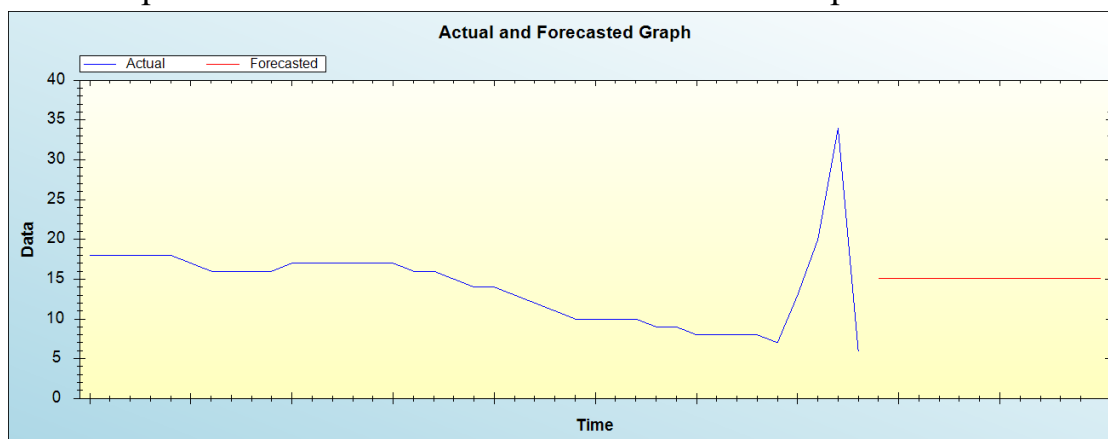


Figure 4: Out-of-sample forecast for Y: actual and forecasted graph



Out-of-Sample Forecast for Y: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	15.1402
2025	15.1402
2026	15.1402
2027	15.1402
2028	15.1402
2029	15.1402
2030	15.1402
2031	15.1402
2032	15.1402
2033	15.1402
2034	15.1402
2035	15.1402

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 constant around 15 deaths per 100 000 live births over the out of sample period.

Conclusion

Maternal mortality in Singapore fell from 49.4 to 8.0 cases per 100,000 live births from 1966 to 2017, while infant mortality rate fell from 27.4 to 2.1 cases per 1000 live births from 1965 to 2019. Maternal deaths in this country are due to indirect causes particularly non-communicable diseases which seem to be on the rise. In this study we applied the single exponential smoothing technique to model and forecast MMR and findings indicate that MMR will hover around 15 deaths per 100 000 live births throughout the out of sample period. Hence, authorities are encouraged to relentlessly attend to local causes of maternal deaths.



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