



DETECTION OF FUTURE TRENDS OF ANNUAL MATERNAL MORTALITY RATE FOR TURKIYE USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Türkiye 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 0.9 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain low over the out of sample period. Therefore, we encourage authorities to relentlessly address local drivers of maternal mortality.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality is an important public health problem especially in low-middle income countries, where the burden of maternal mortality and morbidity is disproportionately high (Musarandega et al. 2021). Sub-Saharan Africa accounts for the biggest percentage of global maternal deaths, as it contributes nearly two-thirds of all maternal deaths (WHO, 2024). SSA is still committed to the sustainable development goals including SDG 3.1 which aims to reduce maternal mortality to less than 70 per 100 000 live births by 2030. However, numerous challenges still persist hindering the achievement of this goal (Vallely et al. 2023; UN, 2015). Many factors contribute to the persistently high maternal mortality rates in Sub-Saharan Africa. These include inadequate access to quality maternal healthcare services, limited availability of skilled birth attendants, poor infrastructure, socioeconomic disparities, cultural beliefs and practices, and weak



health systems (Esther et al. 2023; Flake et al. 2023; Onambele et al. 2023; Dahab et al. 2020; Prata et al. 2010; Graham et al. 2001). Direct causes of maternal deaths such as hemorrhage, hypertensive disorders, sepsis, and obstructed labor, further contribute to maternal morbidity and mortality in the sub-Saharan region (Ngonzi et al. 2016). The objective of this paper is forecast MMR for Türkiye using Holt's linear method. The study findings will inform policy making, planning and allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Amara et al. (2025)	to determine cost of Caesarean section using TDABC in a tertiary-level government hospital in Tunisia	-conducted a retrospective costing study using Time-Driven Activity Based costing (TDABC) at the Maternity Department of Farhat Hached University Hospital Center to estimate the cost of caesarean delivery	The total cost of caesarean delivery in our study was 1,610.83TND (US\$573.04). Personnel costs were the largest cost drivers. The second highest cost was for medical consumables and medicines and investigations ranked third
Hakimi et al. (2025)	To explore significant health disparities in maternal and newborn health among Syrian refugees residing in Turkey	Systematic review	Syrian migrant mothers face a higher risk of anemia, limited access to antenatal care and iron supplements, and higher rates of adolescent pregnancies and home births compared to their native counterparts
Jena et al. (2025)	To estimate the pooled magnitude of neonatal mortality and its association with maternal and child health care in SSA	Systematic review	Neonatal mortality in SSA remains high. Maternal health services such as exposure to antenatal care and institutional delivery and child health services such as early initiation of breastfeeding were related to reducing the burden of neonatal mortality



Lukwa et al. (2024)	To evaluate the effectiveness and value of value-based healthcare interventions in improving maternal health outcomes in Sub-Saharan Africa	Systematic review	The results suggest that VBHC can significantly improve maternal health, evidenced by successful implementations like obstetric units in Sierra Leone and integrated care in South Africa, which improved outcomes and cost-effectiveness
Magdoud et al. (2024)	to determine the Maternal Mortality Ratio (MMR) in the governorate of Tunis and to identify the main causes of maternal death	Secondary data analysis	The postpartum period was the most critical. In fact, 83, 33 % of maternal deaths occurred postpartum. Hemorrhage was the main etiology in 20.8% of cases
Baig et al. (2023)	To Investigate maternal mortality in Southeast Asia, Europe and Africa	Literature review	-Inadequate care is one of the major causes of maternal mortality in majority of regions across the globe -The three delays model plays a significant role in the higher maternal mortality rate
Konlan et al. (2023)	To identify factors that influence women's decision for a CS are synthesized to clarify policy initiatives that improve care	Systematic review	The prevalence of CS was 2.1% to 18.5% of all live births as the socioeconomic status (SES) and demographic factors that influence the rate of CS were higher SES, education, and age; place of birth; urban residence; and women headed household
Mlambo et al. (2023)	to investigate the macro determinants of maternal mortality in Southern African Development Community (SADC) states	A panel data estimation (Generalized Method of Moments) covering the period from 2005–2019 was used to examine how various factors affect maternal mortality	The econometric analysis reveals a significant positive impact of fertility, GDP per capita and HIV on maternal mortality
Okonji et al. (2023)	To assess maternal mortality patterns by age and country in Sub-Saharan Africa	The demographic and health survey data were used for the study	The study found that the patterns of death vary across different countries



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Kükrer et al. (2022)	to examine and compare the rates of cesarean section (CS) and spontaneous vaginal delivery (SVD) in adolescent and adult pregnant women using the Robson ten group classification system (RTGCS)	A retrospective cross-sectional study of 1823 Turkish and Syrian pregnant women who gave birth between September 2020 and August 2021 in a tertiary reference hospital in Turkey's Mediterranean area	Adolescent pregnancy is particularly prevalent among young females with poor levels of education and Syrian adolescent girls. Pregnant adolescent women face a greater risk of obstetric and neonatal problems than pregnant adult women of reproductive age
Nnadi et al. (2022)	to estimate the effect of maternal mortality on economic development in Sub-Sahara African region. Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model	Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model	The explanatory variables in the model were statistically significant at 5% level while other coefficients like maternal mortality, exports and imports conform to the apriori expectations and impacted negatively on the overall GDP
Sezer et al. (2022)	to evaluate pregnancy related maternal deaths in a multi-dimensional manner, focusing on not only demographic and clinical characteristics but also autopsy results by including the maternal death cases having autopsy reports	Secondary data analysis	cardiovascular disease related to maternal mortality has been found to be an increasing, important public health concern to consider for maternal health routines
Limam et al. (2021)	to assess the availability, utilization, and quality of emergency obstetric care services in the Governorate of Sousse (Tunisia)	a cross-sectional study was conducted among public health facilities which performed deliveries in Sousse in 2017. Data were collected by consulting clinical records and registers and interviewing staff using WHO EmOC tools	The study concluded that raising maternity facilities to a minimum level of basic EmOC status would be a major contributing step towards maternal mortality reduction
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease –	Systematic review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related



	10th revision, for maternal mortality (ICD-MM)		infections are the leading causes of maternal deaths in SSA
Oğlak et al. (2021)	to estimate the incidence of maternal near-miss (MNM) morbidity in a tertiary hospital setting in Turkey	retrospective study	Hypertensive disorders and obstetric hemorrhage were the leading conditions related to MNM and MM
Batmaz et al. (2020)	To determine the maternal deaths and the factors affecting them in Elazığ, Turkey	Secondary data analysis	Hypertensive diseases during pregnancy (n=3, 42.8%), pulmonary embolism (n=1, 14.3%) and cerebral thrombosis (n=1, 14.3%) were among the natural causes of maternal deaths. Indirect cause for maternal death was cardiac diseases (n=2, 28.6%)
Ghardallou et al. (2019)	to determine the frequency and the indications of obstetric referrals in a Tunisian tertiary care maternity and to assess the conformity of referral mechanisms with the National Perinatal Programme (NPP) guidelines	a descriptive study was undertaken among women referred to Farhat Hached University Hospital in Sousse, Tunisia with antenatal complications requiring urgent delivery and those referred while in labor or with immediate postpartum complications. The ICD-10 was used to code recorded indications and diagnoses for referrals	Most of the indications for referrals (95.8%) did not conform to the list of referral indications of the NPP. Twenty-eight diagnoses were retained after referrals: the most common of which were prolonged pregnancy (29.5%) and premature rupture of membranes (19.3%). In 41% of women, reasons for referral did not match with diagnoses established at the time of the patients' admission to hospital
Ozel et al. (2018)	To analyze and compare obstetric and neonatal outcomes between Syrian refugees and ethnic Turkish women	Retrospective, observational study	Syrian refugees had increased risks of certain adverse obstetric outcomes, including preterm delivery, PPROM, lower birth weight, and anemia



Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Türkiye. 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 Türkiye 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	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.051397
Sum Square Error (SSE)	150.238100
Mean Square Error (MSE)	3.852259
Mean Percentage Error (MPE)	0.110621
Mean Absolute Percentage Error (MAPE)	3.805363

Residual Analysis for the Applied Model

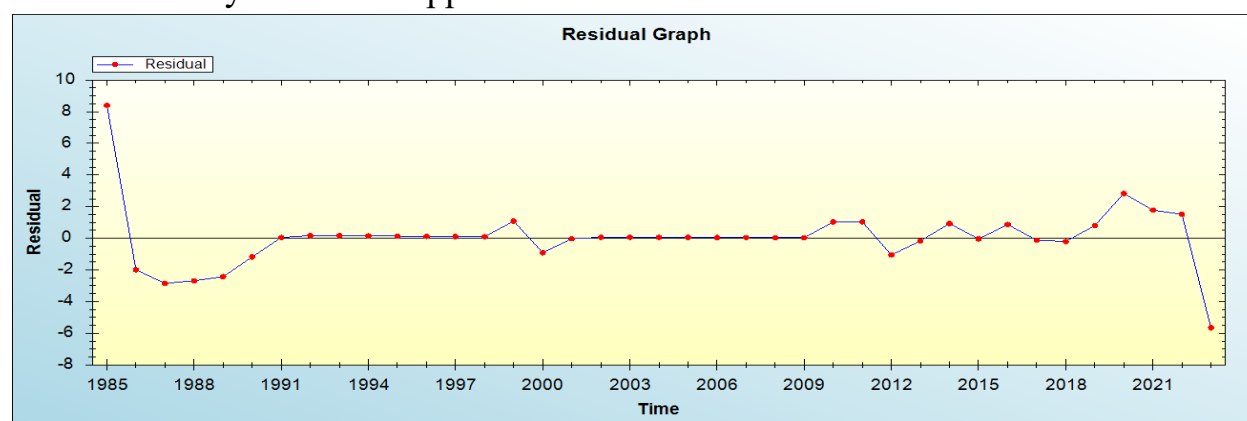


Figure 1: Residual analysis



In-sample Forecast for A

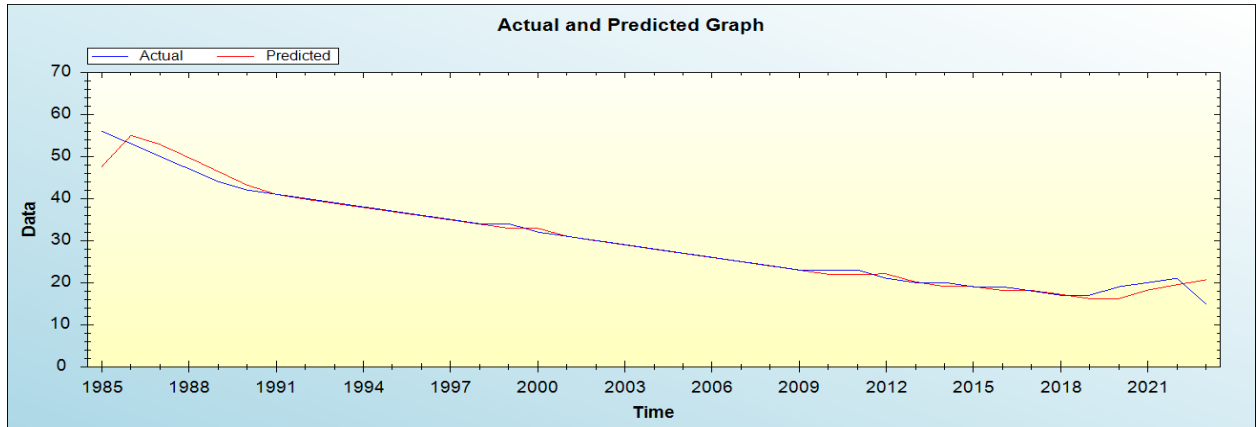


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

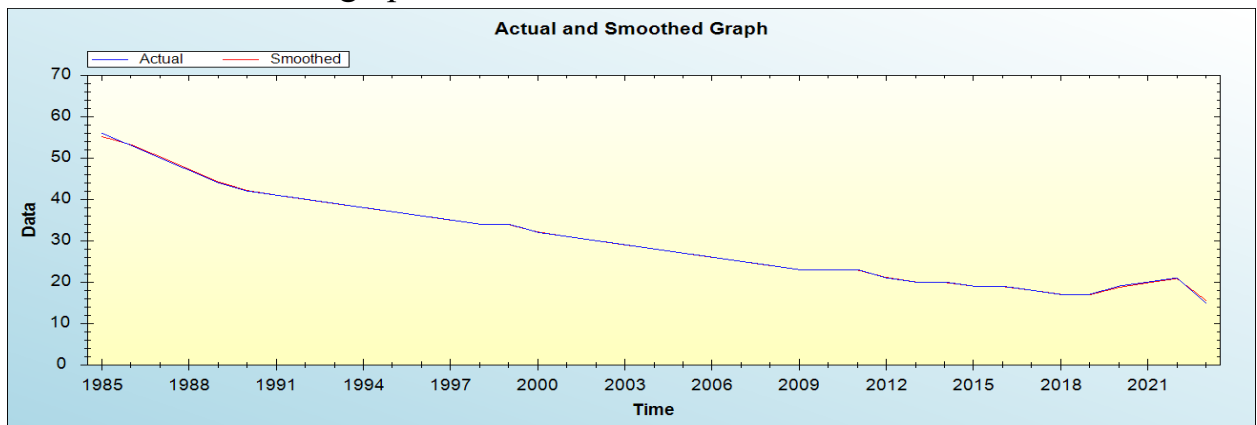


Figure 3: Actual and smoothed graph for A series

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

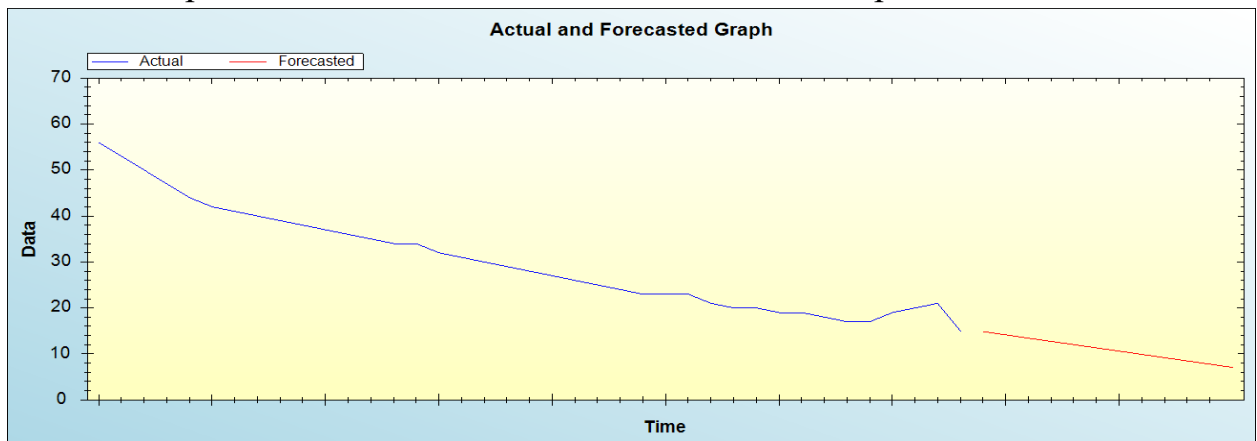


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	14.8570
2025	14.1491
2026	13.4412
2027	12.7333
2028	12.0254
2029	11.3175
2030	10.6096
2031	9.9017
2032	9.1937
2033	8.4858
2034	7.7779
2035	7.0700

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 low over the out of sample period.

Conclusion

In this study we applied the Holt's linear method to model and forecast MMR for Türkiye and findings indicate that MMR will remain low in the forecast period. Therefore, we encourage health authorities to tirelessly address local drivers of maternal deaths.

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