

# Forecasting Maternal Mortality For Djibouti Using The Double Exponential Smoothing Model

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## Abstract

This study uses annual time series data on MMR for Djibouti 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  $\alpha$  and  $\beta$  are 0.8 and 0.2 respectively based on minimum MSE. The results of the study indicate that MMR will continue on a downward path and reach levels around 63 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

**Keyword(s):** - Exponential smoothing, Forecasting, Maternal Mortality Ratio

## Introduction

Maternal mortality is a global public health problem. Nearly 800 women die each day from preventable causes related to pregnancy or childbirth (WHO, 2023). This scourge affects low-middle countries more. According to the WHO, at the global level, the maternal mortality ratio in 2020 was estimated at 233 per 100,000 live births (WHO, 2020). However, during the recent years, a significant decline of maternal mortality ratio at the global level was noted, with a reduction of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). Djibouti has not met the targets set by the agenda 2030 for sustainable Development Goals but a reasonable decline reduction of 45.7% in 20 years has been observed, ranging from 512 per 100,000 Live Births in 2000 to 234 per 100,000 Live Births in 2020 (Yacoub et al. 2025). The objective of this paper is to model and forecast MMR for Djibouti using the double exponential smoothing technique. The study findings are expected to guide policy and allocation of resources to the health sector. The ultimate goal is to substantially reduce all avoidable cases of maternal mortality across the country

## Literature Review

| Author(s)              | Objective(s)                                                                                                                | Methodology                        | Key finding(s)                                                                                                                                                                                                 |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Yacoub et al. (2025)   | To analyze the risk factors associated with maternal death in hospitals at the level 3 maternity hospitals of Djibouti City | Case-control study                 | -The main causes of maternal death are hemorrhagic shock (26.2%); preeclampsia and its complications (20.4%) and then malaria (17.5%)<br>- preeclampsia and its complications (20.4%) and then malaria (17.5%) |
| Compaoré et al. (2025) | to determine the frequencies and                                                                                            | Between 1st February 2008 and 31st | -At the time of our study the burden of                                                                                                                                                                        |

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|                       | causes of severe maternal outcomes (SMO: MNM + MD) in regional and district hospitals in Benin, Burkina Faso and Niger           | October 2010, we conducted an SMO incidence study in 36 hospitals in the three countries                                                                                                                                                                                                                                                                                                          | severe maternal outcomes was high in Benin, Burkina Faso and Niger.<br>-most women had a near miss complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for women with high-risk pregnancies and complications                               |
| Kawuki et al. (2025)  | examines the relationship between maternal mass media exposure and two critical child health indicators: morbidity and mortality | This secondary analysis of the 2017/2018 Benin Demographic and Health Survey (BDHS) included 13,851 women. Childhood morbidity (fever, cough, and diarrhea) and mortality were analyzed as outcomes. Bivariable and multivariable logistic regression and Cox regression models were applied, and results were expressed as odds ratios (OR), hazard ratios (HR), and their adjusted counterparts | Maternal exposure to mass media, particularly radio and television, was associated with increased childhood morbidity. This association could reflect heightened maternal health awareness, leading to increased reporting of symptoms or exposure to misleading health information through media content |
| Birabwa et al. (2024) | To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda   | -retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021.<br>-conducted descriptive analysis and assessed time trends in IMMR                                                                                                                                                                                                | IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths                                               |
| Agballa et al. (2023) | to determine the hospital-based                                                                                                  | conducted a case-control study over two                                                                                                                                                                                                                                                                                                                                                           | The hospital-based maternal mortality                                                                                                                                                                                                                                                                     |

|                           |                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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|                           | maternal mortality ratio and factors associated with maternal deaths                                                                                 | years from 1st January 2020 to 31 December 2021 in four Cotonou hospitals. It included 264 maternal deaths (case) matched to 264 controls by delivery mode. The dependent variable was the status at discharge. Independent variables included socio-demographic characteristics, gynecologic information, medical and gynecologic history as well as type of complications. Univariate and multivariate analysis were performed to identify the factors associated with maternal deaths | ratio was 1403 deaths per 100,000 live births. Age superior than or equal to 30 years old (OR= 3.09; 95% CI= 1.52 to 6.41; p=0.002), admission by a referral from public health facility (OR=4.26; 95% CI= 2.60-7.10; or private health facility (OR= 4.52; 95% CI= 2.49-8.38 ; gestational age less than or equal to 31 weeks (OR=3.77; 95% CI= 2.13 to 6.84 ; occurrence of non-infectious (OR= 1.94; 95% CI= 1.27 to 2.97; p= 0.002) and fetal complications (OR= 1.98; 95% CI= 1.13 to 3.54; p=0.018) were the factors associated to maternal deaths. |
| Musarandega et al. (2021) | to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM) | Systematic literature review                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA                                                                                                                                                                                                                                                                                                                                                                                 |
| Anyia & Enaruna (2020)    | to identify current and emerging causes of MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital            | -The case records of patients who suffered MM in the University of Benin Teaching Hospital, Benin City, Nigeria from 1st January, 2011 to 31st December, 2018 were retrospectively studied<br>-Data on sociodemographic characteristics, clinical diagnosis, and                                                                                                                                                                                                                         | -A progressive decline in MMR was observed in the initial 5 years, with 58% reduction between 2012 (1.48%) and 2015 (0.61%). A further rise in MMR occurred in the last 3 years, climbing 53% from 2016 (0.81%) to 2018 (1.72%)<br>-Maternal mortality occurred in 235                                                                                                                                                                                                                                                                                    |

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|                    |                                                                                                                                                        | primary cause of maternal death were extracted and analyzed                                                                                                                                       | women during the study period, giving a MMR of 1.1% (1,114/100,000 live births). MMR among booked women of 161/100,000 live births was 6 times lower than MMR for referred women of 953/100,000 live births. Almost half (48%) of the MM occurred within 24 hours of admission to hospital, and 74.5% were postpartum. A teenager had 3-fold risk of mortality, age older than 35 years increased risk of dying 2-fold, and grand-multiparity conferred a 3-fold risk of mortality. Those in the lower socioeconomic class were 7 times more likely to suffer mortality |
| Yaya et al. (2018) | To comparatively explore the utilization level of maternal health care, and examine disparities in the determinants of major maternal health outcomes. | used data from two rounds of Benin Demographic and Health Survey (BDHS) to examine the utilization and disparities in factors of maternal health care indicators using logistic regression models | The results of multivariable logistic regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services                                                                                                                                                                                                         |
| Adgoy (2018)       | To explore the key social determinants                                                                                                                 | narrative literature review design                                                                                                                                                                | The continental maternal death trend                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

|                        |                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                         |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        | and ways of coping mechanisms, for the reduction of maternal mortality, among African women living inside the African continent |                                                                                                                                                                                                                                                                                                                                                                            | did not reduce as it was intended by Millennium Development Goals (Goal - 5) and still continues with Sustainable Development Goals (Goal-5), “Achieve gender equality and empower all women and girls” |
| Girum and Wasie (2017) | to identify correlates of maternal mortality in developing countries                                                            | Systematic review                                                                                                                                                                                                                                                                                                                                                          | Maternal mortality is correlated with multiples of socio-economic factors, health care system associated factors, disease burden and their complex interactions                                         |
| Alvarez et al. (2009)  | to describe and determine different factors associated with the maternal mortality ratio in Sub Saharan countries               | An ecological multi-group study compared variables between many countries in Sub Saharan Africa using data collected between 1997 and 2006. The dependent variable was the maternal mortality ratio, and Health care system-related, educational and economic indicators were the independent variables. Information sources included the WHO, World Bank, UNICEF and UNDP | Education and an effective and efficient health system, especially during pregnancy and delivery, are strongly related to maternal death                                                                |

### **Methodology**

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

$D_t$  is the actual value of MMR at time  $t$

$\varepsilon_t$  is the time varying **error term**

$\mu_t$  is the time varying mean (**level**) term

$\rho_t$  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  $t$

$\alpha$  is the exponential smoothing constant for the data

$\beta$  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 Djibouti 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                              | D            |
| Included Observations                 | 39           |
| <b>Smoothing constants</b>            |              |
| Alpha ( $\alpha$ ) for data           | 0.800        |
| Beta ( $\beta$ ) for trend            | 0.200        |
| <b>Forecast performance measures</b>  |              |
| Mean Absolute Error (MAE)             | 15.736375    |
| Sum Square Error (SSE)                | 18255.365312 |
| Mean Square Error (MSE)               | 468.086290   |
| Mean Percentage Error (MPE)           | 0.950898     |
| Mean Absolute Percentage Error (MAPE) | 4.607048     |

### Residual Analysis for the Applied Model

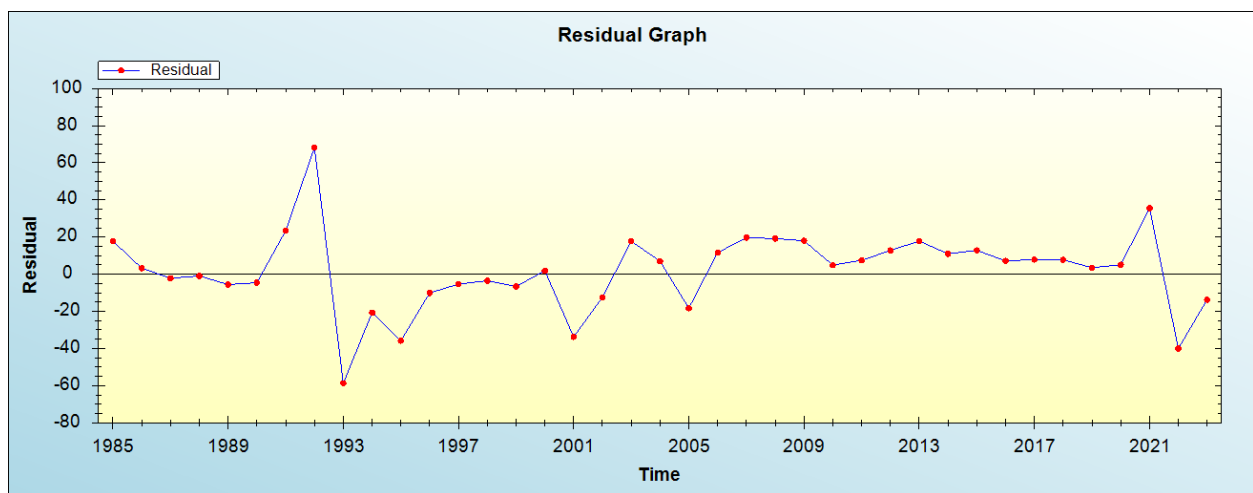


Figure 1: Residual analysis

### In-sample Forecast for D

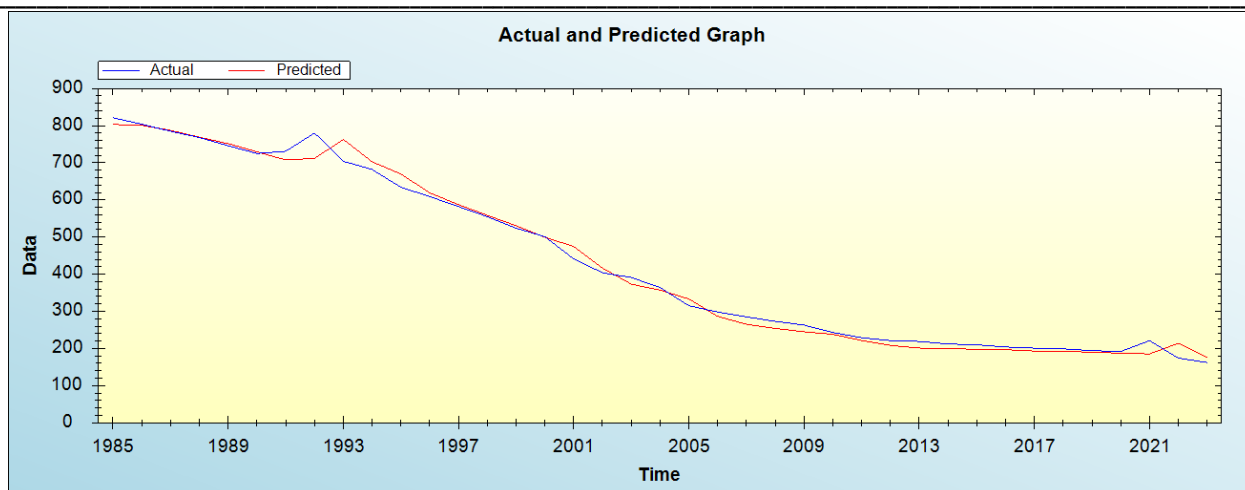


Figure 2: In-sample forecast for the D series

### Actual and Smoothed graph for D series

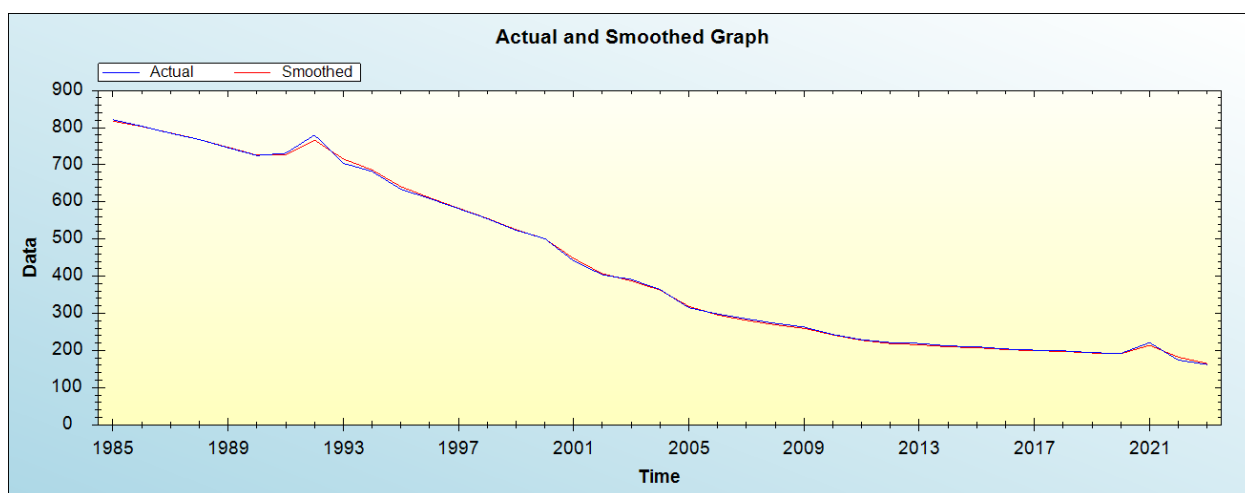


Figure 3: Actual and smoothed graph for D series

### Out-of-Sample Forecast for D: Actual and Forecasted Graph

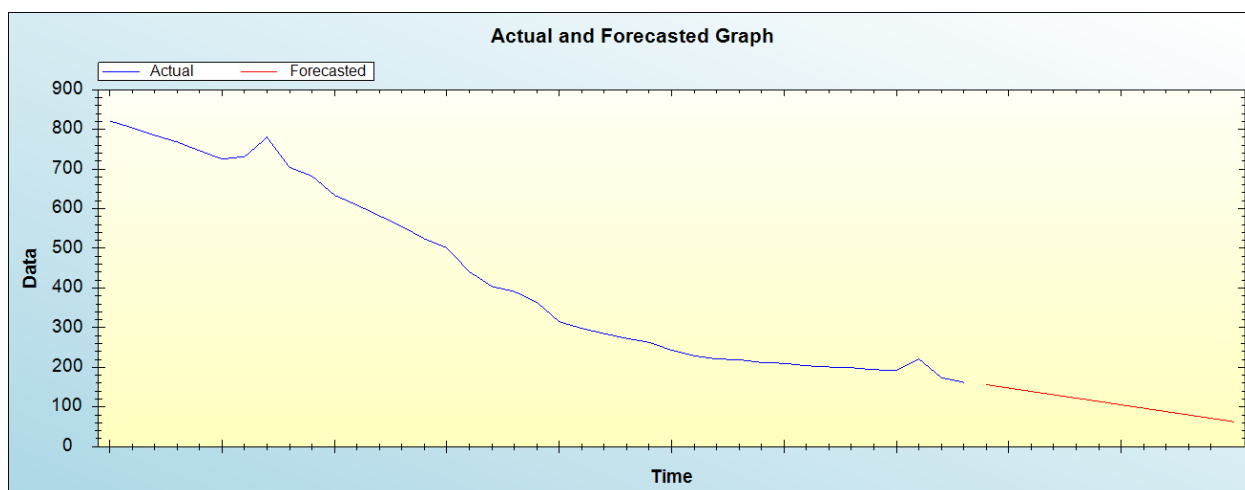


Figure 4: Out-of-sample forecast for D: actual and forecasted graph

Out-of-Sample Forecast for D: Forecasts only

Table 2: Tabulated out-of-sample forecasts

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 156.2701       |
| 2025 | 147.7959       |
| 2026 | 139.3216       |
| 2027 | 130.8473       |
| 2028 | 122.3731       |
| 2029 | 113.8988       |
| 2030 | 105.4245       |
| 2031 | 96.9503        |
| 2032 | 88.4760        |
| 2033 | 80.0017        |
| 2034 | 71.5275        |
| 2035 | 63.0532        |

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 on a downward path and reach levels around 63 deaths per 100 000 live births by 2035.

### **Recommendations & conclusion**

Djibouti has made significant strides in the reduction of maternal mortality during the previous decades; however, the burden of maternal deaths remains high. This reflects huge gaps still exist in the continuum of care. This paper models and projects MMR for Djibouti using the double exponential smoothing technique. The results highlighted that MMR will continue to fall and reach levels around 63 deaths per 100 000 live births by 2035. Hence, we encourage health authorities to adopt the following policy prescription: (1) eradicate 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) perform routine quality improvement activities (4) ensuring availability of adequate commodities and offer retention schemes for all medical staff and (5) creating posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level.

## **References**

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