

## ESTIMATION OF ANNUAL MATERNAL MORTALITY RATE FOR IRAQ USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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### ABSTRACT

This study uses annual time series data on MMR for Iraq 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 0.9 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 62 in 2024 to around 30 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to attend to local factors associated with maternal mortality.

**Keywords:** Exponential smoothing, Forecasting, Maternal Mortality Ratio.

### INTRODUCTION

Maternal health refers to the health of women during pregnancy, childbirth, and the postpartum period (WHO, 2014). Maternal mortality ratio (MMR) is an essential public health indicator because it highlights the overall effectiveness of healthcare delivery systems (King, 2012). Approximately 800 women die per day from avoidable causes related to pregnancy and childbirth (WHO, 2014). Around 45% of postpartum deaths occur within 24 hours (Nour, 2008). The main direct causes of maternal morbidity and mortality include hemorrhage, infection, pregnancy induced hypertension, unsafe abortion, and obstructed labor (WHO, 2014). Nearly all maternal deaths (99%) are reported in developing countries. In 2013, the MMR was 230 per 100,000 live births in developing countries vs. 16 per 100,000 live births in the first world countries. In addition to the between-country variation in maternal mortality, there is a huge disparity within countries; for example, between women with high and low income and between women living in rural and urban areas (Amirian et al. 2014). The Ministry of Health of Iraq recognizes that the health of women and children is important to progress on all UN sustainable development goals, and has committed to improving equity of access to quality maternal and newborn care services in an effort to reach global targets for maternal and neonatal mortality and stillbirth reduction by 2030 (Ministry of Health, 2017). Most births (84%) occur in health facilities, with the private sector playing an important role in delivering services across the continuum of care from pregnancy to childbirth and the postpartum and postnatal (UNICEF, 2018).

The objective of this paper is to model and forecast MMR for Iraq using the double exponential smoothing technique. The findings of this research will inform policy and allocation of resources to the health sector in order to further reduce preventable maternal deaths.

## LITERATURE REVIEW

| Author (s)             | Objective(s)                                                                                                                | Methodology                                                                                                                                                                                                                                                   | Main finding(s)                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Babaey et al. (2025)   | To analyze policies and interventions aimed at reducing maternal mortality in Iran                                          | Qualitative study                                                                                                                                                                                                                                             | This analysis demonstrates that policies and interventions within the Iranian health system have significantly reduced maternal mortality                                                                                                                                                                                                                                                                                       |
| Najafian et al. (2025) | to identify the causes and risk factors associated with maternal mortality in Ahvaz, Iran, to inform targeted interventions | A case-control study was conducted in Ahvaz from 2017 to 2023, involving 100 cases of maternal deaths and 117 controls (mothers with successful pregnancies)                                                                                                  | maternal mortality in Ahvaz is largely influenced by preventable factors such as anemia, hypertension, preeclampsia, and hemorrhage. Additionally, low education and limited access to healthcare services played a significant role in this issue                                                                                                                                                                              |
| Sadoughi et al. (2025) | to design an evaluation model for the National Maternal Mortality Surveillance System (MMSS) in Iran                        | mix method study which was carried out in four phases                                                                                                                                                                                                         | The obtained model includes four axes: (a) the description of the surveillance system (b) the general evaluation planning (c) implementation of the evaluation and (d) post-evaluation follow-ups. Some components of this model are: the purpose and operation of the system, triggers, purpose and objectives of the evaluation, data collection methods and tools, the method of presenting the findings and giving feedback |
| Huda et al. (2024)     | to assess process of registering maternal deaths in Iraq and identifying the main causes of death                           | A cross-sectional study was performed at Iraq Ministry of Health, in which all maternal death records were reviewed. Data concerning demographic characteristics, obstetrical history, and registration process was collected and analyzed using SPSS program | A total of 942 maternal deaths were reviewed, the highest (360 deaths) (Maternal Mortality Ratio 28/100000 live births), registration form was not available in 20.8%. Postpartum hemorrhage was the commonest cause of death (35.1), followed by pulmonary embolism (26.1) and hypertension (15.5). Notification was done in (311; 33.01%) and maternal mortality committee meeting was conducted in 258 (27.4%) of cases      |
| Shaban et al. (2024)   | To determine Maternal mortality and associated Statistical analysis factors in Iraq                                         | Retrospective study                                                                                                                                                                                                                                           | Maternal mortality ratio in the country was (46.1), and COVID19 was the main causative agent for maternal mortality (40%). Most of the dead women were housewives, live in urban places, at bearing age 20-39 years, not complete the primary schools and the place for their delivery was at governmental hospitals                                                                                                            |

|                         |                                                                                                                                                                                                                                     |                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tappis et al. (2023)    | To assess the quality of maternal and newborn care services in Iraq                                                                                                                                                                 | A rapid cross-sectional assessment was conducted in November 2022 to assess the quality of MNH services at private hospitals in Iraq -quality assessment tools were used | while resources are in place for basic and advanced care, there are gaps in knowledge and practice of high-impact interventions that require few or no resources to perform, including skin-to skin thermal care and support for early initiation of breastfeeding                                                                                                                                                              |
| 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%)                                                                                                                                                                                                                                                                          |
| Thamir et al. (2021)    | to identify maternal death cases caused by Coronavirus infection 2019 pneumonia, including disease progression, fetal consequences, and the fatality cause. Patients and methodology                                                | Retrospective study                                                                                                                                                      | COVID-19 pneumonia induces substantial fetal and maternal mortality rates through pregnancy, which should be considered when treating these cases                                                                                                                                                                                                                                                                               |
| Gabrani et al. (2020)   | to identify key factors influencing the utilization of governmental and private primary healthcare services in Albania                                                                                                              | cross- sectional health facility survey using a 4- point Likert scale questionnaire to rank the importance of factors driving services utilization.                      | 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 found that aspects of acceptability and adequacy of services are equally valued                                                                                                                                                                 |
| Obeid et al. (2020)     | to assess the maternal mortality ratio in one of the largest hospitals in Baghdad over eight years including the time of the threat of the so-called Islamic State of Syria and Iraq                                                | A cross-sectional study was undertaken by reviewing the records of mothers who passed away in the hospital from February 2011 to February 2018                           | The maternal mortality was high and obstetric hemorrhage was the main cause of death. In addition, the majority of patients died within the first 12 hours of admission, which is attributed to delays in access to the hospital and the lack of needed facilities during that critical period of time                                                                                                                          |
| Zalvand et al. (2019)   | To review determinants and causes of maternal mortalities during pregnancy, delivery and the puerperium using the International Classification of Diseases-Maternal Mortality (ICD-MM), introduced by the World Health Organization | Systematic review                                                                                                                                                        | The leading direct and indirect causes of death were identified as hemorrhage (30.7%) and hypertensive disorders (17.1%) and circulatory system diseases (8.1%) respectively. Several factors including gravidity, type of delivery, socio-economic status of mothers, locations of birth, death and maternity care venues were found in the original studies as the most important determinant of maternal mortalities in Iran |

|                      |                                                                                                                                                              |                                      |                                                                                                                                                                                                                                                                        |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Akrawi et al. (2017) | to find out the major determinants of maternal near-miss (nm) and maternal deaths (MDS) in Erbil city, Iraq, by comparative analysis of maternal NMS and MDS | hospital-based cross-sectional study | severe preeclampsia and PPH are the main complications that lead to PLTCs. Factors found to be associated with MDS are hepatic dysfunction, multiple/unspecified disorders, arrival as an emergency condition by ambulance, and history of a previous cesarean section |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## METHODOLOGY

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

$\varepsilon_t$  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 Iraq 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          |
| <b>Smoothing constants</b>            |             |
| Alpha ( $\alpha$ ) for data           | 0.900       |
| Beta ( $\beta$ ) for trend            | 0.100       |
| <b>Forecast performance measures</b>  |             |
| Mean Absolute Error (MAE)             | 8.605697    |
| Sum Square Error (SSE)                | 6489.000371 |
| Mean Square Error (MSE)               | 166.384625  |
| Mean Percentage Error (MPE)           | -0.376570   |
| Mean Absolute Percentage Error (MAPE) | 7.010666    |

### Residual Analysis for the Applied Model

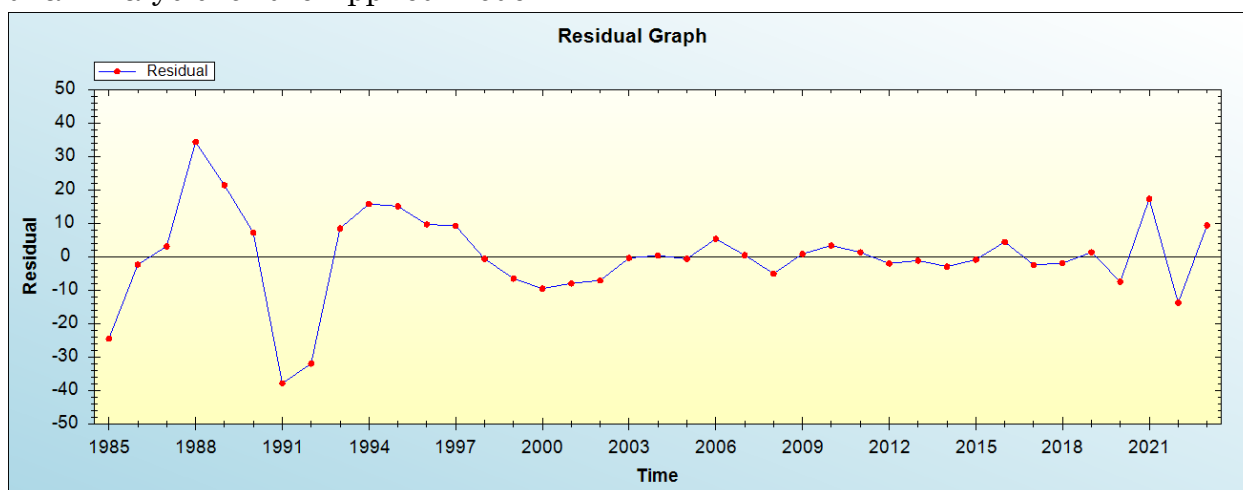


Figure 1: Residual analysis

### In-sample Forecast for A

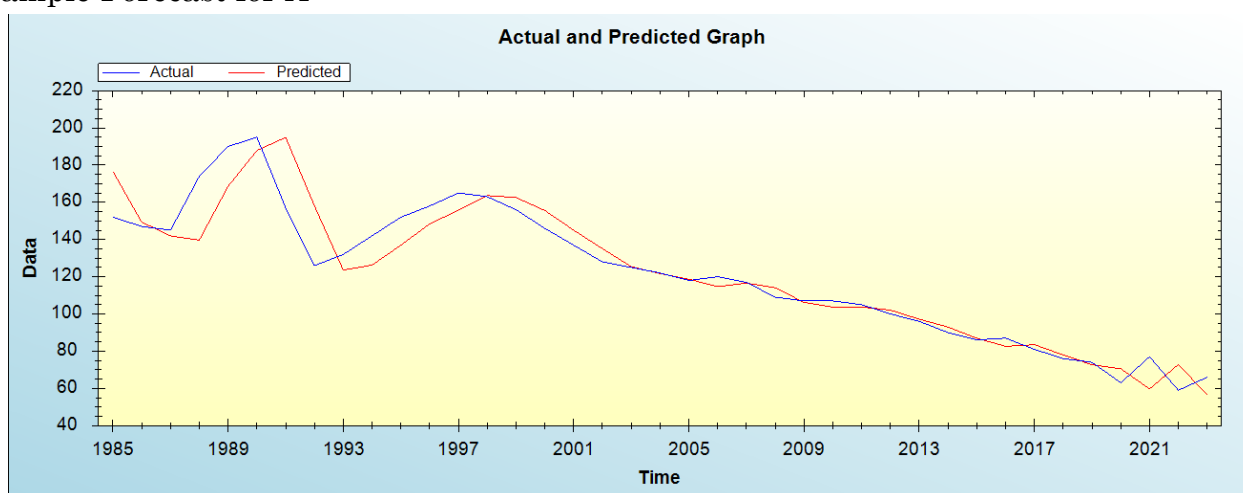


Figure 2: In-sample forecast for the A series

### Actual and Smoothed graph for A series

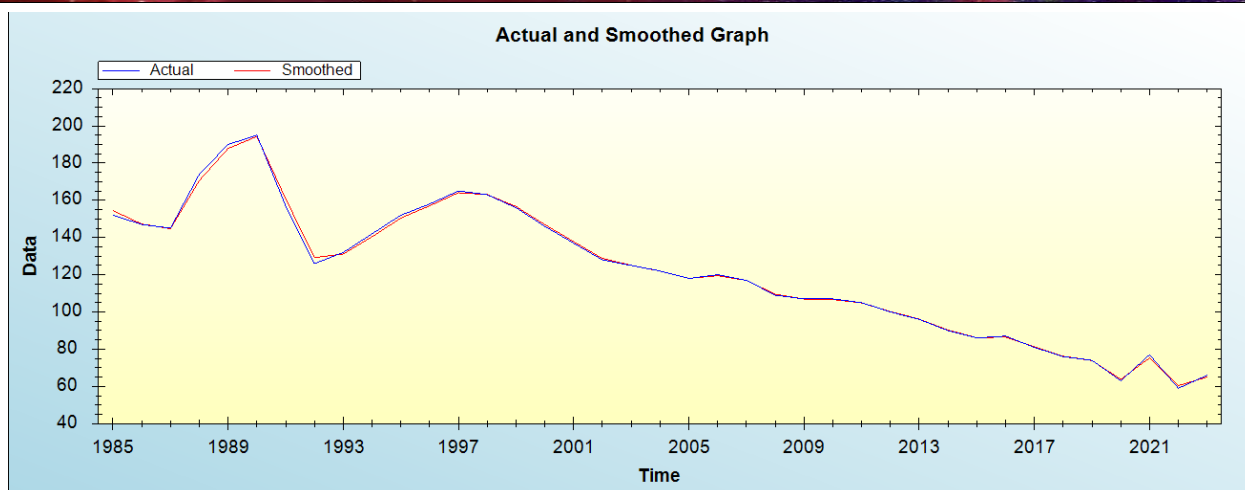


Figure 3: Actual and smoothed graph for A series

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

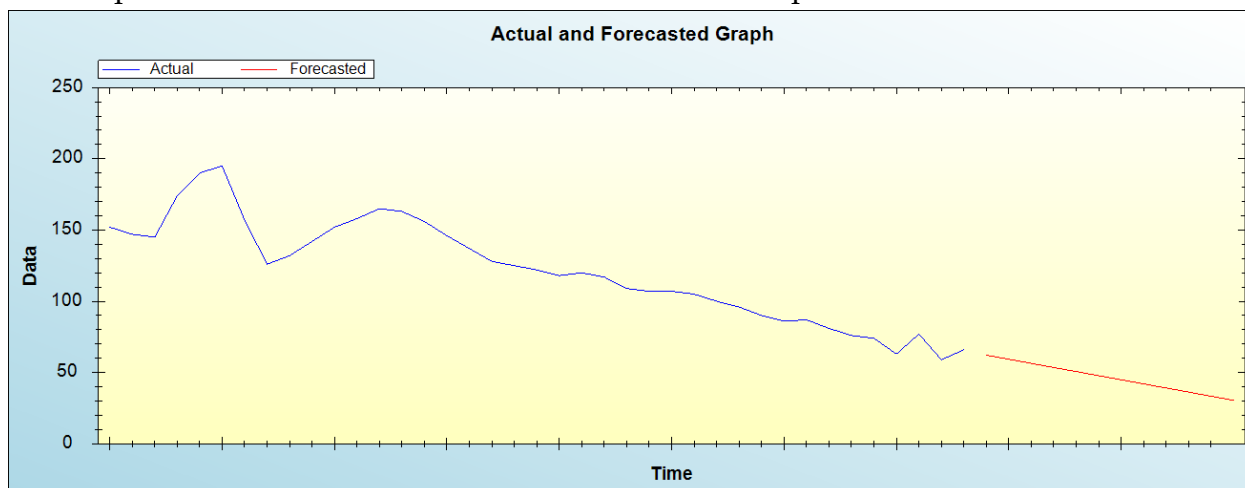


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

## Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 62.1836        |
| 2025 | 59.3016        |
| 2026 | 56.4196        |
| 2027 | 53.5376        |
| 2028 | 50.6556        |
| 2029 | 47.7736        |
| 2030 | 44.8917        |
| 2031 | 42.0097        |
| 2032 | 39.1277        |
| 2033 | 36.2457        |
| 2034 | 33.3637        |
| 2035 | 30.4817        |

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 decline from around 62 in 2024 to 30 deaths per 100 000 live births by 2035.

### RECOMMENDATIONS & CONCLUSION

This paper utilized the double exponential smoothing method to forecast MMR for Iraq and the findings suggest that MMR will decline from around 62 in 2024 to around 30 deaths per 100 000 live births in 2035. Therefore, Iraq authorities must address local causes of maternal mortality.

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