

## APPROXIMATING ANNUAL MATERNAL MORTALITY RATE FOR GUYANA USING THE DOUBLE EXPONENTIAL SMOOTHING APPROACH

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### ABSTRACT

This study uses annual time series data on MMR for Guyana 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 0.1 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 92 in 2024 to around 54 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to address local causes of preventable maternal mortality.

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

### INTRODUCTION

Maternal death is a global public health issue of concern. Approximately 800 women die every day from preventable causes related to pregnancy or childbirth (WHO, 2023). This problem affects low-middle countries more than first world countries. WHO data indicated that at the global level, the maternal mortality ratio (MMR) 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 observed, 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). According to Guyana Country policy profile 2018, maternal mortality in Guyana stood at 111.9 deaths per 100 000 live births in 2020, the reported neonatal mortality rate was 16.1 deaths per 1000 live births in 2022. This data shows that maternal and neonatal mortality are still a problem in this nation. The objective of this paper is to model and forecast MMR for Guyana using the double exponential smoothing technique. The study results are expected to guide policy and allocation of resources to the health sector in order to further reduce maternal deaths to levels below 30 per 100 000 live births.

### LITERATURE REVIEW

| Author(s)             | Objective(s)                                                                                                                                                                                                                        | Methodology       | Main finding(s)                                                                                                                                                                                            |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Marks & Castro (2026) | To examine how MWHs have been implemented across Latin America, analyzing their evolution, the specific needs they address in different countries, and their impact on maternal and neonatal health outcomes throughout the region. | Systematic review | The evolution of MWHs suggests that they address a spectrum of needs beyond their original purposes, such as providing culturally responsive maternal support and psychosocial and early childhood support |
| 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                                                                                                                             |

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|                                |                                                                                                                                                                                          |                                                                                                                                                | maternal and newborn facility care to community connections is an important consideration to ensure equitable access to routine and emergency care.                                                                                                                                                                                                   |
| Tsushima et al. (2026)         | To determine the long-term incidence of dysglycemia and dyslipidemia after GDM and evaluated whether postpartum changes in body mass index (BMI) independently predicted these outcomes. | Prospective cohort study                                                                                                                       | Postpartum BMI increase was independently associated with new-onset dysglycemia. No independent predictor of T2DM progression was identified. Dyslipidemia was independently associated with higher pre-pregnancy BMI and multiparity, whereas postpartum BMI change was not independently associated after multivariable adjustment                  |
| Yue et al. (2026)              | to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research                                                                | Systematic review                                                                                                                              | Positive aPLs significantly increased the risk of miscarriage rate in assisted reproductive technology (ART) and were also associated with total fetal loss, PE, intrauterine growth retardation and placental abruption                                                                                                                              |
| Nunn et al. (2025)             | To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait Islander women contributed to reduced perinatal death rates                            | Retrospective population-based cohort study of all births in Victoria from 2000–2019                                                           | Changes in key maternal characteristics may have contributed to improved perinatal death rates among babies of Victorian Aboriginal and/or Torres Strait Islander women                                                                                                                                                                               |
| Haninger-Vacariu et al. (2024) | To describe pregnancy and delivery outcomes in women with Fabry disease                                                                                                                  | Retrospective cohort-study of women with Fabry disease in Austria using a specific questionnaire and the Austrian Mother–Child Health Passport | The cohort-study in women with Fabry disease showed an increase of pain burden during pregnancies and clearly points to an increased risk for preeclampsia, prematurity, and neonates small for gestational age. With a substantial number of high-risk pregnancies, neonatal outcomes are somewhat worse in Fabry disease than in the general public |
| Alipour et al. (2023)          | to estimate the global prevalence of maternal death causes through a systematic review and meta-analysis                                                                                 | Systematic review                                                                                                                              | The most prevalent causes of maternal deaths, listed in descending order from highest to lowest prevalence, were non-obstetric complications (48.32%), obstetric hemorrhage                                                                                                                                                                           |

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|                             |                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                            | (17.63%), hypertensive disorders of pregnancy, childbirth, and the puerperium (14.01%), other obstetric complications (7.11%), pregnancy with abortive outcome (5.41%), pregnancy-related infection (5.26%), unanticipated complications of management (2.25%), unknown/ undetermined causes (2.01%), and coincidental causes (1.59%), respectively |
| 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                                                                                                                                                                                                                             |
| Schoenborn et al. (2021)    | <p>-to describe the sociodemographic profiles of women who are not legally residing in Belgium</p> <p>-to analyze the associations of registration status with pregnancy outcomes according to socioeconomic status and nationality.</p> | <p>-analyzed data from birth and death certificates taken from the Belgian civil registration system, linked with the National Population Registry (NPR). The data relates to all singleton babies born between 2010 and 2016 (n = 871,283), independent of their mother's NPR registration status</p> <p>-applied logistic regression</p> | Overall, unregistered women have increased risks of adverse perinatal outcomes, but it is likely that the causal mechanisms differ starkly between Belgian, European and non-European women                                                                                                                                                         |
| Morong et al. (2017)        | This study was a retrospective cohort study of cases of in-hospital maternal deaths in the Ochsner Health System (Louisiana, United States) and the Queensland Health System (Australia) from 1995 to 2013                               | -to determine if American and Australian women have a similar rate of preventable maternal death and if the deaths were attributable to the same factors                                                                                                                                                                                   | Women from Louisiana, United States and Queensland, Australia have similar rates of preventable maternal death. No statistically significant factors explained trends in Australian maternal death; American maternal mortality was significantly associated with point of entry into prenatal care, likely influenced by insurance status          |
| Nahidi & Hajifoghaha (2017) | To provide the current situation and trend of MMR in the Eastern Mediterranean region between 1990 and 2015                                                                                                                              | Systematic review                                                                                                                                                                                                                                                                                                                          | Based on the collected data, 36 out of 66 studies met the required criteria and were chosen for analysis. All countries of this region                                                                                                                                                                                                              |

|                             |                                                                                                                                                       |                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                     |
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|                             |                                                                                                                                                       |                                                                                                                                                   | showed a downward trend between 1990 and 2015, and this change varied from 16.30% in Yemen to 76.56% in Lebanon. The maternal mortality reduction was 69.88% in Iran in the same time                                                                                                                                                                                               |
| Schildberger et al. (2017)  | -To investigate the personal meanings and experiences of women with disabilities in regard to pregnancy, childbirth and the puerperium                | Conducted semi-structured interviews                                                                                                              | Participants reported limited acceptance of their life decisions and experienced an environment of discriminatory attitudes. They experienced a lack of support and lack of confidence in their parenting abilities, which negatively influenced their self-efficacy and self-awareness. Violations of personal borders and a feeling of being watched and controlled were reported |
| Bouvier-Colle et al. (2012) | To assess capacity to develop routine monitoring of maternal health in the European Union using indicators of maternal mortality and severe morbidity | Analysis of aggregate data from routine statistical systems compiled by the EUROPERISTAT project and comparison with data from national enquiries | Currently available data on maternal mortality and morbidity are insufficient for monitoring trends over time in Europe and for comparison between countries                                                                                                                                                                                                                        |

## METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

$G_t$  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 Guyana 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                              | G            |
|---------------------------------------|--------------|
| Included Observations                 | 39           |
| <b>Smoothing constants</b>            |              |
| Alpha ( $\alpha$ ) for data           | 0.100        |
| Beta ( $\beta$ ) for trend            | 0.100        |
| <b>Forecast performance measures</b>  |              |
| Mean Absolute Error (MAE)             | 7.572691     |
| Sum Square Error (SSE)                | 10546.642591 |
| Mean Square Error (MSE)               | 270.426733   |
| Mean Percentage Error (MPE)           | -0.523597    |
| Mean Absolute Percentage Error (MAPE) | 5.203390     |

## Residual Analysis for the Applied Model

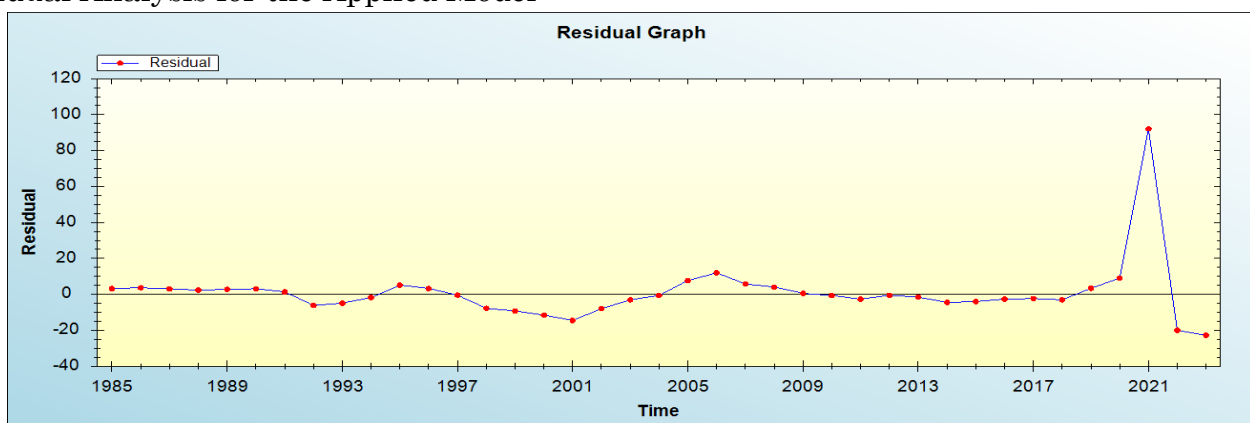


Figure 1: Residual analysis

## In-sample Forecast for G

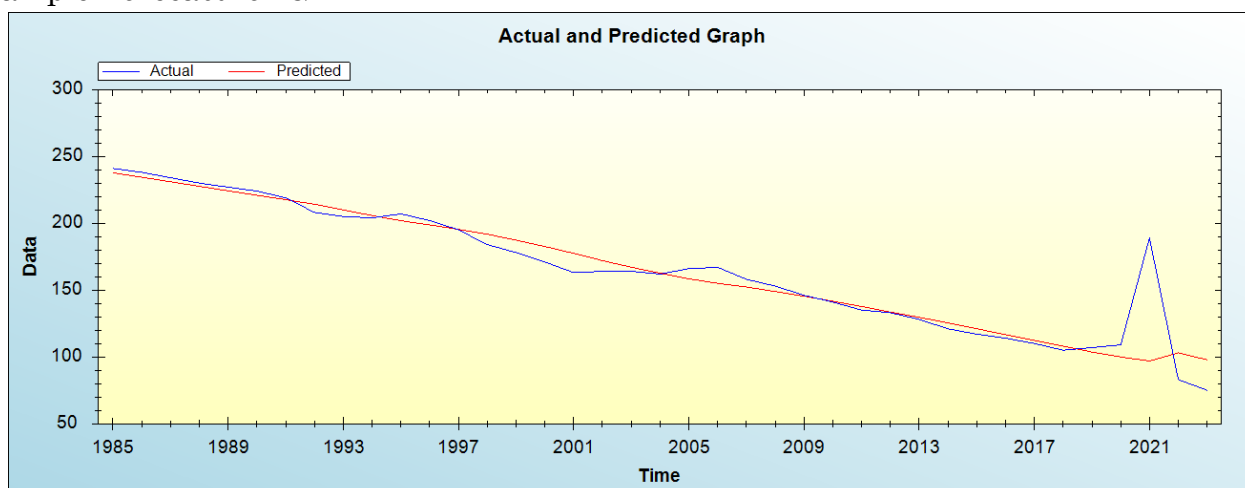


Figure 2: In-sample forecast for the G series

## Actual and Smoothed graph for G series

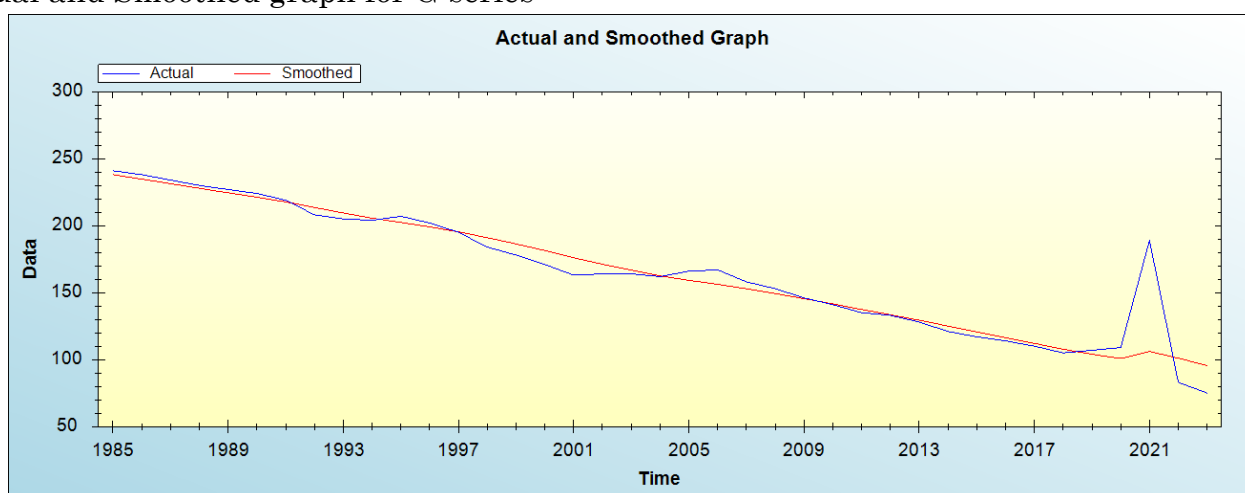


Figure 3: Actual and smoothed graph for G series

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

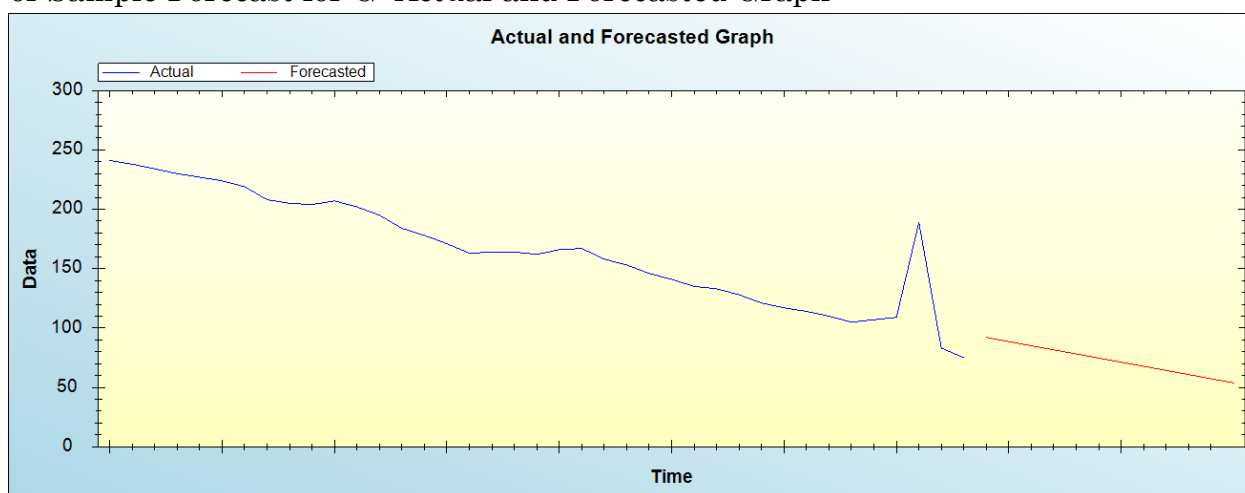


Figure 4: Out-of-sample forecast for G: actual and forecasted graph

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

Table 2: Tabulated out-of-sample forecasts

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 92.0396        |
| 2025 | 88.5667        |
| 2026 | 85.0938        |
| 2027 | 81.6209        |
| 2028 | 78.1480        |
| 2029 | 74.6752        |
| 2030 | 71.2023        |
| 2031 | 67.7294        |
| 2032 | 64.2565        |
| 2033 | 60.7836        |
| 2034 | 57.3107        |
| 2035 | 53.8379        |

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 92 in 2024 to around 54 deaths per 100 000 live births in 2035.

### RECOMMENDATIONS & CONCLUSION

Maternal mortality in this country is relatively high indicating gaps in the continuum of care. The model was applied in this study to project MMR for Guyana and findings indicate that MMR is expected to decline from around 92 in 2024 to around 54 deaths per 100 000 live births in 2035. Hence, we implore authorities in this country to address local factors associated with maternal mortality and ensure quality maternal and child health services are provided at all levels of care.

### REFERENCES

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