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## MATERNAL MORTALITY PROJECTION FOR THE NETHERLANDS USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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### Abstract

This study uses annual time series data on MMR for the Netherlands 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 remain very low over the out of sample period. Therefore, we encourage authorities to relentlessly address local causes of avoidable maternal deaths and continue routine surveillance of severe maternal morbidity.

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

### Introduction

Maternal mortality remains a huge global health issue because of the negative impact it has on the family and community (Geetika et al. 2015). Approximately 80% are as a result of causes directly related to pregnancy (Kwale et al. 2005). The World Health Organization (WHO) data indicates that more than a quarter million women die worldwide because of complications during childbirth or pregnancy (WHO, 2014), with the majority of these deaths occurring in developing countries. For every woman who dies from obstetric complications, many more face injuries, disabilities and infections (WHO, 2010). Most of these deaths and complications could be prevented if all women gave birth with the assistance of skilled midwives (Khanal et al. 2015). The purpose of antenatal care



is to improve and monitor the welfare of both mother and fetus, identify potential problems, prepare women for childbirth and child rearing and respond to their complaints (WHO, 2009). Cardiovascular disorders (CVD) are the leading cause of indirect maternal mortality in European countries, including the Netherlands (Engin-Ustun et al. 2012; Cantwell et al. 2011; Schutte et al. 2010). In the Netherlands an increase in the indirect maternal death ratio was observed between 1993 and 2005 (Schutte et al. 2010). In addition, an increase in direct maternal mortality was observed, which includes (unexplained) sudden deaths. The objective of this paper is to model and forecast MMR for the Netherlands using the double exponential smoothing model. The research findings will stimulate an appropriate national response so that preventable maternal mortality is further reduced.

## **Literature Review**

| <b>Author(s)</b>       | <b>Objective(s)</b>                                                                                                                                                                      | <b>Methodology</b>       | <b>Main finding(s)</b>                                                                                                                                                                                                                                                                                                               |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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                                                                                                             |



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|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 |
| Kornyicki & Fedor (2024)       | to publish findings on the lifestyle factors of pregnant women in Hungary and their impact on early childhood health status by examining changes over time and regional/geographical disparities | Secondary analysis of raw indicators reported by health visitors as per mandatory annual report data for the period of 1997–2019 in Hungary                                | Interventions to improve early childhood health in some counties of Hungary are urgently needed to reduce regional disparities                                                                                                                                                                                                                        |
| Wilhelm et al. (2024)          | To describe the contribution of CA to NMR in Malta, investigating possible associations with known maternal risk factors of maternal age, nationality, and education                             | -Anonymous data for births and neonatal deaths were obtained for 2006–2020 from the National Obstetrics Information System (NOIS) in Malta<br>-applied regression analysis | Between 2006 and 2020, Malta's NMR remained stable. Maternal Nationality, from non-EU low-income countries, was associated with higher neonatal mortality                                                                                                                                                                                             |



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|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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                                                                                                                                                                                                                                                                                   |
| Wami et al. (2022)     | To explore both real maternal and fetoneonatal characteristics associated with Hungarian homebirths                                                                          | Retrospective cohort study                                                                                                                                                                                                                                                                                                                           | Aggregated maternal complications (primary uterine inertia, prolonged second stage labor, and third stage hemorrhage) were prevalent among homebirth cases (1.29% vs. 0.72%, $p < 0.05$ ) and were associated with an average of 11.77% rate of transfer to a health care institution. On the other hand, the rate of operative (vaginal or caesarean) delivery was 26.31% among institutionalized births |
| Lameijer et al. (2019) | to present an extensive overview concerning the specific cardiovascular causes of maternal death and to identify avoidable contributing care factors related to these deaths | Researchers assessed all cases of maternal death due to cardiovascular disorders collected by a systematic national confidential enquiry of maternal deaths published by the Dutch Maternal Mortality and Morbidity Committee on behalf of the Netherlands Society of Obstetrics and Gynecology over a 21-year period (1993–2013) in the Netherlands | The maternal cardiovascular mortality ratio is low in the Netherlands and the main causes of maternal cardiovascular mortality are in line with other European reports                                                                                                                                                                                                                                    |



|                            |                                                                                                                                        |                                      |                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

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



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$\varepsilon_t$  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 the Netherlands 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                              | N         |
| 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)             | 0.579037  |
| Sum Square Error (SSE)                | 20.399678 |
| Mean Square Error (MSE)               | 0.523069  |
| Mean Percentage Error (MPE)           | 0.069731  |
| Mean Absolute Percentage Error (MAPE) | 7.427376  |



## Residual Analysis for the Applied Model

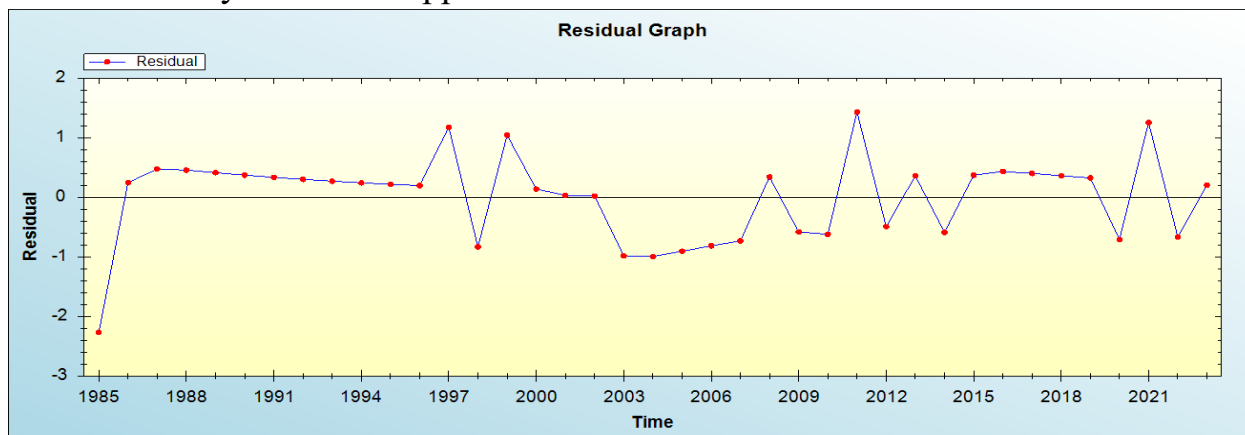


Figure 1: Residual analysis

## In-sample Forecast for N

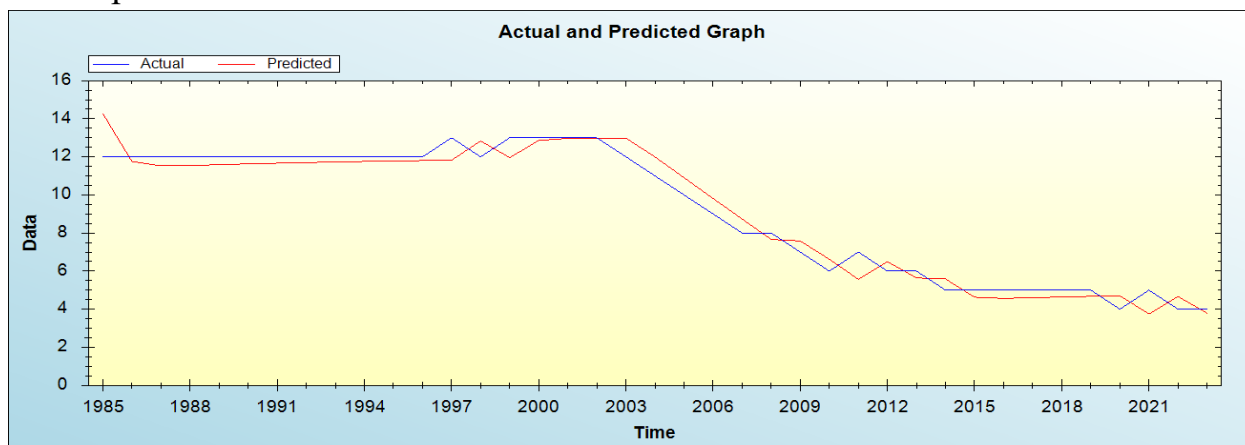


Figure 2: In-sample forecast for the N series

## Actual and Smoothed graph for N series

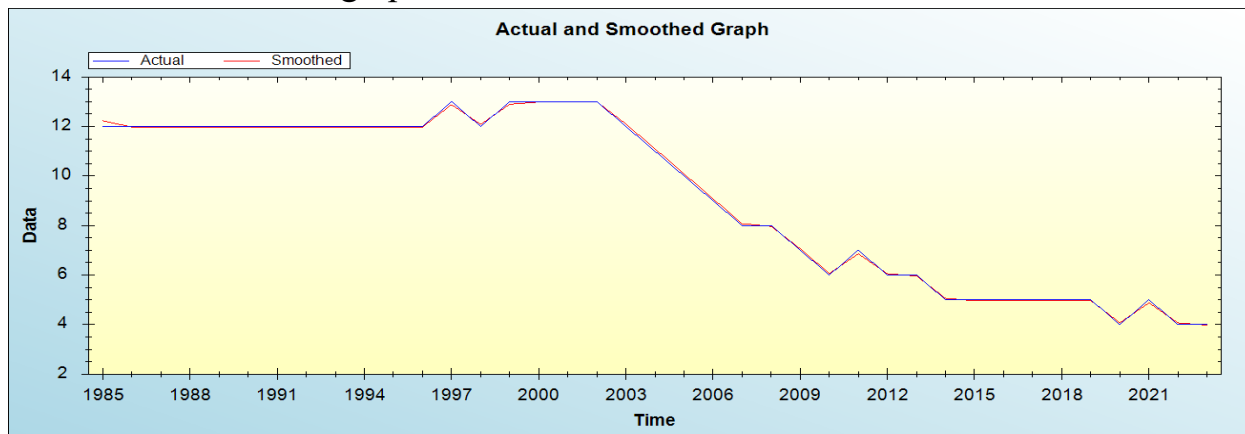


Figure 3: Actual and smoothed graph for N series



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

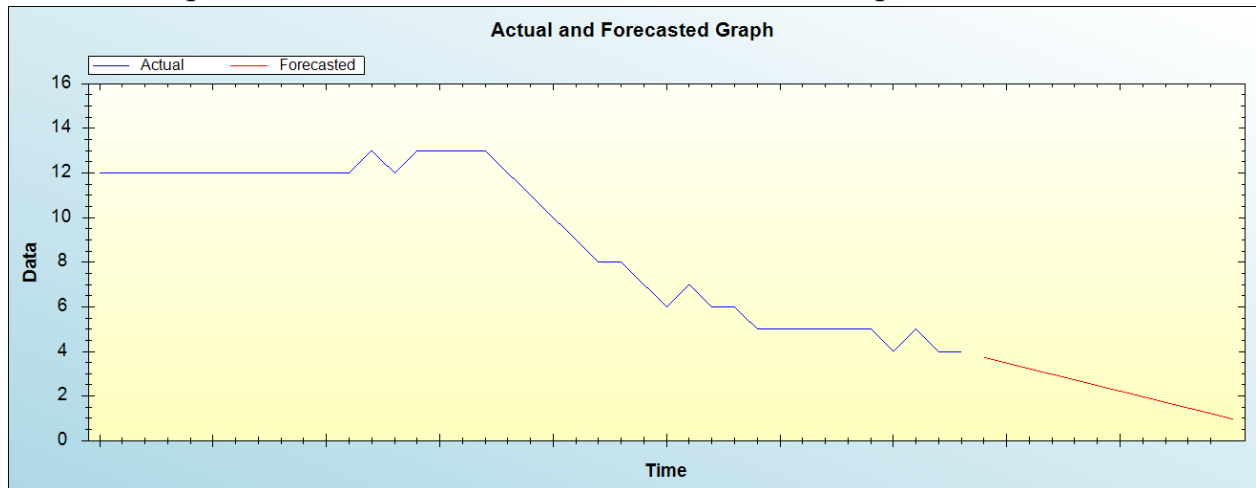


Figure 4: Out-of-sample forecast for N: actual and forecasted graph

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

Table 2: Tabulated out-of-sample forecasts

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 3.7283         |
| 2025 | 3.4770         |
| 2026 | 3.2256         |
| 2027 | 2.9742         |
| 2028 | 2.7229         |
| 2029 | 2.4715         |
| 2030 | 2.2202         |
| 2031 | 1.9688         |
| 2032 | 1.7174         |
| 2033 | 1.4661         |
| 2034 | 1.2147         |
| 2035 | 0.9633         |

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 very low over the out of sample period.



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## **Recommendations & Conclusion**

Maternal mortality is still a problem in Netherlands although MMR is generally low. Indirect maternal mortality is predominant in this country. This paper applied the double exponential smoothing approach to model and forecast MMR for the Netherlands and results indicate that MMR will remain very low over the out of sample period. Hence, authorities are encouraged to address local causes of maternal deaths and continue routine reporting of severe maternal morbidities.

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