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## MAKING USE OF MACHINE LEARNING MODEL FORECASTS TO INFORM MATERNAL HEALTH STRATEGIES IN ROMANIA

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### Abstract

This research article employs annual time series data on MMR for Romania from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The forecast evaluation criteria of the applied model indicate that the ANN (12, 12, 1) model is stable. The neural network model projections revealed that MMR will remain very low throughout the out of sample period. Therefore, we encourage the government to identify and address local causes of preventable maternal deaths.

**Keywords:** ANN, Forecasting, Maternal Mortality Ratio.

### Introduction

Approximately 830 women die every day from preventable causes linked to pregnancy or childbirth globally (WHO, 2018). The majority of maternal deaths are observed in low-middle income countries (WHO, 2018), and 65% of these deaths are reported in sub-Saharan Africa (WHO, 2019). WHO data indicates that maternal mortality ratios are highest where skilled birth attendance is the lowest (WHO, 2019). Most maternal deaths are reported during the intrapartum and peripartum periods (Ahmed et al. 2018; Merdad et a. 2018) highlighting the significance of early access to quality health services for birth and postpartum care. In addition, complications during childbirth and postpartum periods are best attended to in well-resourced and staffed medical facilities. This study utilizes a machine learning model to forecast MMR for Romania. The study findings will guide policy, planning and allocation of resources to the health sector



## Literature Review

| Author(s)                      | Objective(s)                                                                                                                                                                                     | Methodology                                                                                                                                    | Main finding(s)                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 |
| 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                                                                                                                                                                                                                        |



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|                         |                                                                                                                                                                              |                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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                                                                                                                                                                                                                                               |
| 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 fetal-neonatal 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 |
| Miteniece et al. (2020) | investigates access-related barriers (availability, appropriateness, affordability, approachability, and acceptability) to maternity care in Romania, Bulgaria, and Moldova. | cross- country study                                                                                                                                                       | Women who had health complications, those who gave birth by cesarean, and women who gave birth in a public facility and had fewer antenatal check- ups, were more likely to describe facing access- related barriers                                                                                                                                                                                      |
| Lameijer et al. (2019)  | to present an extensive overview concerning the specific                                                                                                                     | Researchers assessed all cases of maternal death due to cardiovascular                                                                                                     | The maternal cardiovascular mortality ratio is low in the Netherlands and the main                                                                                                                                                                                                                                                                                                                        |



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|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                            | cardiovascular causes of maternal death and to identify avoidable contributing care factors related to these deaths                    | 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 | 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

The Artificial Neural Network (ANN) approach, which is flexible and capable of nonlinear modelling; will be applied in this study. The ANN is a data processing system consisting of a large number of highly interconnected processing elements in architecture inspired by the way biological nervous systems of the brain appear like. Since no explicit guidelines exist for the determination of the ANN structure, the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function. This paper applies the Artificial Neural Network



(ANN) approach in predicting annual maternal mortality ratio (MMR) for Romania.

### **Data Issues**

This study is based on annual MMR in Romania 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**

#### **ANN Model Summary**

**Table 1: ANN model summary**

| Variable                     | R                              |
|------------------------------|--------------------------------|
| Observations                 | 27 (after adjusting endpoints) |
| Neural Network Architecture: |                                |
| Input Layer Neurons          | 12                             |
| Hidden Layer Neurons         | 12                             |
| Output Layer Neurons         | 1                              |
| Activation Function          | Hyperbolic Tangent Function    |
| Back Propagation Learning    |                                |
| Learning Rate                | 0.005                          |
| Momentum                     | 0.05                           |
| Criteria:                    |                                |
| Error                        | 0.002884                       |
| MSE                          | 1.896581                       |
| MAE                          | 0.856143                       |



## Residual Analysis for the Applied Model

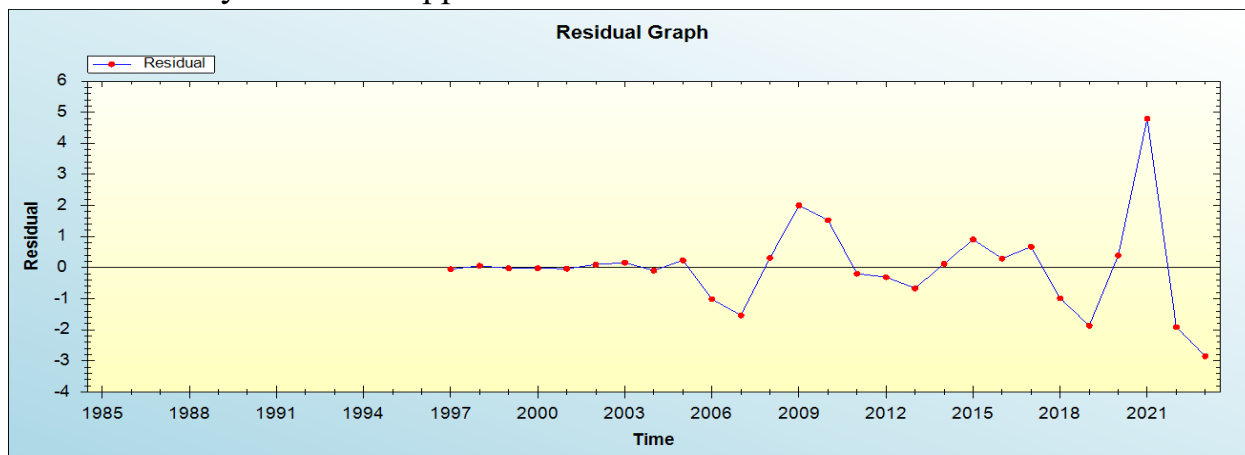


Figure 1: Residual analysis

## In-sample Forecast for R

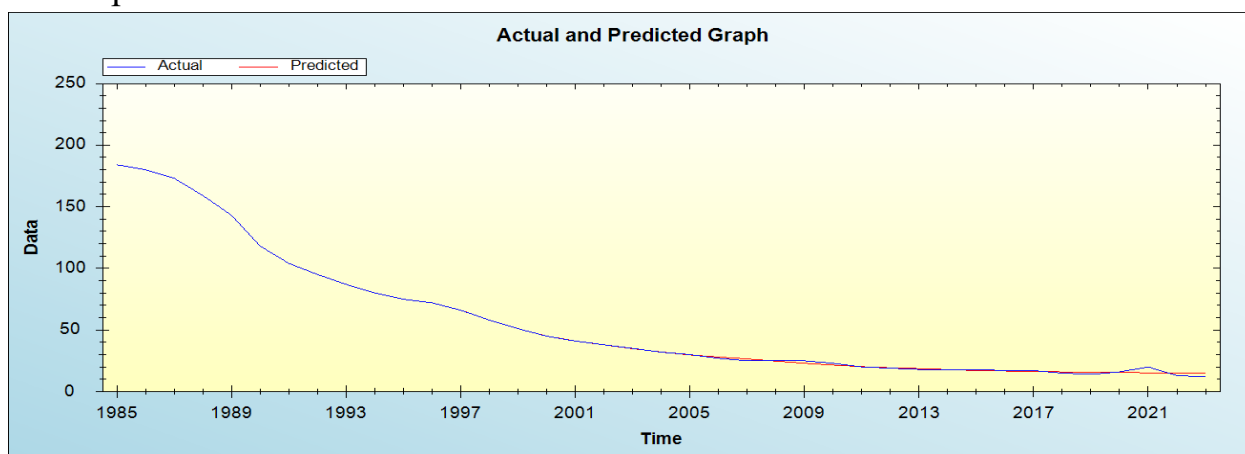


Figure 2: In-sample forecast for the R series

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

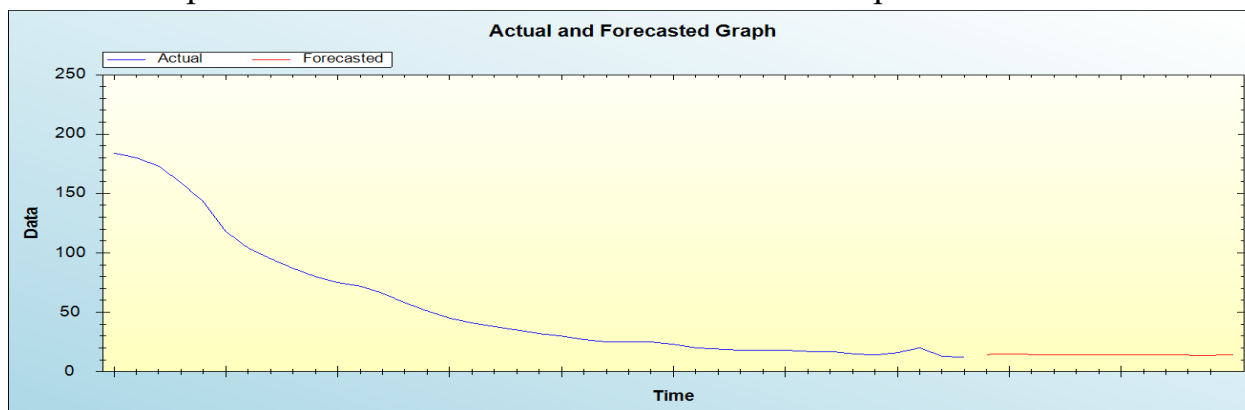


Figure 3: Out-of-sample forecast for R: actual and forecasted graph



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**Out-of-Sample Forecast for R: Forecasts only**

**Table 2: Tabulated out-of-sample forecasts**

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 14.4411        |
| 2025 | 14.8800        |
| 2026 | 14.4371        |
| 2027 | 14.0732        |
| 2028 | 14.2801        |
| 2029 | 14.4733        |
| 2030 | 13.9069        |
| 2031 | 14.2763        |
| 2032 | 14.3506        |
| 2033 | 13.8896        |
| 2034 | 13.8092        |
| 2035 | 13.9598        |

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.

### **Conclusion**

In this paper we applied a machine learning method to project MMR for Romania and findings indicate that MMR will remain very low in the forecast period. Hence, health authorities are encouraged to identify and address local causes of maternal deaths.

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