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## **PREDICTION OF MATERNAL MORTALITY FOR UGANDA USING A MACHINE LEARNING APPROACH**

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### **Abstract**

This research article employs annual time series data on MMR for Uganda 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 high throughout the out of sample period. Therefore, we encourage the government to adopt the suggested 5-fold policy prescription.

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

### **Introduction**

Maternal mortality remains a big public health issue in Uganda. Approximately 1 in 50 maternal deaths are reported in Uganda (Republic of Uganda, 2016). In 2015, UNICEF set a country-specific MMR target of 211 per 100,000 live births by 2017 for Uganda (Republic Uganda, 2015). Unfortunately, in 2016, Ugandan estimates indicated MMR stood at 336 per 100,000 livebirths (UBOS & ICF, 2018). Available data shows that the majority of maternal deaths in Uganda are from potentially avoidable causes such as hemorrhage, hypertensive disorders, and sepsis (Nakimuli et al. 2016; Ngonzi et al. 2016; Kaye et al. 2011). The purpose of this paper is to model and forecast MMR for Uganda using a machine learning approach. The study results are expected to trigger an appropriate national health response that will further reduce preventable maternal deaths to levels below 70 per 100 000 live births by 2030.



## Literature Review

| Author(s)              | Objective(s)                                                                                                                                                        | Methodology                                                                                                                                                                                                                    | Key finding(s)                                                                                                                                                                                                                                               |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Jena et al. (2025)     | To estimate the pooled magnitude of neonatal mortality and its association with maternal and child health care in SSA                                               | Systematic review                                                                                                                                                                                                              | Neonatal mortality in SSA remains high. Maternal health services such as exposure to antenatal care and institutional delivery and child health services such as early initiation of breastfeeding were related to reducing the burden of neonatal mortality |
| Lukwa et al. (2024)    | To evaluate the effectiveness and value of value-based healthcare interventions in improving maternal health outcomes in Sub-Saharan Africa                         | Systematic review                                                                                                                                                                                                              | The results suggest that VBHC can significantly improve maternal health, evidenced by successful implementations like obstetric units in Sierra Leone and integrated care in South Africa, which improved outcomes and cost-effectiveness                    |
| Atuhaire et al. (2023) | To examine the inequalities in utilization of maternal health services between 2006 and 2016 to draw implications for achieving universal health coverage in Uganda | used the Uganda Demographic Health Survey 2006, 2011 and 2016 to analyze inequalities in utilization of antenatal care (ANC4+), skilled birth attendance (SBA), postnatal care (PNC) and a package of maternal health services | Declining inequalities in utilization of maternal healthcare reflect a move towards achieving universal health coverage in Uganda                                                                                                                            |
| Baig et al. (2023)     | To Investigate maternal mortality in Southeast Asia, Europe and Africa                                                                                              | Literature review                                                                                                                                                                                                              | -Inadequate care is one of the major causes of maternal mortality in majority of regions across the globe<br>-The three delays model plays a significant role in the higher maternal mortality rate                                                          |
| Konlan et al. (2023)   | To identify factors that influence women's decision for a CS are synthesized to clarify                                                                             | Systematic review                                                                                                                                                                                                              | The prevalence of CS was 2.1% to 18.5% of all live births as the socioeconomic status (SES) and                                                                                                                                                              |



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|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | policy initiatives that improve care                                                                                                                                                                                                  |                                                                                                                                                                                                                  | demographic factors that influence the rate of CS were higher SES, education, and age; place of birth; urban residence; and women headed household                                       |
| Mlambo et al. (2023)    | to investigate the macro determinants of maternal mortality in Southern African Development Community (SADC) states                                                                                                                   | A panel data estimation (Generalized Method of Moments) covering the period from 2005–2019 was used to examine how various factors affect maternal mortality                                                     | The econometric analysis reveals a significant positive impact of fertility, GDP per capita and HIV on maternal mortality                                                                |
| Okonji et al. (2023)    | To assess maternal mortality patterns by age and country in Sub-Saharan Africa                                                                                                                                                        | The demographic and health survey data were used for the study                                                                                                                                                   | The study found that the patterns of death vary across different countries                                                                                                               |
| Alobo et al. (2022)     | To explore the main factors affecting maternal death and designing a predictive model for estimation of the risk of dying at admission at a major referral hospital in northern Uganda                                                | -This was a retrospective matched case-control study, carried out at Lacor Hospital in northern Uganda, including 130 cases and 336 controls, from January 2015 to December 2019<br>-applied logistic regression | Mortality is high among mothers referred late from other facilities who are HIV positive, aged more than 30years, lack antenatal care attendance, and are delivered by caesarean section |
| Namagembe et al. (2022) | To review maternal deaths at the National Referral hospital in Kampala over a 3-year period (2016-2018) to deter mine causes of death, extent of preventability, proportion of deaths notified and audited as per national guidelines | Trained-multidisciplinary panels (obstetricians and senior midwives) conducted retrospective reviews of maternal deaths that occurred                                                                            | A high proportion (84%) of deaths were preventable. Significant delays to care occurred within health-care facilities                                                                    |
| Nnadi et al. (2022)     | to estimate the effect of maternal mortality on economic development in Sub-Sahara African region. Cross-sectional data analysis of selected member                                                                                   | Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model                                                                             | The explanatory variables in the model were statistically significant at 5% level while other coefficients like maternal mortality, exports and imports conform to the                   |



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|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                           | countries in the region under focus was employed using double-log econometric model                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                  | apriori expectations and impacted negatively on the overall GDP                                                                                                                                                                                                                                            |
| Sserwanja et al. (2022)   | To determine the level of coverage and factors associated with the continuum of maternal care in Uganda                                                                                                               | Used weighted data from the Uganda Demographic and Health Survey (UDHS) 2016                                                                                                                                                                                                                                                                     | The level of coverage of the complete continuum of maternal care was low and varied across regions. It was associated with easily modifiable factors such as early initiation of ANC, exposure to mass media and level of education                                                                        |
| 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 review                                                                                                                                                                                                                                                                                                                                | Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA                                                                                                                                  |
| 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                                                                                                                                            |
| Singh et al. (2016)       | To assess how countries in regions of the world where maternal mortality is highest - South Asia and Sub-Saharan Africa - are performing with regards to providing women with vital elements of the continuum of care | -Used Demographic and Health Survey data -descriptive and multilevel regression analyses were conducted on four key elements of the continuum of care - at least one antenatal care visit, four or more antenatal care visits, delivery with a skilled birth attendant and postnatal checks for the mother within the first 24 hours since birth | —Results indicated that a major drop-out (more than 50%) occurs early on in the continuum of care between the first antenatal care visit and four or more antenatal care visits. Few women (less than 5%) who do not receive any antenatal care go on to have a skilled delivery or receive postnatal care |



## **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 Uganda.

## **Data Issues**

This study is based on annual MMR in Uganda 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                     | U                              |
|------------------------------|--------------------------------|
| 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                        | 0.003631                       |
| MSE                          | 34.989266                      |
| MAE                          | 3.800784                       |



## Residual Analysis for the Applied Model

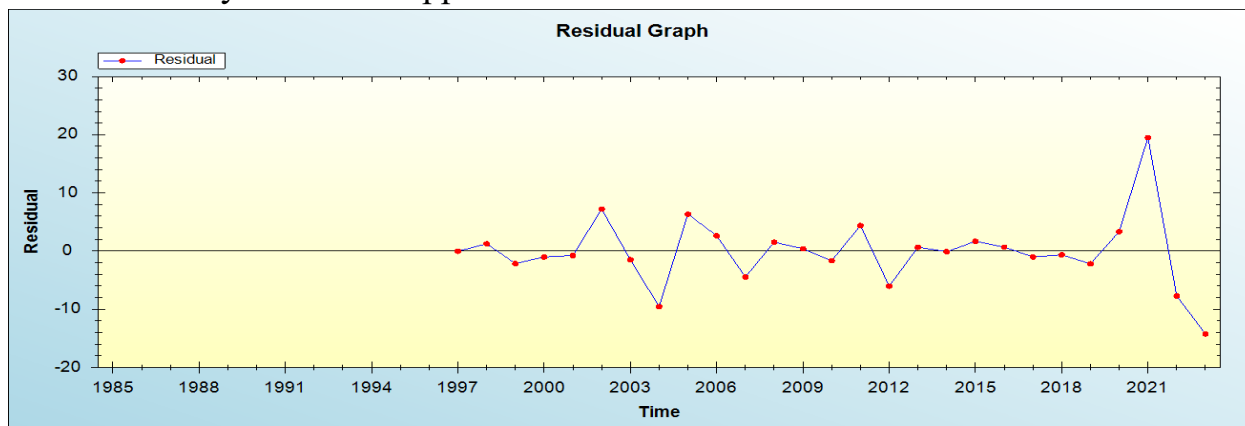


Figure 1: Residual analysis

## In-sample Forecast for U

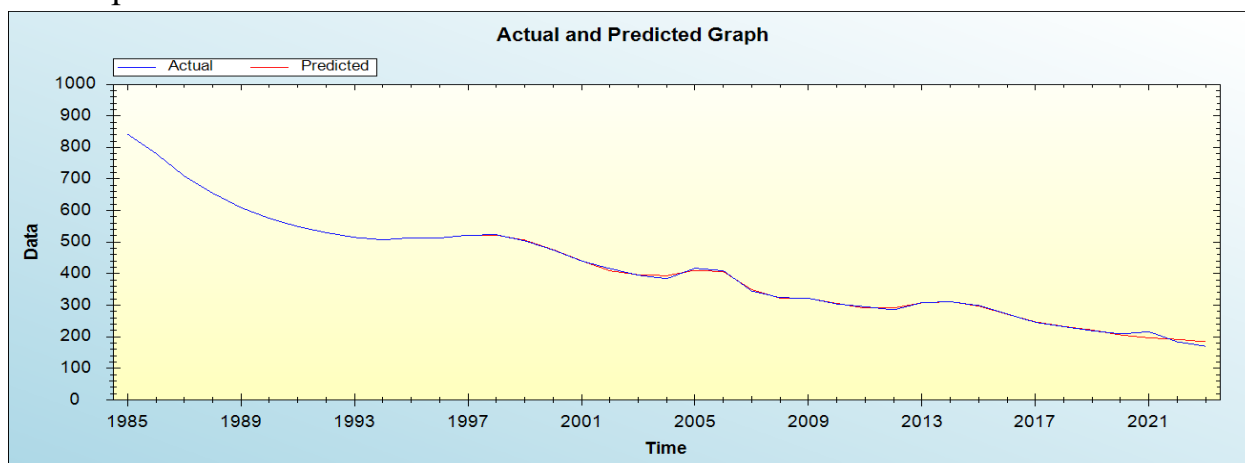


Figure 2: In-sample forecast for the U series

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

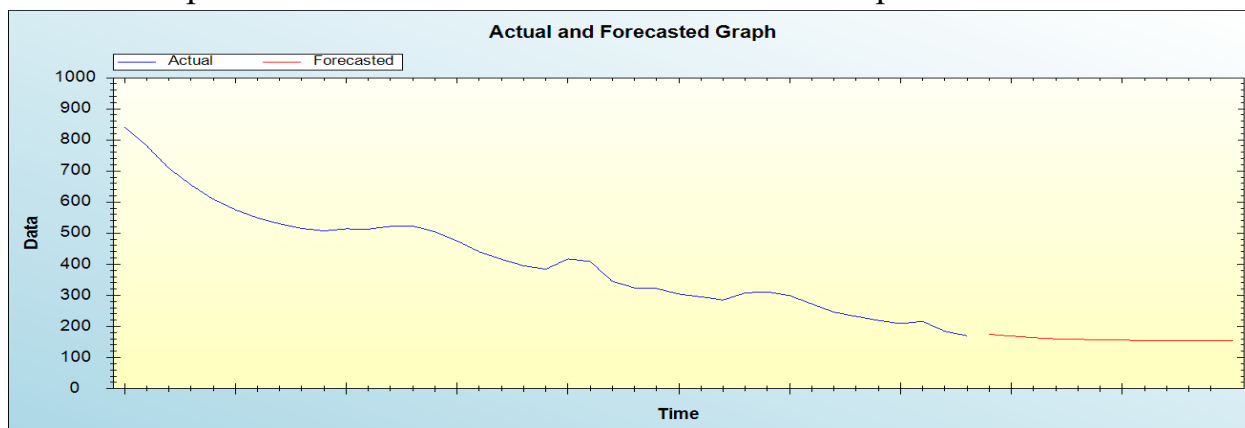


Figure 3: Out-of-sample forecast for U: actual and forecasted graph



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

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

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 174.4952       |
| 2025 | 168.9820       |
| 2026 | 163.5925       |
| 2027 | 159.9082       |
| 2028 | 158.3119       |
| 2029 | 157.1952       |
| 2030 | 155.6937       |
| 2031 | 154.7653       |
| 2032 | 154.0034       |
| 2033 | 153.5576       |
| 2034 | 153.3062       |
| 2035 | 153.0413       |

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 high over the out of sample period.

**Recommendations & Conclusion**

The burden of maternal mortality remains very high in Uganda. The majority of maternal deaths are due to potentially avoidable causes such as hemorrhage, hypertensive disorders, and sepsis. In this study we applied a machine learning technique to model and forecast MMR and findings indicate that MMR will remain high over the out of sample period. Therefore, we encourage health authorities to adopt the following policy prescription: (1) end teenage 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) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) establish posts for obstetricians at government district hospitals especially high volume sites so that



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specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

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