

ANNUAL MATERNAL MORTALITY RATE PREDICTION FOR MONGOLIA USING THE MULTILAYER PERCEPTRON

Smartson. P. NYONI¹,

Thabani NYONI²

¹Independent Researcher & Medical Doctor, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

ABSTRACT

This research article employs annual time series data on MMR for Mongolia 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 slightly above 40 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to address local factors associated with maternal mortality and direct resources towards quality improvement activities.

Keywords: ANN, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

Maternal mortality remains among the top health priorities especially in the developing world which bears the largest burden of preventable maternal deaths. The 3rd sustainable development goal target 3.1 focuses on reducing maternal mortality to levels below 70 deaths per 100 000 live births by 2030 (WHO, 2019, WHO, 2018). Mongolia implemented numerous initiatives targeting all the pillars of the maternal and child health program in the country such as the National Program 'Maternal, Child, and Reproductive Health 2017-2021'. As a result of this strategy, at the end of August 2019, the nationwide Maternal Mortality Ratio (MMR) had declined significantly from 48.6 per 100000 live births in 2016 to 21.2, lower than the target of 25. Neonatal mortality also dropped from the 2016 baseline of 9.2 per 1000 live births to 8.1 (the target is 8.5) (Health Indicators, 2019). Although Mongolia has witnessed a downward trend of maternal mortality it has increased in recent years. By the end of the third quarter of 2021, 68 mothers had died, and the maternal mortality rate had risen to 94.9 per 100000 live births, triple that of the same period of the previous year (Health indicators, 2022). Furthermore, COVID-19 epidemic partly contributed to the rise in maternal mortality. However, other factors such as the availability of human resources, workloads, insufficient policy implementation, poor quality of medical care, and lack of beds had an incremental effect on maternal mortality (Pappu et al. 2025; Adatara et al. 2021). The objective of this paper is to model and forecast MMR for Mongolia using the multilayer perceptron. The findings of this paper are expected to inform policy, planning and allocation of resources to the health sector in order to further reduce preventable maternal deaths across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
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
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
Tran et al. (2023)	To analyze of the state of maternal healthcare in Bayan-Ölgii, Mongolia including its strengths, weaknesses, and future considerations	descriptive single-case study	many potential interventions seem to lie at the community level in order to ensure the health and well-being of women in Bayan-Ölgii before and up to the time that they become pregnant
Chimed-Ochir et al. (2022)	to describe the leading causes of death and disabling conditions and their trends between 1990 and 2019 in the Mongolian population	used the data from the Global Burden of Disease (GBD) 2019 study	Although Mongolia saw substantial improvements across many communicable diseases, maternal and neonatal disorders, and under-5 mortality between 1990 and 2019, non-communicable diseases remained leading causes of mortality
Kabakchieva et al. (2022)	To investigate access-related barriers (availability, appropriateness, affordability, approachability, and acceptability) to maternity	cross-country study	Results show high rates of cesarean births (CB) and a low number of antenatal and postnatal care visits. Informal payments and use of personal connections are common practices

	care in Romania, Bulgaria, and Moldova		
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
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
Yadamsuren et al (2010)	To describe the declining trend in maternal mortality observed in Mongolia from 1992 to 2007 and its acceleration after 2001 following implementation of the Maternal Mortality Reduction Strategy by the Ministry of Health and other partners	Conducted a descriptive analysis of maternal mortality data collected through Mongolia's vital registration system and provided by the Mongolian Ministry of Health	Mongolia achieved a statistically significant annual decrease in its maternal mortality ratio of almost 10 deaths per 100 000 live births over the period 1992–2007. From 2001 to 2007, the maternal mortality ratio in Mongolia decreased approximately 47%, from 169 to 89.6 deaths per 100 000 live births

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 Mongolia.

Data Issues

This study is based on annual MMR in Mongolia 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	M
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	0.006901
MSE	14.896281
MAE	2.165498

Residual Analysis for the Applied Model

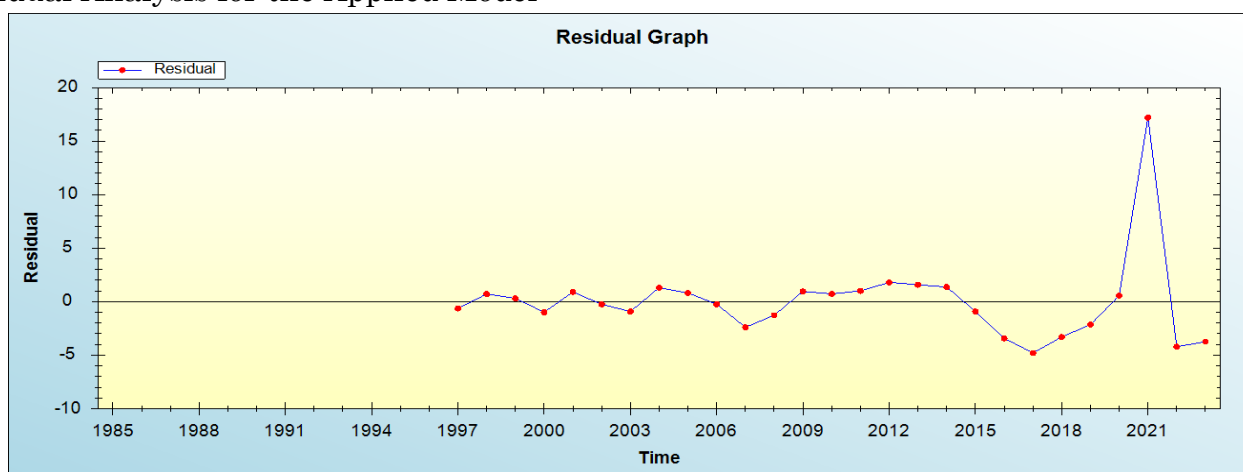


Figure 1: Residual analysis

In-sample Forecast for M

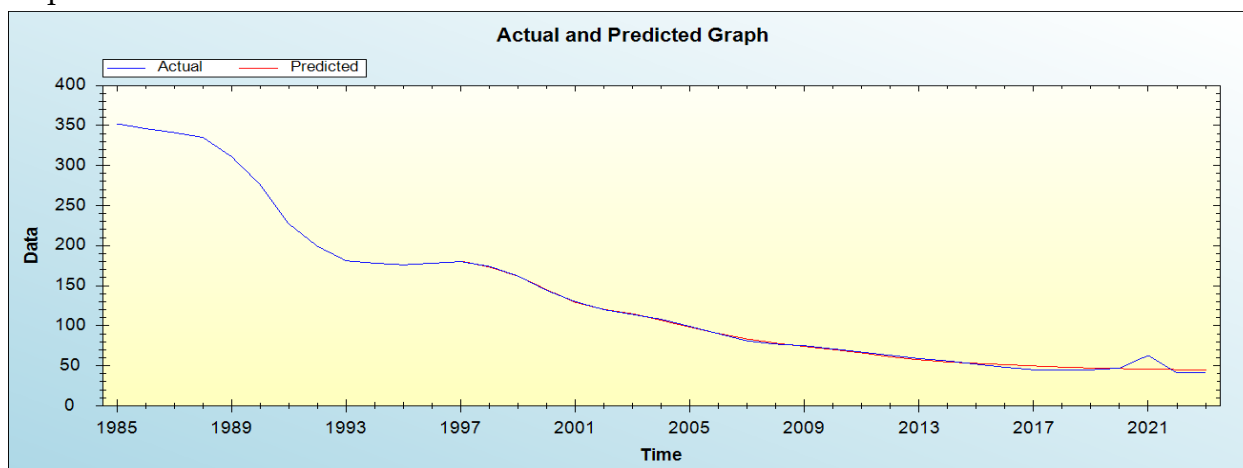


Figure 2: In-sample forecast for the M series

Out-of-Sample Forecast for M: Actual and Forecasted Graph

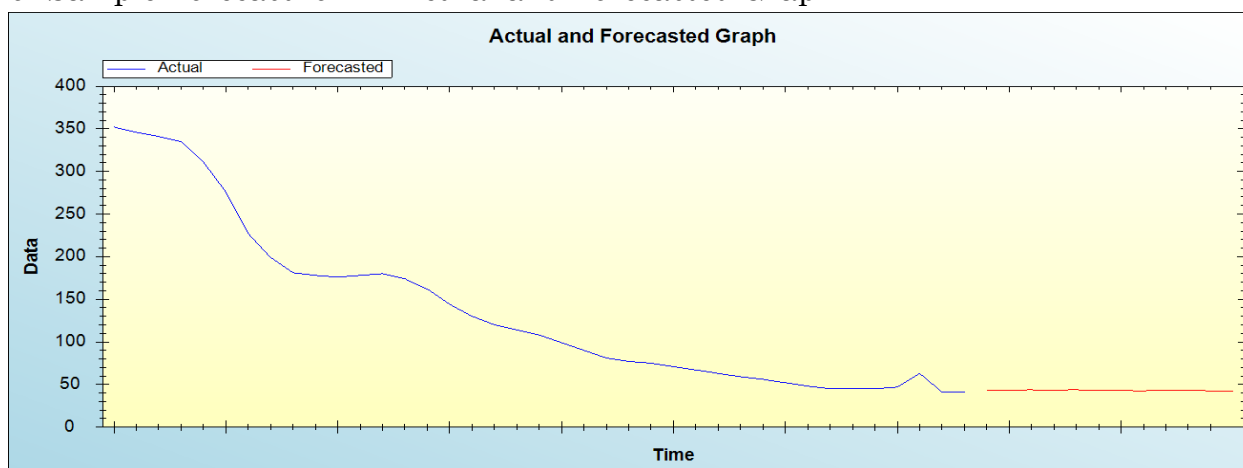


Figure 3: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	43.5096
2025	43.4147
2026	43.6962
2027	43.4726
2028	43.7596
2029	42.7229
2030	42.8344
2031	42.5672
2032	43.0979
2033	43.2384
2034	42.4785
2035	42.5264

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 slightly above 40 deaths per 100 000 live births over the out of sample period

RECOMMENDATIONS & CONCLUSION

Maternal mortality is still a challenge in Mongolia and this means that numerous gaps still exist in the continuum of care. This paper demonstrates the application of the multilayer perceptron neural network approach in forecasting MMR for Mongolia and results indicate that MMR is expected to remain slightly above 40 deaths per 100 000 live births over the out of sample period. Therefore, we encourage authorities to address local factors associated with maternal deaths and channel resources towards quality improvement initiatives.

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