



PROJECTION OF MATERNAL MORTALITY RATE FOR TAJIKISTAN USING THE MULTILAYER PERCEPTRON

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Abstract

This research article employs annual time series data on MMR for Tajikistan 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 hover around 18 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to tirelessly address main drivers of maternal mortality across the country.

Keywords: ANN, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal health is the health status of women during pregnancy, childbirth, and the post -partum period, which incorporates the health care dimension of family planning, preconception, and prenatal and postnatal care to reduce maternal morbidity and mortality (WHO, 2015). Then maternal death refers to death of a woman whilst pregnant or within 6 weeks of termination of pregnancy, regardless of the duration and the site of the pregnancy, from any causes related to or aggravated by the pregnancy or its management but not from accidental or incidental causes according to the World Health Organization (WHO, 2015). Most maternal deaths are recorded in low-middle countries. Approximately 830 women die every day globally as result of pregnancy-related causes, which can be avoided. The World Health Organization estimated that 303,000 women worldwide will have died by the end of 2015 during and following pregnancy and



childbirth. A recent World Health Organization report highlighted that maternal mortality has declined by 43% worldwide; however, maternal death is still high in sub-Saharan Africa and South Asia. The purpose of this study is to model and forecast MMR for Tajikistan using a machine learning technique. The findings of this paper will guide policy making, planning and allocation of adequate resources to the health sector in order to control preventable maternal mortality in this country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Kurvinen et al. (2026)	To examine the social determinants and timing of maternal deaths in Nepal to identify high-risk groups and inform targeted interventions	cross-sectional descriptive study	Maternal deaths were most frequent in Lumbini province, peri-urban and rural areas, and the Tarai region. Socioeconomic disparities were evident, with nearly half of maternal deaths occurring among women from poor households
Yusupova et al. (2026)	to evaluate the impact of a quality improvement (QI) initiative implemented in ten district hospitals from 2021 to 2024 to improve maternal, new born, and childcare to accelerate progress towards achieving the Sustainable Development Goals in Tajikistan	-A baseline assessment was conducted in 2021, with an endline assessment in 2023, using updated WHO quality assessment tools - A multidisciplinary team of national and international experts evaluated hospital performance across three domains: support systems, clinical management, and organization of care.	observed notable improvements in the quality of hospital care, with most facilities progressing from substandard to better-performing categories



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 8, August 2026

Website: usajournals.org

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Feng et al. (2025)	-to analyze trends (1990–2021) and projected (to 2050) MMR in Southeast Asia using the Global Burden of Disease (GBD) 2021 database and addressing gaps in regional granularity	-Data GBD 2021, covering MMR and age-standardized MMR (ASMR) for 1990–2021, stratified by country, age group, and cause -Trend assessment was conducted using the estimated annual percentage change (EAPC), while 30-year projections were generated via an autoregressive integrated moving average (ARIMA) model	The ASMR in Southeast Asia fell by 59%, dropping from 255.88 in 1990 to 104.56 per 100,000 live births by 2021. This decline was primarily driven by reduced rates of maternal hemorrhage and hypertensive disorders. Progress slowed during the 1997 Asian financial crisis yet picked up pace after 2000
Rai et al. (2025)	to examine the current burden of maternal and neonatal disorders in Nepal and to assess any changes over time	Researchers examined the annual Global Burden of Disease Study data on prevalence, deaths, Years Lived with Disability, and Disability-Adjusted Life Years for maternal and neonatal disorders in Nepal for the 1990-2019 period. Estimated annual percentage changes were also calculated to assess the trends of the age-standardized rates of these burden metrics	the prevalence of overall maternal disorder in Nepal decreased by 37% from 128,176 in 1990 to 80,724 in 2019 with Age-Standardized Ratio of 432.07 per 100,000 in 2019 and Estimated Annual Percentage Change of -4.34 (CI 95%: -4.49 to -4.18)
Shrestha et al. (2025)	to estimate the maternal mortality ratio and identify the	retrospective study	The maternal mortality ratio in the study was low in



	causes of maternal deaths using the WHO International Classification of Disease –Maternal Mortality (ICD-MM) tool		comparison to the national data
Eclarin et al. (2024)	to present maternal and perinatal health indicators for the years 2019–2022	This was a cross-sectional review that analyzed data on maternal and perinatal health indicators, generated from submissions of POGS-accredited hospitals (training and service) from January 2019 to December 2022.	The top three-most common indications for primary CS were dysfunctional labor, fetal distress, and malpresentation. Stillbirth, perinatal, and maternal mortality rates showed an increase from 2019 to 2022, with peak rates registered for the year 2021. The top five causes of maternal death are: medical complications, hemorrhage, hypertension, infection, and others (unspecified). The case fatality rate among pregnant patients with confirmed COVID-19 infection was 1.18%
Galabay et al. (2024)	to explore the determinants of maternal mortality in Cagayan Valley, Philippines, for the past five years	The researchers used a convergent parallel mixed-methods research design	Significant findings reveal that most maternal mortality cases were considered high-risk pregnancies and highly associated with the three-delay model validated through the qualitative results
Kwee et al. (2024)	To evaluate the impact of healthcare access on maternal and child mortality rates in the rural region of Kayin State, Myanmar, where disparities in	cross-sectional study design	The findings reveal alarming maternal mortality rates of 250 per 100,000 live births and child mortality rates of 80 per 1,000 live births in rural areas, compared to urban counterparts. Major



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	healthcare services significantly affect vulnerable populations		barriers identified include geographic isolation, economic challenges, and cultural factors limiting healthcare utilization
Phan et al. (2024)	To examine the association between health insurance coverage and antenatal care (ANC) visits during pregnancy	The study 19 utilized data from the 2021-22 Cambodia Demographic and Health Surveys (CDHS). A total of 20 3,162 weighted women who gave birth within two years were included in the analysis. Multiple logistic regression analysis assessed the association between health insurance coverage and pregnant women who attended at least four antenatal care visits during pregnancy	Having health insurance coverage was significantly associated with four or more 31 ANC visits
Win et al. (2024)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Low utilization rates were due to several supply-side constraints
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-seeking practices, timing, and place of deaths	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative sample of 298 284 households	Nineteen per cent of the maternal deaths occurred at home, another 19% in-transit, almost half (49%) in a public facility, and 13% in a private hospital. Hemorrhage contributed to 31% and eclampsia to 23% of the maternal deaths. Twenty-one per cent of the maternal



		-adapted the World Health Organization's 2014 verbal autopsy (VA) questionnaire. Trained physicians reviewed the responses and assigned the cause of death based on the International Classification of Diseases (ICD-10)	deaths occurred due to indirect causes
Jabeen et al. (2023)	To examine the current levels, trends, time of death, and care-seeking practices for hemorrhage-related maternal deaths in Bangladesh	-conducted a secondary analysis with data from the nationally representative 2001, 2010, and 2016 Bangladesh Maternal Mortality Surveys (BMMS) -The cause of death information was collected through verbal autopsy (VA) interviews using a country-adapted version of the standard World Health Organization VA questionnaire	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh
Win et al. (2023)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Poor family income, illiteracy, low education levels, living in poor households, and agricultural and unskilled manual job types of mothers contributed to insufficient antenatal care



Lwin et al. (2022)	To examine factors influencing institutional maternity service utilization and identified the need for improved maternal health outcomes	cross-sectional study design	A greater number of ANC visits and level of the couple's education had a positive association with institutional delivery
Singh et al. (2022)	to inform on potential options for measuring maternal mortality	Applied a case study approach to compare methodologies and estimates of pregnancy-related mortality ratio (PRMR)/maternal mortality ratio (MMR) obtained from four different data sources from similar time periods in Bangladesh, Mozambique, and Bolivia—national population census; post-census mortality survey; household sample survey; and sample vital registration system (SVRS)	For Bangladesh, PRMR from the 2011 census falls closely in line with the 2010 household survey and SVRS estimates, while SVRS' MMR estimates are closer to the PRMR estimates obtained from the household survey. Mozambique's PRMR from household survey method is comparable and shows an upward trend between 1994 and 2011, whereas the post-census mortality survey estimated a higher MMR for 2007. Bolivia's DHS and post-census mortality survey also estimated comparable MMR during 1998–2003
Chham et al. (2021)	to explore the coverage level of the Optimal CoC by (1) measuring the continuity of optimal antenatal care (ANC), skilled birth attendance (SBA) and optimal post-natal care (PNC), (2) identifying the determinants of drop ping out from one service to another and	The study employed data from the Cambodia Demographic Health Survey 2014. We restricted our analysis to married women who had a live birth in the five years preceding the survey (n = 5678). Bi-variate and multivariate	Household wealth was found to be the most influential factor, yet the study discovered also other barriers to optimal maternal health care which need to be addressed



	(3) of not achieving the complete CoC	logistic regression were performed using STATA version 14	
Khachuraeva & Akhmadova (2020)	To present a comparative analysis of the dynamics of maternal mortality (MM) and its structure in the Russian Federation and the Chechen Republic for the period 2010–2017	Comparative analytical study	In the Russian Federation for the period 2010–2017, there was a persistent decrease in maternal mortality by 6.7 %. While in 2010, the maternal mortality rate in the RF was 16.5 %, the indicator in 2017 was 9.8 %. It turned out that the maternal mortality rate in the Chechen Republic for the period from 2010 to 2017 tends to decrease by 32.6 %, but this indicator exceeds the average statistical indicator of maternal mortality in the RF (6.7 %)
Akhter, & Alam. (2019)	-to present the trends of maternal and neonatal mortality - to explain the maternal and neonatal mortality rate by background characteristics and the causes of maternal and neonatal deaths in Bangladesh on the basis of South Asian perspective	The main source of data collection and analysis was the secondary sources, from different journals and project reports published between the years 2001 to May 2018	In Bangladesh, 35% maternal deaths occurred as indirect causes and 9% causes of deaths are still remaining unidentified. hemorrhage (31%) and pre-eclampsia-eclampsia (20%) are found two vital causes of maternal deaths with two more causes which are due to obstructed labor (7%), and termination of pregnancy (1%)
Yamashita et al. (2017)	to examine the current utilization of healthcare services and the effects on the health of women in the Philippines who delivered at home	This was a cross-sectional analytical study, based on a self-administrated questionnaire, conducted from March 2015 to February 2016 in	There were significant differences in the type of birth attendant, area of residence, monthly income, and maternal and child health book usage between women who delivered at home and those who delivered at a facility (P,0.01)



		Muntinlupa, Philippines	
Natalia et al. (2006)	To study the levels and causes of maternal mortality in St. Petersburg, Russian Federation	Researchers collected data about all pregnancy-related deaths in St. Petersburg over the period 1992–2003 using several sources of information. An independent research group reviewed and classified all cases according to ICD-10 and the Confidential Enquiries into Maternal Deaths in the United Kingdom. We tested trends of overall and cause specific ratios (deaths per 100 000 births) for four 3-year intervals using the χ^2 test	The maternal mortality ratio for the study period was 43 per 100 000 live births. A sharp decline of direct obstetric deaths was observed from the first to fourth 3-year interval (49.8 for 1992–94 versus 18.5 for 2001–03). Sepsis and hemorrhage were the main causes of direct obstetric deaths. Among the total deaths from sepsis, 63.8% were due to abortion

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 Tajikistan.



Data Issues

This study is based on annual MMR in Tajikistan 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	T
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	0.034184
MSE	5.301553
MAE	1.254981

Residual Analysis for the Applied Model

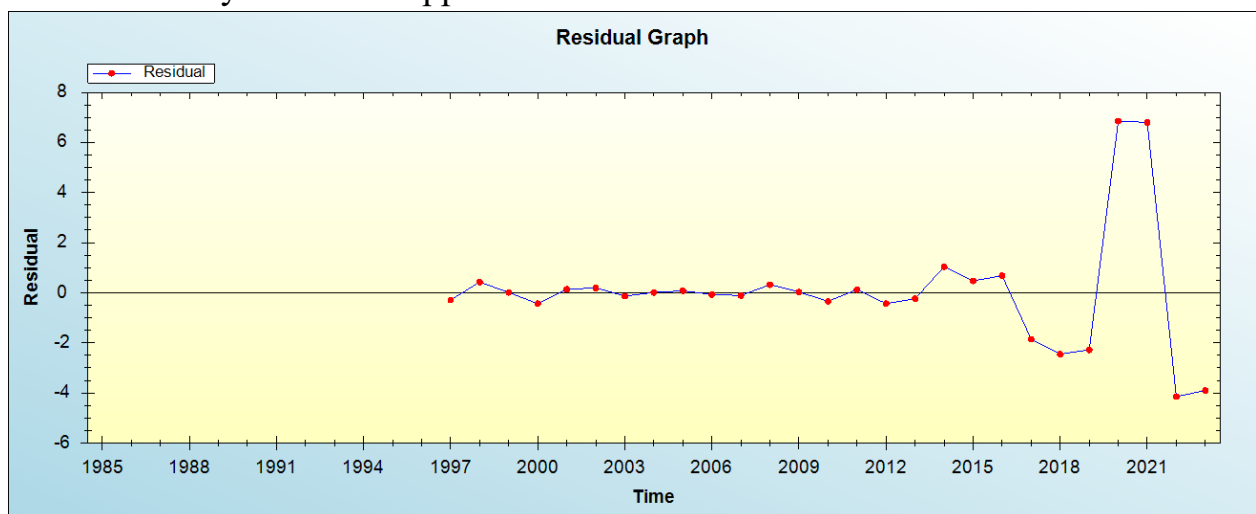


Figure 1: Residual analysis



In-sample Forecast for T

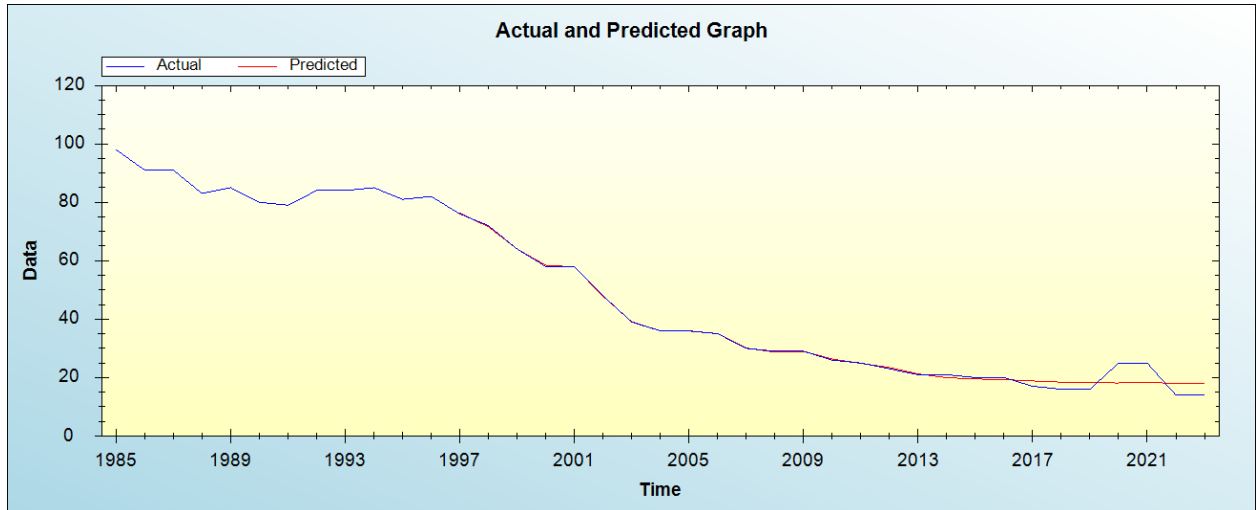


Figure 2: In-sample forecast for the T series

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

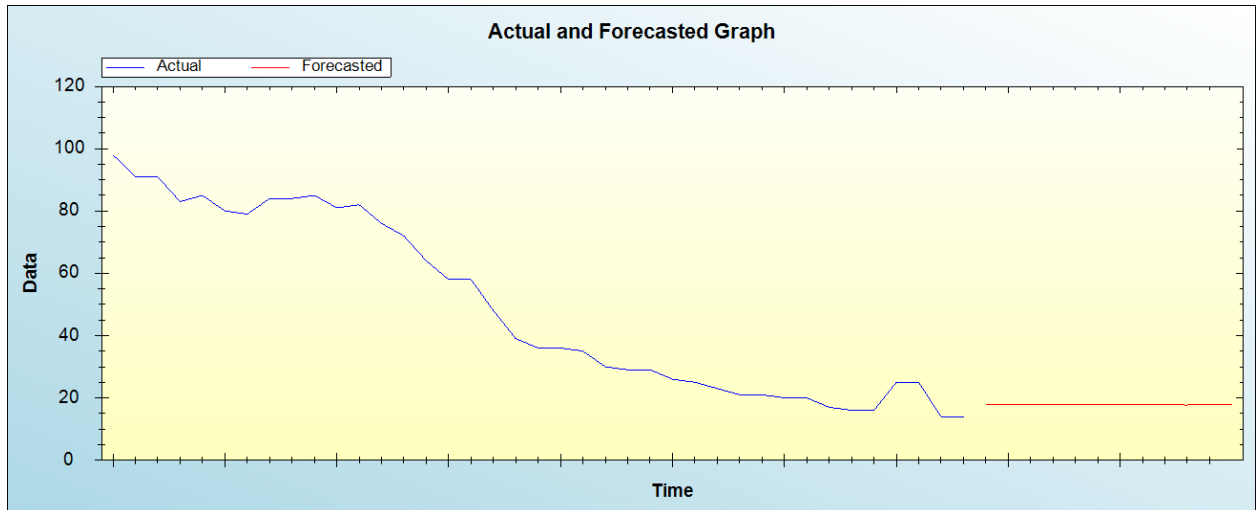


Figure 3: Out-of-sample forecast for T: actual and forecasted graph



Out-of-Sample Forecast for T: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	17.7427
2025	17.8888
2026	17.9957
2027	17.8933
2028	17.7602
2029	17.7417
2030	17.7768
2031	17.9528
2032	17.8314
2033	17.7078
2034	17.7272
2035	17.7726

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 hover around 18 deaths per 100 000 live births throughout the out of sample period.

Conclusion

This study used a machine learning technique to model and forecast MMR for Tajikistan and findings indicate that MMR will hover around 18 deaths per 100 000 live births throughout the out of sample period. Hence, we implore health authorities to direct resources towards addressing local causes of maternal deaths.

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Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 8, August 2026

Website: usajournals.org

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