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UTILIZING THE MULTILAYER PERCEPTRON PROJECTIONS TO INFORM MATERNAL HEALTH INTERVENTIONS IN RUSSIA

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Abstract
This research article employs annual time series data on MMR for Russia 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 13.7 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to address major drivers of preventable maternal mortality across the country.

Keyword(s): - ANN, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality ratio (MMR) is a statistical indicator of the reproductive and somatic health of the female population. MMR reflects not only the quality of obstetric and gynecological care during pregnancy, childbirth, the postpartum period, the adequacy of medical care in life-threatening situations in this category of women, but is also a criterion for assessing the effectiveness of the functioning of the health care system on a global scale (Khachuraeva & Akhmadova, 2020). In addition, MMR has not only medical, but social and economic significance. The indicator reveals the population outcome, all aspects of the country's social life, and most importantly the level of adequacy and efficiency of the health care system (Kulakov, 2014). In the Russian Federation (RF) 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 %. The leading causes of maternal mortality are complications of pregnancy namely severe extragenital pathology, bleeding, gestosis and amniotic fluid embolism (Khachuraeva & Akhmadova, 2020). This research paper models and forecasts MMR for the Russian Federation using a machine learning technique. The results of the study will inform crafting and implementation of maternal and child health policies so as to further reduce avoidable maternal deaths in the 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	cross-sectional descriptive study	Maternal deaths were most frequent in Lumbini province, peri-urban and rural areas, and the Tarai

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	high-risk groups and inform targeted interventions		region. Socioeconomic disparities were evident, with nearly half of maternal deaths occurring among women from poor households
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	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)

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		rates of these burden metrics	
Shrestha et al. (2025)	to estimate the maternal mortality ratio and identify the causes of maternal deaths using the WHO International Classification of Disease –Maternal Mortality (ICD-MM) tool	retrospective study	The maternal mortality ratio in the study was low in 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,	The researchers used a convergent parallel	Significant findings reveal that most maternal mortality cases were

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	Philippines, for the past five years	mixed-methods research design	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 healthcare services significantly affect vulnerable populations	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 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

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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 -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)	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 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	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh

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		version of the standard World Health Organization VA questionnaire	
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	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

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		registration system (SVRS)	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 (3) of not achieving the complete CoC	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 logistic regression were performed using STATA version 14	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
Sitaula et al. (2021)	to determine the MMR and identify the various risk factors and causes of maternal mortality	retrospective study	Despite the availability of comprehensive emergency obstetric care at our center, maternal mortality is still high and almost 75% of deaths were avoidable. The leading contributory factors of maternal mortality are delay in seeking care and delayed referral from other health facilities
Khachuraeva & Akhmadova (2020)	To present a comparative analysis of the dynamics of	Comparative analytical study	In the Russian Federation for the period 2010–2017,

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	maternal mortality (MM) and its structure in the Russian Federation and the Chechen Republic 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 ma ternal 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	This was a cross-sectional analytical study, based on a self-administrated questionnaire,	There were significant differences in the type of birth attendant, area of

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	the Philippines who delivered at home	conducted from March 2015 to February 2016 in Muntinlupa, Philippines	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)
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 c^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 Russia.

Data Issues

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This study is based on annual MMR in Russia 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	0.036044
MSE	4.469893
MAE	1.283871

Residual Analysis for the Applied Model

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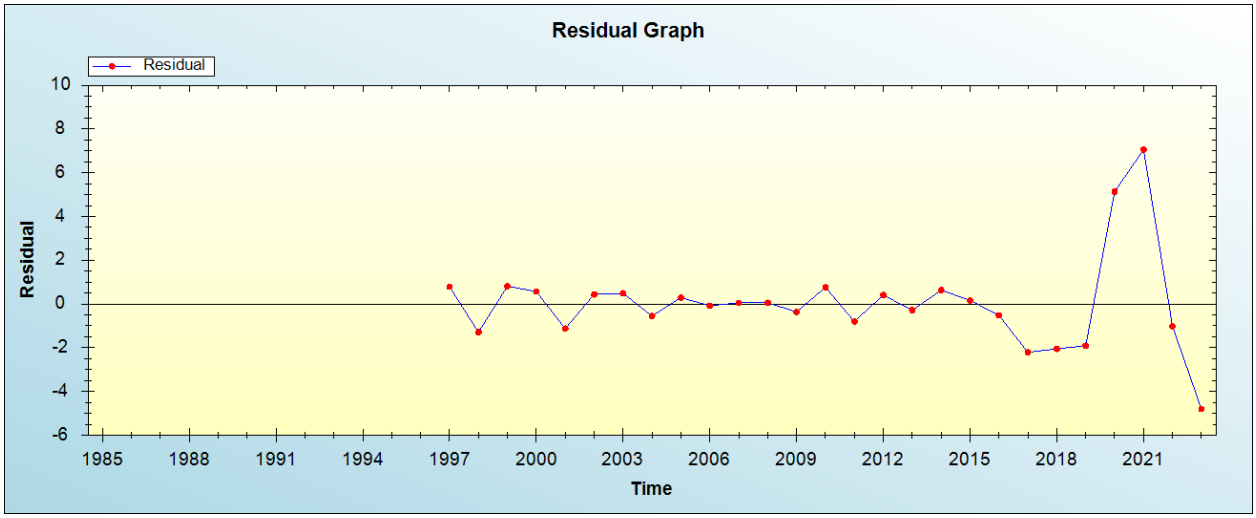


Figure 1: Residual analysis

In-sample Forecast for R

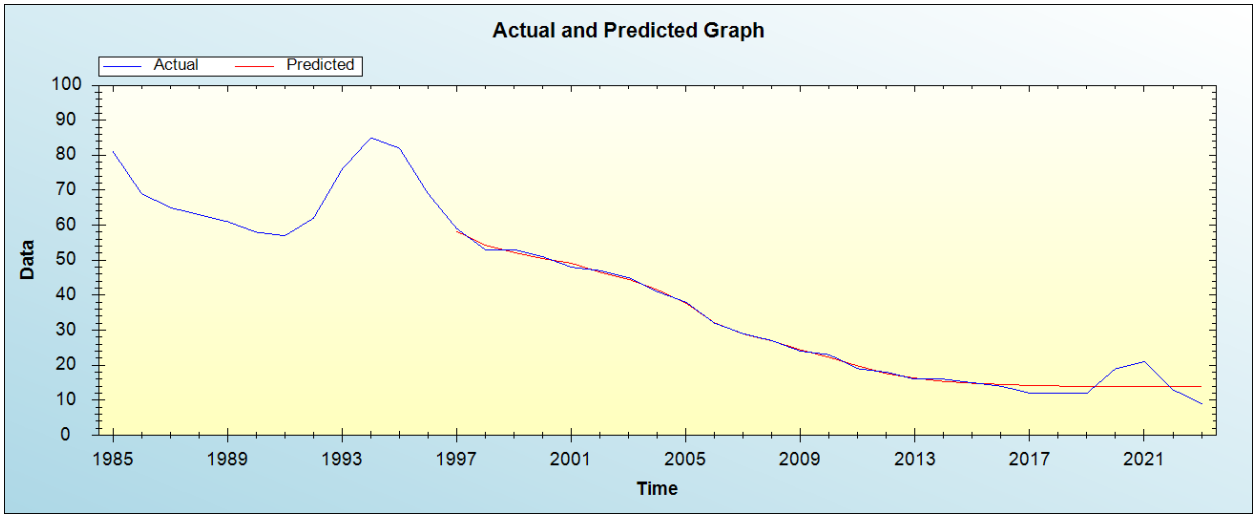


Figure 2: In-sample forecast for the R series

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

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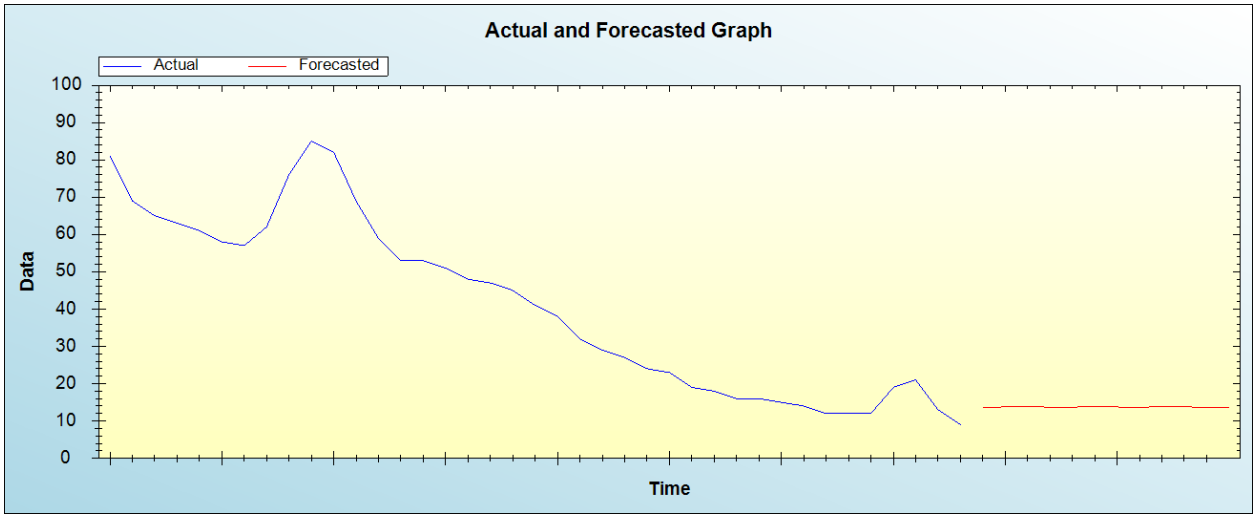


Figure 3: Out-of-sample forecast for R: actual and forecasted graph

Out-of-Sample Forecast for R: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	13.6719
2025	13.7407
2026	13.8251
2027	13.7128
2028	13.7114
2029	13.7936
2030	13.7485
2031	13.6977
2032	13.7790
2033	13.7523
2034	13.7123
2035	13.7176

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.

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It is projected that annual MMR will hover around 13.7 deaths per 100 000 live births over the out of sample period.

Conclusion

Maternal mortality is generally very low in the Russian Federation. The leading causes of maternal mortality are complications of pregnancy namely severe extragenital pathology, bleeding, gestosis and amniotic fluid embolism. In this study we utilized the multilayer perceptron technique to forecast MMR and findings indicate that MMR will hover around 13.7 deaths per 100 000 live births throughout the forecast period. Hence, authorities are encouraged to relentlessly address major drivers of maternal deaths across the country.

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