



PREDICTION OF MATERNAL MORTALITY FOR COLOMBIA USING THE MULTILAYER PERCEPTRON

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Article history:		Abstract:
Received:	7 th May 2026	<i>This research article employs annual time series data on MMR for Colombia 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 fluctuate between 54 to 126 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to address local causes of maternal mortality and direct resources towards quality improvement initiatives.</i>
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INTRODUCTION

Nearly 800 pregnant women die every day globally, with a predominant burden observed in low- and middle-income countries (WHO, 2023). The main causes include severe hemorrhage, infections, and hypertensive disorders (PAHO, 2023). The majority of these complications are preventable or manageable. Timely identification of both individual and population-level risk factors, including consistent health care throughout pregnancy and access to essential services that promote wellbeing, can make a huge difference (Kurjak et al. 2023; Alper et al. 2021). Maternal mortality is an important public problem because of its serious societal, community, and familial consequences (UN, 2016). In Colombia, there has been an increase in maternal mortality since 2013 (Ramos Lafont & Montenegro Martínez, 2023). Hypertensive disorders have emerged as leading causes, followed by hemorrhage, sepsis, and thromboembolic events. Regions with a higher prevalence of unsatisfied basic needs have demonstrated higher maternal mortality rates (Montenegro-Martínez & Asprilla-Cordoba, 2022). These trends also vary among pregnant women based on their educational achievement and type of health insurance coverage (INSD, 2017). During the COVID 19 pandemic maternal mortality rose sharply country wide (Castañeda-Orjuela et al. 2023).

The purpose of this study is to model and project MMR for Colombia using the multilayer perceptron. The findings of this piece of work are envisioned to inform policy and allocation of resources to the health sector. This will help in reducing maternal mortality further.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Key finding(s)
Cuestas et al. (2026)	To analyze whether the proportion of Indigenous and Afro-Colombian populations at the municipality level (admin level 3) is associated with high levels of maternal mortality rates in Colombia between 2017 and 2020	Ecological study	-Maternal mortality rates increased between 2017 and 2020, and the increase was concentrated in municipalities in remote areas -municipalities with a higher proportion of Indigenous and Afro-Colombian populations have higher probabilities of presenting high rates of maternal mortality, and



			when these populations are living in rural areas, maternal mortality increases even more
Mackin et al. (2026)	to understand how levels of MNH care are organized in different country contexts	Scoping review	Three or four levels of MNH facility care were most commonly reported. Linking maternal and newborn facility care to community connections is an important consideration to ensure equitable access to routine and emergency care
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 weight change may help identify women at higher risk of subsequent metabolic abnormalities, particularly dysglycemia, in this high-risk population, although causal relationships cannot be inferred from this observational study
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic literature review	This review offers a thorough overview of the current evidence linking SLE, SS and APS to pregnancy and assisted reproductive outcomes. It identifies existing gaps and proposes future research directions
Cruz-Barbosa et al. (2025)	To describe the sociodemographic and anatomopathological characteristics associated with autopsy-verified maternal mortality cases at a Level-4 hospital in southwestern Colombia (2000–2023)	Descriptive retrospective study	The analysis of 42 autopsies (2000–2023) showed that 85.7% were early maternal deaths. Indirect causes predominated (57.1%, n = 24) over direct (42.9%, n = 18). Septic shock was the main indirect cause (65.2% of indirect), often from endemic infections.



			Hypovolemic shock due to PPH was the main direct cause (50% of direct). A high proportion were from subsidized/uninsured schemes (65.7%) and had a migratory history (20%)
Cresswell et al. (2025)	To obtain updated evidence on causes of maternal death is needed to accelerate progress	Systematic review	Globally, the most common cause of maternal death was hemorrhage (27%; 80% uncertainty interval 22–32), followed by indirect obstetric deaths (23%, 18–30), and hypertensive disorders (16%, 14–19). The proportion of hemorrhage deaths varied substantially by region and was highest in sub-Saharan Africa and Western Asia and Northern Africa.
Goicochea et al. (2025)	to identify and analyze maternal complications associated with adolescent pregnancy, with a particular focus on the Latin American context	Mixed approach methods	adolescent pregnancy in Latin America and the Caribbean entails significant medical risks and negatively affects the integral development of adolescents, a situation that is aggravated by the lack of access to health services, education and by factors such as poverty
Quiroz-Acuña et al. (2025)	To assess maternal mortality trends in LAC women from 1997 to 2019, providing key insights to address this issue.	ecological observational time-series study	Despite overall progress, regional differences in maternal mortality persist across Latin America and the Caribbean. These variations highlight the importance of strengthening maternal health systems, improving access to



			skilled birth attendance, and ensuring quality prenatal and postnatal care
Silvana et al. (2025)	To describe the factors influencing the reduction of maternal mortality during the 2022–2024 management period at Tartagal Hospital (HT)	Participatory Action Research (PAR) with a qualitative-quantitative analysis. Twelve meetings and interviews were conducted with the healthcare team, along with 10 validated surveys administered to obstetric inpatients (10/12/24), and an analysis of hospital databases	intercultural, comprehensive, and territory-based management of pregnancy and childbirth led to a reduction in maternal mortality beginning in 2022. Teamwork and intersectoral collaboration optimized available resources, consolidating a sustainable and effective model for maternal health. However, the greatest challenge lies in maintaining and increasing funding to ensure the continuity of this policy
Salazar Flórez et al. (2025)	to examine the trends in maternal mortality in Colombia and its social disparities based on the area of residence from 2014 to 2021	Ecological study	Maternal mortality rates have increased in recent years, with a more pronounced rise in remote rural areas than in settlements and municipal centers
Nigenda and Serván-Mori (2024)	To discuss the relationship between the availability of human resources for health and the maternal mortality ratio for the period 1990–2021 in Latin America	used secondary data from a global source to show patterns in the relationship between these two aspects and identify gaps in the Latin American and Caribbean regions	Although variations in maternal mortality rate cannot be explained solely through the provision of health personnel, it is important to consider that it is critical to find new modalities on how human resources for health could integrate and create synergies with other resources to increase systems capacity to deliver care according to conditions in each country



Castañeda- Orjuela et al. (2023)	to examine changes in maternal mortality and identify correlates and predictors of excess maternal mortality in Colombia during the pandemic	Analysis of data from the national epidemiological surveillance databases of Colombia (Sivigila)	The COVID- 19 pandemic had considerable impact on maternal health, not only by leading to increased deaths, but also by increasing social health inequity
Rodríguez Hernández et al. (2023)	to analyze the inequalities and inequities in Maternal Mortality (MM) for Chocó (Colombia) between 2010–2018	Mixed method study	The Maternal Mortality Ratio was 224/100 000 live births. The Gini coefficient was 0.35, indicating inequality in the distribution of the number of MM with respect to live births
Critto et al. (2022)	To examine the effects of a pandemic influenza virus on cause-specific maternal mortality time series, using Argentinian vital statistics	-conducted a population-based natural experiment from national vital records of maternal deaths between 1980 and 2017 -applied Join-point regression models	Over this 38-year study, the MMR decreased by 58.6% (69.5 to 28.8 deaths/100,000 live births), transitioning from direct obstetric causes (67.0 to 21.1/100,000 live births; 68.4% decrease) to indirect causes (2.6 to 7.7/ 100,000 live births; 196.2% increase)
Sing 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
Marin et al. (2021)	To describe the epidemiology of NCDs and maternal and child health needs in Venezuelan migrants in major South American host countries	Scoping review	the rate of chronic disease among Venezuelan migrants to range from 9–14% within countries who reported this data. Significant rates of psychiatric conditions such as depression and post-traumatic stress disorder were reported. Other conditions described were ophthalmologic diseases, diabetes, chronic pain, asthma, cough, dyslipidemia and hypertension among others

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 Colombia.

DATA ISSUES

This study is based on annual MMR in Colombia 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

ANN Model Summary

Table 1: ANN model summary

Variable	C
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	0.058088
MSE	7.240675
MAE	1.363219

Residual Analysis for the Applied Model

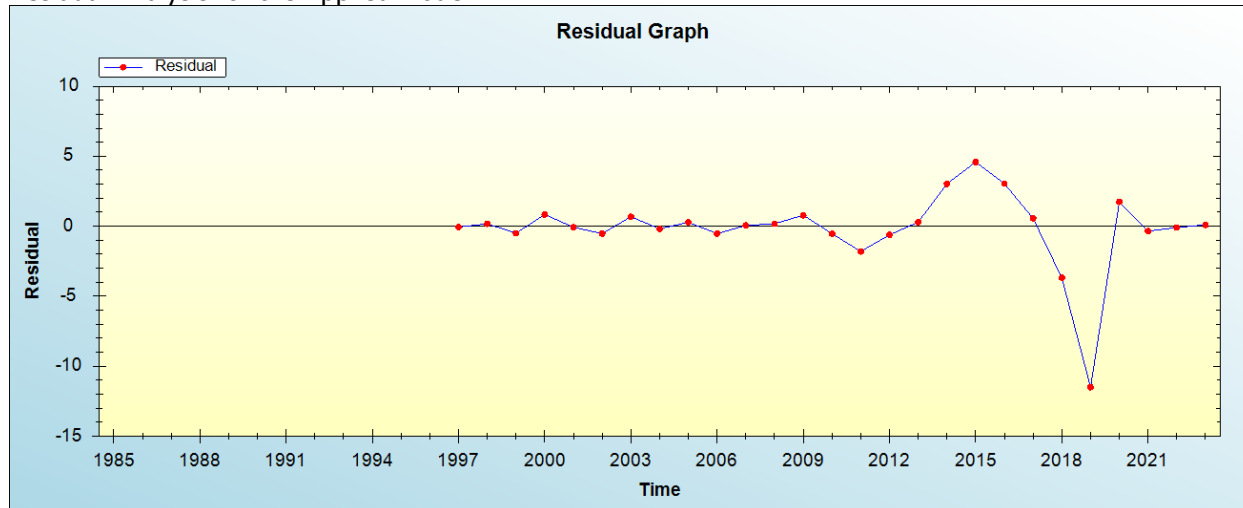


Figure 1: Residual analysis

In-sample Forecast for C

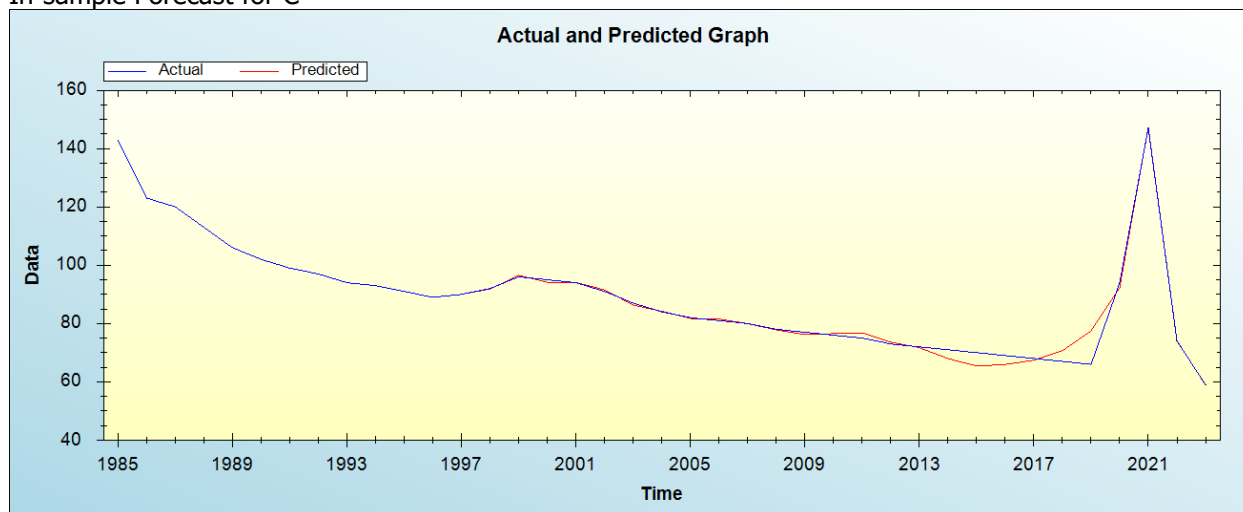


Figure 2: In-sample forecast for the C series

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

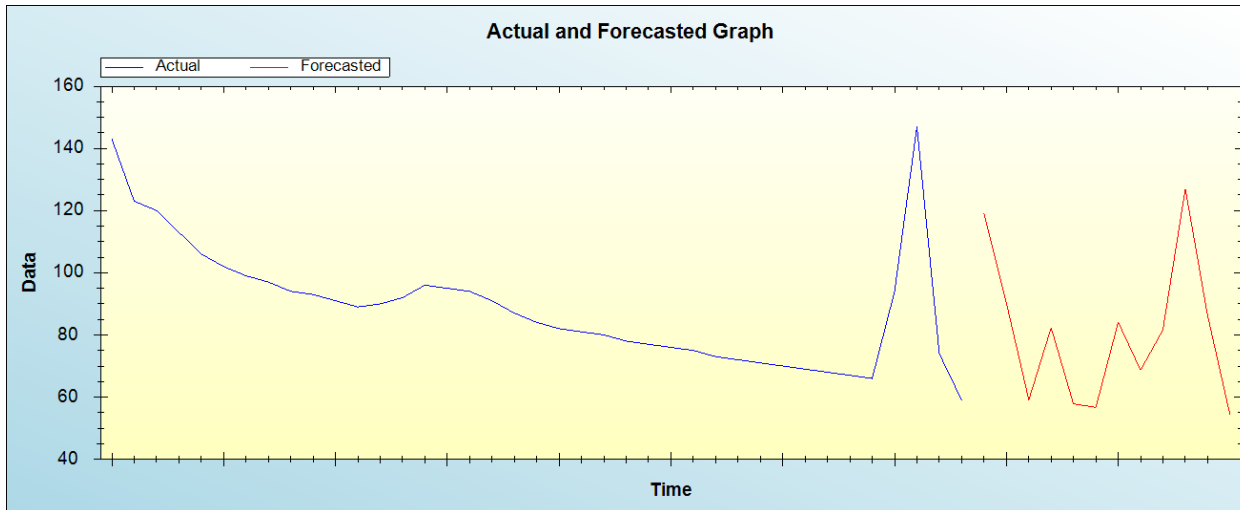


Figure 3: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	119.1468
2025	90.3041
2026	59.1127
2027	82.3234
2028	57.7932
2029	56.7028
2030	84.0973
2031	68.6629
2032	81.6551
2033	126.9626
2034	86.1416
2035	54.2652

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 be fluctuating between 54 to 126 deaths per 100 000 live births over the out of sample period.

RECOMMENDATIONS & CONCLUSION

This paper applies the multilayer perceptron to forecast MMR for Colombia and results indicate that MMR will fluctuate between 54 to 126 deaths per 100 000 live births over the out of sample period. Therefore, we implore health authorities to address local causes of maternal mortality and focus on quality improvement activities.

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