



DETERMINATION OF FUTURE VALUES OF MATERNAL MORTALITY RATE FOR NORWAY USING A MACHINE LEARNING APPROACH

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Abstract

This research article employs annual time series data on MMR for Norway 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 very low throughout the out of sample period. Therefore, we encourage the government to address local drivers of maternal mortality.

Keywords: ANN, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality remains a global health issue of concern due to the negative impact it has on the remaining children, family and community (Geetika et al. 2015). Approximately 80% are as a result of causes directly related to pregnancy (Kwale et al. 2005). The World Health Organization (WHO) statistics indicate that more than a quarter million women die worldwide because of complications during childbirth or pregnancy (WHO, 2014), with the majority of these deaths occurring in developing countries. For every woman who dies from obstetric complications, many more face injuries, disabilities and infections (WHO, 2010). Most of these deaths and complications could be prevented if all women gave birth with the assistance of skilled midwives (Khanal et al. 2015). The purpose of antenatal care is to improve and monitor the welfare of both mother and fetus, identify potential problems, prepare women for childbirth and child rearing and respond to their complaints (WHO, 2009). Norway has one of the world's lowest



maternal and perinatal mortality rates. Cesarean section and operative vaginal delivery rates remain stable, even as induction rates have doubled from 2009 to 2023. These outcomes reflect a high- quality maternity care system (FHI, 2024). The objective of this paper is to model and forecast future trends of MMR for Norway using a machine learning approach. The results will inform policy, planning and allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
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
Arshad et al. (2024)	to assess associations between pregnancy complications and pregnancy- associated maternal mortality (PAM) within 1 year after childbirth in Norway	-Population- based cohort study -applied logistic regression	Complications in the last pregnancy were more strongly associated with PAM than those in the first pregnancy
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



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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
Wilhelm et al. (2024)	To describe the contribution of CA to NMR in Malta, investigating possible associations with known maternal risk factors of maternal age, nationality, and education	-Anonymous data for births and neonatal deaths were obtained for 2006–2020 from the National Obstetrics Information System (NOIS) in Malta -applied regression analysis	Between 2006 and 2020, Malta's NMR remained stable. Maternal Nationality, from non-EU low-income countries, was associated with higher neonatal mortality
Zaigham et al. (2024)	to compare trends in the quality of maternal and neonatal care (QMNC) in Sweden and Norway to 12 other countries from the WHO European Region during the COVID-19 pandemic, and to identify domains for improvement	cross-sectional study	Across Europe, there are significant gaps in the quality of maternal-neonatal healthcare services. Although women giving birth in Sweden and Norway reported higher QMNC scores in all subdomains except for “reorganizational changes due to COVID-19,” there is room for improvement and shared learning across Europe
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



Johansen et al. (2017)	to determine how serious adverse events in obstetrics were assessed by supervision authorities in Norway	Researchers selected cases investigated by supervision authorities during 2009- 2013. We analyzed information about who reported the event, the outcomes of the mother and infant, and whether events resulted from errors at the individual or system level	The supervision authorities investigated 1 in 1000 births, mainly in response to complaints issued from patients or relatives. System errors were the most common cause of deficiencies in maternity care
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

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 Norway.

Data Issues

This study is based on annual MMR in Norway 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	0.075055
MSE	0.099242
MAE	0.197636

Residual Analysis for the Applied Model

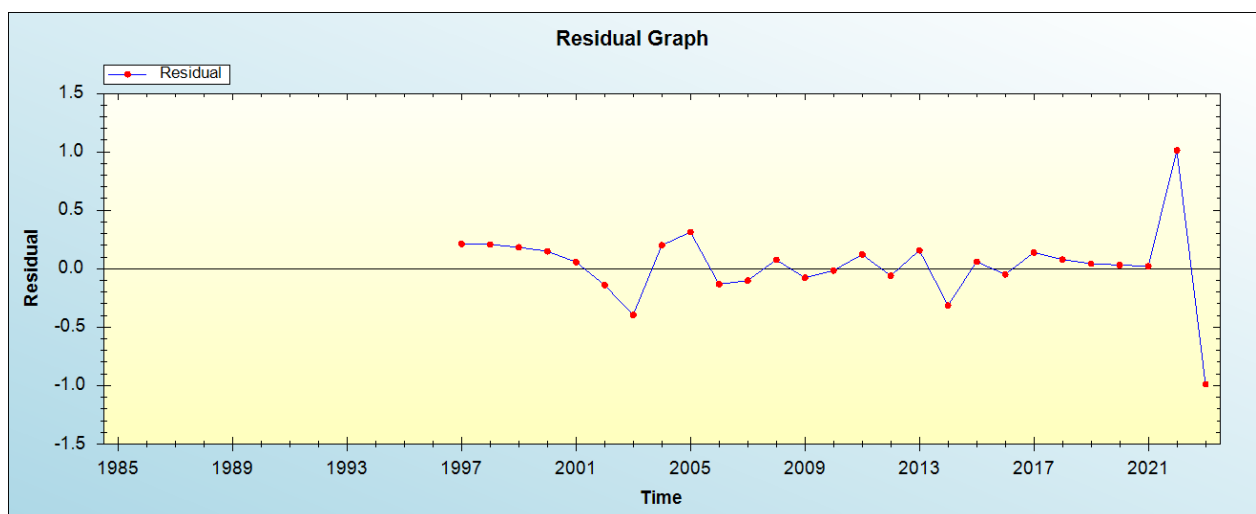


Figure 1: Residual analysis



In-sample Forecast for R

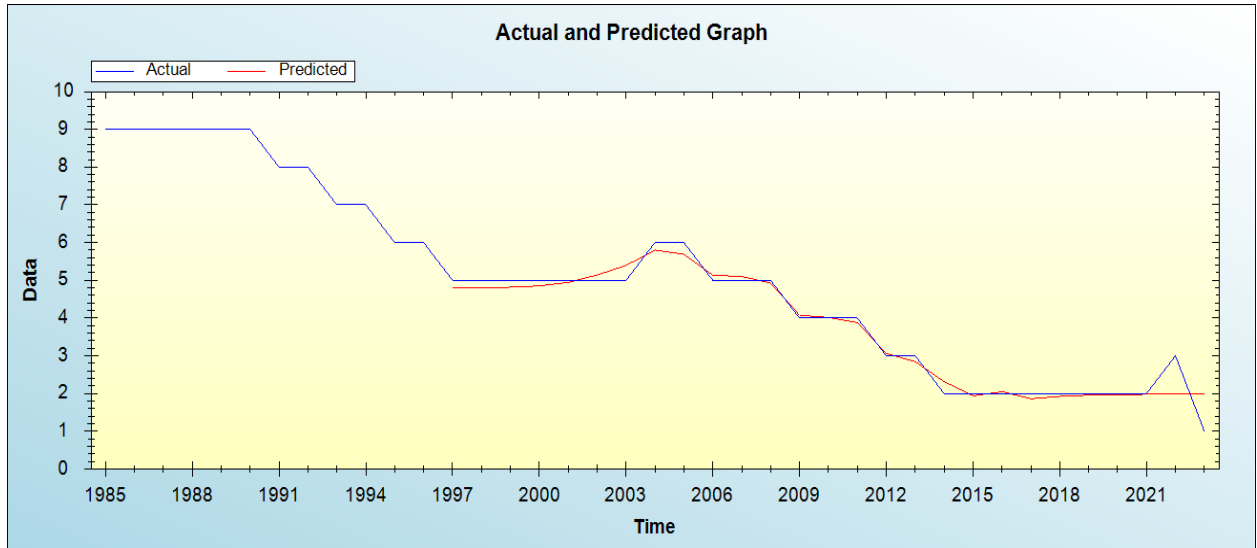


Figure 2: In-sample forecast for the R series

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

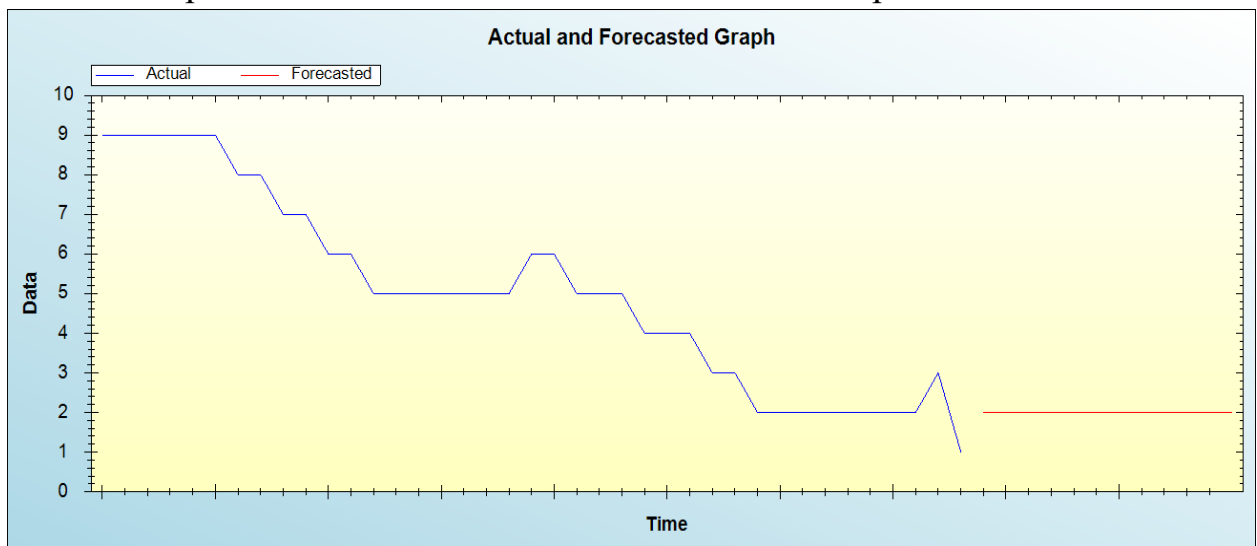


Figure 3: Out-of-sample forecast for R: actual and forecasted graph



Out-of-Sample Forecast for R: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	1.9926
2025	1.9946
2026	1.9930
2027	1.9944
2028	1.9940
2029	1.9946
2030	1.9938
2031	1.9941
2032	1.9937
2033	1.9951
2034	1.9936
2035	1.9948

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 very low over the out of sample period.

Conclusion

Norway has very low maternal mortality rates reflecting high quality of maternal health services provided during the antenatal, childbirth and puerperium periods. In this study we applied the machine learning technique to model and forecast MMR for Norway and results indicate that MMR will remain very low over the out of sample period. Hence, authorities in Norway are encouraged to relentlessly attend to local causes of maternal deaths.

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