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DETERMINING FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR SLOVENIA USING A MACHINE LEARNING METHOD

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

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

Introduction

According to Slovenia country health profile 2023, Slovenia's estimated population size in 2022 stood at 2 107 180 inhabitants. The gross domestic product in the same year was 32 546 Euros per capita and the unemployment rate stood at 4%. Slovenia's obesity rates have been going up, and are higher than the EU averages. Close to 19.4 % adults identified as obese in 2019. While above the EU average (16.0 %), Slovenia's rates are increasing more slowly: the rates in 2014 were 18.6 % in Slovenia and 14.9 % across the EU. Poor dietary and physical activity habits can underpin the risk of overweight and obesity. These figures confirm that non communicable diseases (NCDs) have become a big health issue in this country and definitely NCDs significantly contribute to indirect maternal deaths. Maternal mortality ratio (MMR) is generally low in Slovenia. As of 2020, the maternal mortality rate stood at 4.5 deaths per 100 000 live births (Policy country profile-2018). The aim of this paper is to forecast MMR for Slovenia using a machine learning approach. The study findings will inform policy, planning and allocation of resources to the health sector that corrective measures are implemented.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Camarinha et al. (2026)	to estimate Severe Maternal Morbidity (SMM) rates and trends among public hospital deliveries in Portugal, 2010-2018,	A register-based observational cross-sectional study was conducted using public hospital	Trends in SMM between 2010 and 2018 in Portugal show an increase, particularly for blood transfusion. Risk factors included age,

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	and identify associated factors	admission delivery episodes	hospitalization length, intensity of diagnoses and procedures, and ICD-10-CM/PCS coding
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
Kotríková et al. (2025)	Analysis of maternal mortality and identification of risk factors for maternal deaths in Slovakia in the years 2007–2023	Retrospective population-based descriptive analysis of maternal mortality from 2007 to 2023 based on the International Classification of Diseases—Maternal Mortality 10th edition (ICD-MM). Selected demographic characteristics were analyzed, and statistical data from official sources and the enhanced surveillance system were compared	he most common causes of death were cardiovascular diseases (22.0%), amniotic fluid embolism (11.0%), viral infections (10.1%), obstetrics hemorrhage (8.3%) and hypertensive disorders of pregnancy, childbirth and puerperium (8.3%)
Kotríková et al. (2025)	Analysis of coincidental maternal	Retrospective population analysis	the study highlighted the

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	mortality in Slovakia in the years 2007–2024 from the database of the Slovak Gynecological and Obstetric Society (enhanced surveillance system)	of maternal mortality from 2007 to 2024 focused on coincidental maternal deaths	problem of under-recognition of coincidental maternal deaths, despite its significant impact on public health
Vargová et al. (2025)	Analysis of life-threatening maternal morbidities and their subsequent treatment in intensive care units in Slovakia during the years 2012–2021	A descriptive, population-based study of 747 cases of mothers admitted to intensive care units (ICU)	Severe postpartum hemorrhage, hypertensive disorders and sepsis remain the leading cause of ICU admissions
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

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			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
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
Pintassilgo et al. (2023)	(1) to describe the characteristics of childbirth in Portugal according to the place of birth, and (2) to analyze the association between homebirth assistance and perinatal, neonatal, and infant mortality rates	Researchers performed a descriptive, correlational analysis of the official datasets of live births in Portugal (census-based) produced by the National Institute of Statistics.	In 2020, home births had more similarities with hospital births than to births occurring in any "other place". Furthermore, considering the 1995–2020 timeframe, home births with specialized assistance were negatively correlated with perinatal, neonatal, and infant mortality, and home births with non-

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			specialized professional assistance or those that were unassisted showed a positive correlation with these mortality rates
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 feto-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
Korencan et al. (2017)	to determine the course and outcomes of pregnancy and childbirth in	retrospective study	cents were found. Conclusions. The results of the study show that

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	adolescents compared to women aged 20-24 years in Slovenia		adolescent pregnancy is related to higher health risks for pregnant adolescents and their newborns

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 Slovenia.

Data Issues

This study is based on annual MMR in Slovenia 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	S
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	0.025678

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MSE	0.098953
MAE	0.224245

Residual Analysis for the Applied Model

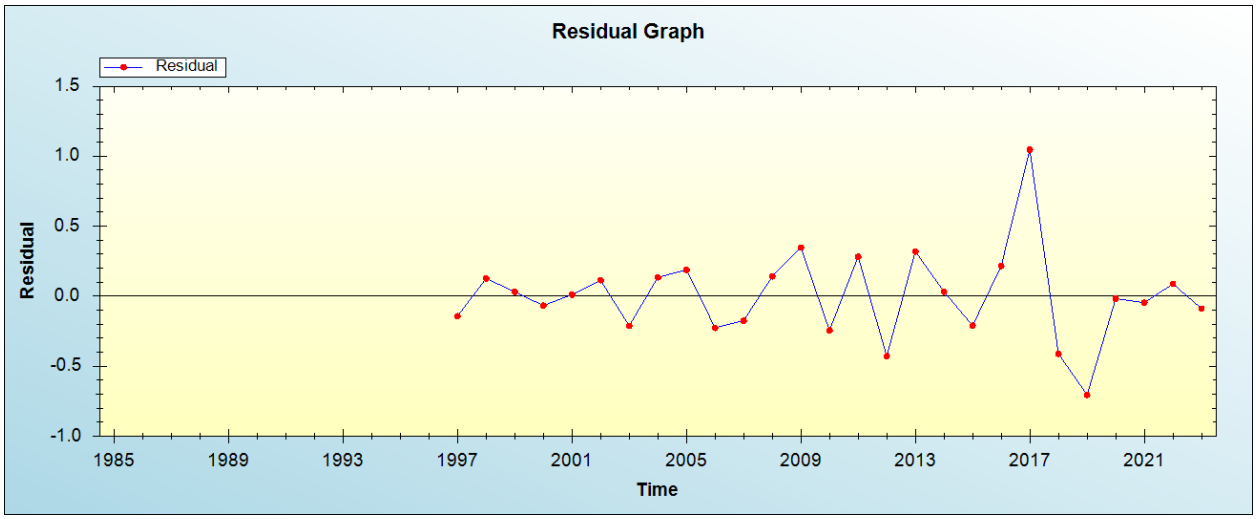


Figure 1: Residual analysis

In-sample Forecast for S

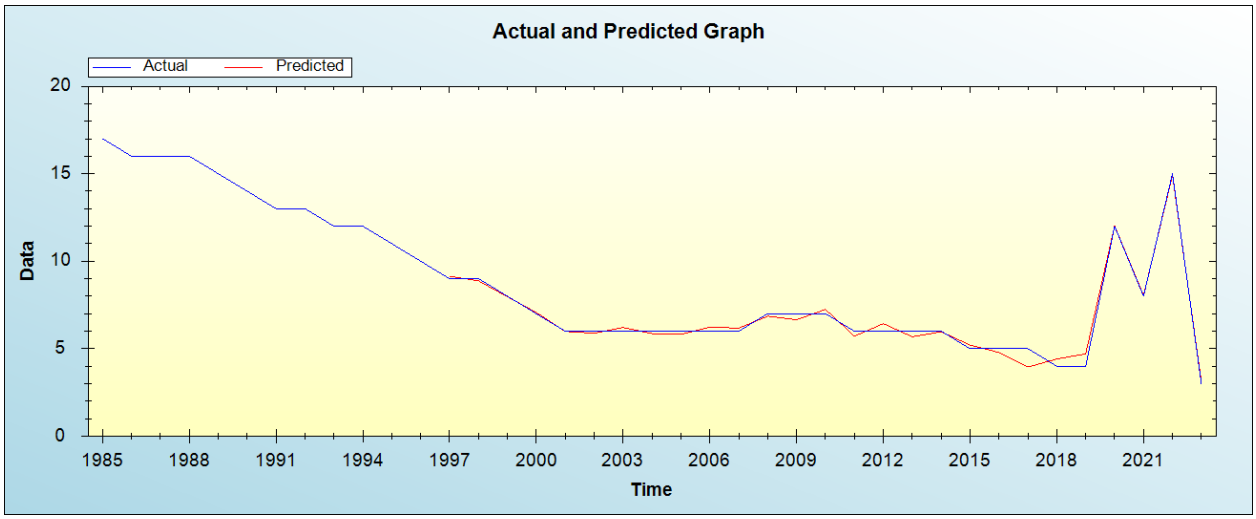


Figure 2: In-sample forecast for the S series

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

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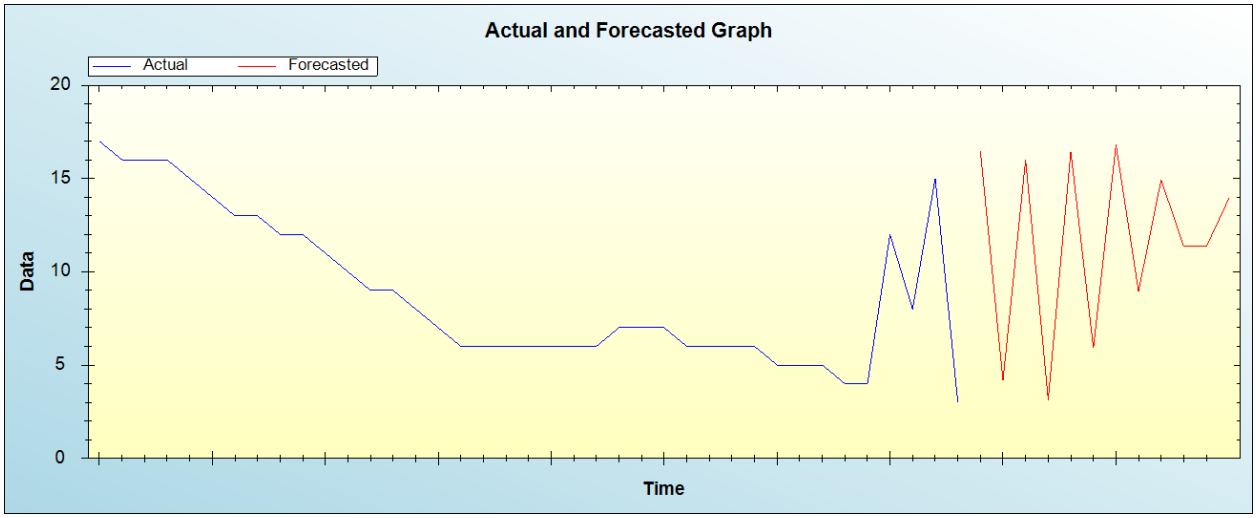


Figure 3: Out-of-sample forecast for S: actual and forecasted graph

Out-of-Sample Forecast for S: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	16.4558
2025	4.1682
2026	15.9914
2027	3.1486
2028	16.4396
2029	5.9136
2030	16.8121
2031	8.9465
2032	14.9355
2033	11.3539
2034	11.3526
2035	13.9371

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 low over the out of sample period.

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Conclusion

In this paper we applied a machine learning technique to model and forecast MMR for Slovenia and results indicate that MMR will remain low over the out of sample period. Hence, authorities are encouraged to address major drivers of maternal mortality.

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