



## **PREDICTION OF MATERNAL MORTALITY FOR CANADA USING THE MULTILAYER PERCEPTRON**

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| <b>Article history:</b>                      |                                              | <b>Abstract:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| <b>Received:</b> 30 <sup>th</sup> March 2026 | <b>Accepted:</b> 28 <sup>th</sup> April 2026 | <i>This research article employs annual time series data on MMR for Canada 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 below 20 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to relentlessly address local causes of preventable maternal mortality.</i> |
|                                              |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

**Keywords:** ANN, Forecasting, Maternal Mortality

### **INTRODUCTION**

Maternal mortality remains a big public health challenge particularly for low-middle income countries (WHO, 2024; WHO, 2023; WHO, 2012). Canada has managed to implement a successful maternal and child health program as demonstrated by its low rate of maternal mortality, however recent reports have highlighted some worrisome trends. Indirect causes of death are emerging in Canada and across the developed world, as major drivers of maternal mortality (Mc Call et al. 2017; Nair et al. 2017). In depth analysis indicates discrepancies in outcomes between regions and population groups within Canada. In North America, Canada has the lowest maternal mortality rate (MMR).

This is largely due to factors such as universal coverage of physician services, women's education, perinatal care and access to birth control (Benoit, 2015). The Public Health Agency of Canada (PHAC) revealed that there was a variation in pregnancy related mortality between 5.1 and 11.9 per 100,000 deliveries for the period 1999/2000 to 2014/2015. PHAC also revealed that severe maternal morbidity, peaking in 2013/2014, was 7.4 deaths per 100,000 pregnancies.

The objective of this paper is to model and predict future trends of MMR for Canada using the multilayer perceptron. The results of the study will inform policy and allocation of resources to the health sector in order to keep maternal mortality under control.

### **LITERATURE REVIEW**

| <b>Author(s)</b>     | <b>Objective(s)</b>                                                                     | <b>Methodology</b>            | <b>Key finding(s)</b>                                                                                                                                                                        |
|----------------------|-----------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ray et al. (2026)    | To quantify the association between the number of SMM indicators and maternal mortality | Population based cohort study | Maternal death may be associated with the number of SMM indicators and occur in certain identifiable groups of women                                                                         |
| 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 |



|                            |                                                                                                                                                                                         |                                            |                                                                                                                                                                                                                                                                                                                                                     |
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|                            |                                                                                                                                                                                         |                                            | 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                                                                                                                                         |
| 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. |
| 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                                                                                                                                                            |



|                                |                                                                                                                                                               |                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                      |
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|                                |                                                                                                                                                               |                                                                                                                                                                                                                                                                              | 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 |
| 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                                         |
| Silva et al. (2024)            | To assess maternal mortality (MM) in Brazilian Black, Pardo, and White women                                                                                  | evaluated the maternal mortality rate (MMR) using data from the Brazilian Ministry of Health public databases from 2017 to 2022. We compared MMR among                                                                                                                       | Black women presented higher MMR in all years, in all geographic regions, age groups, and causes. In Brazil, Black skin color is a key MM determinant                                                                                                                                                                                                                                                                |



|                      |                                                                                                                                           |                                                                                                                                                                                                |                                                                                                                                                                                                                                                                    |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      |                                                                                                                                           | Black, Pardo, and White women according to the region of the country, age, and cause. For statistical analysis, the Q2 test prevalence ratio (PR) and confidence interval (CI) were calculated |                                                                                                                                                                                                                                                                    |
| 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<br>-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) |
| Aoyama et al. (2019) | To explore the association between maternal mortality and maternal age                                                                    | Nationwide population-based cohort study                                                                                                                                                       | province of residence, maternal comorbidity, residence income quintile, and extremes of maternal age, especially those 45 years or older, were associated with SMM and mortality.                                                                                  |

**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 Canada.

**DATA ISSUES**

This study is based on annual MMR in Canada 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                     | 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                     | 0.048878                    |
| MSE                       | 0.092829                    |
| MAE                       | 0.234346                    |

#### Residual Analysis for the Applied Model

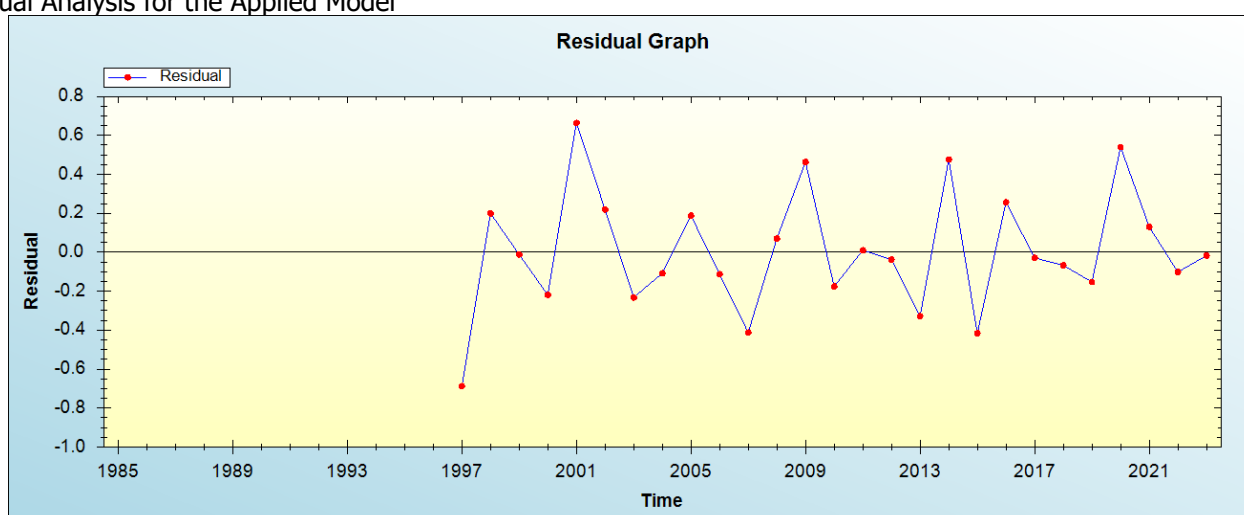


Figure 1: Residual analysis

#### In-sample Forecast for C

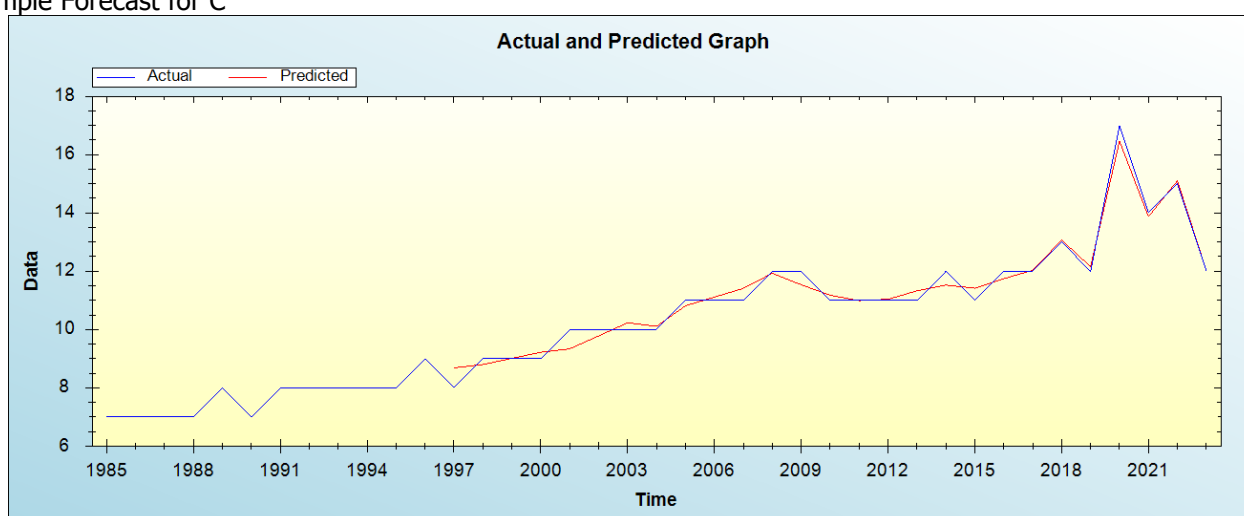


Figure 2: In-sample forecast for the C series

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

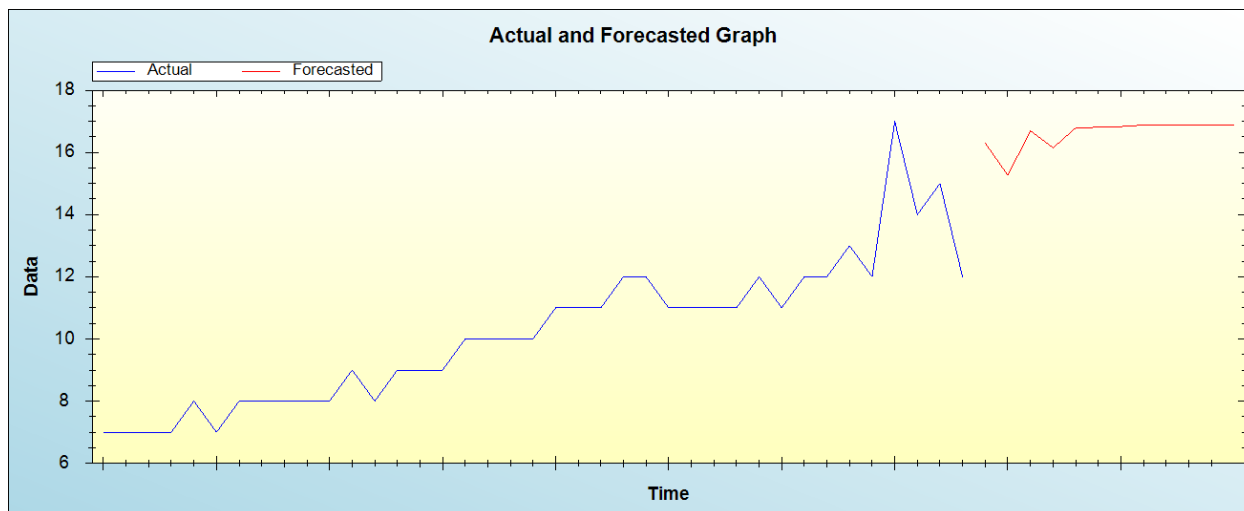


Figure 3: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 16.3023        |
| 2025 | 15.2623        |
| 2026 | 16.6958        |
| 2027 | 16.1453        |
| 2028 | 16.7871        |
| 2029 | 16.8085        |
| 2030 | 16.8287        |
| 2031 | 16.8790        |
| 2032 | 16.8932        |
| 2033 | 16.8930        |
| 2034 | 16.8898        |
| 2035 | 16.8903        |

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 below 20 deaths per 100 000 live births over the out of sample period.

## RECOMMENDATIONS & CONCLUSION

Maternal mortality is generally low in Canada because of the huge investments in healthcare. This paper projects MMR for Canada using the multilayer perceptron neural network and the results indicate that MMR will remain below 20 deaths per 100 000 live births over the out of sample period. Therefore, we encourage health authorities to address local causes of maternal deaths. In addition, focus should be placed on

continuous surveillance of severe maternal morbidities (SMM) and attend to the root causes.

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