



MATERNAL MORTALITY PROJECTION FOR THE WEST BANK AND GAZA USING A MACHINE LEARNING TECHNIQUE

Smartson. P. NYONI 1

Thabani NYONI 2

1Independent Researcher & Medical Doctor, Harare, Zimbabwe

2Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract

This research article employs annual time series data on MMR for the West Bank and Gaza 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 19.4 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to relentlessly address local causes of maternal mortality.

Keywords: ANN, Forecasting, Maternal Mortality Ratio

Introduction

The war in Gaza had numerous adverse effects on pregnant women and their children. Critical infrastructure was destroyed, and medical supply chains were disrupted and accessibility of medical services became extremely difficult (Qureshi et al. 2024). Moreover, hundreds of healthcare workers were killed, and many others have been wounded or detained, while the majority suffered poor living conditions and high burn out (Aldabbour et al. 2025; WHO, 2024). Food and drinking water shortages and severe distress among the population have aggravated the effect of mass displacement on the population of the Gaza Strip (Aldabbour et al. 2025; Aldabbour et al. 2024; Alnabih et al. 2024). Problems associated with mass displacement and instability also have a negative impact on maternal health seeking behavior and reduce pregnant women's access to



available healthcare (Miskeen, 2024; Tingkai et al. 2023). In the Gaza Strip, the maternal mortality ratio over the period 2018-2022 averaged 30 per 100 000 live births. According to the Palestinian Ministry of Health, the neonatal mortality rate stood at 6.6 per 1000 live births in 2022 and the stillbirth rate was 6.0 per 1000 births. In addition, high proportions of antenatal care (100%), skilled birth attendance (100%) and facility-based delivery (99.4%) is a testimony that the health care system was robust (PCBS, 2021). The objective of this paper is to model and forecast MMR for the West Bank and Gaza using a machine learning technique. The results of the study are expected to guide policy and adequate allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Jamaluddine et al. (2026)	To assess the impact of war on maternal and neonatal mortality and health care utilization among pregnant refugee women in the Gaza Strip	Retrospective study	The conflict in the Gaza Strip was associated with substantial increases in maternal and neonatal mortality and preterm births. Utilization of health services remained high but delivery locations shifted to lower-level facilities and hospital stays shortened, raising concerns about the quality of care
Aldabbour et al. (2025)	to explore maternal and neonatal health, as well as antenatal care (ANC) access during the war in Gaza	cross-sectional study	The most common reason for the lack of ANC was the inability to afford transportation. Moreover, 69.46% adhered to folic acid and iron supplementation. Most (90.42%) participants reported moderate to high stress levels, with 40.92% and 33.93% feeling almost always or often endangered. The prevalence of LBW was 10.8%, and the median weight was 3100 g
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



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 1, January 2026

Website: usajournals.org

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

Kaddoura et al. (2024)	to assess the feasibility of establishing a prospective cohort of mothers and their full-term and preterm babies in Lebanon, examining the association between social determinants, preterm birth, and developmental outcomes amidst the nation's multifaceted crises	Prospective cohort study	Early analysis reveals significant stress and reduced quality of life among mothers, particularly those with preterm infants, against a backdrop of declining birth rates and health care worker exodus. Conducting research in crisis settings like Lebanon presents unique methodological and ethical challenges but remains crucial for understanding and improving health outcomes in vulnerable populations
Dimassi et al. (2023)	to review the maternal health outcomes of disadvantaged Lebanese and refugee pregnant women seeking ANC services at primary healthcare centers (PHCs) in Lebanon	A retrospective chart review was conducted at twenty PHCs in Lebanon, including Ministry of Public Health (MOPH) and United Nations Relief and Works Agency for Palestine refugees (UNRWA) facilities	Syrians had reduced odds of C-sections, and Beqaa, Mount Lebanon, and South Lebanon regions had reduced odds of abortion. Suboptimal ANC visits and history of C-section increased the odds of C-section and abortion in the current pregnancy. As for preterm onset, the study showed an increased likelihood for it to occur when being Palestinian, having current C-section delivery, experiencing previous preterm onset, and enduring complications at the time of delivery
Assaf et al. (2023)	to analyze the nutritional status in the Palestinian Territory by analyzing published data from 2011 to 2023	Systematic review	The prevalence rates of underweight, overweight, and obesity among school children in the West Bank were 7.3%, 14.5%, and 15.7%, respectively. Age, gender, and living area were significant predictors of being overweight among school children. The prevalence rates of overweight and obesity among adults in Palestine were 57.8% and 26.8%, respectively
McCall et al. (2023)	to assess whether the characteristics, management and outcomes of women varied between Syrian and Palestinian refugees, migrant women of other nationalities and Lebanese women giving birth at a public tertiary centre in Beirut, Lebanon	This was a secondary data analysis of routinely collected data from the public Rafik Hariri University Hospital (RHUH) between January 2011 and July 2018	Syrian refugees in Lebanon had similar obstetric outcomes compared to the host population, except for very preterm birth. However, Palestinian women and migrant women of other nationalities appeared to have worse pregnancy complications than the Lebanese women



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 1, January 2026

Website: usajournals.org

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

Pinchas-Mizrachi et al. (2022)	To examine the disparities in breast cancer-related mortality rates among women from urban areas compared to rural areas in Israel	This was a retrospective, follow-up study on mortality from breast cancer among 894,608 Israeli women born between the years of 1940 and 1960	A higher incidence of mortality from breast cancer in Israel was found among urban women compared to rural women (1047.8/100,000 compared to 837/100,000, respectively)
Rebeiz et al. (2022)	To identify the lessons learned from women who died during pregnancy or childbirth in Lebanon between 2018 and 2020	case series and synthesis of maternal deaths between 2018 and 2020 that were reported by healthcare facilities to the Ministry of Public Health in Lebanon	A total of 49 women died before, during, or after childbirth, with hemorrhage being the most frequent cause (n=16). The possible factors that would have prevented maternal deaths included a prompt recognition of clinical severity, availability of blood for transfusion and magnesium sulfate for eclampsia, adequate transfer to tertiary care hospitals comprising specialist care, and involvement of skilled medical staff in obstetric emergencies
Rottenstreich et al. (2020)	To determine the prevalence of obstetric ICU admissions in one medical center in Israel and to characterize this population	In this retrospective study the files of women coded for pregnancy, birth, or the perinatal period and admission to the ICU were pulled for data extraction (2005–2013)	Most pregnancies (71.2%) were uneventful prior to admission. ICU admissions were divided equally between direct (usually hemorrhage) and indirect (usually cardiac disease) obstetric causes
Morong et al. (2017)	This study was a retrospective cohort study of cases of in-hospital maternal deaths in the Ochsner Health System (Louisiana, United States) and the Queensland Health System (Australia) from 1995 to 2013	-to determine if American and Australian women have a similar rate of preventable maternal death and if the deaths were attributable to the same factors	Women from Louisiana, United States and Queensland, Australia have similar rates of preventable maternal death. No statistically significant factors explained trends in Australian maternal death; American maternal mortality was significantly associated with point of entry into prenatal care, likely influenced by insurance status
Nahidi & Hajifoghaha (2017)	To provide the current situation and trend of MMR in the Eastern Mediterranean region between 1990 and 2015	Systematic review	Based on the collected data, 36 out of 66 studies met the required criteria and were chosen for analysis. All countries of this region showed a downward trend between 1990 and 2015, and this change varied from 16.30% in Yemen to 76.56% in Lebanon. The maternal mortality reduction was 69.88% in Iran in the same time



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 the West Bank and Gaza.

Data Issues

This study is based on annual MMR in the West Bank and Gaza 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	W
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	0.027711
MSE	4.494241
MAE	1.108856



Residual Analysis for the Applied Model

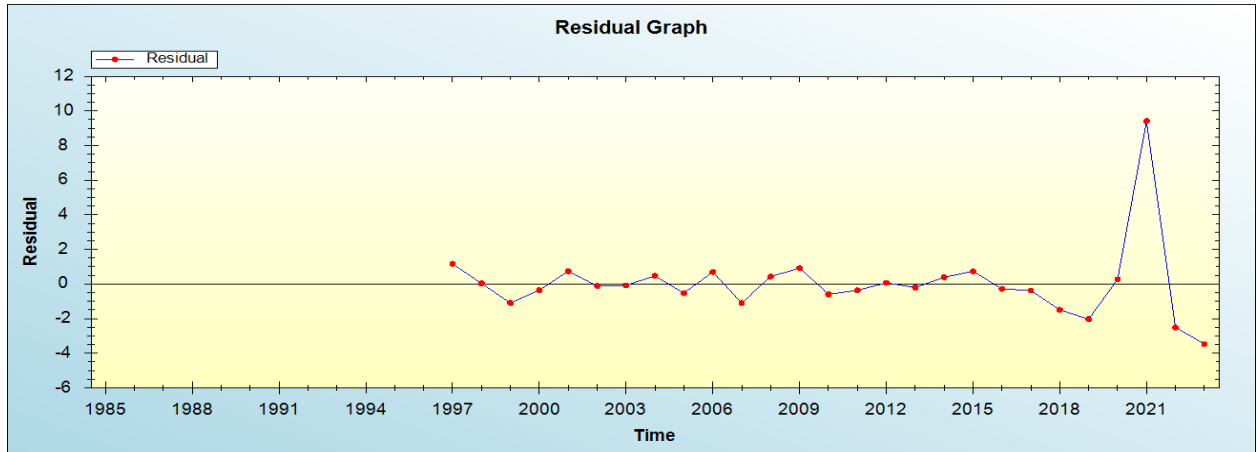


Figure 1: Residual analysis

In-sample Forecast for W

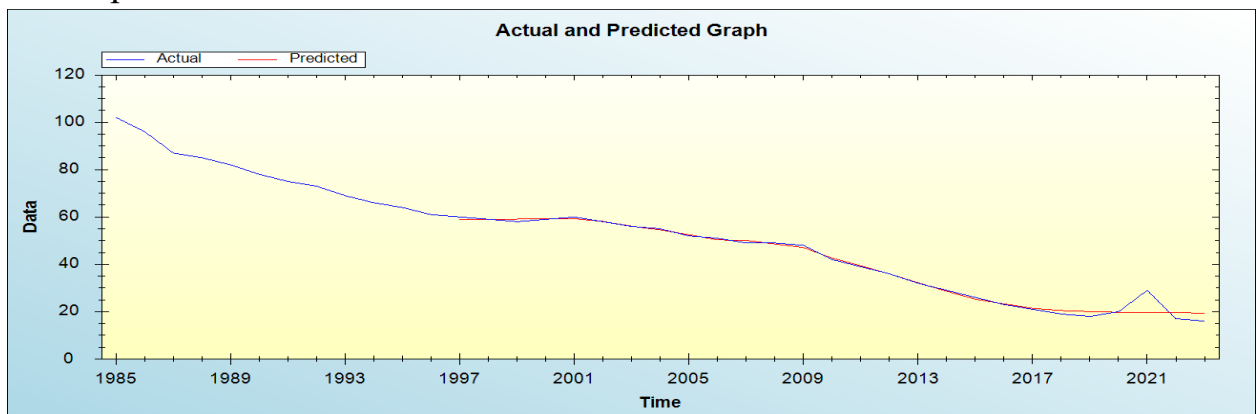


Figure 2: In-sample forecast for the W series

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

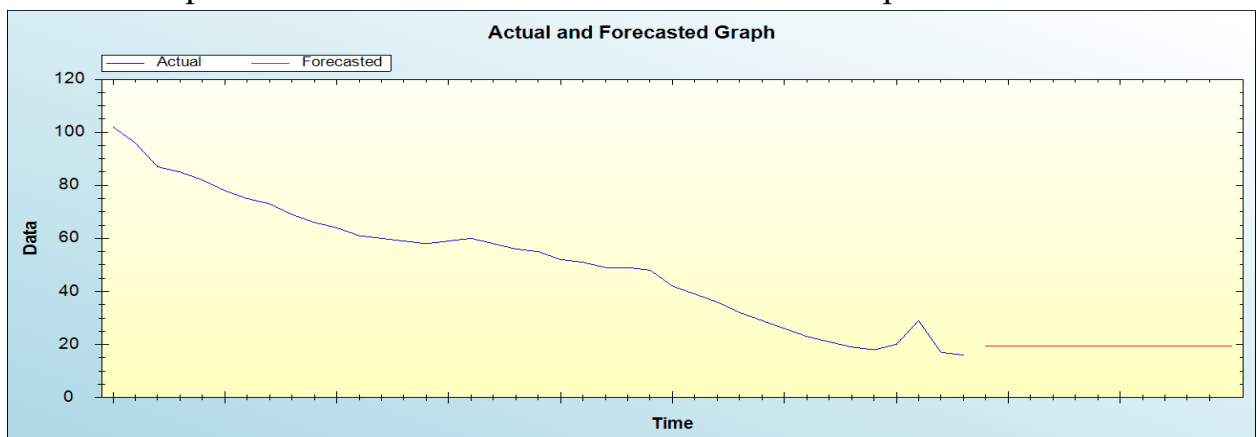


Figure 3: Out-of-sample forecast for W: actual and forecasted graph



Out-of-Sample Forecast for W: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	19.4193
2025	19.4131
2026	19.4159
2027	19.3976
2028	19.4106
2029	19.3981
2030	19.3896
2031	19.3977
2032	19.3940
2033	19.3983
2034	19.3935
2035	19.3932

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 hover around 19.4 deaths per 100 000 live births throughout the out of sample period.

Conclusion

Provision of healthcare services including maternal health services in conflict affected zones is usually a big challenge because of the destruction of infrastructure, displacement of people and disruption of supply chains. In this paper we modelled and forecasted MMR for the West Bank and Gaza, and findings indicate that MMR will hover around 19.4 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage health authorities to tirelessly address local causes of maternal mortality.

References

1. Aldabbour B., Abuabada A., Lahlouh A., Halimy M., Elamassie S., and Sammour AA (2024). Psychological impacts of the Gaza war on Palestinian young adults: a cross-sectional study of depression, anxiety, stress, and PTSD symptoms. BMC Psychol. 12(1):696.



2. Aldabbour B., Dardas L.A., Hamed L., Alagha H., Alsaiqali R., and El-shanti N (2025). Emotional exhaustion, depersonalization, and personal accomplishment: exploring burnout in Gaza's healthcare workforce during the war. *Middle East Curr Psychiatry*. 2025;32(1):25
3. Aldabbour B., El-Jamal M., Abuabada A., Al-Dardasawi A., Abusedo E., and Abu Daff H (2025). The psychological toll of war and forced displacement in Gaza: A study on anxiety, PTSD, and depression. *Chronic Stress*. 9:24705470251334943.
4. Alnabih A., Alnabeh N.A., Aljeesh Y., and Aldabbour B (2024). Food insecurity and weight loss during wartime: a mixed-design study from the Gaza strip. *J Health Popul Nutr*. 43(1):222.
5. Ministry of Health Gaza (2023). Annual report 2022. Ministry of Health, Southern Governates, Gaza Strip. Gaza City: Available from: <https://www.moh.gov.ps/portal/annual-report-moh-gaza-2023/>.
6. Miskeen E (2024). The impact of the military conflict in Sudan on maternal health: a mixed qualitative and quantitative study. *PeerJ*. 2024;12: e17484.
7. Palestinian Central Bureau of Statistics (PCBS) (2021). Palestinian Multiple Indicator Cluster Survey 2019–2020. Survey findings report. Available from: <https://www.unicef.org/sop/reports/palestinian-multiple-indicator-cluster-survey>
8. Qureshi Y.A., Dawas K., and Maynard N.D (2024). Excess deaths in Gaza. *Lancet Global Health*. 12(9): e1395.
9. Tingkai Z., Qiwei H., Sol R., and Kun T (2023). Does armed conflict lead to lower prevalence of maternal health-seeking behaviours: theoretical and empirical research based on 55 683 women in armed conflict settings. *BMJ Global Health*. 8(8): e012023.
10. World Health Organization (2024). WHO / Gaza health situation [Internet]. Geneva: WHO; 4 October 2024 [cited 2025 Jul 11]. Available from: <https://media.un.org/unifeed/en/asset/d326/d3268585>