



PROJECTING MATERNAL MORTALITY FOR UKRAINE USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

Smartson P. NYONI 1

Thabani NYONI 2

1Independent Researcher & Medical Doctor, Harare, Zimbabwe

2Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract

This study uses annual time series data on MMR for Ukraine from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes Holt's double exponential smoothing model. The optimal values of smoothing constants α and β are 0.9 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain low over the out of sample period. Therefore, we encourage authorities to address local factors associated with maternal mortality.

Keywords: Exponential smoothing, 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). Nearly 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). According to the Office for the Coordination of Humanitarian Affairs (OCHA) as of June 2016, the ongoing conflict in Ukraine has caused 2008 civilians' deaths, and the displacement within Ukraine of around 1.75 million people. Among them, almost 1.1 million are women (Ukraine, 2015). Pregnant women, women with young children, and these children themselves are among the most vulnerable groups within populations affected by conflict (Degomme & Guha-Sapir, 2010). In crisis situations, access to health services is limited, which raises the risk of newborn and maternal mortality (Casey et al. 2015). The objective of this paper is to model and forecast future trends of MMR for Ukraine using the double exponential smoothing technique. The study results will inform policy, planning and allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Feng et al. (2025)	-to analyze trends (1990–2021) and projected (to 2050) MMR in Southeast Asia using the Global Burden of Disease (GBD) 2021 database and addressing gaps in regional granularity	-Data GBD 2021, covering MMR and age-standardized MMR (ASMR) for 1990–2021, stratified by country, age group, and cause -Trend assessment was conducted using the estimated annual percentage change (EAPC), while 30-year projections were generated via an autoregressive integrated moving average (ARIMA) model	The ASMR in Southeast Asia fell by 59%, dropping from 255.88 in 1990 to 104.56 per 100,000 live births by 2021. This decline was primarily driven by reduced rates of maternal hemorrhage and hypertensive disorders. Progress slowed during the 1997 Asian financial crisis yet picked up pace after 2000
Krupelnyska et al. (2025)	to examine the self-assessed mental health of pregnant women and new mothers (PNM) who faced relocation	This report presents findings from a study conducted as part of the Perinatal Mental Health for Refugee Women (PMH-RW) Project. This cross-	The financial burden and socio-economic background of pregnant and new mothers during wartime migration can define their



		sectional study used data from 191 PNM who are either internally displaced persons (IDP) or refugees (REF)	mental health resilience
Rai et al. (2025)	to examine the current burden of maternal and neonatal disorders in Nepal and to assess any changes over time	Researchers examined the annual Global Burden of Disease Study data on prevalence, deaths, Years Lived with Disability, and Disability-Adjusted Life Years for maternal and neonatal disorders in Nepal for the 1990-2019 period. Estimated annual percentage changes were also calculated to assess the trends of the age-standardized rates of these burden metrics	the prevalence of overall maternal disorder in Nepal decreased by 37% from 128,176 in 1990 to 80,724 in 2019 with Age-Standardized Ratio of 432.07 per 100,000 in 2019 and Estimated Annual Percentage Change of -4.34 (CI 95%: -4.49 to -4.18)
Shrestha et al. (2025)	to estimate the maternal mortality ratio and identify the causes of maternal deaths using the WHO International Classification of Disease –Maternal Mortality (ICD-MM) tool	retrospective study	The maternal mortality ratio in the study was low in comparison to the national data
Eclarin et al. (2024)	to present maternal and perinatal health indicators for the years 2019–2022	This was a cross-sectional review that analyzed data on maternal and perinatal health indicators, generated from submissions of POGS-accredited	The top three-most common indications for primary CS were dysfunctional labor, fetal distress, and malpresentation. Stillbirth, perinatal, and maternal



		hospitals (training and service) from January 2019 to December 2022.	mortality rates showed an increase from 2019 to 2022, with peak rates registered for the year 2021. The top five causes of maternal death are: medical complications, hemorrhage, hypertension, infection, and others (unspecified). The case fatality rate among pregnant patients with confirmed COVID-19 infection was 1.18%
Galabay et al. (2024)	to explore the determinants of maternal mortality in Cagayan Valley, Philippines, for the past five years	The researchers used a convergent parallel mixed-methods research design	Significant findings reveal that most maternal mortality cases were considered high-risk pregnancies and highly associated with the three-delay model validated through the qualitative results
Kwee et al. (2024)	To evaluate the impact of healthcare access on maternal and child mortality rates in the rural region of Kayin State, Myanmar, where disparities in healthcare services significantly affect vulnerable populations	cross-sectional study design	The findings reveal alarming maternal mortality rates of 250 per 100,000 live births and child mortality rates of 80 per 1,000 live births in rural areas, compared to urban counterparts. Major barriers identified include geographic



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 10, October 2026

Website: usajournals.org

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

			isolation, economic challenges, and cultural factors limiting healthcare utilization
Phan et al. (2024)	To examine the association between health insurance coverage and antenatal care (ANC) visits during pregnancy	The study 19 utilized data from the 2021-22 Cambodia Demographic and Health Surveys (CDHS). A total of 20 3,162 weighted women who gave birth within two years were included in the analysis. Multiple logistic regression analysis assessed the association between health insurance coverage and pregnant women who attended at least four antenatal care visits during pregnancy	Having health insurance coverage was significantly associated with four or more 31 ANC visits
Win et al. (2024)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Low utilization rates were due to several supply-side constraints
Hossain et al. (2023)	To report the current level and major causes of maternal deaths in Bangladesh, focusing on care-seeking practices, timing, and place of deaths	-analyzed data from the 2016 Bangladesh Maternal Mortality and Health Care Survey (BMMS), conducted with nationally representative sample of 298 284 households	Nineteen per cent of the maternal deaths occurred at home, another 19% in-transit, almost half (49%) in a public facility, and 13% in a private hospital. Hemorrhage contributed to 31% and eclampsia to



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 10, October 2026

Website: usajournals.org

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

		-adapted the World Health Organization's 2014 verbal autopsy (VA) questionnaire. Trained physicians reviewed the responses and assigned the cause of death based on the International Classification of Diseases (ICD-10)	23% of the maternal deaths. Twenty-one per cent of the maternal deaths occurred due to indirect causes
Jabeen et al. (2023)	To examine the current levels, trends, time of death, and care-seeking practices for hemorrhage-related maternal deaths in Bangladesh	-conducted a secondary analysis with data from the nationally representative 2001, 2010, and 2016 Bangladesh Maternal Mortality Surveys (BMMS) -The cause of death information was collected through verbal autopsy (VA) interviews using a country-adapted version of the standard World Health Organization VA questionnaire	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh
Win et al. (2023)	to summarize all possible factors influencing maternal mortality in CLMV countries	Systematic review	Poor family income, illiteracy, low education levels, living in poor households, and agricultural and unskilled manual job types of mothers contributed to insufficient antenatal care



Lwin et al. (2022)	To examine factors influencing institutional maternity service utilization and identified the need for improved maternal health outcomes	cross-sectional study design	A greater number of ANC visits and level of the couple's education had a positive association with institutional delivery
Singh 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
Chham et al. (2021)	to explore the coverage level of the Optimal CoC by (1) measuring the continuity of optimal antenatal care	The study employed data from the Cambodia Demographic Health Survey 2014. We	Household wealth was found to be the most influential factor, yet the study discovered also other



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 10, October 2026

Website: usajournals.org

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

	(ANC), skilled birth attendance (SBA) and optimal post-natal care (PNC), (2) identifying the determinants of drop ping out from one service to another and (3) of not achieving the complete CoC	restricted our analysis to married women who had a live birth in the five years preceding the survey (n = 5678). Bi-variate and multivariate logistic regression were performed using STATA version 14	barriers to optimal maternal health care which need to be addressed
Sitaula et al. (2021)	to determine the MMR and identify the various risk factors and causes of maternal mortality	retrospective study	Despite the availability of comprehensive emergency obstetric care at our center, maternal mortality is still high and almost 75% of deaths were avoidable. The leading contributory factors of maternal mortality are delay in seeking care and delayed referral from other health facilities
Khachuraeva & Akhmadova (2020)	To present a comparative analysis of the dynamics of maternal mortality (MM) and its structure in the Russian Federation and the Chechen Republic for the period 2010–2017	Comparative analytical study	In the Russian Federation for the period 2010–2017, there was a persistent decrease in maternal mortality by 6.7 %. While in 2010, the maternal mortality rate in the RF was 16.5 %, the indicator in 2017 was 9.8 %. It turned out that the maternal mortality rate in the Chechen Republic for the period from 2010 to 2017 tends to



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, **Issue** 10, **October** 2026

Website: usajournals.org

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

			decrease by 32.6 %, but this indicator exceeds the average statistical indicator of maternal mortality in the RF (6.7 %)
Akhter, & Alam. (2019)	-to present the trends of maternal and neonatal mortality - to explain the maternal and neonatal mortality rate by background characteristics and the causes of maternal and neonatal deaths in Bangladesh on the basis of South Asian perspective	The main source of data collection and analysis was the secondary sources, from different journals and project reports published between the years 2001 to May 2018	In Bangladesh, 35% maternal deaths occurred as indirect causes and 9% causes of deaths are still remaining unidentified. hemorrhage (31%) and pre-eclampsia-eclampsia (20%) are found two vital causes of maternal deaths with two more causes which are due to obstructed labor (7%), and termination of pregnancy (1%)
Yamashita et al. (2017)	to examine the current utilization of healthcare services and the effects on the health of women in the Philippines who delivered at home	This was a cross-sectional analytical study, based on a self-administrated questionnaire, conducted from March 2015 to February 2016 in Muntinlupa, Philippines	There were significant differences in the type of birth attendant, area of residence, monthly income, and maternal and child health book usage between women who delivered at home and those who delivered at a facility (P,0.01)
Natalia et al. (2006)	To study the levels and causes of maternal mortality in St.	Researchers collected data about all pregnancy-related deaths in St.	The maternal mortality ratio for the study period was 43 per 100 000 live



	Petersburg, Russian Federation	Petersburg over the period 1992–2003 using several sources of information. An independent research group reviewed and classified all cases according to ICD-10 and the Confidential Enquiries into Maternal Deaths in the United Kingdom. We tested trends of overall and cause specific ratios (deaths per 100 000 births) for four 3-year intervals using the χ^2 test	births. A sharp decline of direct obstetric deaths was observed from the first to fourth 3-year interval (49.8 for 1992–94 versus 18.5 for 2001–03). Sepsis and hemorrhage were the main causes of direct obstetric deaths. Among the total deaths from sepsis, 63.8% were due to abortion
--	--------------------------------	---	--

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Ukraine. In exponential smoothing forecasts are generated from the smoothed original series with the most recent historical values having more influence than those in the more distant past as more recent values are allocated more weights than those in the distant past. This study uses the Holt's linear method (Double exponential smoothing) because it is an appropriate technique for modeling linear data.

Holt's linear method is specified as follows:

Model equation

$$U_t = \mu_t + \rho_t t + \varepsilon_t$$

Smoothing equation

$$S_t = \alpha U_t + (1-\alpha)(S_{t-1} + b_{t-1})$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (S_t - S_{t-1}) + (1-\beta)b_{t-1}$$

$$0 < \beta < 1$$



Forecasting equation

$$f_{t+h} = S_t + hb_t$$

U_t is the actual value of MMR at time t

ε_t is the time varying **error term**

μ_t is the time varying mean (**level**) term

ρ_t is the time varying **slope term**

t is the trend component of the time series

S_t is the exponentially smoothed value of MMR at time t

α is the exponential smoothing constant for the data

β is the smoothing constant for trend

f_{t+h} is the h step ahead forecast

b_t is the trend estimate (slope of the trend) at time t

b_{t-1} is the trend estimate at time $t-1$

Data Issues

This study is based on annual MMR in Ukraine 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	U
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.945358
Sum Square Error (SSE)	307.114589
Mean Square Error (MSE)	7.874733
Mean Percentage Error (MPE)	-0.135454
Mean Absolute Percentage Error (MAPE)	7.204368



Residual Analysis for the Applied Model

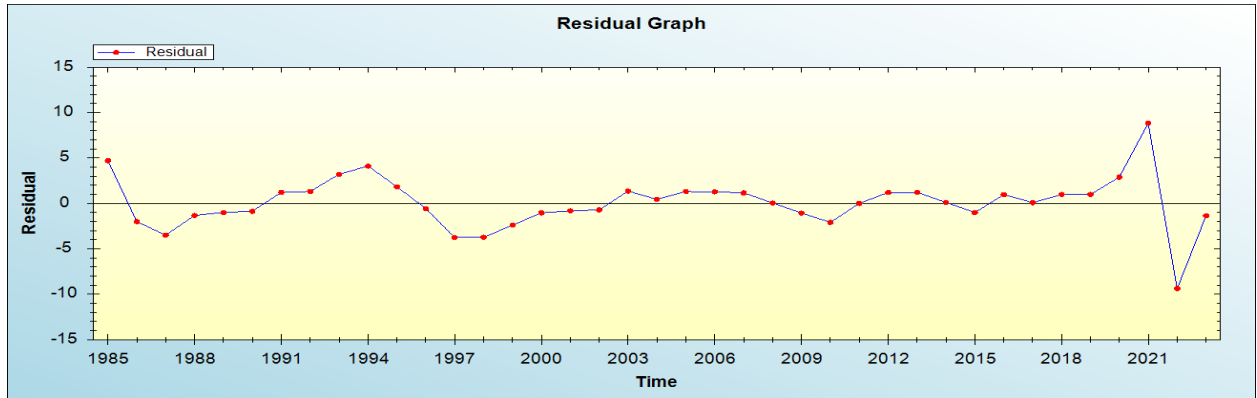


Figure 1: Residual analysis

In-sample Forecast for U

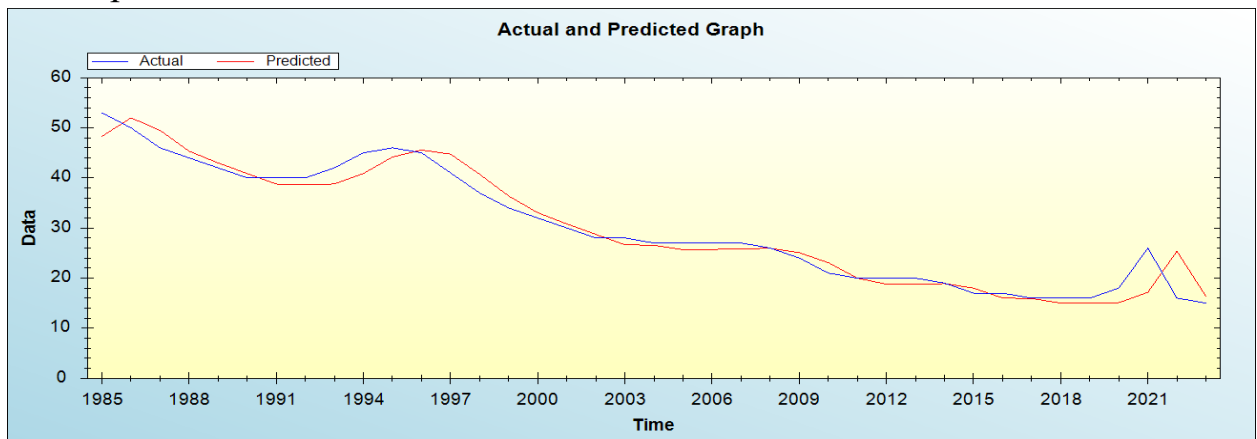


Figure 2: In-sample forecast for the U series

Actual and Smoothed graph for U series

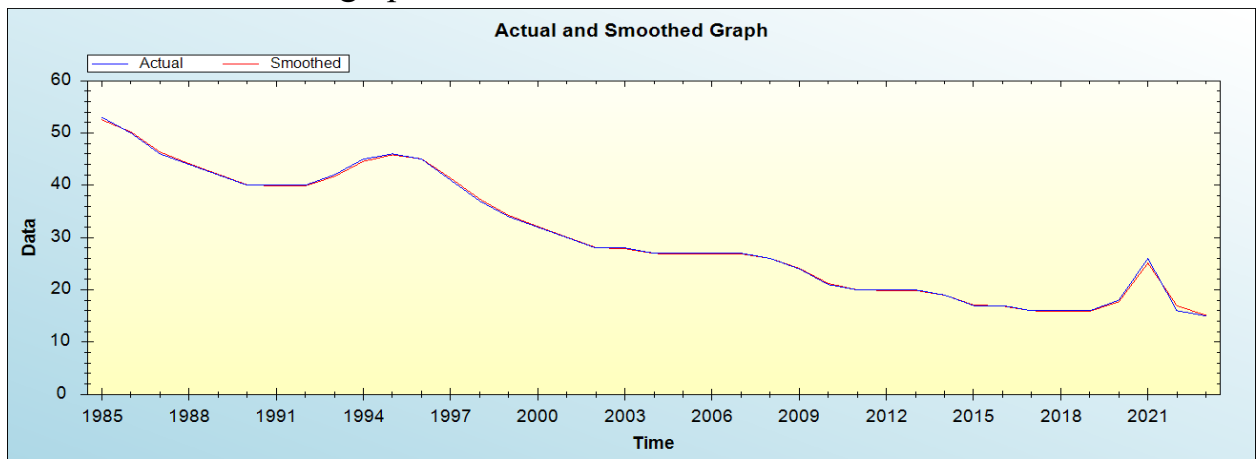


Figure 3: Actual and smoothed graph for U series



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

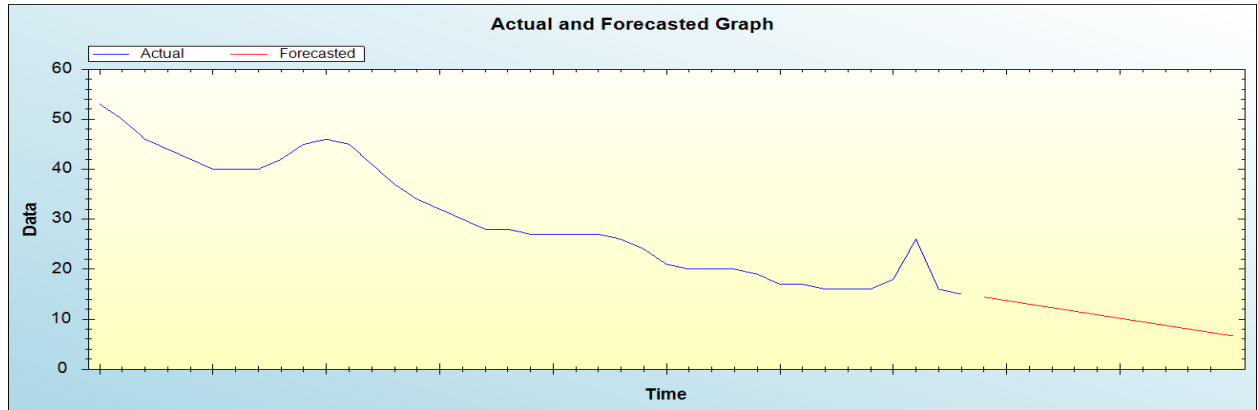


Figure 4: Out-of-sample forecast for U: actual and forecasted graph

Out-of-Sample Forecast for U: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	14.4264
2025	13.7177
2026	13.0090
2027	12.3003
2028	11.5917
2029	10.8830
2030	10.1743
2031	9.4657
2032	8.7570
2033	8.0483
2034	7.3397
2035	6.6310

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 the out of sample period.



Conclusion

This study utilized the double exponential technique to model and project MMR for Ukraine and findings indicate that MMR will remain low in the forecast period. Therefore, we implore authorities to address local drivers of maternal mortality.

References

1. Casey S.E., Chynoweth S.K., Cornier N., Gallagher M.C., and Wheeler E.E (2015). Progress and gaps in reproductive health services in three humanitarian settings: Mixed-methods case studies. *Confl. Health* 2015, 9, 1.
2. Degomme O and Guha-Sapir D (2010). Patterns of mortality rates in Darfur conflict. *Lancet* 2010, 375, 294–300.
3. Geetika S., Mohan L., Tejbir S., and Shyam S.D (2015). To study the utilization of antenatal services among the pregnant women of rural Amritsar: An international study. *International Journal of current Research*, 2015; 7(5), p. 5789-15792.
4. Khanal V., Mishra R.S., and Karkee R (2015). Under-utilization of antenatal care services in Timor-Leste: results from demographic and health survey 2009-2010. *BMC Pregnancy and Childhood*, 2015;15(211)
5. Kvale G., Olsen B.E., Hinderaker S.G., Ulstein M., and Bergsjø P (2005). Maternal Deaths in Developing Countries: A Preventable Tragedy, *Norsk Epidemiology*, 2005; 15(2) p. 141-149.
6. Ukraine (2015). Ukrainian Ministry of Social Policy, Official Web-Site. Available online: http://www.mlsp.gov.ua/labour/control/uk/publish/article?art_id=189926&cat_id=107177
7. WHO (2009). WHO Recommended Interventions for Improving Maternal and Newborn Health (2nd edition). Geneva: WHO Department of Making Pregnancy Safer; 2009.
8. WHO (2010). WHO, UNICEF, UNIFPA, The World Bank. Trends in maternal mortality 1990-2008: Global Health Observatory. Geneva: WHO Publication; 2010



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 10, October 2026

Website: usajournals.org

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

-
9. WHO (2014). WHO, UNICEF. Every Newborn: an action plan to end preventable deaths. Geneva: World Health Organization; 2014. Available from: <http://www.everynewborn.org/Documents/Full-action-plan-EN.pdf>.