



ANNUAL MATERNAL MORTALITY RATE CALCULATION FOR UZBEKISTAN USING HOLT'S LINEAR METHOD

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 Uzbekistan 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 below 30 deaths per 100 000 live births over the out of sample period. Therefore, we encourage authorities to attend to local factors associated with maternal mortality

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality is an important public health problem particularly in developing countries, where the burden of maternal mortality and morbidity is disproportionately high (Musarandega et al. 2021). Sub-Saharan Africa contributes the highest proportion of global maternal deaths, as it contributes nearly two-thirds of all maternal deaths (WHO, 2024). SSA is still committed to the sustainable development goals including SDG 3.1 which focuses on the reduction of maternal mortality to levels below 70 per 100 000 live births by 2030. However, numerous challenges still persist hindering the achievement of this goal (Vallely et al. 2023; UN, 2015). Several factors contribute to the persistently high maternal mortality rates in Sub-Saharan Africa. These include inadequate access to quality maternal healthcare services, limited availability of skilled birth attendants, poor infrastructure, socioeconomic disparities, cultural



beliefs and practices, and weak health systems (Esther et al. 2023; Flake et al. 2023; Onambele et al. 2023; Dahab et al. 2020; Prata et al. 2010; Graham et al. 2001). Direct causes of maternal deaths such as hemorrhage, eclampsia, sepsis, and obstructed labor, further contribute to maternal morbidity and mortality in the sub-Saharan region (Ngonzi et al. 2016). Uzbekistan has witnessed improved population health outcomes, with improved coverage of services. Over the past decade, Uzbekistan has made notable strides in key health indicators, including an increase in life expectancy at birth from 66 years in 1993 to 72 years in 2022 (WHO, 2023), alongside significant decline of under-five mortality from 17 in 1993 to 13 in 2022 per 1,000 live births (UNFPA, 2023). According to the World Health Organization, over the period 2000-2020, maternal mortality ratio (MMR) in Uzbekistan declined from 43 deaths per 100 000 live births to 30 deaths per 100 000 live births. The purpose of this paper is to model and forecast MMR for Uzbekistan using Holt's linear method. The study findings will assist in designing health policies, planning and allocation of adequate resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Yusupova et al. (2026)	to evaluate the impact of a quality improvement (QI) initiative implemented in ten district hospitals from 2021 to 2024 to improve maternal, new born, and childcare to accelerate progress towards achieving the Sustainable Development Goals in Tajikistan	-A baseline assessment was conducted in 2021, with an endline assessment in 2023, using updated WHO quality assessment tools - A multidisciplinary team of national and international experts evaluated hospital performance across three domains: support systems, clinical management, and organization of care.	observed notable improvements in the quality of hospital care, with most facilities progressing from substandard to better-performing categories
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	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



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.

		an autoregressive integrated moving average (ARIMA) model	1997 Asian financial crisis yet picked up pace after 2000
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 hospitals (training and service) from January 2019 to December 2022.	The top three-most common indications for primary CS were dysfunctional labor, fetal distress, and malpresentation. Stillbirth, perinatal, and maternal 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



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.

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 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 -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)	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 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)	Postpartum hemorrhage remains the primary cause of maternal mortality in Bangladesh



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.

		-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	
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 (ANC), skilled birth attendance (SBA) and optimal post-natal care (PNC), (2) identifying the	The study employed data from the Cambodia Demographic Health Survey 2014. We 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	Household wealth was found to be the most influential factor, yet the study discovered also other barriers to optimal maternal health care which need to be addressed



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.

	determinants of drop ping out from one service to another and (3) of not achieving the complete CoC	regression were performed using STATA version 14	
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 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)



Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Uzbekistan. 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

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

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 Uzbekistan 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)	1.555857
Sum Square Error (SSE)	339.499102
Mean Square Error (MSE)	8.705105
Mean Percentage Error (MPE)	0.122638
Mean Absolute Percentage Error (MAPE)	3.103912

Residual Analysis for the Applied Model

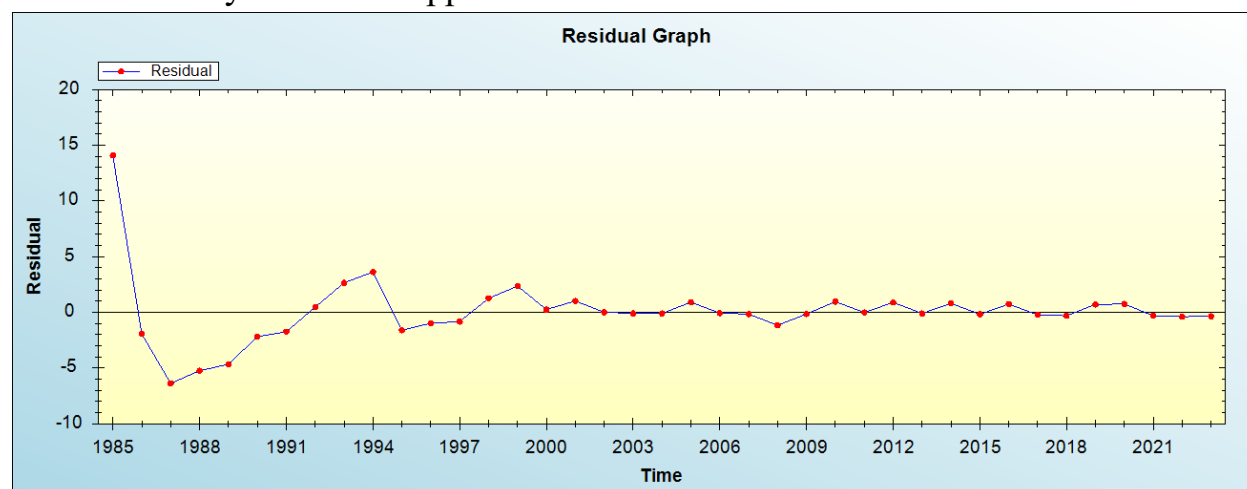


Figure 1: Residual analysis



In-sample Forecast for U

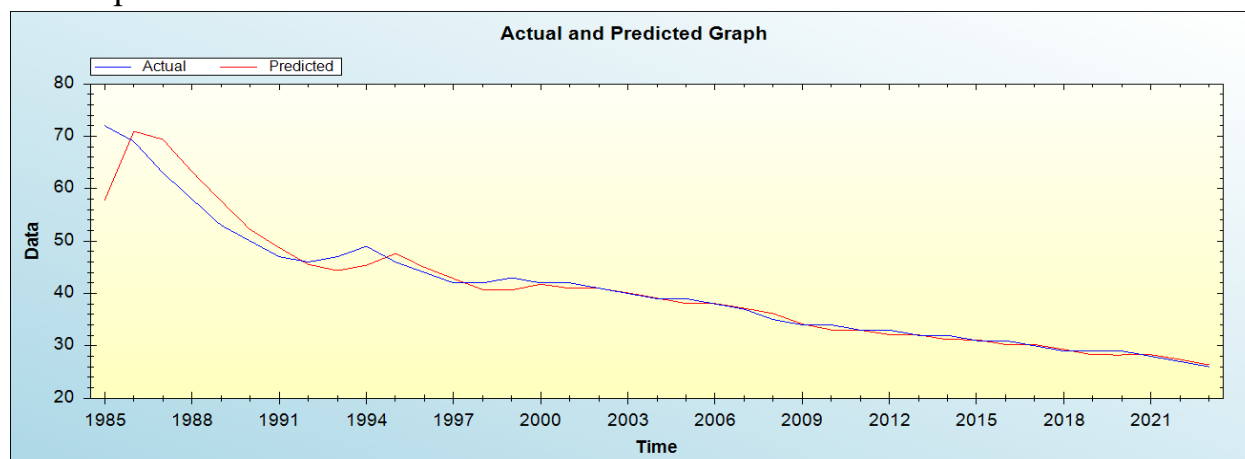


Figure 2: In-sample forecast for the U series

Actual and Smoothed graph for U series

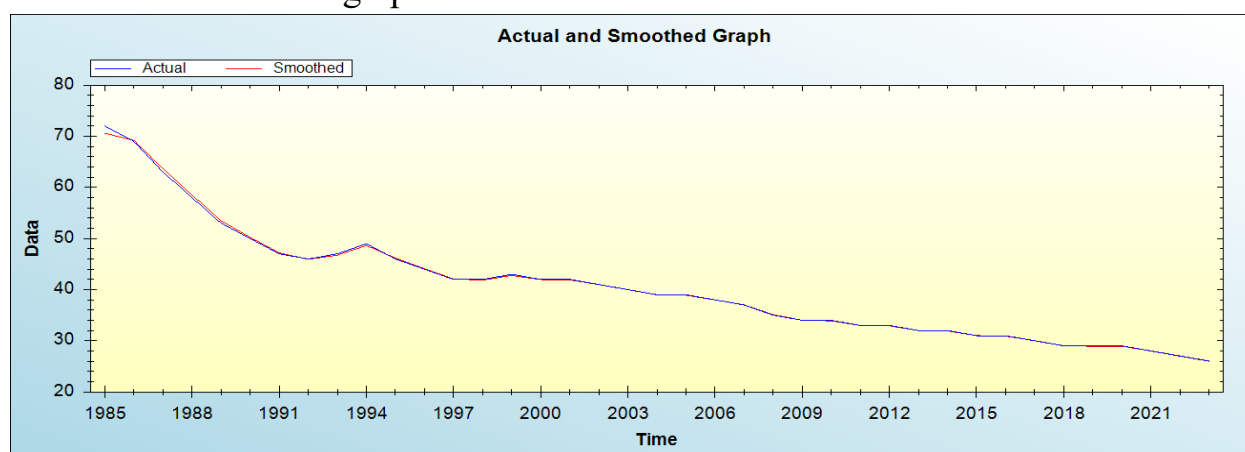


Figure 3: Actual and smoothed graph for U series

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

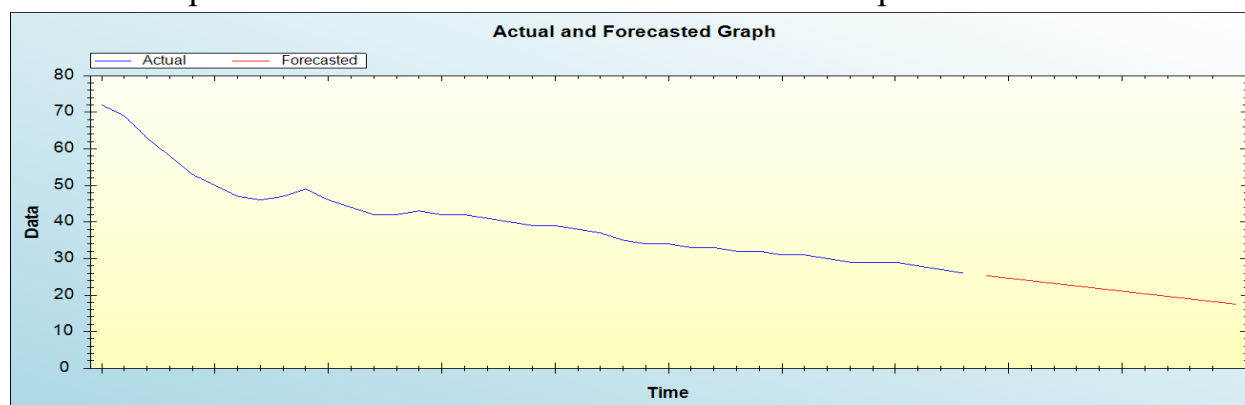


Figure 4: Out-of-sample forecast for U: actual and forecasted graph



Out-of-Sample Forecast for U: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	25.3283
2025	24.6201
2026	23.9120
2027	23.2039
2028	22.4958
2029	21.7877
2030	21.0796
2031	20.3714
2032	19.6633
2033	18.9552
2034	18.2471
2035	17.5390

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

Conclusion

In this study, we applied the double exponential smoothing approach to model and forecast MMR for Uzbekistan and findings indicate that MMR will remain below 30 deaths per 100 000 live births over the out of sample period. Hence, we implore authorities in this country to relentlessly address local causes of maternal mortality.

References

1. Dahab R and Sakellariou D (2020). Barriers to accessing maternal care in low-income countries in Africa: A systematic review. *Int. J. Environ. Res. Public Health* 2020, 17, 4292.
2. Esther A.Q., Yahaya H., Esther A.O., Aboagye-Mensah P., Blessing A.J., and Ikome T.E (2023). A Scoping Review on Influence of Socioeconomic Status



-
- on Antenatal Care Utilization and Pregnancy Outcomes in Sub-Saharan Africa. MedRxiv 2023, 28, 514–519.
3. Flake S (2022). Lack of Access to Maternal Healthcare in Sub-Saharan Africa. Ballard Brief 2022, 2022, 4.
 4. Graham W.J., Bell J.S., and Bullough C.H.W (2001). Can skilled attendance at delivery reduce maternal mortality in developing countries? In Safe Motherhood Strategies: A Review of the Evidence 2001; Elsevier: Amsterdam, The Netherlands.
 5. Musarandega R., Nyakura M., Machekano R., Pattinson R., and Munjanja S.P (2021). Causes of maternal mortality in Sub-Saharan Africa: A systematic review of studies published from 2015 to 2020. J. Glob. Health 2021, 11, 04048.
 6. Ngonzi J., Tornes Y.F., Mukasa P.K., Salongo W., Kabakyenga J., Sezalio M., Wouters K., Jacquem Y., and Van Geertruyden J.-P (2016). Puerperal sepsis, the leading cause of maternal deaths at a Tertiary University Teaching Hospital in Uganda. BMC Pregnancy Childbirth 2016, 16, 207.
 7. Onambe L., Guillen-Aguinaga S., Guillen-Aguinaga L., Ortega-Leon W., Montejo R., Alas-Brun R., Aguinaga-Ontoso E., Aguinaga-Ontoso I., and Guillen-Grima F (2023). Trends, Projections, and Regional Disparities of Maternal Mortality in Africa (1990–2030): An ARIMA Forecasting Approach. Epidemiologia 2023, 4, 322–351.
 8. Prata N., Passano P., Sreenivas A and Gerdt C.E (2010). Maternal Mortality in Developing Countries: Challenges in Scaling-Up Priority Interventions. Womens Health 2010, 6, 311–327.
 9. United Nations (2015). Goal 3: Ensure Healthy Lives and Promote Well-Being for All at All Ages. Available online: <https://tinyurl.com/29nvv5f5>
 10. United Nations Population Fund (2023). Maternal Mortality in Uzbekistan. <https://www.unfpa.org/data/world-population/UZ>
 11. Vallely L.M., Calvert B., De Silva M., Panisi L., Babona D., Bolnga J., Duro-Aina T., Noovao-Hill A., Naidu S., and Leisher S (2023). Improving maternal and newborn health and reducing stillbirths in the Western Pacific



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.

-
- Region—Current situation and the way forward. Lancet Reg. Health West. Pac. 2023, 32, 100653.
12. World Health Organization (2023). Uzbekistan: Country Profile – Life Expectancy (2000–2023). <https://data.who.int/countries/860>
 13. World Health Organization (2024). Maternal Mortality. Available online: <https://x.gd/J31vG>.
 14. World Health Organization (WHO) (2019) Trends in Maternal Mortality 2000 to 2017: Estimates from WHO, UNICEF, UNFPA, the World Bank Group and the United Nations Population Division: Policy Summary.