



APPROXIMATION OF FUTURE VALUES OF ANNUAL MATERNAL MORTALITY FOR PAPUA NEW GUINEA USING HOLT'S LINEAR METHOD

Smartson. P. NYONI 1

Thabani NYONI 2

1 Independent Researcher & Medical Doctor, Harare, Zimbabwe

2 Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract

This study uses annual time series data on MMR for Papua New Guinea 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 0.5 and 0.9 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain high over the out of sample period. Therefore, we encourage health authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Papua New Guinea (PNG) is a country in the Pacific with over 9 million inhabitants (UNDP, 2019; PNG, 2015). There are four regions in PNG that are made up of 22 provinces and one autonomous region. Approximately 80% of the population resides in rural and remote areas with poor road infrastructure making it difficult to access medical services. Health care services are offered at aid posts, primary care medical facilities, district hospitals and referral hospitals. In addition, above 800 languages are spoken across the country (Eberhard et al. 2019) making the provision of health care challenging. PNG has one of the highest maternal mortality rates (MMR) and infant mortality rates (IMR) in the Asia-Pacific region (Dennis, 2018; UN, 2015; Williams, 2014). The major causes of maternal mortality are obstetric bleeding (30%), infection (5%), embolism (15%) eclampsia (14%) and abortion (7%) (Count down 2030; PNG, 2015). This



country faces numerous health challenges that include inadequate healthcare facilities, shortage of healthcare workers, equipment, drugs and commodities, and limited water and sanitation infrastructure (PNG, 2015; World Bank, 2011). The purpose of this paper is to model and forecast MMR for PNG using Holt's linear method. The study findings are expected to guide policy making, planning and allocation of resources to the maternal and child health program in order to further reduce avoidable maternal deaths across the country.

Author(s)	Objective(s)	Methodology	Main finding(s)
Leno et al. (2024)	to estimate the proportion of women who had completed the different stages of the continuum of maternal health care (four antenatal visits, given birth under the care of qualified personnel, and received postnatal care within 42 days of delivery	cross-sectional analytical study	found that 26.9% of women had completed all stages of the maternal health care continuum, while 73.1% had not. While 56.7% received four antenatal visits, only 29.5% delivered under the care of a qualified healthcare professional. Key factors associated with discontinuity were not attending school (AOR 1.825: 1.594–2.089), unemployment (AOR 4.588: 3.983–5.285), having two or more living children (AOR 1.890: 1.016–1.296), and not receiving a free Long-Lasting Insecticidal Net at the first Antenatal Care
Cisse et al. (2023)	to analyze maternal and child health indicators using CCI	-performed a secondary analysis of Guinea demographic and health surveys (DHS) focused on women aged 15 to 49 and their children aged 1 to 4	This study showed an increase in CCI between 2012 and 2018
Li et al. (2023)	to assess the prevalence and determinants of ANC, SBA and PNC services amongst women in PNG	The study was conducted using the 2016–2018 Papua New Guinea Demographic and Health Survey. A total of 5248	the prevalence rates of ANC, SBA and PNC services were 52.3%, 58.7% and 26.6%, respectively. Women's



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 4, April 2026

Website: usajournals.org

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

		reproductive-age women were considered as the analytical sample. The outcome variables were utilization of ANC, SBA and PNC services. Chi-square test, multivariable logistic regression and dominance analysis were conducted. Statistical significance was set at $p < 0.05$.	employment, education, media exposure, distance to health facility, household wealth, region, residence and parity were determinants of MHS utilization
Manamo et al. (2023)	to examine the socio-economic differentials of under-five mortality in Botswana within the framework of equality and equity	The was based on the data from 2001 and 2011 Botswana Population and Housing Censuses and the 2017 Botswana Demographic Survey. One census method was used to indirectly estimate under five mortalities for different socio-economic groups using Princeton west model life tables.	socio-economic disparities in under-five mortality disfavoring the worse-off exist in all the selected socio-economic variables
Chacha et al. (2022)	review the current cardiac obstetrics practice, gaps, and potential areas of improvement.	Systematic review	With an increasing number of women with pre-existing cardiac conditions becoming pregnant, the contribution of CVD to maternal mortality is also growing. Consequently, there is a need for accurate diagnosis and appropriate care of pregnant women with CVD to minimize adverse outcomes
Zegeye et al. (2022)	To investigate the magnitude and trends in socioeconomic and geographic-related inequalities in SBA in Guinea from 1999 to 2016 and neonatal mortality rate (NMR) between 1999 and 2012	The study derived data from three Guinea Demographic and Health Surveys (1999, 2005 and 2012) and one Guinea Multiple Indicator Cluster Survey (2016). For analysis, we used the 2019 updated WHO	Disproportionate inequalities in SBA and NMR exist among disadvantaged women such as the poor, uneducated, rural residents, and women from regions like Mamou region



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 4, April 2026

Website: usajournals.org

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

		Health Equity Assessment Toolkit (HEAT). The study analyzed inequalities in SBA and NMR using Population Attributable Risk (PAR), Population Attributable Fraction (PAF), Difference (D) and Ratio (R)	
Isaacson et al. (2021)	to evaluate the prevalence and outcome of twin pregnancies in Botswana	Quantitative analysis	Adverse birth outcomes are common among twins in Botswana, and are often severe
Mohamed et al. (2021)	to determine whether the health crisis in Comoros is attributable to the consequences of the chronic political instability	semi-structured interviews with key informants	political instability and lack of proper leaders' hip from the Government undermine the establishment of health policies which contributed dramatically to the decline in health performance
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Millimouno et al. (2019)	to evaluate the maternal deaths surveillance and response (MDSR) system at the health district level in Guinea	descriptive cross-sectional study was conducted, using an innovative digital approach called District. Team, from April to September 2017	-In total, 23 (61%) district medical officers (DMOs) participated in the study. Out of health districts (87%) which had updated guidelines and standards for the MDSR, 4 (20%) did not apply the content. In two health districts (8.7%), not all health facilities had maternal deaths notification forms. Three districts (13%) did not have maternal death review committees -The weaknesses identified were, among



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 4, April 2026

Website: usajournals.org

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

			others, insufficiency of human resources and lack of financial resources
Robbers et al. (2019)	to provide an overview of research on key maternal and neonatal health (MNH) indicators conducted approximately over the past 11 years in PNG comparing research findings to global MNH estimates of the indicators	Comparative study	There was considerable variation in mortality indicators (maternal mortality ratio, neonatal mortality rate and stillbirth) reported across studies in PNG. Mortality was generally higher in rural areas. Rates of sexually transmitted infections (STIs) in pregnancy were consistently high, while anemia in pregnancy, preterm birth and low birth weight varied widely between studies and settings
Akhter et al. (2018)	to present, analyze and interrelate recent data to find barriers to achieving set MDG 5 targets by 2015	literature review has been done as a main method of data collection from Elsevier, Lancet, WHO, UNICEF, BBMS, NIPORT published from 2001 to May 2018	approximately 80% of maternal deaths could be averted if women had access to essential maternity and basic health care services
Oyekale et al. (2018)	To analyze the effect of maternal education and fertility on child survival in the Islands of Comoros	The 2012 Demographic and Health Survey (DHS) data were used. A two-stage probit regression method was used for data analysis	The results showed that about 75% of the children's mothers had given birth to between one and five children, while more than half did not have any form of formal education

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

P_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 Papua New Guinea 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	P
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.500
Beta (β) for trend	0.900
Forecast performance measures	
Mean Absolute Error (MAE)	5.737658
Sum Square Error (SSE)	3058.278041
Mean Square Error (MSE)	78.417386
Mean Percentage Error (MPE)	-0.062013
Mean Absolute Percentage Error (MAPE)	2.264738

Residual Analysis for the Applied Model

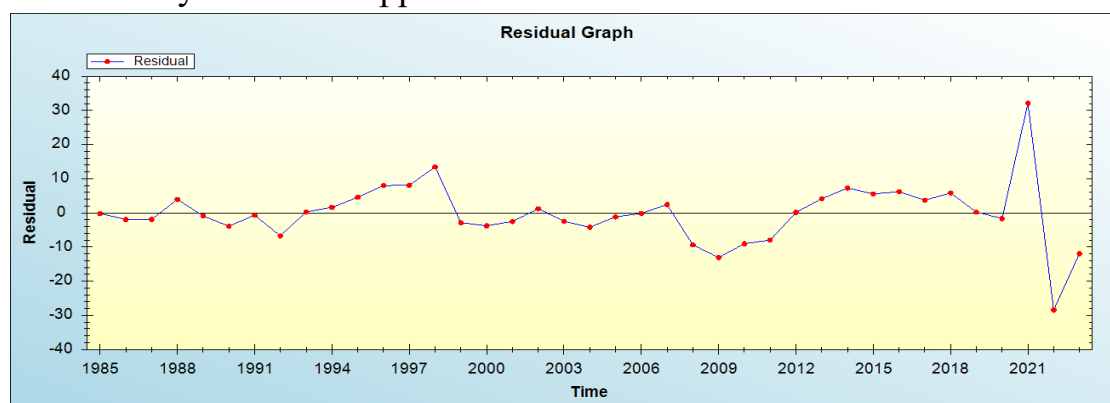


Figure 1: Residual analysis

In-sample Forecast for P

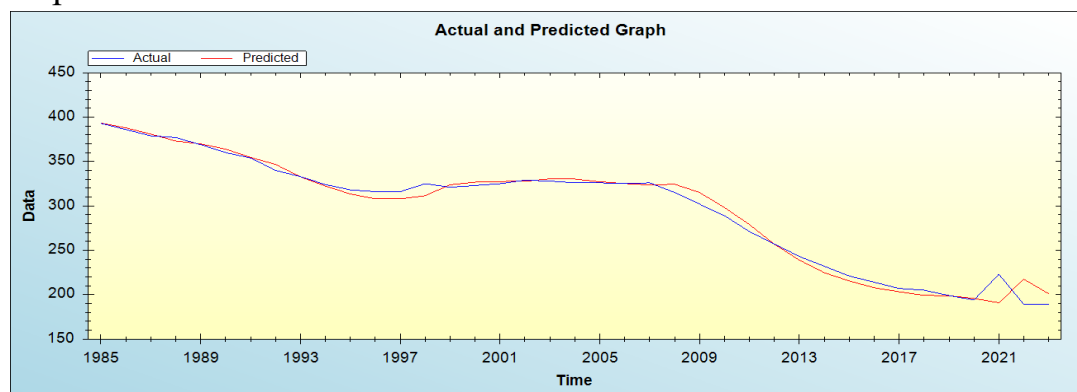


Figure 2: In-sample forecast for the P series



Actual and Smoothed graph for P series

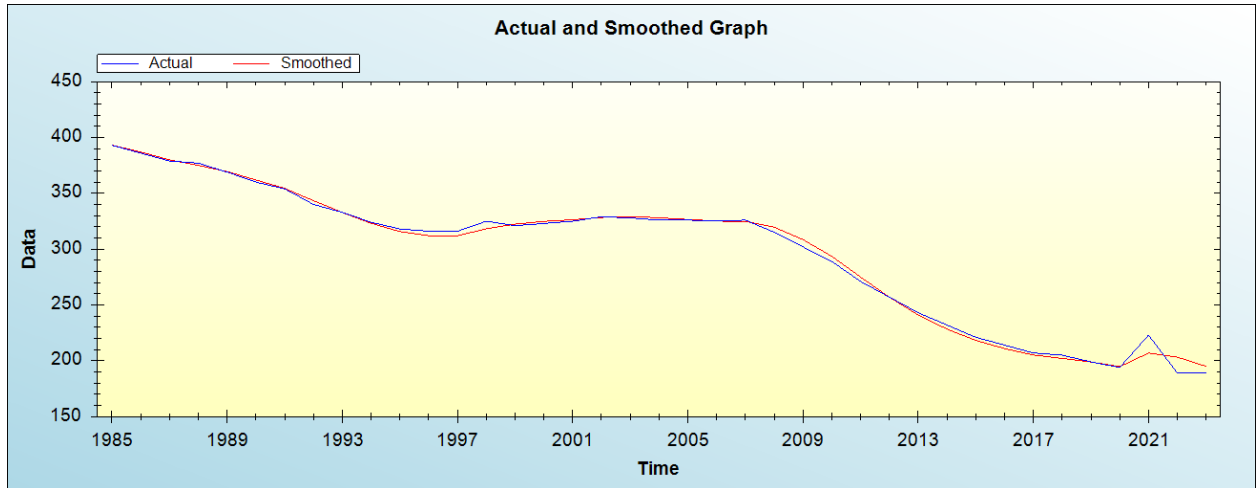


Figure 3: Actual and smoothed graph for P series

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

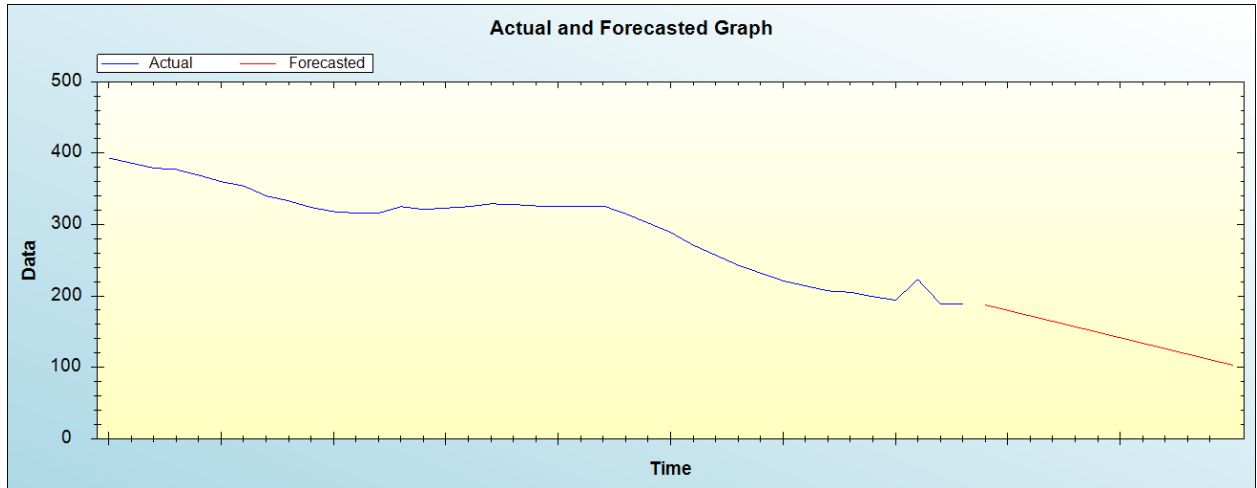


Figure 4: Out-of-sample forecast for P: actual and forecasted graph



Out-of-Sample Forecast for P: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	187.2998
2025	179.6416
2026	171.9834
2027	164.3252
2028	156.6670
2029	149.0088
2030	141.3506
2031	133.6924
2032	126.0342
2033	118.3760
2034	110.7178
2035	103.0596

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 continue to fall but still remain high over the out of sample period.

Recommendations & Conclusion

PNG has one of the highest maternal mortality rates and infant mortality rates in the Asia-Pacific region. The major causes of maternal mortality are obstetric bleeding, infection, embolism eclampsia and abortion. This country faces numerous health challenges that include inadequate healthcare facilities, shortage of healthcare workers, equipment, drugs and commodities, and limited water and sanitation infrastructure. In this study we model and forecast MMR for PNG and findings indicate that MMR is expected to fall but still remain high over the out of sample period. Hence, authorities are encouraged to adopt the following policy prescription: (1) end teenage pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) improve quality of maternity services by conducting routine quality improvement activities (4) ensure availability of



adequate medical supplies and medical staff in all medical facilities and (5) create posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

References

1. Countdown 2030. Countdown country dashboards– Papua New Guinea. 2018 [cited 2019 Apr 24]; Available from: <http://profiles.countdown2030.org/#/ds/PNG>.
2. Dennis A (2018). Reducing maternal mortality in Papua New Guinea: contextualizing access to safe surgery and anesthesia. *Anesth Analg.* 2018;126(1):252–259.
3. Eberhard D., Gary F., and Charles D (2019). *Ethnologue: languages of the World Papua New Guinea.* Available from: <https://www.ethnologue.com/country/PG>.
4. PNG (2015). Department of National Planning and Monitoring., Papua New Guinea– millenium development goals fund summary report 2015.
5. UN (2015). United Nations ESCAP. A.U., Making it happen– Asia Pacific Regional MDGs Report 2014/15– Technology, finance and statistics for sustainable development in Asia and the Pacific 2015, Bangkok: United Nations ESCAP, ADB & UNDP.
6. UNDP (2019). About Papua New Guinea: United Nations Development Programme. Available from: http://www.pg.undp.org/content/papua_new_guinea/en/home/countryinfo.html. 2019 [cited 2018 Oct 12].
7. Williams C (2014). Maternal deaths and their impact on children in Papua New Guinea. *Aust N Z J Public Health.* 2014; 38:405–407.
8. World Bank (2011). Reproductive health at a glance Papua New Guinea. 2011, New York (NY): World Bank.