



MAKING USE OF SINGLE EXPONENTIAL SMOOTHING MODEL PREDICTIONS TO INFORM MATERNAL HEALTH STRATEGIES IN RWANDA

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 Rwanda from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes single exponential smoothing model. The optimal value of the smoothing constants α is 0.3 based on minimum MSE. The results of the study indicate that MMR will remain very high hovering around 249 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Sub-Saharan Africa continues to report high maternal mortality rates which account for around 66% of global maternal deaths (WHO, 2019). The main causes of maternal mortality in Rwanda are mostly avoidable. These are postpartum hemorrhage (PPH), hypertensive disorders, abortion, and obstructed labor (Ngabonzima et al. 2020; Benimana et al. 2018). Rwanda's institutional delivery rate rose very fast in recent decades from 28% in 2005 to 93% in 2019/2020 (National Institute of Statistics of Rwanda, 2020). This increase offers an opportunity for the provision of quality maternity services. However, in some facilities healthcare providers may become overloaded due to higher numbers of patients and continue to work in constrained environments, which may increase



severe maternal outcomes (Tunçalp et al. 2015). In other similar settings, where the implementation of life-saving evidence-based interventions for women coming to deliver at hospitals was not evident, the increased facility delivery rates did not lead to improved quality of care and resulted in severe maternal outcomes (Veenstra et al. 2022; Nelissen et al. 2013). According to the Rwanda Demographic Health Survey (RDHS) 2014–2015, the MMR dropped from 1071 in 2000 to 210 in 2015, whereas the percentage of institutional deliveries increased from 27% to 91% over the same period (Rwanda Institute of Statistics, 2015; Rwanda Institute Statistics, 2002). Rwanda has demonstrated a strong political will to improve the quality of maternal and newborn health services. One of the measures taken to achieve this was the introduction in 2009 of maternal death audits (MDA) on a routine basis nationwide. The objective of this paper is to model and forecast MMR for Rwanda using the single exponential smoothing model. The study findings are expected to inform policy, planning and allocation of resources to the health sector so that preventable maternal mortality is further reduced.

Literature Review

Author (s)	Objective(s)	Methodology	Main finding(s)
Hotchkiss et al. (2025)	To assess the impact of a large, complex health systems strengthening program on maternal health care utilization in the DRC.	A difference-in-differences approach was applied using population-based household survey data at base line (2014) and endline (2017) from treatment and matched comparison areas in three provinces	The health systems strengthening program significantly increased the probability of facility-based delivery, but had no significant impact on receiving at least four ANC visits. Qualitative findings suggest that uptake of ANC was constrained by travel distance, time burdens, limited community outreach, and cultural norms discouraging early ANC initiation
Ngavele et al. (2025)	to determine the frequency, causes, and associated factors of maternal mortality in the	retrospective descriptive	The results show that the frequency of maternal deaths in the health zone was 0.11%. Hemorrhage was the leading cause of maternal death in the



	health zone of Bunia in Ituri province		Bunia health zone, accounting for 45.95%. Delays in seeking medical care were the most significant factor associated with maternal deaths, representing 22.95%. Insufficient technical facilities were the most significant structural factor, representing 50.82%. Delays in care were the primary factor linked to midwives, at 67.21%
Tayebwa et al. (2025)	To assess the incidence of severe maternal outcomes (SMO) and process indicators among maternity waiting home (MWH) users and non-users in a rural Rwandan hospital	-conducted a retrospective cohort study among women who were eligible for admission to the MWH (users and non-users) at Ruli Hospital in Rwanda and had delivered between January 2015 to December 2019	The leading cause of SMO was post-partum hemorrhage (PPH) (87.5% among MWH users and 45.1% among non-users), followed by sepsis and hypertensive disorders.
Matongo et al. (2024)	to determine the frequency of serious maternal morbidity at the Ruashi military hospital (DRC) with a view to ensuring good care and monitoring of pregnant women	descriptive study	The incidence of maternal morbidity was 24.2%, of which 32.4% had anemia followed by hemorrhage with 27% and finally sepsis and uterine subinvolution with 5.4% each
Mwene-Batu et al. (2024)	to describe the trends as well as the epidemiological profile and causes of reported institutional maternal deaths between 2013 and 2022 in Eastern DRC	retrospective descriptive study	Overall, 62,6% of the deaths were reported from secondary hospital. Most deaths were of married women in their thirties (93.5%). Almost half (47.8%) had not completed four antenatal consultations. The main direct causes of death were, in decreasing order of frequency: post-partum hemorrhage (55.2%),



			uterine rupture (14.0), hypertensive disorders (8.4%), abortion (7.7%) puerperal infections (2.8%) and placental abruption (0.7%)
Tayebwa et al. (2021)	To compare maternal and perinatal outcomes among MWH users and non-users through a retrospective cohort study	Data were collected through obstetric chart reviews and analyzed using STATA version 15	MWH users had more spontaneous vaginal deliveries compared to non-users (38.6% versus 16.8%) and less cesarean sections (57.7% versus 76.7%). Maternal morbidities such as postpartum hemorrhage occurred less frequently among users than non-users (2.13% versus 5.64%)
Ramazani et al. (2021)	To measure the mortality rate in health facilities in eastern DRC and identifies the associated risk factors	analytical epidemiological study based on retrospective data maternal deaths recorded in 59 health facilities, in three health zones in the southern part of Maniema province in east DRC	The maternal mortality rate was estimated at 620 deaths per 100,000 live births, of which 46% of maternal deaths were related to a parturients' delayed decision in seeking healthcare in time (first delay)
Zhang et al. (2021)	To explore the relationship between self-reported insecurity of mothers and maternal health-seeking behaviors and diseases in children in the DRC	Applied logistic regression	Conflicts increase mothers' insecurities and negatively affect children's development
Shon et al. (2018)	to evaluate the costs and benefits of the MCH project	conducted a cost-benefit analysis (CBA) using a benefit-cost ratio (BCR)	The benefits of reduced maternal mortality and the mortality of infants and children aged under 5 years were estimated as USD 681,416, USD 4,332,376, and USD 1,710,184, respectively, in monetary terms



Odette et al. (2017)	to analyze the etiologies of maternal deaths occurring in a tertiary hospital in DRC	This is a descriptive cross-sectional study with retrospective data collection of maternal deaths that occurred in the reference provincial hospital Jason Sendwe from 2013 to 2015. All cases of maternal deaths in line with the definition of World Health Organization have been included.	Bleeding with 61.04% was the leading cause of maternal death followed by eclampsia (31.58%). Indirect causes were dominated by heart disease (30.0%)
Sayinzonga et al. (2017)	to identify characteristics, causes and contributory factors of severe maternal outcomes in Rwanda, using standard indicators for quality of care	prospective case-control study	Despite the use of life saving interventions, SMO are frequent. Mortality index was found to be low at the level of district hospitals. SMO were associated with long stay at the hospital and stillbirth
Rulisa et al. (2015)	To determine the prevalence and factors associated with severe ('near miss') maternal morbidity and mortality in the University Teaching Hospital of Kigali- Rwanda	cross sectional study	The prevalence of severe maternal outcomes was 11 per 1000 live births. The maternal near miss ratio was 8 per 1000 live births. The majority of severe obstetric morbidity and mortalities resulted from: sepsis/peritonitis (30.2 %)– primarily following caesarean deliveries, hypertensive disease (28.6 %), and hemorrhage (19.3 %). Majority of patients were found to be of lower socioeconomic status, referred from district hospitals to the tertiary care center, and resided in the eastern part of the country



Sayinzoga et al. (2015)	To present the results of 5 years of implementing health facility-based maternal death audits in Rwanda, showing maternal death classification, identification of substandard (care) factors that have contributed to death, and conclusive recommendations for quality improvements in maternal and obstetric care	Nationwide facility-based retrospective cohort study	Almost 3 quarters of the deaths (71.6%) occurred at district hospitals. In 44.9% of these cases, death occurred in the post-partum period. Seventy per cent were due to direct causes, with post-partum hemorrhage as the leading cause (22.7%), followed by obstructed labor (12.3%). Indirect causes accounted for 25.7% of maternal deaths, with malaria as the leading cause (7.5%). Health system failures were identified as the main responsible factor for the majority of cases (61.0%); in 30.3% of the cases, the main factor was patient or community related
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Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Rwanda. 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 single exponential smoothing technique because it is an appropriate technique for modeling data without a trend and seasonal pattern

The single exponential smoothing model is specified as follows;

$$R(t) = \beta(t) + \varepsilon(t)$$

Where $\beta(t)$ is a constant at time t , $\varepsilon(t)$ is a stochastic error term

$R(t)$ OR R_t is the actual value of the time series variable at time t

The forecast equation is then expressed as follows:

$$F_{t+1} = \alpha R_t + (1-\alpha) F_t$$

Where F_t is the forecast value of variable R at time t

F_{t+1} is the forecast value of variable R at time $t+1$

α is the smoothing constant



Data Issues

This study is based on annual MMR in Rwanda 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	R
Included Observations	39
Smoothing constant	
Alpha (α)	0.300
Forecast performance measures	
Mean Absolute Error (MAE)	347.844892
Sum Square Error (SSE)	23796410.271824
Mean Square Error (MSE)	610164.365944
Mean Percentage Error (MPE)	-25.980972
Mean Absolute Percentage Error (MAPE)	33.115168

Residual Analysis for the Applied Model

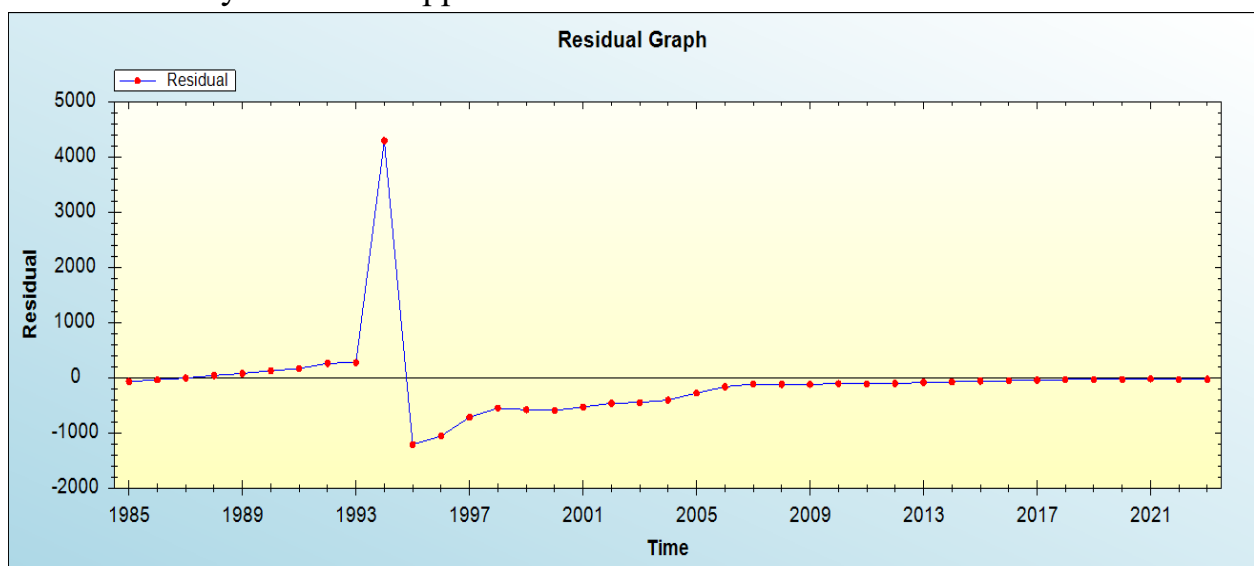


Figure 1: Residual analysis



In-sample Forecast for R

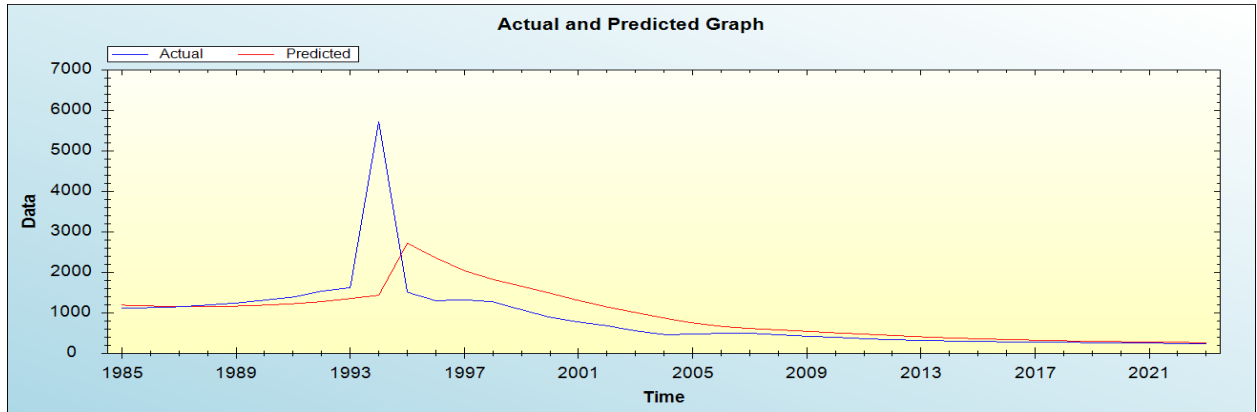


Figure 2: In-sample forecast for the R series

Actual and Smoothed graph for R series

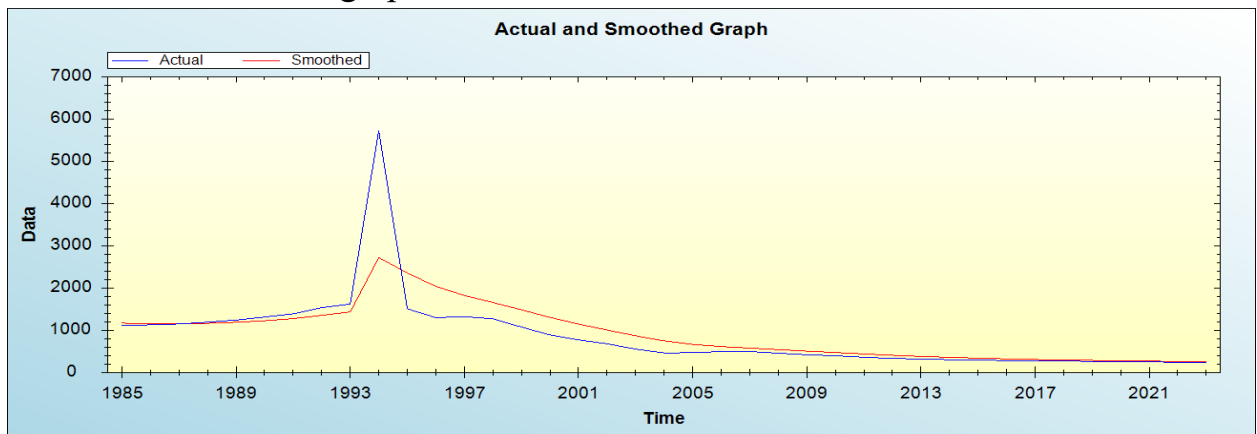


Figure 3: Actual and smoothed graph for R series

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

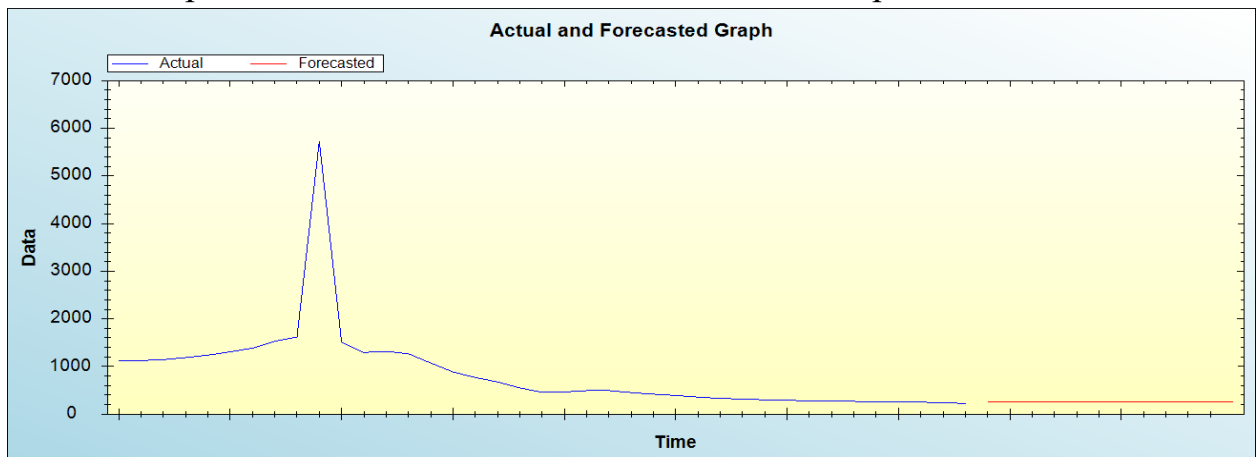


Figure 4: Out-of-sample forecast for R: actual and forecasted graph



Out-of-Sample Forecast for R: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	249.4295
2025	249.4295
2026	249.4295
2027	249.4295
2028	249.4295
2029	249.4295
2030	249.4295
2031	249.4295
2032	249.4295
2033	249.4295
2034	249.4295
2035	249.4295

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 very high hovering around 249 deaths per 100 000 live births over the out of sample period.

Recommendations & Conclusion

The burden of maternal mortality is still high in Rwanda reflecting deficiencies that still exist in the continuum of care. This paper applies the single exponential smoothing technique to model and forecast MMR and results indicate that MMR is expected to remain high hovering around 249 deaths per 100 000 live births throughout the forecast period. Hence, we encourage authorities to adopt the following policy prescription: (1) end adolescent 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) conduct routine quality improvement activities such as refresher courses and mentorship programs (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. Benimana C., Small M., and Rulisa S (2018). Preventability of maternal near miss and mortality in Rwanda: a case series from the university teaching hospital of Kigali (CHUK). PLoS One. 13(6): e0195711. doi: 10.1371/journal.pone.0195711
2. National Institute of Statistics of Rwanda (2020). Demographic Health Survey. National Institute of Statistics of Rwanda Ministry of Finance and Economic Planning.
3. Nelissen E.J., Mduma E., Ersdal H.L., Evjen-Olsen B., van Roosmalen J.J., and Stekelenburg J (2013). Maternal near miss and mortality in a rural referral hospital in northern Tanzania: a cross-sectional study. BMC Pregnancy Childbirth. 13(1):1–10. doi: 10.1186/1471-2393-13-141 7.
4. Ngabonzima A., Kenyon C., Hategeka C., Utuza A.J., Banguti P.R., and Luginaah I (2020). Developing and implementing a novel mentorship model (4+1) for maternal, newborn and child health in Rwanda. BMC Health Serv Res. (2020) 20:1–11. doi: 10.1186/s12913-020-05789-z
5. Rwanda National Institute of Statistics (2002). In: Rwanda National Institute of Statistics, editor. Rwanda demography and health survey. Rwanda; 2000. p. 2002.
6. Rwanda National Institute of Statistics (2015). Rwanda demography and health survey 2014–2015. Rwanda: Rwanda National Institute of Statistics; 2015.
7. Tunçalp Ö., Were W., MacLennan C., Oladapo O.T., Gülmezoglu A.M., and Bahl R (2015). Quality of care for pregnant women and newborns—the WHO vision. BJOG. (2015) 122(8):1045. doi: 10.1111/1471-0528.13451
8. Veenstra E.D., Herklots T., Said Mbarouk K., Meguid T., Franx A., and Jacod B (2022). Too busy to care? Analysing the impact of system-related factors



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- on maternal mortality in Zanzibar's referral hospital. J Obstet Gynaecol. 42(7):2917–23. doi: 10.1080/ 01443615.2022.2113769
9. World Health Organization (2019). Trends in Maternal Mortality 2000–2017: Estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division.