Western European Journal of Medicine and Medical Science
Volume 4, Issue 07, July 2026
https://westerneuropeanstudies.com/index.php/3
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ANNUAL MATERNAL MORTALITY RATE FORECASTING FOR THE REPUBLIC OF SOUTH AFRICA USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for South Africa 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 0.7 and 0.5 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall and reach levels below 30 deaths per 100 000 live births by 2035. Therefore, we encourage health authorities to adopt the suggested 5-fold policy prescription.

Keyword(s): - *Exponential smoothing, Forecasting, Maternal Mortality Ratio*

Introduction

Ending preventable maternal mortality as agreed at the UN General assembly in 2015 by all UN member states will remain a global health priority (UN, 2018). WHO data indicates that in 2017, 295,000 women died as a result of pregnancy- or childbirth-related complications, of which, 99% were reported in low-middle income countries. Sub-Saharan Africa bears the largest burden of maternal deaths with a maternal mortality ratio (MMR) of 920/100,000 live births, compared to only 20/100,000 live births in developed countries (WHO, 2018; Saving mothers giving life, 2016). Statistics indicate that maternal mortality in the Republic of South Africa is increasing (Dorrington et al. 2016). By the end of 2015, its MMR had increased from 150/100,000 in 1990 to 154.1/100,000 in 2014 (Dorrington et al. 2016). The MMR for South Africa is calculated based on current institutional maternal mortality recorded in public medical facilities, and does not include maternal deaths happening in community and private facilities. This means that this country's MMR could be higher than what is currently being reported (NCCEMD, 2018; SAHR, 2015; Buchmann, 2011). The reduction in deaths from non-pregnancy related infections and the success of PMTCT programme in pregnancy and beyond have been hailed as the main reason for the decline in institutional MMR in South Africa during the past few years (NCCEMD, 2018). The objective of this study is to model and forecast MMR for the Republic of South Africa using the double exponential smoothing technique. The study findings are expected to facilitate crafting and implementation of effective health strategies that will further reduce preventable maternal deaths to levels below 70 deaths per 100 000 live births by 2030.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)

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Lenkoane et al. (2025)	to explore and describe the factors motivating women to attend antenatal care services before 16 weeks gestation	qualitative, exploratory and descriptive design study	Six themes were identified as the factors motivating early antenatal attendance in Lesotho, namely 1) confirmation of pregnancy, 2) concern for fetal well-being, 3) optimizing maternal well-being, 4) awareness raising through health education, 5) motivation from family and friends and 6) cultural and social expectations
Singh & Swain (2025	to explore the factors influencing CDMR and its effect on maternal and fetal outcomes	Prospective cohort study	The prevalence of CDMR was 21.35%, which was relatively higher than the World Health Organization's recommended guidelines
Nonyane et al. (2024)	To identify and describe determinants associated with avoidable perinatal deaths at a district hospital in Lesotho and strategies to curb their occurrence.	A retrospective descriptive study was conducted using 142 anonymized obstetric records from January 2018 to December 2020.	A concerning number of perinatal deaths were secondary to avoidable patient factors, namely a delay in seeking medical care, inappropriate responses to antepartum hemorrhage, and inadequate responses to poor fetal movements.

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			Medical personnel factors are also worth observing, namely incorrect use of partograph, insufficient notes to comment on avoidable factors and 'other' medical personnel problems
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
Mahada et al. (2023)	to explore the strategies used to reduce the maternal death rate and improve the provision of quality maternal healthcare services based on participant experiences in selected hospitals of the Vhembe district, Limpopo Province	qualitative approach using a phenomenological design	several factors, such as the lack of material resources, shortage of staff, incompetent staff and poor infection control, affect the quality of maternal health services in the Vhembe district
Mohale & Nyangu (2023)	To describe the psychological experiences of midwives regarding maternal deaths at two selected public hospitals in Lesotho	A qualitative, phenomenological inquiry was employed to collect data from a purposively selected sample of 10 midwives through face-to-face interviews	Psychological experiences such as trauma, shock, fear, stress, depression, loss of trust, helplessness, bad dreams, and insomnia were reported by the

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			midwives after the occurrence of maternal deaths. They resorted to individual coping strategies such as crying, alcohol and other substance-related use, and recreational activities
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
Mmusi-Phetoe & Masaba (2021)	To develop a model for reducing maternal mortality in South Africa	qualitative approach	Four themes emerged: (1) age at first pregnancy; (2) birth intervals, risks in pregnancy and hospitalization; (3) the use of contraception; and (4) HIV status. All themes that emerged revealed inattention to reproductive

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			health (RH) needs, resulting in poor RH outcomes as an area of concern
Teasdale et al. (2021)	To implement a rapid quality improvement project to improve ANC retention at seven health facilities in Eswatini (October-December 2017)	anonymous tablet-based audio assisted computer self-interview (ACASI) surveys	The type of rapid quality improvement intervention implemented may be useful in improving patient-provider relationships although whether it can improve retention remains unclear
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
Bomela (2020)	To assess and analyses the causes of maternal mortality according to sociodemographic factors in South Africa	The causes of maternal deaths were assessed with respect to age, province, place of death, occupation, education and marital status. Data were obtained from the vital registration database of Statistics South Africa	The study shows evidence of variations in the causes of death among different socio-demographic subgroups. These variations indicate that more attention has to be given to the role played by socio-demographic factors in maternal mortality
Damian et al. (2019)	to systematically review the estimates made of maternal and neonatal mortality	Systematic review	: Estimates from both global metrics and institutional reporting,

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	in the period from 1990 to 2015 in South Africa and determine trends over this period		although widely divergent, indicate South Africa has not achieved MDG 4a and 5a goals but made a significant progress in reducing maternal and neonatal mortality
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
Mmusi-Phetoe et al. (2016)	To identify and describe the social determinants of maternal and neonatal mortality in South Africa	A qualitative study using audio-taped individual interviews was conducted	Findings revealed that poverty was an underlying factor to the vulnerability to illness and death of the mothers and their neonates
Madzimbamuto et al. (2014)	To determine the underlying causes of maternal deaths reported in 2010, to categorize contributory factors and to prioritize appropriate interventions based on the identified causes, to prevent further deaths.	Case-notes for maternal deaths were reviewed by a panel of five clinicians, initially independently then discussed together to achieve consensus on assigning contributory factors, cause of death and whether each death was avoidable or not at presentation to hospital. Factors contributing to maternal deaths were categorized into organizational/management, personnel, technology/equipment/supplies, environment and barriers to accessing healthcare	The high number of contributory factors demonstrates poor quality of care even where deaths were not avoidable: 14/23 (61%) of direct deaths were considered avoidable compared to 12/32 (38%) indirect deaths. Highest ranking categories were: failure to

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			recognize seriousness of patients' condition (71% of cases); lack of knowledge (67%); failure to follow recommended practice (53%); lack of or failure to implement policies, protocols and guidelines (44%); and poor organizational arrangements (35%). Half the deaths had some barrier to accessing health services

Methodology

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

$A_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t$

Smoothing equation

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

$0<\alpha<1$

Trend estimation equation

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

$0<\beta<1$

Forecasting equation

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

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A_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 South Africa 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	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.700
Beta (β) for trend	0.500
Forecast performance measures	
Mean Absolute Error (MAE)	13.317540
Sum Square Error (SSE)	17238.357227
Mean Square Error (MSE)	442.009160
Mean Percentage Error (MPE)	-0.345696

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Mean Absolute Percentage Error (MAPE)	7.576338

Residual Analysis for the Applied Model

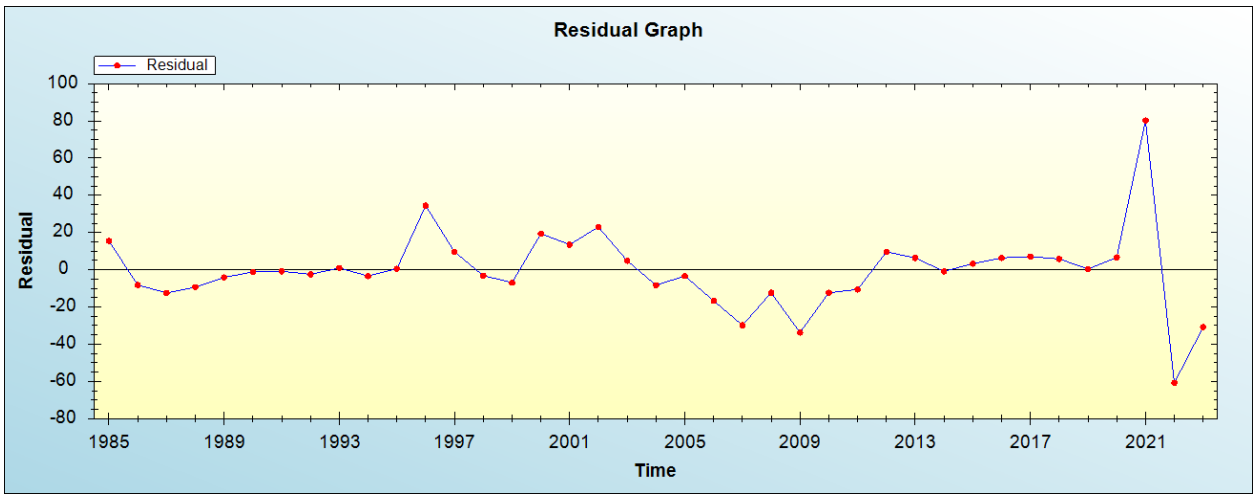

Figure 1: Residual analysis

In-sample Forecast for A

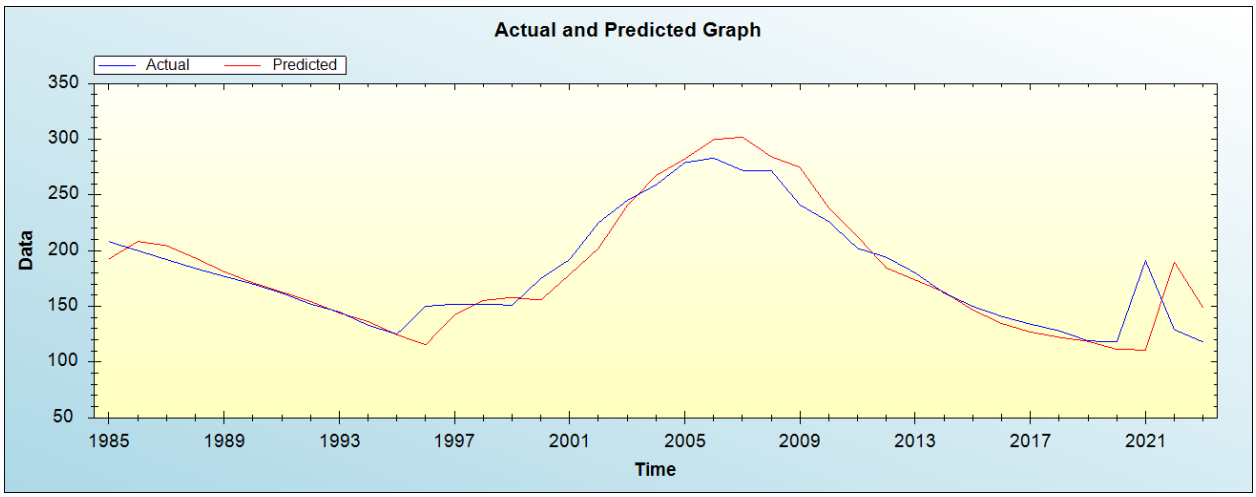

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

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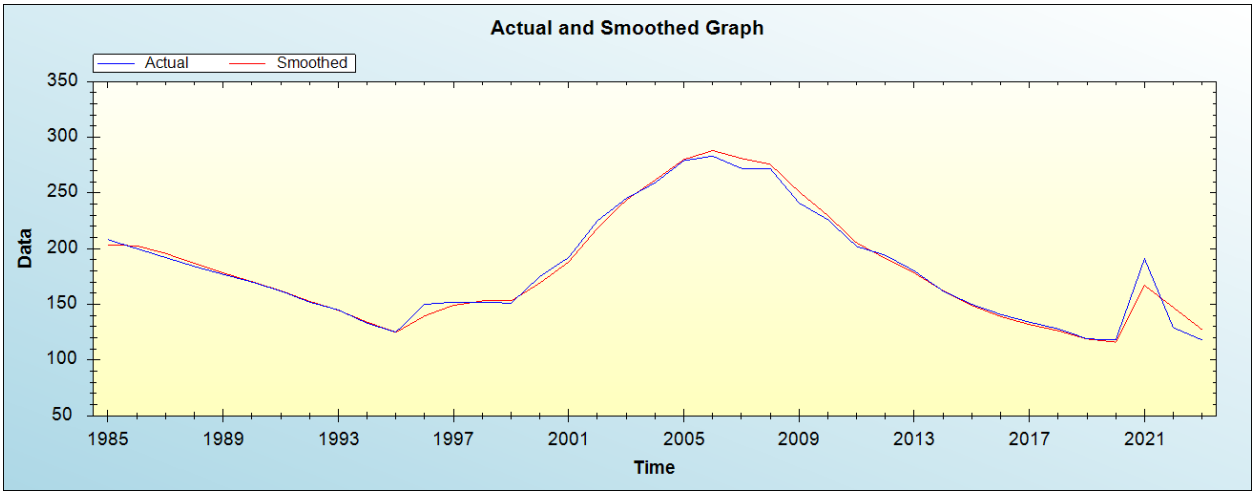

Figure 3: Actual and smoothed graph for A series

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

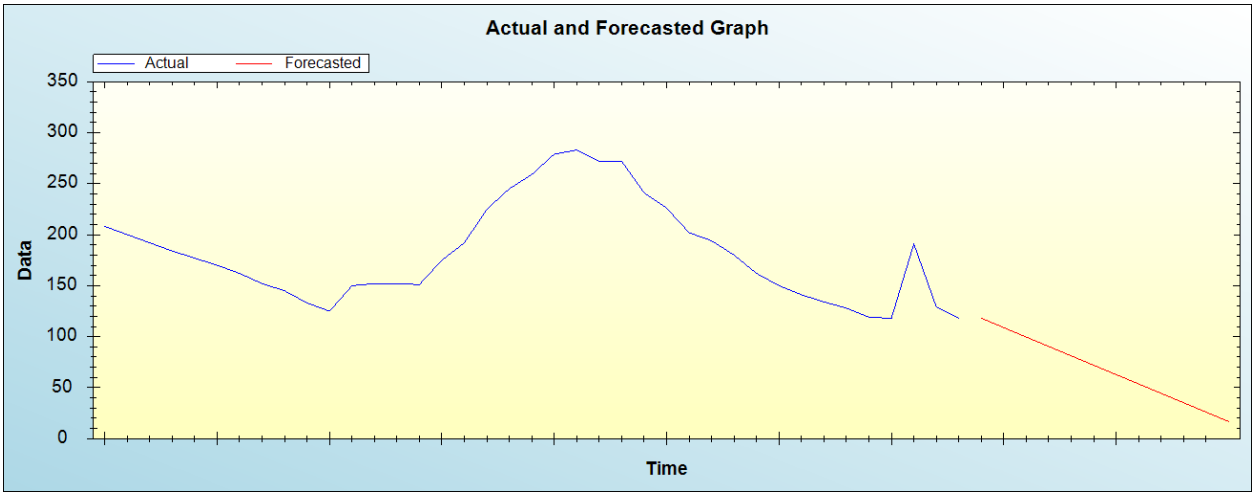

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	118.0438
2025	108.8386
2026	99.6334
2027	90.4281

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2028	81.2229
2029	72.0177
2030	62.8125
2031	53.6073
2032	44.4020
2033	35.1968
2034	25.9916
2035	16.7864

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 and reach levels below 30 deaths per 100 000 live births by 2035.

Conclusion

Maternal mortality remains a critical public health challenge in the Republic of South Africa, underscoring the urgent need for targeted government interventions across the maternal continuum of care. Utilizing a double exponential smoothing model, this study projects a sustained decline in the Maternal Mortality Ratio (MMR), reaching fewer than 30 deaths per 100,000 live births by 2035. To accelerate and sustain this trajectory, policymakers should implement a five-fold strategic framework:

i. ***Curtailed Adolescent Pregnancy:*** Enforce legal prohibitions against early child marriage while expanding secondary education for girls and embedding comprehensive sexual and reproductive health education in school curricula.

ii. ***Expanded Service Coverage:*** Enhance the equitable distribution and coverage of maternal and child healthcare services nationally.

iii. ***Continuous Quality Improvement:*** Institutionalize routine clinical audits and quality improvement programs across healthcare facilities.

iv. ***Resource & Workforce Optimization:*** Safeguard supply chains to ensure uninterrupted access to essential medical supplies and maintain adequate staffing levels in all facilities.

v. ***Specialized Care Access at First-Referral Level:*** Establish dedicated obstetrician posts in high-volume general and district hospitals. Alternatively, attach obstetrics and gynecology registrars to high-volume district sites under the direct supervision of provincial consultants to decentralize specialist care.

References

[1] Akhter, S., Mburu, G., & Chowdhury, M. (2018). Barriers to achieving Maternal Mortality Ratio targets in developing countries: A literature review. *The Lancet*, 391, S45–S52.

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[2] Bomela, N. J. (2020). Social determinants of maternal mortality in South Africa: An analysis of vital registration data. *BMC Public Health*, 20(1), Article 1582. https://doi.org/10.1186/s12889-020-09688-4
[3] Buchmann, E. J. (2011). Monitoring maternal mortality in South Africa: Challenges and progress. *South African Medical Journal*, 101(9), 628–631.
[4] Chacha, F., Mtimkulu, N., & Mogale, R. (2022). Cardiac disease in pregnancy: A systematic review of obstetrics practice, challenges, and outcomes in Sub-Saharan Africa. *Cardiovascular Journal of Africa*, 33(4), 210–218.
[5] Damian, D. J., Njau, B., Lisasi, E., Msuya, S. E., & Boulle, A. (2019). Trends in maternal and neonatal mortality in South Africa (1990–2015): A systematic review. *BMC Pregnancy and Childbirth*, 19(1), Article 290. https://doi.org/10.1186/s12884-019-2438-2
[6] Dorrington, R. E., Bradshaw, D., Laubscher, R., & Nannan, N. (2016). *Rapid mortality surveillance report 2014*. South African Medical Research Council.
[7] Isaacson, K., Mokgothu, C., & Mabote, L. (2021). Prevalence and birth outcomes of twin pregnancies in Botswana: A quantitative analysis. *African Journal of Reproductive Health*, 25(3), 88–96.
[8] Lenkoane, M., Mofokeng, T., & Khoza, L. (2025). Factors motivating early antenatal care attendance among pregnant women in Lesotho: A qualitative study. *African Journal of Primary Health Care & Family Medicine*, 17(1), Article e1204.
[9] Madzimbamuto, F. D., Ray, S. C., Mogobe, K. D., Ramogola-Masire, D., Phillips, R., & Alonso, M. (2014). A root-cause analysis of maternal deaths in Botswana: Contributory factors and avoidable health systems failures. *Journal of Public Health Policy*, 35(3), 320–334. https://doi.org/10.1057/jphp.2014.16
[10] Mahada, T., Tshitangano, T. G., & Mudau, A. G. (2023). Strategies to reduce maternal death rate and improve the provision of quality healthcare services in selected hospitals of Vhembe District, Limpopo Province. *Nursing Reports*, 13(3), 1251–1270. https://doi.org/10.3390/nursrep13030107
[11] Manamo, M., Letamo, G., & Keetile, M. (2023). Socio-economic differentials and trends in under-five mortality in Botswana: A demographic assessment. *PLOS ONE*, 18(5), Article e0285412. https://doi.org/10.1371/journal.pone.0285412
[12] Mmusi-Phetoe, R. M., & Masaba, B. B. (2021). A conceptual model for reducing maternal mortality in South Africa: A qualitative inquiry. *Health SA Gesondheid*, 26, Article 1580. https://doi.org/10.4102/hsag.v26i0.1580
[13] Mmusi-Phetoe, R. M., Wright, S. C. D., & Mulaudzi, F. M. (2016). Social determinants of maternal and neonatal mortality in South Africa. *Curationis*, 39(1), 1–9. https://doi.org/10.4102/curationis.v39i1.1522
[14] Mohale, M., & Nyangu, I. (2023). Psychological experiences of midwives following maternal deaths in public hospitals in Lesotho: A phenomenological study. *BMC Nursing*, 22(1), Article 204. https://doi.org/10.1186/s12912-023-01362-x
[15] National Committee for Confidential Enquiries into Maternal Deaths. (2018). *Saving mothers 2014–2016: Seventh triennial report on confidential enquiries into maternal deaths in South Africa*. National Department of Health.
[16] Nonyane, R., du Plessis, E., & Clase, J. (2024). Identifying avoidable causes of perinatal deaths in a district hospital in Lesotho. *Curationis*, 47(1), Article 2497. https://doi.org/10.4102/curationis.v47i1.2497

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https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed
This article/work is licensed under CC Attribution-Non-Commercial 4.0

[17] Saving Mothers Giving Life. (2016). *Saving Mothers, Giving Life annual report 2015*. United States Agency for International Development.

[18] Singh, P., & Swain, S. (2025). Caesarean delivery on maternal request (CDMR) and its impact on maternal and neonatal outcomes: A prospective cohort study. *International Journal of Gynecology & Obstetrics*, 168(2), 312–320.

[19] South African Health Review. (2015). *South African health review 2014/15*. Health Systems Trust.

[20] Teasdale, C. A., Adams, J. H., & Mntambo, M. (2021). Rapid quality improvement interventions to improve retention in antenatal care: Lessons from Eswatini. *BMC Health Services Research*, 21(1), Article 512. https://doi.org/10.1186/s12913-021-06521-8

[21] United Nations. (2018). *Sustainable Development Goals report 2018*. United Nations Publications.

[22] World Health Organization. (2018). *Trends in maternal mortality 2000 to 2017: Estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division*. World Health Organization.