Annals of Medicine and Medical Sciences (AMMS)
Volume 04, 2025, *Page No.: 77 to 82*
Available at: *http://ammspub.com*

Original Article

OPEN ACCESS

Forecasting Maternal Mortality Ratio of India based on the Impact of Gross National Income

Divya Sharma [1], Dr. Pooja Soni [2], Dr. Utkarsh Khare [2], Dr. Ajit Singh Solanki *[3]

[1]Assistant Professor and Statistician, Department of Community Medicine, Ananta Institute of Medical Science and Research Centre, Rajsamand, Rajasthan.
[2]Assistant Professor, Department of Community Medicine, Ananta Institute of Medical Science and Research Centre, Rajsamand, Rajasthan.
[3]Assistant Professor, Department of Statistics, Bhupal Nobles University, Udaipur, Rajasthan.

*Corresponding Author: Dr. Ajit Singh Solanki; *ajit@bnuniversity.ac.in*

Abstract

Background: Many women in reproductive age-span succumb to complications during and following pregnancy and childbirth or abortion. Gross National Income affects the MMR by directly relating to the social factors. Previous and projected reductions in maternal mortality of India and the impact of gross national income were not examined. The present study plans to compare maternal mortality of previous years and forecast the next 5 years of the same mortality based on the influence of Gross National Income by using Double Exponential Smoothing Model. ***Method:*** In this study, secondary data on the Maternal Mortality Ratio of India from 2001-03 to 2018-20 have been compiled from the Sample Registration System. Also, gross national income record from 1990 to 2020 data was mined from World Bank national accounts and OECD National Accounts data files. The time series approach Double Exponential Smoothing model was applied for forecasting. Minitab version 22 was used in the analysis. ***Results:*** The results revealed that MMR of India was statistically different in past years and there was a significant negative correlation between MMR and GNI (-0.95, p-value = 0.01). All Results are significant at $p<0.05$. A double exponential smoothing model (DESM) was fitted for the best forecast with MAPE (%) = 2.47. ***Conclusions:*** GNI had an impact on lowering maternal mortality, which caused the predicted maternal mortality to steadily decline. The Indian government should use GNI to reduce MMs at a high level, support pregnant women, and improve the health care system.

Keywords: ***Forecast, Maternal Mortality Ratio, India, Gross National Income***

Introduction

As per the World Health Organization, "Maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes". Maternal mortality is considered a measure of the socio-economic development and reproductive health of women in a region. Many women in reproductive age-span succumb to complications during and following pregnancy and childbirth or abortion [4].

With the UN announcing the Sustainable Development Goals [SDGs] and establishing the goal for Maternal Mortality ratio [MMR], the study on 'MMR forecasting' in the Indian context aims to understand the time needed to reach this goal and the practical feasibility of reducing MMR to 70 per one lac live births [4].

Maternal Mortality Estimation Inter-Agency Group (MMEIG) provides global estimates of MMR. As per the UN MMEIG 2020 report, "Trends in maternal mortality 2000 to 2020", the MMR of India has declined from 384 in 2000 to 103 in 2020 whereas Global MMR has declined from 339 in 2000 to 223 in 2020. The average annual rate of reduction (ARR) in global MMR during the 2000-2020 periods was 2.07% whereas India's MMR has declined by 6.36%, which is significantly better than the global decline [5]. India has seen a substantial drop in its MMR, with figures currently around 97 per 100,000 live births [6], a significant improvement from previous decades. This decline in MMR is linked to the economic development of India, allowing for better access to healthcare services and improved innovative maternal health programs. Although the national MMR has decreased, certain states in India still have considerably higher rates, highlighting the need for targeted interventions in these regions.

With the economic development of the nation, the Gross National Income has significantly increased over the last decades. Gross National Income affects the MMR by directly relating to the social factors. The gross national income (GNI), previously known as the gross national product (GNP), is the total amount of factor income earned by the residents of a country. It is equal to gross domestic product (GDP), plus factor incomes received from non-residents by residents, minus factor income paid by residents to non-residents [7].

Received: January 18, 2025; **Revised:** March 01, 2025; **Accepted:** March 04, 2025

The social Factors affecting the Maternal Mortality Rate (MMR) in India include: lack of access to quality healthcare, inadequate prenatal care, early marriage, malnutrition, unsafe abortions, inadequate infrastructure in rural areas, low levels of education and awareness among women, and socio-cultural practices that hinder healthcare seeking behavior. Innovative maternal health schemes in India targeting the above factors over the last decades have made it possible to achieve the UN 2030 MMR goal [8].

The present study aims to compare the MMR of previous years and forecast for the next 5 years based on the influence of Gross National Income (GNI) by using the Double Exponential Smoothing [DES] Model.

Material and methods

In this study, secondary time series data of Maternal Mortality Ratio data of India of years 2001-03, 2004-06, 2007-09, 2010-12, 2011-13, 2014-16, 2015-17, 2016-18, 2017-19, 2018-20 have been compiled from the periodic bulletin of Sample Registration System (SRS). Also, gross national income record from year 1990 to 2020 data was mined from World Bank national accounts data, and OECD National Accounts data files. The popular Double Exponential Smoothing Technique was used to forecast maternal mortality and the time required to attain the SDG 3.1 goal [2]. These 10 data point MMR observations meet the sample size requirement of DES [1]. With such restrictions in the number of observations, forecasting MMR in India has been done using the appropriate exponential smoothing method (double exponential smoothing). The association between GNI (Gross National Income) and maternal mortality ratio has been established using Pearson's correlation.

Double Exponential Smoothing method

This study uses an exponential smoothing technique to simulate and predict future trends in the Maternal Mortality Ratio in India. Forecasts are produced using the smoothed original series in exponential smoothing, where the most recent historical values have a greater impact than those from the farther past since the latter are given less weights. Holt's linear method, also known as double exponential smoothing, is used in this work because it is a suitable methodology for modeling linear data [3].

The double exponential smoothing method, designed by Holt, for the time series data's trend [8]. Under this technique, the most recently observed periods are prioritized above all others as compared to the other exponential smoothing methods, this priority declines exponentially with increasing observational distance or age. The exponential smoothing technique makes the model simple as the time series has no trends and seasonal components. Holt's linear method is expressed as follows:

Model Equation

$M_t = \mu_t + \rho_t T + \epsilon_t$

Smoothing Equation

$S_t = \alpha M_t + (1-\alpha)(L_{t-1} + B_{t-1})$

$0 < \alpha < 1$

Trend Estimation

$B_t = \beta (S_t - S_{t-1}) + (1-\beta)B_{t-1}$

$0 < \beta < 1$

Forecasting Equation

$\mathbf{F_{t+d}} = L_t + hB_t$

Where M_t is the actual Maternal Mortality Ratio 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 time series

S_t is the exponentially smoothed value of Maternal Mortality Ratio at time t

α is the exponentially smoothing constant for the data

β is the smoothing constant for trend

$\mathbf{F_{t+d}}$ is the d step ahead forecast

B_t is the trend estimate at time t

B_{t-1} is the trend estimate at time t - 1

The MINITAB version 22.0 output was employed in this investigation since it reduces the forecast errors of the existing data series.

For a good forecast, the values of **Forecast Performance Measure - Mean Absolute Error** (MAE) and Mean Absolute Percentage Error (MAPE) should be as small as possible. The prediction capability of MAPE (Lewis, 1982) For MAPE (%) <10 prediction capability is highly accurate; between 10-20, MAPE (%) is good prediction capability and below 20 MAPE (%) is marked as reasonable prediction capability [10].

Wilcoxon Rank Sum Test

The Wilcoxon Rank Sum Test is a non-parametric test employed to examine data that does not follow normally distributed. By splitting the mortality series into two distinct populations, the Bera-Jarque estimate was employed in this work to verify the abnormality of the mortality series [12]. Population 1 and 2 are 1997- 2009 and 2010-2020 respectively, with n1 and n2 representing past and recent mortality respectively. Populations were sorted using the Wilcoxon Rank Sum Test in the following order: n1+n2 measurements from 1 (smallest) to n1+n2 (biggest), with ties taken into account by the average of the ranks assigned to the measures. The rank sum for measurements from the past mortalities 1 (T1) and the rank measurements from the recent mortalities 2 (T2) are then calculated.

The following hypothesis (two-tailed) was used to test the differences between these two groups:

H_0: Maternal mortality has no true median difference.

H_1: Maternal mortality has a true median difference.

In mathematical notations, these hypotheses can be written as –

H_0: $M_1 - M_2 = 0$

H_1: $M_1 - M_2 \neq 0$

Where, M1 and M2 represent medians of recent and past maternal mortality, respectively. The result will be significant at $p < 0.05$.

Result

MMR Forecast in India by DES method

The observations were analyzed, modeled, interpreted, and forecasted for the next three years (2018 to 2021). Firstly, monthly maternal mortality series were plotted without transformation, it is evident that MMR in India is declining, which is quite sharp from 2015.

Table 1: National Maternal Mortality ratio

	Period											
	1997-98	1999-01	2001-03	2004-06	2007-09	2010-12	2011-13	2014-16	2015-17	2016-18	2017-19	2018-20
MMR -India Total	398	327	301	254	212	178	167	130	122	113	103	97

Source: NITI Aayog (GOI)

The data has been extracted from the periodic release of MMR bulletin SRS, Office of the Registrar General of India. Table 1 represents time series data in which study variable has been extracted at ten points of time (2001-03, 2004-06, 2007-09, 2010-12, 2011-13, 2014-16, 2015-17, 2016-18, 2017-19, 2018-2020). The raw data was extracted from the MMR bulletin SRS, Office of the Registrar General of India, and plotted to observe the Maternal Mortality Ratio pattern from 1997 to 2020.

The original time series data, also called 'unit series', despite a decreasing trend and with no seasonal variations (from visual inspection), the series have been tested to check the presence of trend, seasonality, and stationarity. Table 2 shows the time series as non-stationary, despite of declining trend and the absence of seasonal changes (according to ocular inspection). The parameter estimates of the DESM model are statistically significant and indicate the variations in maternal mortalities. (**Table 2**). The optimal values of smoothing constants α and β are 1.23 and 0.02 respectively based on minimum Mean Square Error (MSE). The model used in Table 2 will provide better and more accurate forecast estimates of MMR. The forecast performance measure in Table 2 also indicates that the prediction capability of the model based on MAPE is highly accurate.

Table 2: Double Exponential Smoothing Model and Relationship between Maternal Mortality Ratio and Gross National Income

Model Information	**Parameters**	**Estimates**	**SE**	**P value***	**Pearson correlation MMR and GNI**	**P value**
ESM (Double Exponential Smoothing Model)	Alpha (Level) Gamma Beta	1.23 0.03 0.02	0.017 0.24	0.001 0.003	-0.95	0.01
Forecast Performance Measure	Mean Absolute Error (MAE) Sum Square Error (SSE) Mean Square Error (MSE) Mean percentage Error (MPE) Mean Absolute Percentage Error (MAPE)		1.08 564.88 5.63 -0.24 2.47			
Test	**Name of test**		**Output**		**Remarks**	
Stationarity Test	Augmented Dicky fuller test		p-value* = 0.86		Non-stationary data	

*MM: Maternal Mortality; GNI: Gross National Income; SE: Standard Error; *Results are significant at P value < 0.05*

Evaluating maternal mortality in different period

Bera-Jarque procedures indicate that Skewness and Kurtosis do not hold the conditions of normality. The data is skewed on the right side because of skewness = 0.82 and Kurtosis = -0.44. Table 3, the Wilcoxon Rank Sum test was used to test whether the medians of the two groups are different, group 1: the year 1997 to 2007 and group 2: the year 2009 to 2019. The results are significant and the null hypothesis is rejected as the P <0.05. Therefore, there is a significant difference in maternal mortality in the early and late mortalities.

Table 3: Hypothesis Test Summary

Null Hypothesis	**Test**	**Sig.**	**Decision**
The medians of maternal mortalities are the same across categories	Wilcoxon Rank Sum Test	.002*	Reject the null hypothesis.

*The significance level is .05. *Exact significance is displayed for this test.*

Impact of GNI on Reducing Maternal Mortality

The Pearson correlation between annual maternal deaths and GNI is statistically significant (P value<0.05) and is trending downward, indicating that maternal deaths fall as GNI rises. There is a strong negative correlation between GNI and maternal mortality. (**Table 2**) The increase in GNI from 1997 to 2019 corresponds to a decrease in maternal mortalities.

Forecasted Maternal Mortality

Table 4 represents the actual, predicted, and forecasted values of maternal mortalities. The predicted Maternal mortalities are from 1997 to 2019, and the forecasted maternal mortalities are from 2020 to 2022. The predicted maternal mortalities are very close to the actual maternal mortalities. This is why the forecasted values by the double exponential smoothing method are reliable and easy to apply.

Table 4: Maternal Mortality Ratio (MMR) Forecast of India (2020-2024)

Period	**Forecast**	**Lower 95% confidence limit**	**Upper 95% confidence limit**
2020	83.025	73.132	92.9169
2021	66.987	49.322	84.6522
2021	50.950	25.297	76.6028
2022	34.912	1.209	68.6160
2023	18.875	-22.906	60.6556
2024	10.23	-32.56	52.03

Source: Author's computation

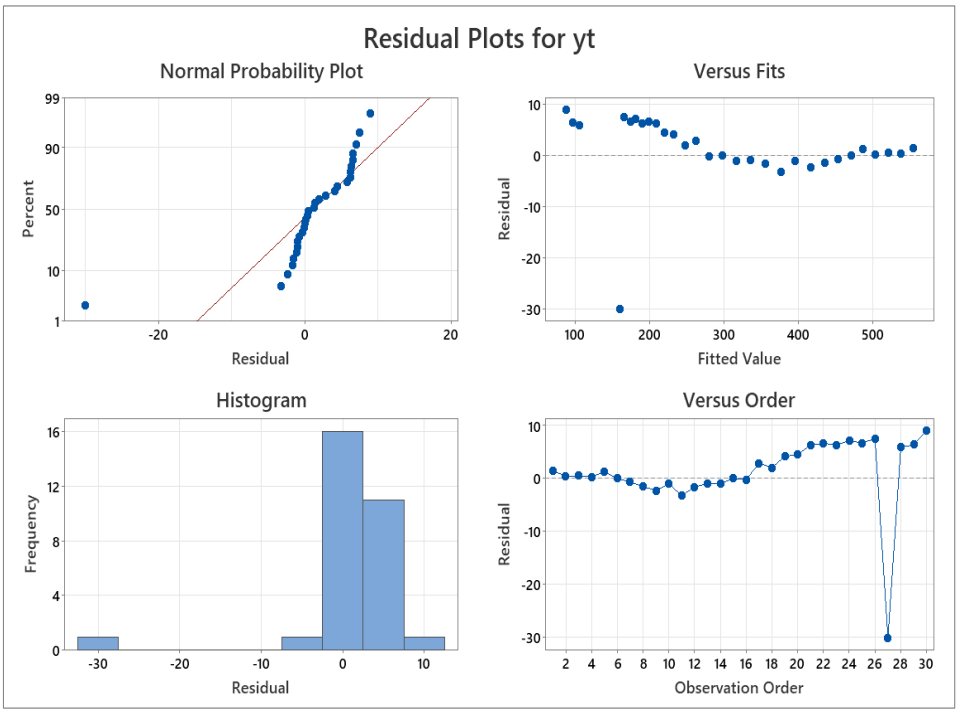

Figure 1: Double Exponential Smoothing Model Residual Plot

Figure 1 shows that the distribution of residuals for the Double Exponential Smoothing model is statistically significant, indicating the normality of the residuals.

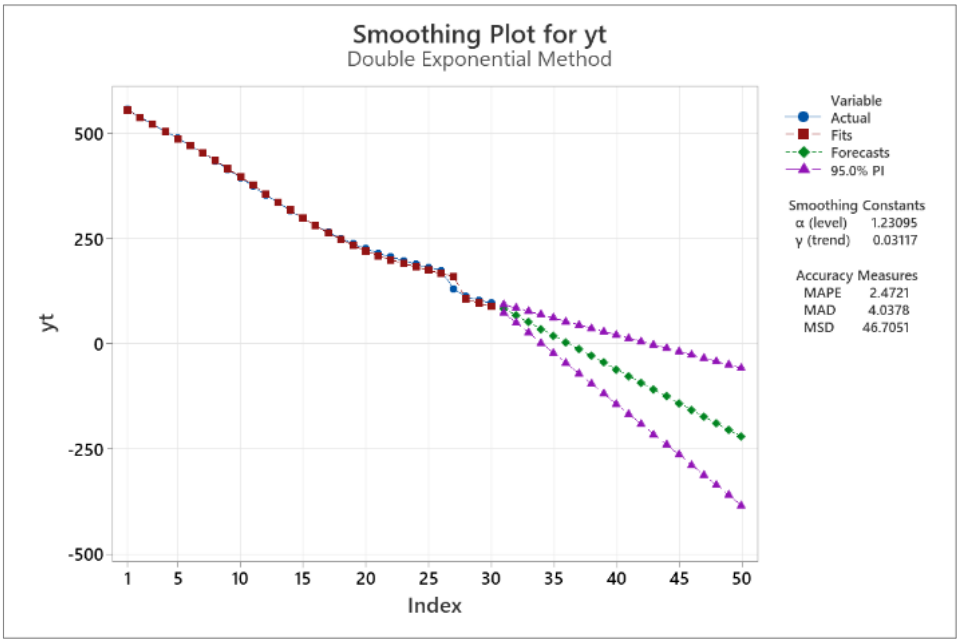

Figure 2: MMR actual, Predicted, and future prediction plot using the Double Exponential Smoothing model in India (1950 2050).

According to [**Figure 2**], the Double Exponential Smoothing model's projected MMR for 2000-2020 was comparable to the historical and expected rates. The future prediction line (green) stretches to the future of MMR in India from the endpoints of the actual line (black) and the prediction line (red). The Plot of the 10-year MMR future forecast [**Figure 2**]. According to the Double Exponential Model's estimate, India's MMR is expected to continue to fall around 2025.

Discussion

This study compared maternal mortality of previous years and forecasted the next 5 years of the same mortality based on the influence of Gross National Income (GNI) by using DESM (Double Exponential Smoothing Model). Time series data of Maternal Mortality Ratio data in India for years 2001-03, 2004-06, 2007-09, 2010-12, 2011-13, 2014-16, 2015-17, 2016-18, 2017-19, 2018-20 have been compiled from the periodic bulletin of Sample Registration System (SRS) together with GNI (Gross National Income) data from 2011 to 2019 has been complied.

In our study, the medians of maternal mortalities are different across the two periods group 1: year 1997 to 2007 (past mortalities) and group 2: year 2009 to 2019 (recent mortalities). Compared to previous programs, the NRHM, which was implemented in 2005, focused substantially more time and resources on improving the health system. The Government of India established the National Health Mission (NHM) in 2013 by merging the National Rural Health Mission (NRHM) and the National Urban

Health Mission (NUHM) to carry out the necessary structural changes in the public health care and delivery system in India [13]. The NHM design's Reproductive-Maternal-Neonatal-Child and Adolescent Health (RMNCH+A) services improve the healthcare system and aid in accomplishing important health and demographic objectives [13]. By reducing MMR, NRHM programs like the Janani Suraksha Yojana (JSY) have significantly increased the frequency of institutional deliveries and prenatal care visits [13]. The results of our study have established the impact of maternal and child health care programs.

The application of the DESM model is a bit complicated and not user-friendly but it has been used in the forecasting in previous studies in "forecasting adolescent fertility Rate in Niger" [9]. In our study, the forecasted value of MMR will steadily decrease These findings are comparable to those made by Maral Der Sar Kissian in African nations, who demonstrated that the average from 1990 to 2005, maternal mortality ratios reduced from 695.82 to 562.18, reaching the MDG-5 pillar [14]. Additionally, a negative relationship between yearly maternal mortality and GNI suggested that GNI has a positive impact on lowering maternal mortality in India. GNI demonstrated a strong impact on maintaining steadily declining mortalities, even if the expected maternal mortality did not increase much.

The model identification revealed that the compiled time series data is non-stationary, absence of seasonal variation, and the model with the least performance measures such as MAPE, MAE, and MSE are used for the forecasting accuracy as shown in Table 2. The model with the least performance measure is best -fitted model for forecasting of MMR of India. In the study by Pierre et. al 2020 [12], a double exponential smoothing model (DESM) was fitted for the best forecast, and ARIMA and linear regression models for a quick forecast. In the study by Pangestu, and Andayani, 2023 suggests that the performance measure MAPE (9.21%) is more reliable in predicting the spread of COVID-19 in Indonesia [11]. If the current mortality rate and health programmes remain the same then the model will be applicable.

Limitation

Primary data and strategically targeted causes of maternal mortality from pregnant women's perspectives were not available for this investigation. It interferes with the external elements' contribution to model fitting. Future studies, however, future research and studies can focus on examining the impact of the primary cause and associated complications that contribute to maternal deaths, particularly in rural villages.

Conclusion

The DESM model is the most effective at producing accurate forecasts, regardless of its complexity. The Indian government should allocate a significant portion of GNI to the health care system, promote routine prenatal care, train midwives regularly, and devolve infrastructure for pregnant women to lower maternal mortality at an advanced level.

Abbreviations

ARR: Annual Rate of Reduction
DES: Double Exponential Smoothing
DESM: Double Exponential Smoothing Model
GDP: Gross Development Product
GNI: Gross National Income
GNP: Gross National Product
GOI: Government of India
JSY: Janani Suraksha Yojana
MAE: Mean Absolute Error
MAPE: Mean Absolute Percentage Error
MDG: Millenium Development Goal
MM: Maternal Mortality
MMEIG: Maternal Mortality Estimation Inter-Agency Group
MMR: Maternal Mortality Ratio
MPE: Mean Percentage Error
MSE: Mean Square Error
NHM: National Health Mission
NRHM: National Rural Health Mission
NUHM: National Urban Health Mission
OECD: Organisation for Economic Cooperation and Development
RMNCH+A: Reproductive-Maternal-Neonatal-Child and Adolescent Health
SDG: Sustainable Development Goal
SRS: Sample Registration System
SSE: Sum Square Error
UN: United Nations
WHO: World Health Organization

Data Availability

All computing datasets are accessible from the corresponding author for a specific purpose.

Declaration

Ethical Approval and Consent to Participate

Ethical approval was not required since this was a secondary data analysis.

Consent for publication

A written approval was taken on 05 April 2022, from the Archive Department of The Demographic and Health Surveys (DHS) Program- India to use the data for research and publication purposes.

Funding

The study was self-funded, with resources allocated from the researchers' means. No external funding sources were involved.

Authors' contributions

Divya Sharma reviewed the literature, conducted the analysis, and wrote the first draft of the paper; Dr. Pooja Soni supervised the data analysis, interpretation, and discussion of the results, and edited the paper; Dr. Utkarsh Khare helped in acquiring and interpreting the data, and edited the paper; Dr. Ajit Singh Solanki developed the concept for the study, supervised the data analysis, interpretation and discussion of the results, and edited the paper.

Submission Acknowledgement

We thank Bridgette Wellington, Data Archivist at The Demographic and Health Surveys (DHS) Program, for permitting us to use the data for research and publication purposes.

Conflicts of Interest

The study's authors affirm that there are no conflicts of interest in the study.

References

[1] Hanke, J. E., & Wichern, D. (2015). Business Forecasting (9th ed., p. 363). Noida, India: Pearson Education, Inc.

[2] Kasapoglu, O.A. (2016). Selection of the Forecasting Model in Health Care. Journal of Hospital & Medical Management, 2(2:13), 1-13.

[3] Holt, C. C. (2004). Forecasting Seasonals and Trends by Exponentially Weighted Moving Averages. International Journal of Forecasting, 20, 5-10

[4] Bulletin on maternal mortality (no date) SRS - Maternal Mortality Bulletin | Government of India. Available at: https://censusindia.gov.in/census.website/data/SRSMMB (Accessed: 17 February 2025).

[5] MMR of India declined from 384 in 2000 to 103 in 2020: UN Mmeig 2020 report (no date) Press Information Bureau. Available at: https://www.pib.gov.in/PressReleasePage.aspx?PRID=2003432 (Accessed: 17 February 2025).

[6] SAMPLE REGISTRATION SYSTEM (SRS)-BULLETIN 2020 VOLUME 55-I (2020) Office of the Registrar General & Census Commissioner, India (ORGI) Available at: https://censusindia.gov.in/nada/index.php/catalog/42687 (Accessed: 17 February 2025).

[7] Todaro, Michael P.; Smith, Stephen C. (2012). Economic development (11 ed.). Addison-Wesley. ISBN 978-0-13-801388-2.

[8] Meh C, Sharma A, Ram U, Fadel S, Correa N, Snelgrove JW, Shah P, Begum R, Shah M, Hana T, Fu SH, Raveendran L, Mishra B, Jha P. Trends in maternal mortality in India over two decades in nationally representative surveys. BJOG. 2022 Mar;129(4):550-561. doi: 10.1111/1471-0528.16888. Epub 2021 Sep 15. PMID: 34455679; PMCID: PMC9292773.

[9] Smartson. P. NYONI, Thabani NYONI, "Utilizing Holt's Double Exponential Smoothing Technique to Draft Effective Adolescent Health Policies to Address High Teenage Pregnancy Rates and Child Births in Niger" Published in International Research Journal of Innovations in Engineering and Technology - IRJIET, Volume 7, Issue 2, pp 263-268, February 2023.

[10] Lewis, C. D. (1982). Industrial and Business Forecasting Methods: A Practical Guide to Exponential Smoothing and Curve Fitting. London, UK: Butterworth Scientific.

[11] Pangestu, A. I., & Andayani, P. (2023). Implementation of Holt-Winter Exponential Smoothing Method to Forecast the Spread of Covid-19. Indonesian Journal of Mathematics and Applications, 1(2), 13-24.

[12] Pierre. J, & Mugabushaka (2020). Forecasting Maternal Complications Based on the Impact of Gross National Income Using Various Models for Rwanda Journal of Environmental and Public Health Volume 2020, Article ID 7692428, 8 pages.

[13] Sharma, D., Solanki, A.S., Soni, P., Khare, U. (2024). Inter-State Disparities in Maternal Mortality Ratio in India-Two Decade Analysis. In: Sharma, N., Goje, A.C., Chakrabarti, A., Bruckstein, A.M. (eds) Data Management, Analytics and Innovation. ICDMAI 2024. Lecture Notes in Networks and Systems, vol 998. Springer, Singapore. 443-458 page.

[14] M. DerSarkissian, C. A. ompson, and O. A. Arah, "Time series analysis of maternal mortality in Africa from 1990 to 2005," Epidemiology Community Health, vol. 67, no.12, 2013.