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Forecasting Infant Mortality Rate using Exponential Smoothing and Moving Averages Techniques

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Abstract

Infant Mortality Rates (IMR) are important indicators of health status of any country. This research presents Time Series Analysis using Exponential Smoothing and Moving Averages (MA). Six years data on infant mortality covering 2016 to 2021 was obtained from Yobe State Specialist Hospital Damaturu. We used Single Exponential Smoothing, which at α =2, the model showed a smoothed trend of infant mortality over the period of 72 months. A forecast made based on this smoothed trend indicated a constant rate of infant mortality over the period of 8 months with MAPE = 17.9165, MAD = 4.5133 and MSD = 30.2982. We also studied nature of trend using Moving Averages (MA) and forecast made at length = 4 showed a constant rate of forecast over the period of 8 months with MAPE = 19.3504, MAD = 4.8377, and MSD = 34.1556. Based on the three accuracy measures, single exponential smoothing method presented a better fit to the data. Highest infant mortality was observed in 2021 with total death of 331 which represents 17.08% of the total deaths.

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1.0 Introduction

The rate at which infants die both in pediatrics and nursery wards, is of great concern and one tries to find out the factors militating against infants' survival in the hospital. Literary, mortality is the occurrence of death at a particular period and is affected by sex, occupation, technology development, social class, standard of living and health care. The measurement of health of living condition of a country is an important future of any preventives or improvement program. Rarely, it is possible to attempt to carry out all desirable preventive health work in area at once, it is therefore, essential to be able to access the fluctuation in the health of the community from time to time, so as to identify the most pressing problems and steps taking towards alleviating or minimizing them. Child mortality is a fundamental measurement of a country's level of socio-economic development as well as the quality of life.

Infant mortality refers to the death of a child born alive before its first birthday and has been a problem to humans for decade and strategies have been planned to reduce its occurrence. It has for many decades been regarded as the best index for health services and social circumstances of an area, lending to be high in places with bad housing, overcrowding, ignorance and poor services because babies are the most vulnerable in the community.

Increased population concentration throughout the world also has effect. The shrinking globe has also exposed one's traditional way of life to the stimulus or distortion of the cultural value, extended family unit which have always bothered the mother and the child

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from severe physical and social deprivation are tending to break up.

Several literatures pointed out education level, wealth index, age, region, and religion as major factor that lead to high childhood mortality in Nigeria Yaya *et al.* (2017), Adepoju *et al.* (2012), Adewusi *et al.* (2018). Recently, Azuh *et al.* (2021) discussed the impact of socioeconomic and environmental factors on mortality rate in south western of Nigeria. Their findings showed education level, source of water supply type of household toilet facility and household waste disposal practices as significant factors on mortality rate. Other researchers pointed region, residence, age, educational level and wealth status as significant variables related to infant mortality rate in Nigeria Fasina *et al.* (2020) and Shobiye *et al.* (2022). Diseases causing child mortality have connections with hygiene condition and unclean environment these are not limited to dirty feeding bottles, utensils, inadequate disposal of household refuse, poor storage water, to mention but few Jinadu and Fabiyi (1991) and NBS (2011). Other reports have shown that maternal education is a significant factor influencing child survival Caldwell (2009). Children from poorer or rural households are reported to be more vulnerable than their counterparts from other regions. United Nations Children's Fund (2010).

The infant mortality must be viewed boldly and broadly as the product of both material (example toilet facility and waste disposal practice) and non-materials aspect (culture and believe) of total society and it's merely as the product of group of diseases which require only medical treatment or medically trained personnel for their prevention and care. This study focuses on exponential smoothing and moving averages models on infant mortality cases and to see which model is the best and accurate, investigate the expected future death cases, estimate the current level of infant mortality and to investigate which month has the highest infant mortality cases. This study intends to cover seven years, hence, it will be based on monthly observations for seven years, i.e. from 2016 to 2021.

Lots of work has been done on mortality statistics, particularly in the developed countries. It is important to point out that it has not been a common practice to use statistical techniques or methods in the analysis of medical data. The works reviewed in this study were mainly reports on studies carried out by some professional bodies. The infant/child mortality in highly developed countries has fallen dramatically with improved nutrition, better housing, provision of antenatal services and provision of child health services.

Infant/child: An infant mortality can be defined as the number of deaths which occurred under one year per 1000 live birth or infant/child born in a specified year dying before reaching the first birth day subject to current age-specific mortality rates and expressed as a rate per 1,000 live births United Nations Children's Fund (2012); UN Inter-agency Group for Child Mortality Estimation, (2013).

Olalekan (2014) in his project titled "Time Series Analysis of trend in registered deaths in Kaduna State" the study employ trend model, moving averages (M.A) and single exponential smoothing to forecast based on registered number of deaths. Based on three deterministic measures: Mean Absolute Deviation (M.A.D), Mean Absolute Percentage Error (M.A.P.E), Mean Standard Deviation (M.S.D) Ibrahim and Bala (2017). It was shown that linear trend analysis model were the best and produce the most accurate result and it shows that death rate is dependent on population see Akinyemi *et al.* (2015) and Patel *et al.* (2021). Aregawi *et al.* (2014) on their study "Time Series Analysis of Trends in Malaria Cases and Deaths at Hospitals and the Effect of Antimalarial Interventions, 2001–2011, Ethiopia" the study employed time series analysis to data from 41 hospitals in malaria risk areas to assess trends of malaria cases and deaths during pre-intervention (2001–2005) and post-interventions (2006–2011) periods where the results revealed that, Among all ages, confirmed malaria cases in 2011 declined by 66% (95% confidence interval [CI], 44–79%) and by 37% (CI, 20%–51%) compared to the level predicted by pre-intervention trends. In children under 5 years of age, malaria admissions and deaths fell by 81% (CI, 47%–94%) and 73% (CI, 48%–86%) respectively. Optimal breakpoint of the trend lines occurred between January and June 2006, consistent with the timing of malaria interventions. Over the same period, non-malaria cases and deaths either increased or remained unchanged, the number of malaria diagnostic tests performed reflected the decline in malaria cases, and rainfall remained at levels supportive of malaria transmission.

Appiah *et al.* (2015) conducted a study titled "Times Series Analysis Of Malaria Cases In Ejisu- Juaben Municipality" where they founds the forecast was to have an oscillatory trend for some time and then remain constant for the period of two years from 2014 and 2016. Therefore hospitals in the municipality should expect a reduction in the number of malaria cases.

Trinh *et al.* (2022) considered data on infant mortality from 2001 to 2019 in France. They calculated Infant Mortality Rate (IMR) aggregated by month. They used jointpoint regressions to identify inflection points and assess the linear trend for each segment. They performed exploratory analyses for overall IMR, as well as by age at death subgroups (early neonatal, late neonatal and post- neonatal) and by sex. For the period under study (19 years), they found out a total infant deaths of 53, 077 for an average IMR of 3.63/1000

(4.00 in male and 3.25 in female); 24.4% of the deaths occurred during the first day of life and 47.8% during the early neonatal period. They further ex plained that the joint point analysis identified two inflection points in 2005 and 2012 and the IMR decreased sharply from 2001 to 2005, decreased slowly from 2005 and 2012 and increased significantly from 2012 onward.

2.0 Materials and methods

This research presents Time Series Analysis using Exponential Smoothing and Moving Averages (MA). This approach is chosen because it eliminate outliers from datasets to make the trend clearer and also has advantage in being able to adapt the seasonal component and change trends Ostertagova and Ostertag (2012) and Anggrainingsih *et al.* (2015). Six years data on infant mortality covering 2016 to 2021 was obtained from Yobe State Specialist Hospital Damaturu. We usedp[Single Exponential Smoothing and Moving Averages. Single Exponential Smoothing (SES) is a very popular scheme to produce a smoothed Time Series. Whereas in Moving Averages of the past observations are weighted equally, Exponential Smoothing assigns exponentially decreasing weights as the observation get older. In other words, recent observations are given relatively more weight in forecasting than the older observations for prediction. Exponential smoothing is actually a way of "smoothing" out the data by eliminating much of the "noise" (random effects). This method provides an exponentially weighted moving average of all previously observed values and it is appropriates for data with no predictable upward or downward trend. Following Anggrainingsih *et al.* (2015) at each period ***t***, an exponentially smoothed level, L_t, is calculated which updates the previous level, L_{t-1}, as the best current estimate of the unknown constant level, β_0, of the time series. Formally, Sharma and Sharma (2012) defined the exponential smoothing formula as:

$$F_{t+1} = L_t \quad (1)$$

$$L_t = \alpha Y_t + (1-\alpha)L_{t-1} \quad (2)$$

And Since that is the best estimate of β_0, it will be the forecast for the next data value of the time series, F_{t+1}.

$$F_{t+1} = \alpha Y_t + (1-\alpha)F_t \quad (3)$$

Where,

F_{t+1} = forecast for the next period.

α = smoothing constant. Higher values of α allow the time series to be swayed quickly by the most recent observation; lower values keep the smoothed time series "flatter" as not that much weight will be given to the most recent observation and the value $(1-\alpha)$ is called the damping factor.

Y_t = Observed value of series in period *t*.

F_t = Old forecast for period *t*.

L_t = Revised Estimate of the Level at time *t*. and

The forecast F_{t+1} is based on weighting the most recent observation Y_t with a weight α and weighting the most recent forecast F_t with a weight of $1-\alpha$.

According to Sharma and Sharma (2012) the implication of exponential smoothing can be better seen if the previous equation is expanded by replacing F_t with its components as follows:

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

$$= \alpha Y_t + (1-\alpha)(F_{t-1}\ \alpha Y_{t-1} + (1-\alpha)F_{t-1})$$

$$= \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + (1-\alpha)^2F_{t-1} \quad (4)$$

If this substitution process is repeated by replacing F_{t-1} by its components, F_{t-2} by its components, and so on the result is:

$$F_{t+1} = \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + \alpha(1-\alpha)^2Y_{t-2} + \alpha(1-\alpha)^3Y_{t-3} + - - - + \alpha(1-\alpha)^{t-1}Y_t \quad (5)$$

Therefore, $F_{t+1}$is the weighted moving average of all past observations.

We can as well represent the measures of accuracy or reliability of the forecast Sharma and Sharma (2012) as:

$$MAPE = \frac{1}{n}\sum\left|\frac{Y_t - F_t}{Y_t}\right| * 100$$

$$MSD = \frac{1}{n}\sum(Y_t - F_t)^2$$

$$MAD = \frac{1}{n}\sum|Y_t - F_t|$$

Here, n is the number of observations, Y_t is observed value of the series in period *t* and F_t is the forecasted value of the period *t.*

3.0 Results and discussions

This section presents the data as well as the analysis and the interpretation of the results. Exponential Smoothing and Moving Average Time Series methods are employed, and the analysis is conducted using statistical software called 'Minitab'. Figure 1 showing the number of infant mortality rate. From the figure above there is high infant mortality in the 2016 and 2020 than the other years. Figure 2 shows the generated time series plot from Minitab which displays the series and the fitted values, along with the forecast. In both the session and graph windows, the smoothing constant used and three measures to help determine the accuracy of the fitted values: MAPE, MAD, and MSD are displayed respectively. Then from the graph it shows there is high infant death between Decembers to March 2019, than the other months.

Figure 3 shows Minitab generated the default time series plot which displays the series and the fitted values. The fitted value pattern lags behind the data pattern. This is because the fitted values are the Moving Averages (MA) from the previous time unit and also displayed in the session window are three measures to help determine the accuracy of the fitted values: MAPE, MAD, and MSD. The forecast along with the corresponding lower and upper 95%

prediction limit are also displayed between 2016 to 2021.

Table 1: Showing record of infant death from 2016 - 2021.

Years	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2016	20	31	24	33	24	18	31	35	29	31	32	32
2017	24	27	25	27	27	34	24	34	20	33	22	28
2018	21	31	27	34	28	39	33	20	29	26	27	27
2019	25	25	19	32	29	22	41	32	24	29	36	20
2020	21	31	23	33	28	27	32	24	28	25	22	24
2021	25	33	27	34	19	23	31	29	29	33	28	20

Source: Record office, YSSH, Damaturu.

Table 2: Showing the summary of infant mortality

YEARS	INFANT MORTALITY	PERCENTAGES (%)
2016	325	16.77
2017	322	16.62
2018	320	16.51
2019	321	16.56
2020	319	16.46
2021	331	17.08
TOTAL	1938	100

Source: Record office, YSSH, Damaturu.

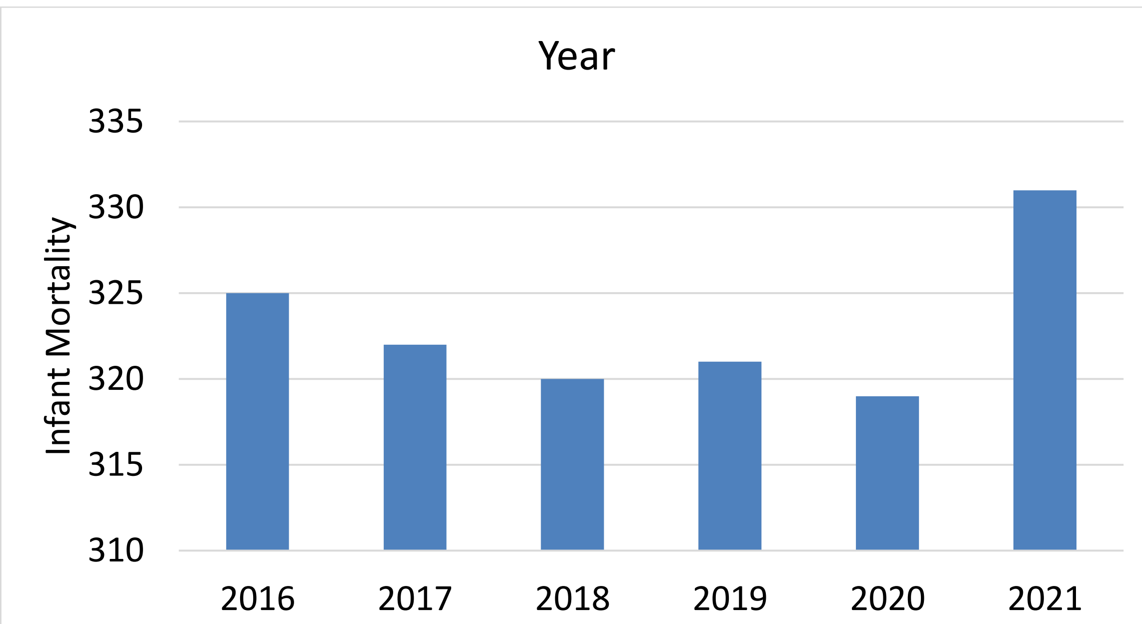

Figure 1: Shows infant mortality from 2016 to 2021

Single Exponential Smoothing for infant mortality from 2016-2021

Data infant mortality
Length 72
Smoothing Constant
Alpha 0.2
Accuracy Measures
MAPE 17.9165
MAD 4.5133
MSD 30.2982

Table 3: Results of Single Exponential Smoothing for infant mortality from 2016-2021

	Time	Infant mortality	Smooth	Predict	Error
			2016		
1	Jan	20	24. 0000	25. 0000	-5. 0000
2	Feb	31	25.4000	24.0000	7.0000
3	Mar	24	25.1200	25.4000	-1.4000
4	Apr	33	26.6960	25.1200	7.8800
5	May	24	26.1568	26.6960	-2.6960
6	Jun	18	24.5254	26.1568	-8.1568
7	Jul	31	25.8204	24.5254	6.4746
8	Aug	35	27.6563	25.8204	9.1796
9	Sep	29	27.9250	27.6563	1.3437
10	Oct	31	28.5400	27.9250	3.0750
11	Nov	28	28.4320	28.5400	-0.5400
12	Dec	21	26.9456	28.4320	-7.4320
			2017		
13	Jan	24	26.3565	26.9456	-2.9456
14	Feb	27	26.4852	26.3565	0.6435
15	Mar	25	26.1882	26.4852	-1.4852
16	Apr	27	26.3505	26.1882	0.8118
17	May	27	26.4804	26.3505	0.6495
18	Jun	34	27.9843	26.4804	7.5196
19	Jul	24	27.1875	27.9843	-3.9843
20	Aug	31	27.9500	27.1875	3.8125
21	Sep	20	26.3600	27.9500	-7.9500
22	Oct	33	27.6880	26.3600	6.6400
23	Nov	22	26.5504	27.6880	-5.6880
24	Dec	28	26.8403	26.5504	1.4496
			2018		
25	Jan	21	25.6722	26.8403	-5.8403
26	Feb	31	26.7378	25.6722	5.3278
27	Mar	27	26.7902	26.7378	0.2622
28	Apr	34	28.2322	26.7902	7.2098
29	May	28	28.1858	28.2322	-0.2322
30	Jun	39	30.3486	28.1858	10.8142
31	Jul	33	30.8789	30.3486	2.6514
32	Aug	20	28.7031	30.8789	-10.8789
33	Sep	19	26.7625	28.7031	-9.7031
34	Oct	26	26.6100	26.7625	-0.7625
35	Nov	27	26.6880	26.6100	0.3900
36	Dec	15	24.3504	26.6880	-11.6880
			2019		
37	Jan	25	24.4803	24.3504	0.6496
38	Feb	22	23.9843	24.4803	-2.4803
39	Mar	19	22.9874	23.9843	-4.9843
40	Apr	32	24.7899	22.9874	9.0126
41	May	29	25.6319	24.7899	4.2101
42	Jun	22	24.9055	25.6319	-3.6319
43	Jul	31	26.1244	24.9055	6.0945
44	Aug	32	27.2996	26.1244	5.8756
45	Sep	24	26.6396	27.2996	-3.2996
46	Oct	29	27.1117	26.6396	2.3604
47	Nov	36	28.8894	27.1117	8.8883
48	Dec	20	27.1115	28.8894	-8.8894
			2020		
49	Jan	21	25.8892	27.1115	-6.1115
50	Feb	32	27.1114	25.8892	6.1108

	Time	Infant mortality	Smooth	Predict	Error
51	Mar	23	26.2891	27.1114	-4.1114
52	Apr	33	27.6313	26.2891	6.7109
53	May	28	27.7050	27.6313	0.3687
54	Jun	27	27.5640	27.7050	-0.7050
55	Jul	32	28.4512	27.5640	4.4360
56	Aug	24	27.5610	28.4512	-4.4512
57	Sep	28	27.6488	27.5610	0.4390
58	Oct	25	27.1190	27.6488	-2.6488
59	Nov	22	26.0952	27.1190	-5.1190
60	Dec	24	25.6762	26.0952	-2.0952
			2021		
61	Jan	25	25.5409	25.6762	-0.6762
62	Feb	33	27.0328	25.5409	7.4591
63	Mar	27	27.0262	27.0328	-0.0328
64	Apr	34	28.4210	27.0262	6.9738
65	May	19	26.5368	28.4210	-9.4210
66	Jun	23	25.8294	26.5368	-3.5368
67	Jul	31	26.8635	25.8294	5.1706
68	Aug	29	27.2908	26.8635	2.1365
69	Sep	29	27.6327	27.2908	1.7092
70	Oct	33	28.7061	27.6327	5.3673
71	Nov	28	28.5649	28.7061	-0.7061
72	Dec	20	26.8519	28.5649	-8.5649

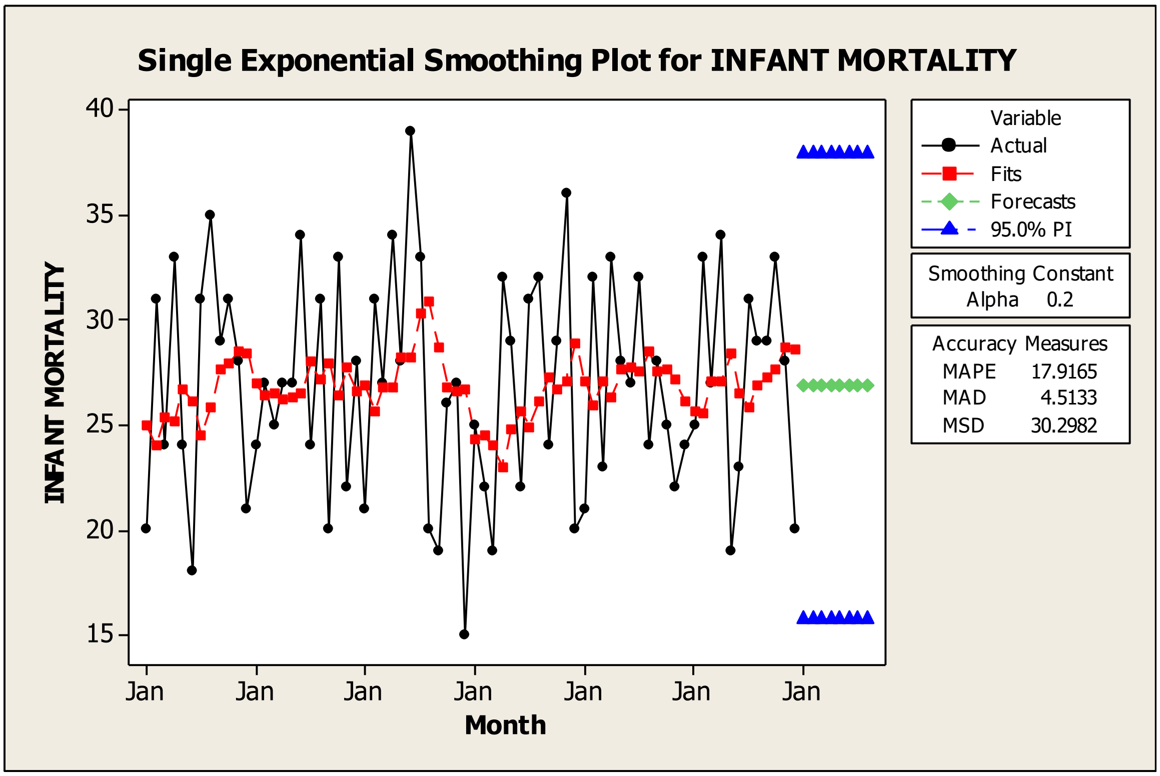

Figure 2: Single Exponential Smoothing plot for infant mortality from 2016-2021

Moving Average for infant mortality

Data INFANT MORTALITY
Length 72
NMissing 0
Moving Average

Length 4
Accuracy Measures
MAPE 19.3504
MAD 4.8377
MSD 34.1556

Table 4: Moving average for infant mortality

	Time	Infant mortality	MA	Predict	Error
			2016		
1	Jan	20	*	*	*
2	Feb	31	*	*	*
3	Mar	24	27.500	*	*
4	Apr	33	26.375	*	*
5	May	24	25.625	*	*
6	Jun	18	26.750	27.500	-9.500
7	Jul	31	27.625	26.375	4.625
8	Aug	35	29.875	25.625	9.375
9	Sep	29	31.125	26.750	2.250
10	Oct	31	29.000	27.625	3.375
11	Nov	28	26.625	29.875	-1.875
12	Dec	21	25.500	31.125	-10.125
			2017		
13	Jan	24	24.625	29.000	-5.000
14	Feb	27	25.000	26.625	0.375
15	Mar	25	26.125	25.500	-0.500
16	Apr	27	27.375	24.625	2.375
17	May	27	28.125	25.000	2.000
18	Jun	34	28.500	26.125	7.875
19	Jul	24	28.125	27.375	-3.375
20	Aug	31	27.125	28.125	2.875
21	Sep	20	26.750	28.500	-8.500
22	Oct	33	26.125	28.125	4.875
23	Nov	22	25.875	27.125	-5.125
24	Dec	28	25.750	26.750	1.250
			2018		
25	Jan	21	26.125	26.125	-5.125
26	Feb	31	27.500	25.875	5.125
27	Mar	27	29.125	25.750	1.250
28	Apr	34	31.000	26.125	7.875
29	May	28	32.750	27.500	0.500
30	Jun	39	31.750	29.125	9.875
31	Jul	33	28.875	31.000	2.000
32	Aug	20	26.125	32.750	-12.750
33	Sep	19	23.750	31.750	-12.750
34	Oct	26	22.375	28.875	-2.875
35	Nov	27	22.500	26.125	0.875
36	Dec	15	22.750	23.750	-8.750
			2019		
37	Jan	25	21.250	22.375	2.625
38	Feb	22	22.375	22.500	-0.500
39	Mar	19	25.000	22.750	-3.750
40	Apr	32	25.500	21.250	10.750
41	May	29	27.000	22.375	6.625
42	Jun	22	28.500	25.000	-3.000

	Time	Infant mortality	MA	Predict	Error
43	Jul	31	27.875	25.500	5.500
44	Aug	32	28.125	27.000	5.000
45	Sep	24	29.625	28.500	-4.500
46	Oct	29	28.750	27.875	1.125
47	Nov	36	26.875	28.125	7.875
48	Dec	20	26.875	29.625	-9.6253
			2020		
49	Jan	21	25.625	28.750	-7.750
50	Feb	32	25.625	26.875	5.125
51	Mar	23	28.125	26.875	-3.875
52	Apr	33	28.375	25.625	7.375
53	May	28	28.875	25.625	2.375
54	Jun	27	28.875	28.125	-1.125
55	Jul	32	27.750	28.375	3.625
56	Aug	24	27.500	28.875	-4.875
57	Sep	28	26.000	28.875	-0.875
58	Oct	25	24.750	27.750	-2.750
59	Nov	22	24.375	27.500	-5.500
60	Dec	24	25.000	26.000	-2.000
			2021		
61	Jan	25	26.625	24.750	0.250
62	Feb	33	28.500	24.375	8.625
63	Mar	27	29.000	25.000	2.000
64	Apr	34	27.000	26.625	7.375
65	May	19	26.250	28.500	-9.500
66	Jun	23	26.125	29.000	-6.000
67	Jul	31	26.750	27.000	4.000
68	Aug	29	29.250	26.250	2.75
69	Sep	29	30.125	26.125	2.875
70	Oct	33	28.625	26.750	6.250
71	Nov	28	*	29.250	-1.250
72	Dec	20	*	30.125	-10.125

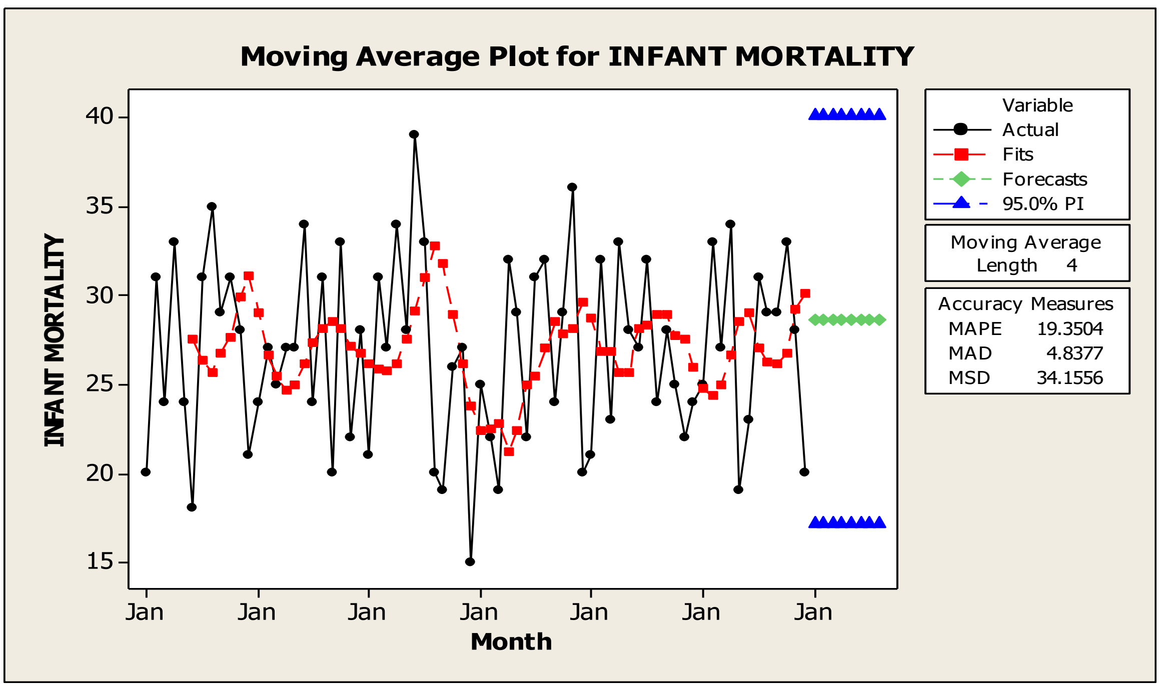

Figure 3: Moving Average plot for infant mortality from 2016-2021

Table 4: Model performance summary

	MEASURES OF ACCURACY		
MODEL	MAPE	MAD	MSD
Single Exponential	17.9165	4.5133	30.2982
Moving Average	19.3504	4.8377	34.1556

The three accuracy measures, MAPE, MAD, and MSD, where 17.9165, 4.5133, and 30.2982 respectively for the Single Exponential Smoothing model, compared to 19.3504, 4.8377 and 34.1556 respectively for the Moving Average fit. One can judge that Single Exponential Smoothing method provided a better fit to these data.

4.0 Conclusion

Infant mortality is a continuous problem bedeviling our society such that children of younger ages are highly affected. This research applied Exponential Smoothing and Moving Averages (MA) Time Series techniques. From the analysis and findings, the Exponential Smoothing model at α =2 showed a smoothed trend of infant mortality over the period of 72 months and forecast was made based on the smoothed nature of the trend which indicate a constant rate of infant mortality over the period of 2 months with MAPE = 17.9165, MAD = 4.5133 and MSD = 30.2982. Nature of trend was also studied using Moving Averages (MA) analysis and forecast was made based the trend at length = 4 which showed a constant rate of forecast over the period of 8 months with MAPE = 19.3504, MAD = 4.8377, and MSD = 34.1556. From The three accuracy measures, one can conclude that single exponential smoothing method provided a better fit to these data. From the analysis 2021 has the highest mortality cases with total death of 331 which amounts to 17.08% of the total deaths. There is highest infant death between December to March, than the other months. Our results further support assertions in the exiting literature as mentioned in the introduction and literature review sections of this paper. The data in this paper can be applied using machine learning algorithm.

Declarations

Ethics approval and consent to participate

Not Applicable

Consent for publication

All authors have read and consented to the submission of the manuscript.

Availability of data and material

Not Applicable.

Competing interests

All authors declare no competing interests.

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