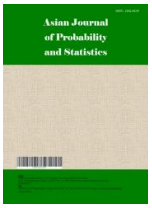

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Modeling Infant Mortality Risk Factors using Logistic Regression Model and Spatial Analysis in Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author ECK designed the study, performed the data collection and statistical analysis, discussed the results and wrote the first draft of the manuscript. Authors EL and AA managed the supervision of the study. All authors read and approved the final manuscript.

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Abstract

Globally, infant mortality is used as an important indicator for healthcare status hence an important tool for evaluation and planning of public health strategies. Despite of numerous interventions by governments aimed at reducing infant mortality, high rates are still reported in Kenya. A lot of resources are channeled towards its control leading to low productivity hence impacting the household economic welfare and national GD. The specific objective was to establish risk factors and the spatial variation of infant mortality in Kenya by analyzing the 2014 Kenya Demographic Health Survey data. A fully Bayesian paradigm and logistic regression model were used to determine infant mortality risk factors and spatial variation in Kenya. Demographic, socioeconomic and environmental factors were found to have significant effect on infant mortality. Counties from the northern parts of Kenya, Rift Valley, Central, Eastern, Nyanza, Coastal and Western parts of Kenya showed a high level of infant deaths. Infant mortality is high in arid and semi-arid areas and coastal areas due to high prevalence of infectious diseases and inadequate water supply, health facilities and low education levels. Infant mortality varies significantly across regions in Kenya due to cultural activities, and weather patterns hence exists spatial autocorrelation among neighboring regions.

Keywords: Mortality; logistic regression; spatial analysis; spatial autocorrelation.

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1 Introduction

Health is perceived as the most important part of any national economic growth policy which aims at ensuring the quality of life for all citizens. Infant mortality refers to the death of an infant before attaining one year of age while infant mortality rate refers to the number of death of newborns before reaching one year divided by the number of live births in that year usually per 1,000 live births set as the international standard according to [1]. It has for long remained a serious health problem in developing countries where a lot of public resources and individual efforts have been channeled towards its control and eradication which would have otherwise been used for development. This has led to a huge loss of individual efforts resulting in low productivity hence negatively impacting their household economic welfare and the national GDP. [2] in a study to compare infant mortality in the USA with the situation in low-income countries found that infant mortality remains a serious health problem globally despite several interventions by governments. These cases are caused by poor maternal health, inappropriate care during pregnancy and delivery, poor hygiene, poor management of complications during pregnancy and lack of qualified personnel during delivery. Infant mortality is also caused by nutritional and maternal factors such as maternal age at birth, birth interval, occupation, and education level, source of drinking water, infrastructure and electrification, both public and private amenities for quality healthcare delivery. Despite numerous interventions by governments and Non- Governmental Organizations such as the Government's Big Four Agenda on Universal Healthcare and Sustainable Development Goals, Kenya still reports very high infant mortality rates contrary to the Millennium Development Goal four MDG-4 targets towards the reduction of infant and child mortality by at least two-thirds by 2015. Kenya has witnessed an impressive decline in infant mortality over the past years and it is estimated at 52 deaths per 1,000 live birth registering a decline from 73 deaths between the years 2003 and 2014. According to [3], socioeconomic, environmental and demographic factors have a huge impact on infant mortality rates in Kenya. These socioeconomic factors include maternal education level, marital status, occupation, religion, household wealth index among while demographic factors are birth order, mother's age at birth, type of birth, preceding birth interval, breastfeeding habits, mother's state of health at birth, infant's size at birth, infant's gender. On the other hand, environmental factors associated with infant mortality include the place of residence, place of delivery, region, source of drinking water, type of toilet facility among other factors. This poses a huge economic burden and loss of resources by individual households and governments due to the high cost of hospitalization and emergency care expenses channeled towards its control. Several studies on infant and child mortality have focused mainly on nutritional and biological factors that cause infant's deaths with total disregard to environmental and socioeconomic factors that also affect infant survival chances in equal measure hence there was a need to determine infant mortality risk factors. Also, statistical methods have not been fully utilized in determining those factors that cause infant mortality in Kenya. However, the Logistic regression model has been extensively used in analyzing neonatal and malaria mortalities. This study sought to utilize logistic regression model to determine the most significant socioeconomic, demographic and environmental factors also to assess the spatial variation of infant mortality in Kenya. Identifying these factors and infant mortality distribution patterns in the country help researchers, policymakers, and the government in formulating policies to address infant deaths.

2 Literature Review

Globally, infant mortality is the most sensitive health indicator in the world hence an important tool for economic and health strategic planning for the government. Infant mortality is associated with socioeconomic factors which include maternal healthcare and public health practices, wealth index per household, nutritional factors such as hygiene and water sanitation, and environmental factors hence a complex multi-national situation that needs serious interventions to control [4]

[5] using the Logistic Regression model, examined determinants that are highly associated with neonatal and infant mortality in Ghana. He established that malaria and other infectious diseases such as tuberculosis, diarrhea, anemia highly caused infant mortality. According to [6], poor breastfeeding habits, unhygienic conditions and lack of treated bed nets strongly caused infant mortality. It also showed that lack of adequate healthcare facilities, medical experts, poor maternal health care and inappropriate management of complications like breech presentation contributed to stillbirths. [7] also found that infants with low birth weights are less likely to survive if they are not given appropriate attention. They found that low birth weight is estimated to

contribute 11% of total infant mortality while perinatal problems contributed about 44% of infant mortalities in Kenya while infectious diseases such as diarrhea and respiratory problems contributed about 30% of these mortalities.

Out of 4.6 million infants born yearly, about 18,000 die in their first year of life due to environmental pollution due to increased industrialization and thus depletion of the essential Ozone layer which prompted governments to set stringent laws and regulations to help in curbing the scorching effect of environmental degradation by recycling waste and planting more trees. [8] carried out research to establish effects of air pollution on infants and children. They established that infants exposed to pollutants are at a high risk of dying due to their immature and vulnerable respiratory systems. Also, [9] found that infants born in coastal regions are at risk of surviving due to the high prevalence of malaria and other infectious diseases.

[10] found that in nomadic and pastorals African communities, about 1.8% of infant mortalities are caused by infectious and parasitic diseases that adversely affect these communities due to their regular movement in the Savannah where there is a high prevalence of malaria, respiratory diseases and other parasitic diseases like diarrhea, flu, and polio due to inadequate food supply, poor water, and environmental sanitation, inadequate health care and lack of skilled labor. To mitigate this, development agencies and governments worldwide signed eight Millennium Development Goals whose goal number four of these eight objectives was to reduce infant mortality by at least two-third globally especially in the developing countries between 1990 and 2015.

[11] used a Bayesian spatial-temporal model for infant and child mortality concerning malaria prevalence in Kenya. They established that there exists a huge relationship in the factors contributing to infant and child mortality in adjacent regions of Western Kenya where high-altitude regions have lower mortality compared to low altitude areas. They also established that spatial variation was higher compared to variation due to time and therefore there is reduced seasonal influence on mortality as compared to variation due to space. [12] in a study to compare infant mortality between infants born and raised in urban regions to those of rural areas found that infant mortality in urban areas is higher compared to rural places where at least 60 deaths per 1000 live births were reported in informal urban settlements such as Kibera slums Kenya. It is perceived that people living in rural areas and informal settlements and slums exhibit low education level, low income, lack of infrastructure and good housing, lack of social amenities such as good toilet facility, clean drinking water, basic health facilities and thus affecting the survival chances of an infant.

[13] and [14] found that there is an inverse relationship between parental education level and income on infant mortality where high levels of mortality are associated with low parental education and unemployment hence there was a need for government interventions to ensure equal access to education. These findings are in agreement with those of [15] who found that there exists a strong correlation between education and infant mortality because educated mothers are more likely to seek health care providers, communicate and explain the signs and symptoms of diseases, improved management of infectious diseases through improved immunization and hygiene, use of modern family planning methods to ensure good birth interval to improve the nutritional status of infants. This also agrees with the findings of [16] who also carried out a study using the Cox PH model and descriptive statistics, and they established that socioeconomic factors such as parental education, household income, occupation and marital status of the mother and demographic factors played a vital role in the survival chances of infants.

[17,18] using bivariate and multivariate analysis found that children born to teenage mothers have a high risk of mortality compared to those of fully matured mothers. Infants born to younger mothers are in many cases malnourished and underweight hence low chances of survival. They also argued that teenage mothers are psychologically immature and mentally stressed due to their early pregnancies. Consequently, infants born by aging mothers experience similar problems to those of teenage mothers due to repeated births which lead to depletion associated with it and other birth complications.

[19] found that quick succession pregnancies have a negative impact on the survival chances of an infant. They established that a short birth interval highly correlated with high mortality rates due to the mother's nutrition depletion and hence reduced immunity of the child. Using the Cox PH model, [20] established that birth order plays a crucial role in the survival of infants in Zimbabwe. They found that multiple births such as triplets, quadrable, and other higher-order births exhibit high mortality rates compared to singles and twins. This is

associated with lack of proper food supplements or malnutrition and abuse of drugs by the mother during pregnancy or gestation period.

[21] used the Logistic Regression method to determine causes of infant mortality and they found that biological factors such as birth type (breech presentation or normal), birth interval, marital status and household number proved to significantly contribute to infant mortality. They also found that over 135 per 1,000 mortality cases are reported in infants born to illiterate mothers compared to 16 per 1,000 lives born to literate counterparts in Ethiopia. This reason is due to a lack of knowledge and awareness on the use of contraceptives and modern ways of controlling the number of childbirths and short preceding birth intervals.

3 Materials and Methods

3.1 Source of data

This study used secondary data obtained from the Kenya Demographic Health Survey (KDHS 2014) which was carried out in collaboration with Kenya National Bureau of Statistics (KNBS). The outcome variable was the survival status of an infant (alive or dead) whereas the independent variables (X_i) used to predict the dependent variable include socio-economic, demographic and environmental factors.

3.2 Variables

There are two types of variables in this study namely dependent and independent variable. The dependent variable (Y) in the event of an infant dying before reaching one year of age while the independent variables (X_i) are used to predict the dependent variable. Independent variables are categorized into socio-economic, environmental, and demographic factors.

3.3 Logistic regression model

Logistic regression model is a predictive model that is used when the outcome variable is categorical whereas predictor variables are either continuous or categorical and not normally distributed. It is an appropriate model in medical and epidemiology studies where dependent variables are dichotomous for example dead or alive. Logistic regression is used to examine the effects of predictor variables on the probability of an infant reaching one year. Let $\boldsymbol{y_{ij}}$ be the event of an infant being either alive or dead and this is denoted by:

$$\boldsymbol{y_{ij}} = \begin{cases} 1, & \text{if an infant dies before reaching one year of age} \\ 0, & otherwise \end{cases} \tag{1}$$

$i = 1,2\ldots, k$ and $j=1,2\ldots, p$

Where $\boldsymbol{k}$ represents the number of infant mortalities in regions $\boldsymbol{j}$ while $\boldsymbol{p}$ represents the number of regions under investigation. Let $\boldsymbol{\pi}$ denote the probability of success (death of an infant die before reaching one year) then,

$$P\,(y_{ij} = 1) = \pi_{ij}, \quad P\,(y_{ij} = 0) = 1\text{-}\pi_{ij} \qquad \text{And } Y_i \sim \text{Bernoulli } (\pi_i)$$

Let $X_{n\times(k+1)}$ represent a single level binary logistic regression with $\boldsymbol{K}$ independent variables for infant mortality, therefore,

$$X=\begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\ 1 & x_{21} & x_{22} & \cdots & x_{2k} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix} \sim n \times (k+1), \quad \beta=\begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix} \sim (k+1) \times 1 \tag{2}$$

Where X =design matrix or regression matrix and $\beta= (k+1) \times 1$ refers to the vector of unknown parameters and constants. It also refers to regression coefficients associated with explanatory variables x_i. Logistic regression function is given by:

$$\pi_i = \frac{e^{\beta_o+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_{ik}}}{1+e^{\beta_o+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_{ik}}} = \frac{e^{X_i\beta}}{1+e^{X_i\beta}} \quad (3)$$

Where $\boldsymbol{\pi_i}$ (i=1,2, …, n) is the probability of an i^{th} event of an infant dying before one year of age given predictor variables (x_i)

3.4 Odds Ratio (OR)

Odd Ratio is the ratio of the probability of the occurrence to the non-occurrence of an event. The Odds ratio is the exponential of the estimated coefficients exp $(\hat{\beta})$ in logistic regression and for each continuous covariate $\boldsymbol{j}$, where exp $(\hat{\beta})$ is the predicted change in Odds for the $\boldsymbol{j}$ predictor variable. Since independent variables are multiple in this study, they are categorized into $\boldsymbol{k}$ levels and their Odds ratios (OR) determined,

$$OR= \left[\frac{P(Y=1/x_i)}{1-P(Y=1/x_i)}\right]= \left[\frac{\pi}{1-\pi}\right]=exp(\beta_o + \beta_1 X_1+,\dots,+\beta_k X_k) \quad (4)$$

Logit function= log (OR)

$$OR=Log\left[\frac{P(Y=1/x_i)}{1-P(Y=1/x_i)}\right]=Log\left[\frac{\pi}{1-\pi}\right]=(\beta_o + \beta_1 X_1+,\dots,+\beta_k X_k)=\sum_{j=0}^{k}\beta_j X_{ij} \quad (5)$$

Where $I =1,2,\dots, n$ and $j=0,1,2,\dots, k$

$Log\left[\frac{\pi}{1-\pi}\right]$ has a significant role in the analysis of contingency tables ("log Odds") which has two columns and many rows of values of x.

3.5 Assumptions of logistic regression

Unlike ordinary least squares, logistic regression violates the assumptions of predictor variables such as linearity, normality, heteroscedasticity, and multicollinearity by making assumptions that there is little or no multicollinearity, there is the linearity of independent variables and logs Odds, it requires a large sample size as the reliability of estimates declines with the size of the samples, it requires the dependent variable to be binary and also assumes that $P(Y = 1)$ is the probability of an event occurring.

3.6 Maximum likelihood estimation of logistic regression

Maximum likelihood estimation (MLE) is the most appropriate method for estimating Logistic regression model parameters due to its restrictive nature of the underlying assumptions of a large sample size. Consider the logistic regression function:

$$\pi_i = \frac{e^{\beta_o+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_{ik}}}{1+e^{\beta_o+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_{ik}}} = \frac{e^{X_i\beta}}{1+e^{X_i\beta}} \quad (6)$$

The likelihood function is given by:

$$l(\beta, Y = 1/\mathrm{X} = \mathrm{x}_i) =\prod_{i=1}\left[\frac{exp^{X_i'\beta}}{1+exp^{X_i'\beta}}\right]^{\sum_{i=1}^{n}\mathrm{y_I}}\left[1-\left[\frac{exp^{X_i'\beta}}{1+exp^{X_i'\beta}}\right]^{n-\sum_{i=1}^{n}\mathrm{y_I}}\right] \quad (7)$$

And its log-likelihood function is:

$$l=\sum_{i=1}^{n}\left[\mathrm{y_I}\ log\left(\frac{exp^{X_i'\beta}}{1+exp^{X_i'\beta}}\right)\right]+(n-\sum_{i=1}^{n}\mathrm{y_I})\ log\left(\frac{exp^{X_i'\beta}}{1+exp^{X_i'\beta}}\right) \quad (8)$$

3.7 Likelihood ratio test

Likelihood ratio test (x^2) is a null hypothesis test that assumes all regression coefficients except the constants are zero and is commonly used for assessing the overall fit for logistic regression model and the degrees of freedom are obtained by subtracting the number of parameters in models. It is used to assess how good a diagnostic test is by determining the most appropriate diagnostic tests. Two models are tested and the results of one model are compared to that of the other model based on ratios of their likelihoods. The likelihood ratio test is found by subtracting two times log-likelihood ($-2LL$) for the full model from the log-likelihood for the intercept model only. It uses the ratio of the maximized likelihood function for the intercept model L_0 over the maximized likelihood function for the full model L_1. The likelihood ratio test is given by:

$$x^2 = -2 \log \left(\frac{L_0}{L_1}\right) = -2[\ \log(L_0) - \log(L_1)] = -2\ [LL_0 - (LL_1)] \qquad (9)$$

Where LL_0 is the log-likelihood value for the intercept model while LL_1 is the log-likelihood value for the full model. It also compares the chi-square value at different degrees of freedom and its p-value shows the probability variation. The null hypothesis is rejected at a 5% interval level of significance and we conclude that the explanatory variable effect is zero. If the likelihood test is significant, then at least one of the independent variables significantly relates to the dependent variables.

4 Results and Discussions

4.1 Logistic regression model results for infant mortality in Kenya

This section presents the logistic regression model results for individual explanatory variables that determine infant survival status. To categorically conclude that an independent variable is significant or not, individual variables were fitted into a logistic regression model and were considered significant at 0.05% confidence level and the results presented in **Error! Reference source not found.**1.

Table 1. Logistic regression results for individual predictor variables

Variable	**Std. Error**	**z-value**	**p-value**	**OR**	**95% CI**	
Lower Upper						
1.**Age in 5 years Group**						
15-19 (ref category)	-	-	-	1	-	-
20-24	0.2140	-3.892	<0.0001	0.53	0.29	0.66
25-29	0.2099	-3.995	<0.0001	0.41	0.29	0.65
30-34	0.2093	-4.530	<0.0001	0.39	0.26	0.58
35-39	0.2086	-5.704	<0.0001	0.30	0.2 0.16	0.46
40-44	0.2083	-6.798	<0.0001	0.24	0.14	0.36
45-49	0.2079	-7.488	<0.0001	0.21		0.32
2.**Marital status**						
Never married (ref category)	-	-	-	1	-	-
Married	0.0949	-5.242	<0.0001	0.61	0.51	0.73
Living Together	0.1108	-6.744	<0.0001	0.47	0.38	0.59
Widowed	0.1030	-9.296	<0.0001	0.38	0.31	0.47
Divorced	0.1209	-5.555	<0.0001	0.51	0.40	0.65
Separated	0.1114	-4.486	<0.0001	0.62	0.49	0.75
3.**Maternal Education**						
No Education (ref category)	-	-	-	1	-	-
Primary	0.0319	-4.089	<0.0001	0.88	0.82	0.93
Secondary	0.0464	6.962	<0.0001	1.26	1.26	1.51
Tertiary	0.0872	7.621	<0.0001	1.64	1.66	2.31
4.**Occupation**						
Not employed *(ref category)*	-	-	-	1	-	-

Variable	Std. Error	z-value	p-value	OR	95% CI	
Employed	0.0416	-4.943	<0.0001	0.81	0.75	0.88
5.**Region**						
Central (reference category)	-	-	-	1	-	-
North Eastern	0.0585	5.556	<0.0001	1.38	1.23	1.55
Eastern	0.0466	9.273	<0.0001	1.54	1.41	1.69
Western	0.0574	7.643	<0.0001	1.55	1.39	1.74
Rift Valley	0.0441	10.67	<0.0001	1.60	1.47	1.75
Nyanza	0.0401	-9.962	<0.0001	0.67	0.62	0.73
Nairobi	0.0953	2.357	0.0184*	1.25	1.04	1.51
6. **Religion**						
Catholic (ref category)	-	-	-	1	-	-
Protestant	0.0366	-6.923	<0.0001	0.78	0.72	0.83
Muslim	0.0443	-4.524	<0.0001	0.82	0.75	0.89
Others	0.0822	-3.262	0.0011**	0.76	0.65	0.90
7. **Type of residence**						
Rural	0.0291	-2.337	0.0195 *	1.19	0.94	1.28
Urban (reference category)	-	-	-	1	-	-
8. **Source of drinking water**						
Piped water	0.0361	-2.881	0.0039**	0.90	0.84	0.97
Well water	0.0334	-7.991	<0.0001	0.77	0.72	0.82
Surface water	0.0524	-2.451	0.0142 *	0.88	0.79	0.97
Other	1.0166	0.674	0.5000	1.99	0.27	14.56
9. **Type of toilet facility**	-	-	-	1	-	-
Flush toilet *(ref category)*	0.0584	-4.287	<0.0001	1.78	1.03	1.29
Pit latrine	0.0612	-6.707	<0.0001	1.68	1.01	1.28
No facility						
10. **Gender of child**						
Female *(ref category)*	-	-	-	1	-	-
Male	0.0268	7.023	<0.0001	1.21	1.15	1.27
11. **child is twin**						
Single *(reference category)*	-	-	-	1	-	-
1st multiple	0.0778	15.34	<0.0001	0.3	0.26	0.35
2nd multiple	0.0724	-20.25	<0.0001	0.33	0.2	0.27
3rd multiple	1.2248	-2.697	0.007**	0.04	0.00	0.41
12. **Wealth index**						
Very poor	0.0414	3.666	<0.0001	1.50	1.36	1.65
Poor	0.0358	-3.920	<0.0001	1.27	1.12	1.35
Middle	0.0392	1.650	0.0989 *	1.07	0.99	1.15
Rich *(reference category)*	-	-	-	1	-	-
Very rich	0.0484	8.372	<0.0001	0.87	0.89	0.96
13. **Has mosquito net**						
No (*reference category)*	-	-	-	1	-	-
Yes	0.0268	-3.945	<0.0001	0.90	0.85	0.95

Maternal age was categorized into seven equal sub-groups between 15-49 years to determine the reproductive stage that loses most infants and it was found that infant mortality is higher for adolescents (15-19) years and oldest mothers (45-49) experience high mortality risks compared to those for mothers between 25-44 years. Using P-values, Odds ratios, and confidence intervals, the age of the mother was found to be a significant factor in determining infant survival chances. The Odds of mothers between 20-24 years of age were 0.53 times less likely to occur to those of mothers between 15-19 years (OR 0.53, 95% CI 0.29-0.66) where mothers between 15-19 years were used as the reference category. The Odd of mothers between 25-29 years were found to be 0.41 times less likely to lose infants than those for mothers between 15-19 years (OR 0.41, 95% CI 0.29-0.65). The Odds of mothers between 30-34 years were found to be 0.39 times less likely to lose infants compared to those for mothers between 15-19 years (OR 0.39, 95% CI 0.26-0.58). Also, the Odds for infant mortality for mothers 35-39 years was found to be 0.30 times less likely to lose infants than those for mothers between 15-19 years (OR 0.30, 95% CI 0.20-0.36). The Odds for mothers between 40-44 years group were found to be 0.24 less likely to die than those for mothers between 15-19 years (OR 0.24, 95%CI 0.16-0.36). It was also found that the Odds of mothers between 45-49 years were 0.21 less likely than those of younger mothers between 15-19 years group (OR 0.21, 95% 0.14-0.32). These findings show that infant mortality tends to decrease as maternal age increases which was consistent with the findings by [4] and [18] who argued that teenage mothers lack both physical and psychological maturity which poses a high challenge during pregnancy, delivery and post-delivery periods. Consequently, infants born by aging mothers experience similar problems to those of teenage mothers due to repeated births which lead to depletion associated with it and other birth complications [22].

Maternal education was categorized into various levels namely; no education, primary, secondary and tertiary levels, and P-values and Odds ratios were calculated. The Odds of mothers with primary education were found to be 0.88 times less likely to die as to those of mothers with no education at all (OR 0.88, 95%CI 0.82-0.93). It was found that Odds of infant mortality for mothers with secondary education were 1.26 times likely to survive than those of mothers with no education (OR 1.26 95%CI 1.26-1.51). Consequently, the Odds of infant mortality for mothers with tertiary education were found to be 1.64 times likely to survive than those of mothers with no education (OR 1.64, 95%CI 1.64-2.31). This study found maternal education an important indicator in determining the survival chances of infants and this was in agreement with what [23] found on the education level of the mother as infant mortality is concerned.

Respondents were classified as either very poor, poor, middle level, rich, and very rich and according to this study, infants from wealthier households experience low mortality since they have access to quality healthcare, quality and balanced diet, clean drinking water, and safe environment to grow compared to poor and middle-class counterparts who experience high malnutrition hence making them more vulnerable. This study finds that infant mortality increases with a decrease in household wealth index where according to these findings, infants from poor households who don't afford improved diet, access to clean drinking water, good toilet facility and living in unhealthy living conditions had a higher risk of dying compared to their peers from rich households. The Odds of infant death were found to be 1.50 times higher for infants from very poor households than those from rich ones with (OR 1.50, 95% CI 1.36 to 1.65). It was also established that the Odds for infants from poor households was 1.27 as likely to die as those from rich households (OR 1.27, 95% CI 1.12 to 1.35). The Odds of infant mortality for the middle wealth quintile were found to be 1.07 times as likely to occur than those from rich households (OR 1.07, 95% CI 0.99 to 1.15). It was also found that Odds of an infant dying were 0.87 times less likely to die for infants from very rich households' category than those from the rich category (OR 0.87, 95% CI 0.86-0.96). These results were consistent with the findings of [4] who found that wealth index highly influences infant survival chances where infants born to poor parents experience high chances of mortality.

The marital status of the mother was also fitted to determine its significance in this study and was categorized as either married, never married, living together, widowed, separated, or divorced. It was found that the marital status of the mother affects the chances of infant survival because marriage improves the well-being, health status, and moral support of the mother during the gestation period and when raising the child. The Odds of infant mortality was found to be 0.61 times less likely for infants born to married women than those of unmarried women (OR 0.61, 95% CI 0.51-0.73) where unmarried category was used as the reference category. Odds for couples living together were found to be 0.47 times less likely to lose their infant than those who are not married (OR 0.47, 95% CI 0.38-0.59). It was also found that the Odds for widowed, divorced, and separated women were 0.38, 0.51, and 0.61 times less likely to lose infants as unmarried women (OR 0.38, 95% CI 0.31-0.47), (OR 0.51, 95% CI 0.4-0.65) and (OR 0.61, 95% CI 0.49-0.75) respectively. This was consistent with the study by (4) which argued that single mothers experience high poverty rates and lack of formal employment which in turn leads to increased mortality risk.

The Odds of infant mortality due to place of residence was 1.19 times likely to occur for infants in rural areas than for those infants born and raised in the urban regions (OR 1.19, 95% CI 0.94-1.279). Regional factors that vary regionally prove to significantly contribute to infant mortality cases in Kenya. High malaria prevalence regions and other parasitic infections but with poor health care facilities and other social amenities experienced high rates of infant mortality which affirms that environmental factors contributed to infant mortality as suggested by (Naz et al., 2017;); [24]. According to these results, the Odds of infant mortality in the Rift Valley are 1.60 times higher than in the central region (OR 1.60, 95% CI 1.23-1.55) where the central region was used as a reference category. The Odds of infant mortality were found to be 1.54 as likely to occur for infants living in the eastern region as those living in the central region (OR 1.54, 95% CI 1.41-1.69). This study also showed that the Odds of infant mortality were 1.55 as likely to occur for infants living in the western region as to those in the central region. The Odds of infant mortality were found to be (OR 1.38, 95% CI 1.23-1.55), (OR 1.25, 95% CI 1.04-1.51) for infants living in North Eastern and Nairobi regions respectively. Whether or not an infant slept under a treated mosquito net, the data were fitted into the logistic regression model and the results presented above. This shows that the mosquito net is essential in ensuring the survival of infants by preventing them from surging malaria cases in Kenya. The Odds of infant mortality were found to be 0.9 less likely to occur for infants who sleep under a treated mosquito net as to those who do not (OR 0.9, 95% CI 0.85-0.95). Infants from malaria-endemic zones and who did not utilize treated mosquito nets experienced high mortality rates compared to their counterparts who slept under the mosquito net.

4.2 Non-Linear Effects of Maternal Age on Infant Mortality

The non-linear effect of maternal age on infant mortality is shown in **Error! Reference source not found.**. It presents the posterior mean of the smooth function and its 95% confidence interval level. This figure shows that there is a non-linear association between the age of the mother and infant mortality hence showing that as the age of the mother increases, infant mortality deceases and vice-verse. This agrees with the findings of [18] and [17] who argued that teenage mothers lack both physical, psychological maturity and mental preparedness which poses a high challenge during pregnancy, delivery and post-delivery periods which increases the chances of losing their infants.

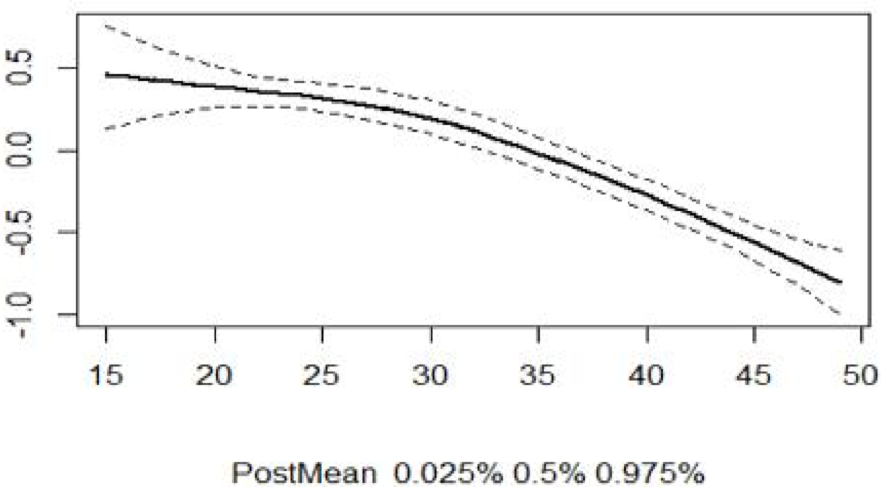

Fig. 1. Age of respondent

4.3 Spatial Distribution of Infant Mortality in Kenya

Bayesian approach that allows for complex and flexible hierarchical modeling of epidemiological problems as well as yielding reliable predictions and estimates was employed to determine the spatial effects of infant mortality in Kenya. This study utilized the penalized regression splines, penalized likelihood, and B-splines proposed by [25] to perform semi-parametric modeling that allows spatial variation in the outcome variables was used in determining the regional variation of infant mortality by analyzing the associated infant mortality risk factors. The assumption of linearity between dependent variables and covariates gives misleading results leading to misinterpretation. To cater to this anomaly, a flexible semi-parametric model that combines both parametric and semi-parametric models was preferred. A zero-mean Gaussian process was used to model spatially unstructured random effects while Gaussian Markov Random Fields was used to model spatial effects in the model.

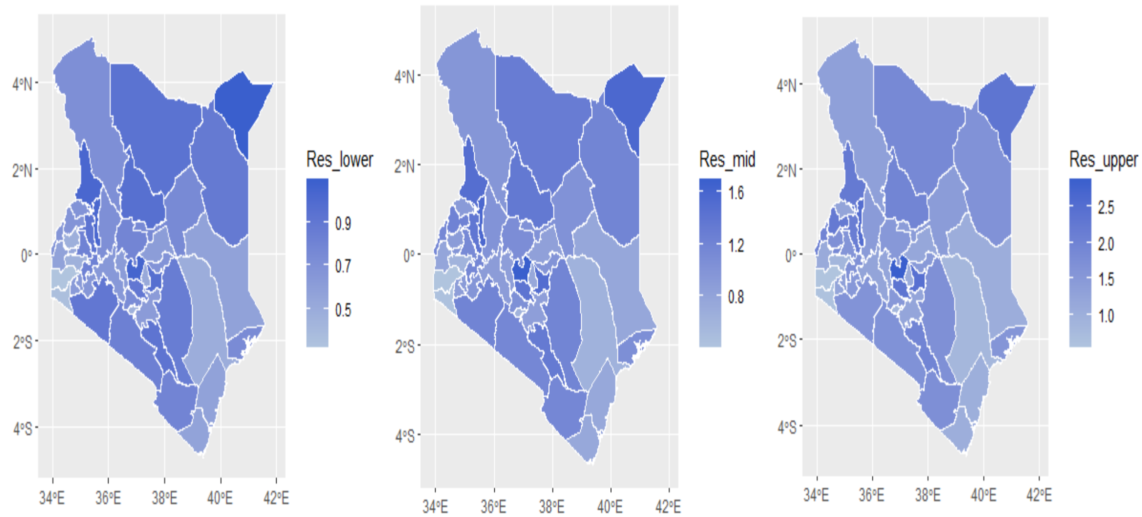

Fig. 2. Spatial Effects of Infant Mortality Per County

The spatial variation of infant mortality in Kenya is presented in **Error! Reference source not found.** which represents the geographical map of Kenya segmented into 47 county governments where Res_lower, Res_Mid, and Res_Upper represent 0.25, 0.5, and 0.975 credible intervals. Counties with very dark blue shading show a high level of infant mortality while those with light blue shading show lower levels of infant mortality. According to these figures, counties from the northern part of Kenya including Mandera, Garissa and Wajir, counties from the Rift Valley region including Elgeyo Marakwet, West Pokot, Turkana, Narok, Samburu, and Kajiado exhibited high levels of infant mortality. Also, counties from the Central, Eastern, Nyanza, and Western parts of Kenya such as Busia, Siaya, Marsabit, Kitui, Embu, Nyeri, and Makueni counties showed a high level of infant mortality. These results show that infant mortality varies significantly across regions and counties in Kenya and that there exists spatial-autocorrelation among neighboring regions that share almost similar characteristics such as ethnicity, cultural activities, and weather patterns. These findings were consistent with the findings of [26] who found that there is very strong correlation in regions that share common neighborhood. Lack of plausible factors related to infant survival in some regions such as literacy levels, wealth index, proximity to healthcare facilities, and access to clean drinking water leads to increased cases of infant mortality and morbidity. This variation could be due to uneven resource distribution such as improved sanitation facilities, healthcare systems, utilization of antenatal care, immunization programs, sensitization on hygiene, improved diet and malaria, and other infectious disease control programs.

5 Conclusion and Recommendation

This study found that there is a significant relationship between infant mortality and demographic, socioeconomic, and environmental factors. Maternal age, gender of the child, and birth order were significant factors of infant mortality. However, the size of the child at birth and duration of breastfeeding were excluded from the study due to a large amount of missing data which would have otherwise led to misleading information. It also established that younger mothers experience a high rate of infant mortality compared to mature ones. This was attributed to mental and physical maturity and psychological preparedness and also economic stability among adults. Socioeconomic factors such as wealth index, marital status, education level, source of income, the type of toilet facility, and religion were all found to be significant covariates of infant mortality. It was found that infants born and raised by wealthy parents had higher chances of survival while those from poor households experienced higher mortality risk. This was attributed to factors such as nutrition, clothing, healthcare, hygiene, and sanitation. It was found that mothers working in the informal sector and getting little wages have a higher probability of losing their newborns due to lack of basic needs and good healthcare compared to those working in formal employment where some have medical insurance scheme. It also established that infants from poor households who do not afford improved diet, access to clean drinking water, good toilet facility and living in unhealthy living conditions had a higher risk of dying compared to those from the rich households. Maternal education level was revealed to be a very important factor in ensuring infant survival where infants of mothers with at least primary education experience a lower risk of dying compared to infants born to completely illiterate ones. Education helps in influencing the cultural norms and beliefs in the society that pertains to infant care and feeding practices including utilizing modern health practices, immunization which boosts infants' survival chances. The type of toilet facility and the source of drinking water per household was also found to have a significant relationship with infant mortality.

Environmental factors including region of residence, place of delivery, type of place of residence were found to have a significant association with infant mortality. Infants living in rural areas experienced high mortality compared to their counterparts living in urban areas which were greatly attributed to the proximity to healthcare facilities. Region and county of residence were also found to be associated with infant mortality where counties in the northeastern region, rift valley, and coastal region experienced high infant mortality due to infectious diseases and lack of adequate health care facilities and other essentials such as clean drinking water. Place of delivery was also found to be an important covariate of infant mortality. Mothers who gave birth without the help of qualified healthcare personnel risk losing their infants compared to those who deliver under specialized care in healthcare facilities. It was found that infants from households with no toilet facility experience a high mortality rate due to infectious diseases related to hygienic conditions.

This study found that infant mortality varies spatially in Kenya due to uneven resource distribution such as improved sanitation facilities, healthcare systems, immunization programs, sensitization on hygiene, improved diet and malaria control programs, and other infectious disease control programs. It found that spatial variation in infant mortality exist in regions which share common neighborhood due to factors such as literacy levels, wealth index, proximity to healthcare facilities, and access to clean drinking water leads to increased cases of infant mortality and morbidity in arid and semi-arid regions who are majorly pastoralists.

Identifying infant mortality risk factors will help policymakers in developing tailor-made strategies and policies aimed at reducing this burden. It recommends that specialized care attention if required during and after delivery and in cases of multiple births. This study also recommends improvement of the diet and nutrition of expectant mothers as well as encouraging them to give birth at the healthcare facilities assisted by qualified health attendants. This study encourages the improvement of maternal health during and after delivery to reduce cases of infant mortality. It also encourages that mothers should give birth in their productive ages between 25 and 35 years since the findings of this study show that teenage and old mothers tend to lose their infants. Birth interval should also be emphasized to discourage mothers from having multiple births during a short span of time of less than 2 years. This study recommends follow-up studies to determine other factors that cause deaths of infants as this will help curb the problem. This study did not establish whether higher birth orders had significant effects since singletons had the highest percentage in the sample data hence further studies are needed to unravel whether an increase in birth order increases mortality risk.

It established that there exists a strong correlation among counties that share common boundaries since people living in these regions share similar cultures and traditions and experience same weather conditions. It recommends campaigns programs on immunization and utilization of mosquito nets in malaria endemic zones and other infectious diseases be carried out by the national and county governments. It also recommends that sensitization on utilization of antenatal and post-natal care and trained health personnel during delivery to reduce loss of infants. Both county and national governments should ensure there is sufficient supply of clean drinking water in the arid and semi-arid regions which experience serious weather conditions and droughts. Also, national and county governments are encouraged to improve education infrastructure so that it is easily accessed by the underprivileged population. This will equip them with knowledge on utilization of health attendants as well as family planning practices which will reduce the number of children per mother.

Competing Interests

Authors have declared that no competing interests exist.

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