The African Centre of Excellence in Data Science

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ANALYSIS OF UNDER FIVE CHILD MORTALITY IN EAST AFRICAN COMMUNITY

By

Ruth BYIRINGIRO

Registration Number:219014042

A dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Science in Data Science in Biostatistics

Supervisor: Dr. François NIRAGIRE

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DECLARATION

I declare that this dissertation entitled “**Analysis of under-five child mortality in East African Community**” is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institution.

Student Name: Ruth BYIRINGIRO

Signature:

APPROVAL SHEET

This dissertation entitled "**Analysis of under-five child mortality in East African Community**" written and submitted by **Ruth BYIRINGIRO** in partial fulfilment of the requirements for the degree of Master of Science in Data Science majoring in Biostatistics is hereby accepted and approved. The rate of plagiarism tested using Turnitin is 19% which is less than 20% accepted by ACE-DS.

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Dr. François NIRAGIRE
Supervisor

24.8.2021

Dr. Ignace KABANO
Head of Training

DEDICATION

To almighty God
To my beloved family, Brother and sisters
To relatives and friends
To all my classmates
To all lecturers

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I wish to acknowledge various people who have contributed to this research project either directly or indirectly and make this research possible.

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ABSTRACT

The survival rate of under-five children is promising but still very low in East Africa Community (EAC) region. This study aimed at studying the survival patterns of children in EAC and thus depict the underlined factors associated to the persistent low survival rate of children in EAC and thus outline some of the policies recommendations to tackle the crisis. Therefore, contribute, on the basis of a quantitative analysis outcome, to the realization of the third target of Sustainable Development Goal (SDG 3.2) of ensuring child survival.

Data were requested and obtained via DHS program website. From under-five children (KR)'s file and following the inclusion criteria of being aged 5 years or less at the date of interview, a total of 7856 children in Rwanda, 10233 children in Tanzania, and 13192 children in Burundi met these criteria and thus included into the current study. Both univariate and multivariate analysis was performed to identify variables that are statistically associated with child survival in Burundi, Rwanda, and Tanzania using both cox-proportional hazard model and Gamma frailty model.

The univariate analysis revealed that all 12 variables considered in this study found to be statically associated with child survival in Burundi, Rwanda, and Tanzania. The country level multivariate analysis revealed that place of residence, preceding bird interval, number of living children, sex of the child, and duration of breast feeding are the potential determinants of child survival in Tanzania. In Rwanda, mother's education, preceding bird interval, birth order, number of living children, and duration of breast feeding are the country's specific factors affecting child survival in the same country. In the last country covered by the current study (Burundi), mother's education level, age of the mother at first birth, wealth index, type of toilet facility, preceding birth interval, number of living children, and duration of breast feeding affect the survivorship of children.

Our findings indicated that child survival in Burundi, Rwanda, and Tanzania is associated with countries' specific factors. Therefore, the researcher recommended the adoption of country's specific policies to ensure the improvement of child survival for all countries.

Key word: Under-five children, DHS, Child survival, Hazard ratio; EAC

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LIST OF ABBREVIATIONS

ACE-DS: **A**frican **C**entre **of E**xcellence **in D**ata **S**cience

ANC: **A**nte**n**atal **C**are

CPHM: **C**ox **P**roportional **H**azard **M**odel

DHS: **D**emographic **H**ealth **S**urvey

EA: **E**numerator **A**reas

EAC: **E**ast **A**frican **C**ommunity

HR: **H**azard **R**atio

IMR: **I**nfant **M**ortality **R**ate

MDGs: **M**illennium **D**evelopment **G**oals

PSU: **P**rimary **S**ampling **U**nits

SDGs: **S**ustainable **D**evelopment **G**oals

SEA: **S**outh **E**ast **A**sia

SSA: **S**ub-**S**aharan **A**frica

TDHS: **T**anzania **D**emographic **and H**ealth **S**urveys

U5MR: **U**nder-five **M**ortality **R**ate

UNICEF: **U**nited **N**ations **I**nternational **C**hildren's **E**mergency **F**und

CHAPTER 1: INTRODUCTION

1.0. Background

Child and infant mortality is among the most significant sensitive measures of a country's social economic and health status (Mwangi Muriithi, 2015). Under-five mortality rates decreased globally by around 53 percent between 1990 and 2015, with a rapid decrease beginning in 2000 due to massive efforts to meet the Millennium Development Goals (MDGs). The annual decline in under-five mortality increased from 1.9 percent before 2000 to 4 percent between 2000 and 2015 (Hategeka, Tuyisenge, Bayingana, & Tuyisenge, 2019).

Worldwide, under-five mortality was 93 deaths per 1000 live births in 1990 and decreased to 39 deaths per 1000 live births in 2017. Around 2.6 million babies globally die before one month of age each year, one million of them take their first and last breath at birth. Each of these deaths is a sad event, especially as the vast majority are preventable (Strategy, 2018).

High rates of mortality are detected in Sub-Saharan Africa (SSA) and South-East Asia (SEA). These two regions share about 80 percent of the global child mortality. For instance, in 2017 UNICEF reported that these regions share nearly the same burden: 39 percent of all deaths occurred in SEA region whereas 38 percent occurred in SSA region in the same year (Estimation, 2017). Moreover, SSA had a child mortality rate of 76 deaths per 1000 live births in 2017. This is translated to 2.7 million deaths of babies (Malderen et al., 2019).

Improving child survival remains one of the most important health challenges in SSA, a region that accounts for half the global burden of under-five mortality while having approximately 13 percent of the world's population and 25 percent of births globally. Many countries have struggled to reach the fourth MDG aimed at decreasing under-five mortality by two third between 1990 and 2015, indicating that many children have a high probability of dying before their fifth year of life (Hategeka, Tuyisenge, Bayingana, & Tuyisenge, 2019).

Neonates and infants are at higher risk of dying compared to those aged 2 years and above. Like under-five children, neonates are also mostly dying in SSA and in SEA. Generally, African has the highest neonatal death rate of 28.0 per 1000 births, this indicates that under-five child mortality in Africa region is still high but lower in America, Western Pacific, and Europe (Grady et al., 2017). It shows that if Africa needs to reduce the mortality rate of under-five to meet the SDG target by 2030, the annual mortality reduction rate of under-five should be 4.5 percent or more (Strategy, 2018).

A series of strategies have been suggested and applied over the past two decades to decrease child death and increase child health in developing countries. Some of these policies include improving costs for health care, easy access to healthcare, increasing mothers 'education, and poverty reduction. For all of these measures, in many developing nations, under-five and child mortality rates remain high (Lartey, Khanam, & Takahashi, 2016).

Much progress has been made in the East African Community (EAC) toward reducing child mortality. This was due to strong political will, investments in strong health systems that prioritize babies born in the poorest and most vulnerable areas, and significant improvements in children's general immunization status. Despite the successes in reducing child mortality in EAC, child-related mortality remains high across all EAC member states. The average child mortality stood at 71.3 deaths per 1000 births in 2018. This is still very far from the SDG3.2 set target of 25 deaths per 1000 births to be achieved by 2030 (East & Community, 2018).

The current progress suggests that if the trend remains constant. It will not be easy for EAC member states to achieve SDG3.2 target of lowering U5MR to 25 deaths per 1,000 births by 2030. The situation is even worse in rural areas in the same region. This is due to a number of factors including among others: a substandard child breastfeeding period (less than 6 months), born at home or not taken for postnatal check, and poverty. Under-five child mortality was shown that it can vary from region to region (Y & S, 2016).

The estimated Infant Mortality Rate (IMR) for the 2017/2018 reporting period in EAC was 47 per 1000 infants for Burundi, 43 deaths per 1000 births for Tanzania, 43 deaths per 1000 births in Uganda, 39 deaths per 1000 births for Kenya, and 32 deaths per 1000 births for Rwanda. This gives a weighted average of 39.6 deaths per 1000 live births for the EAC region. The average death rate of under-five children ranged from 93 deaths per 1000 births in South Sudan; 78 deaths per

1000 births in Burundi, 52 deaths per 1000 births in Kenya, 50 deaths per 1000 births in Rwanda, 64 deaths per 1000 births in Uganda, and 67 deaths per 1000 births in Tanzania (East & Community, 2018).

Generally, the major causes of infant mortality in EAC include among others: premature birth complications (15 percent), intrapartum complications (11 percent), pneumonia (13 percent), diarrhea (9 percent), and malaria (7 percent). Of all deaths in under-fives, 45 percent of them was associated with under-nutrition, while 80 percent of them are due to low birth weight of newborns. In addition, certain emerging childhood conditions, apart from traditionally known ones, have had some significant impact on child health. Such conditions include: cardiac problems, injuries, chronic respiratory diseases, acquired cardiac diseases, cancers of childhood, diabetes, and obesity (Liu et al., 2000).

It is against this background that the researcher wants to apply survival models (as opposed to the mostly used classical models) to investigate the factors that contribute to the persistence of high child mortality rates in EAC and thus contribute on the basis of the research findings to the achievement of SDG3.2 of ensuring child survival.

1.1. Problem statement

SSA is still the region with the world's top under-five mortality rate with 78 deaths per 1,000 live births in 2018. This is 16 times more than the average ratio of under-five mortality for high-income countries. The recent UNICEF report shows that the SSA region carries 39 percent of global child deaths(Cao et al., 2019) .

Despite the progress made by EAC member's states towards reducing child mortality rate, the reported infant mortality rate for the period 2017-2018 has shown that the region had an average IMR of 39.6 deaths per 1,000 births. Similarly, child-related mortality remains also high across all EAC partner states. The estimated average under-five mortality rate is 71.3 deaths per 1,000 live birth in the same region. These rates are far above the SDG3.2 target of lowering U5MR to 25 deaths per 1,000 births by 2030 (East & Community, 2018).

In addition, few researches have been done on the particularly factors contributing to newborns' deaths by assuming a constant probability of dying across all age groups. The U5MR is known to be higher among neonates. A point highlighting a need for special attention during the child survival analysis (Grady et al., 2017).

The higher child mortality rates in EAC stresses the need for more researches with emphasis on the use of new methodologies and focusing on newborns. Thus, the researcher used cox regression and Frailty models to depict the survival patterns of children from all levels over time as opposed to classical models that are assuming independence of mortality over calendar time (Ayele, Zewotir, & Mwambi, 2017).

1.2. Objectives of the research

1.2.1. Main objective

The key aim of the research is to assess the main determinants of under-five child mortality in the East Africa Community.

1.2.2. Specific objectives

- ✓ To compare under-five child mortality for selected countries in EAC and their determinants.
- ✓ To identify the main determinants of child mortality and show the shape of child survival in EAC.
- ✓ To provide some recommendations to the government in reducing under-five child mortality in EAC.

1.3. Significance of the study

Many retrospective studies have been made to establish the factors that lead to under-five child mortality in East African Community but those studies produce biased results when classical modeling techniques are used. Survival analysis approaches are usually more appropriate compared to other methods (Grady et al. 2017). This study will help to make comparison as previous researchers work for only one country in the EAC but with this combined study, East Africa Community countries will all be ready to act for the same results and recommendations. This will help the government and the child health organization to make strategies for reducing under-five child mortality, therefore contribute to meet the SDG target in EAC countries and the rest of the world.

1.4. Definition of key terms

Sometimes the literature uses different terminology. This section explains the main words used in the context of this study. According to DHS reports:

- **Neonatal mortality:** is the probability of dying within the first month of life
- **Post neonatal mortality** is the probability of dying between the first month of life and the first birthday.
- **Infant mortality:** is the probability of dying between birth and the first birthday
- **Child mortality:** is the probability of dying between the first and the fifth birthday
- **Under-five mortality:** is the probability of dying between birth and the fifth birthday
- **Survival analysis:** is a statistical method or tool used to analyze time to events data.
- **An event:** is the result of an individual unit of scientific interest in various studies such as sociology, biology, demographics, medicine, employment, etc.

1.5. Organization of the thesis

This thesis is divided into five parts. The first chapter, which is the introduction of the study which includes the background, the summary of the problem, the objectives of the study, the importance of the study, definitions of the study's key terms and limitations. The second chapter describes the theoretical and conceptual framework of the study, summarizes the literature related to this research, more precisely, Mosley and Chen's model on the factors of under-five mortality, identifies variables included in the conceptual framework. The third chapter provides a section of the methodology. It discusses the type of data used in this study and the various approaches used in the path of analysis. The fourth introduces the study's data analysis and findings and the fifth chapter includes discussion, conclusion, and recommendations.

CHAPTER 2: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. Literature review

Globally, through using data from RDHS (François, Niragire, Wangombe, & Achia, 2011), their study has been concentrated heavily on the relationship between socioeconomic factors, demographic or biological factors, environmental factors and child mortality in Rwanda. The main objective of their study was to identify and rank order the main factors that lead to child survival in Rwanda between 2000 and 2005 by based RDHS. Cox proportional hazard model and frailty model were used to identify the main factors that lead to child mortality in Rwanda. They found that partner's education, province of residence and mother's education, birth status, and wealth index. The study found that child mortality in Rwanda change due to unobserved factors that were not included in RDHS at household level.

The study conducted at Uttar Pradesh to determine the effect of socioeconomic, environmental, health-related, and nutritional factors on children's under-five mortality. They found that infant mortality rate was 64 deaths per 1,000 live births and U5MR was 78 deaths per 1,000 live births. Moreover, they found that boys had a higher mortality rate compared to girls during the neonatal period and girls had higher U5MR than boys. They also found that infant mortality rates in rural areas were considered higher than in urban areas. The survival analysis results of their study showed that the main factors associated with under-five child mortality in Uttar Pradesh were: women's age in years, total children ever born, births in the last five years, number of living babies, currently breastfeeding, cigarette smoking, urge for more infants, size of babies at birth, delivery by cesarean section, ANC visits and birth order (Saroj, Murty, & Kumar, 2018).

Unlike (Saroj et al., 2018), (Nasejje, Mwambi, & Achia, 2015) conducted a study in Uganda to understand observed and non-observed determinants of under-five child mortality using both frequentist and Bayesian survival analysis approaches. Their study revealed that Uganda is one of the high-infant mortality countries in SSA. It had under-five child mortality of 151.3 deaths per 1000 births in 2000 and it was decreased to 125 and 90 deaths per 1000 births in 2005 and 2011 respectively. Their study found also that the number of births in the past year, the sex of the child, and the sex of the head of the household were the main factors associated with increased risks of under-five child mortality in Uganda. However, non-observed factors including among others: access to food, child care, sanitation also have an influence on child mortality in Uganda.

In a study carried out in Kenya, the goal was to evaluate the effect on infant and child mortality of socio-economic and demographic variables. The infant mortality rate was 52.29 deaths per 1000 births, low birth weight was associated with a higher risk of death where mortality due to low birth weight was 13 percent compared to 2 percent for average birth weights. Using the cox proportional hazard model, the study found that mother's education, mother's wealth, and occupation of the mother are the major socio-economic factors influencing infant mortality and child mortality, and demographic factors such as the province of residence, maternal age, place of delivery, children born smaller than average size, birth order, access to piped water, access to better toilet facilities, proper treatment of human waste, child sex has an effect on infant mortality and child mortality in Kenya. They advise policymakers and program managers in the child health sector to implement effective strategies to improve the condition of children under five years of age (Mwangi Muriithi, 2015).

Ethiopia, like other African countries has high child mortality rates. The aim of the study was to assess the impact of socioeconomic, demographic, environmental, health and nutritional factors of under-five child mortality in Ethiopia. Kaplan Meier method was used to estimate the survival time of the child. By using the Cox proportional hazard model and stratified cox proportional model, they found that mother's education, first-born mother's age, sex, father's occupation, preceding birth interval, place of delivery, number of pregnancy antenatal visits, breastfeeding and contraceptive use factors influence child survival. The study confirm that risk of child mortality in Ethiopia is variable from region to region (Ayele & Zewotir, 2016).

2.2. Conceptual framework

The selection of the current research’s variables was adapted from the conceptual model of child survival determinants in developing countries developed by Mosley and Chen (Url et al., 1984).

Mosley and Chen’s model show how an aggregate of risk factors affects the trend of under-five mortality. Proximate and social determinants associate with each other and contribute to under-five mortalities. Health, nutrient deficiency factors associated with maternal, personal illness, and injury-related factors affect a child directly or indirectly by giving him a healthy and illness status (Url et al., 1984).

In this context, several proximate determinants and indirect variables that influence the risk of morbidity and mortality are defined as shown by Figure 1 displays the detailed relationship among variables.

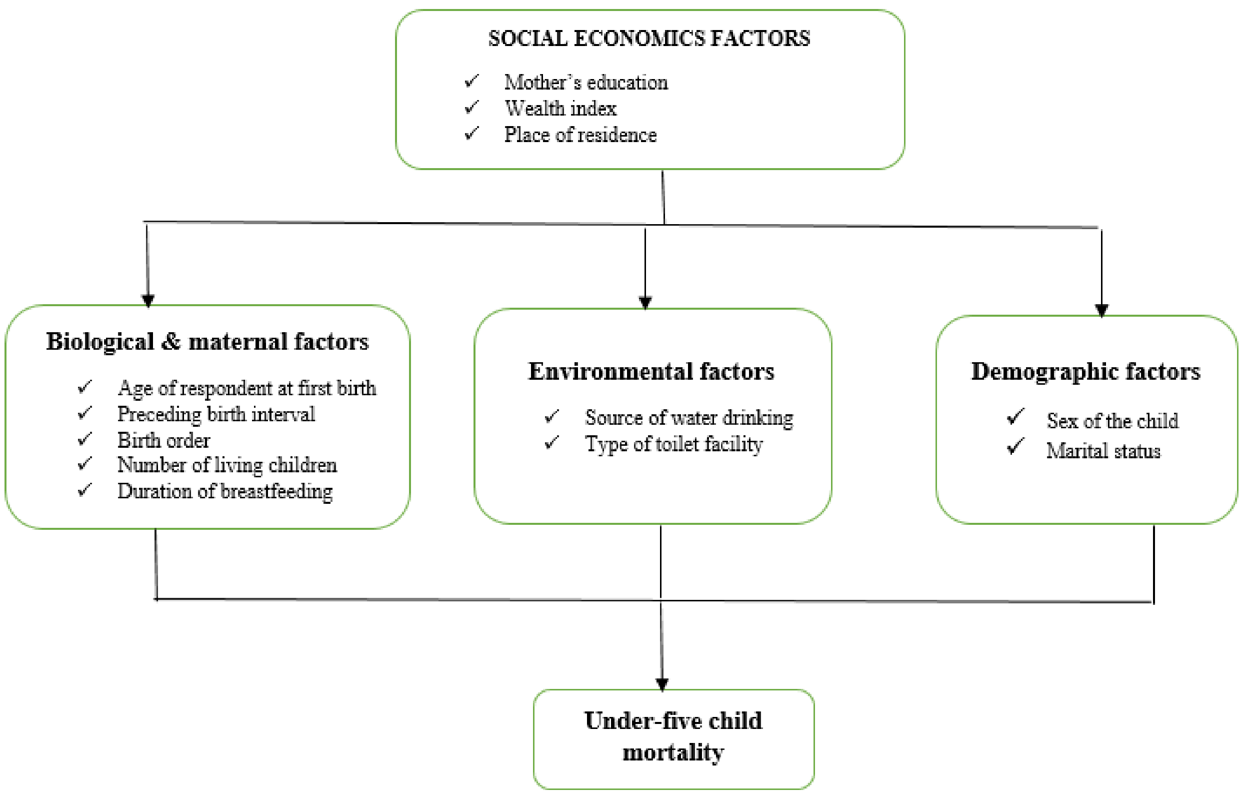

Figure 1:Conceptual framework for the study of child survival

Adapted from Mosley and Chen (Url et al., 1984)

2.2.1. Environmental factors

Environmental factors have a great impact on child mortality as they affect the transmission of diseases causing agents to children and mothers (Url et al., 1984). This included floor materials, access to safe drinking water, access to good improved sanitation, cooking fuels, and even roofing materials. Environmental factors are considered a source of the agent-causing disease exposure.

These environmental factors affect the occurrence of diarrhea and other infectious diseases, which are among the causes of childhood death, particularly in developing countries. Nearly 90 percent of diarrhea deaths worldwide are related to unsafe water, poor sanitation, or poor hygiene (Kosek, Bern, & Guerrant, 2003).

2.2.2. Social-economic factors

Socio-economic variables include the schooling of mother and father, employment of father and mother, wealth index, place of residence, and the mother's marital status. They work as close causal factors to affect child mortality and wellbeing (Url et al., 1984). This is due to the interaction of socio-economic factors and the proximate factors. Socio-economic factors may influence childhood exposure to bad environment, maternal behavior of mothers, and even behavior seeking health, thereby influencing child mortality. The impact of mother's education on child survival and health was well recorded among the socio-economic factors. Unlike uneducated mothers, educated mothers are less likely to experience a child death. It may be justified by the benefits of education, which include economic advantages and the ability to access health care services and live a modern life (Perry, 1999).

2.2.3. Bio-demographic factors

In child mortality studies, a variety of bio-demographic factors were identified. These factors, also refer to as maternal influences (Url et al., 1984). The bio-demographic factors have an independent direct impact on childbearing survival. This affects the child's wellbeing pre and post-birth, and in certain cases influences the care behavior of the mother towards the child survival (United Nations Population, 2011). These include the length of the preceding birth interval, birth order, mother's age at a child's birth, child's sex, birth weight, and gestation at the child's birth.

Due to the lack of information in some DHS data files, all variables were not considered in this study but this study covers the most fundamental variables outlined by other researchers. Table 1 summarizes the variables considered in this study.

CHAPTER 3: METHODOLOGY

This chapter discusses the framework of the methods used to collect, clean and analyze data.

3.1. Description of the study area

EAC is "an intergovernmental regional organization consisting of six countries which are: Burundi, Kenya, Rwanda, South Sudan, Uganda, and Tanzania". The headquartered of EAC is located in Arusha in Tanzania. The EAC contains 177 million residents, of which more than 22 percent live in urban with 2.5 million square kilometers of land area (Border, n.d.).

The EAC's work is driven by its Contract that formed the Community. It was firstly approved by three countries members which are: Kenya, Tanzania, and Uganda on 30th November 1999 and entered into force on 7th July 2000. On 18th June 2007, Burundi and Rwanda agreed to the EAC Contract and became complete Community members with effect from 1st July 2007. On 15th April 2016, South Sudan agreed to the Contract, and on 15th August 2016, it became a full Member (East & Community, 2018).
The key aim of the EAC is to establish policies and services for the promotion of Cooperation between its member states in a broad range of areas including: political, economic, social, cultural affairs, research and technology, security, and legal and judicial affairs (Border, n.d.).

3.2. Research Design

The current study is a retrospective survival analysis of cross-sectional secondary data from the 2015 Rwanda Demographic and Health Survey (RDHS), 2016 Tanzania Demographic and Health Survey (TDHS), and 2017 Burundi Demographic and Health Survey (BDHS).

3.3. Data and source

This research used secondary data from DHS for three EAC countries. Nonetheless, to determine the risk factors associated with the higher mortality rate, the researcher selected three EAC countries based on the following criteria:

The first criterion was to select two countries with the highest U5MR and whose the past five years DHS data available, and accessible. The second criterion was being a country with lower U5MR for comparison purposes.

Thus, Tanzania, Burundi met the first criteria and Rwanda met the second criterion with 53, 58.5, and 35 deaths per 1000 births respectively (Cao et al., 2019).

Datasets of these countries were requested from DHS program and downloaded from their website (https://www.dhsprogram.com/data/available-datasets.cfm). Demographic and Health Surveys (DHS) are "nationally-representative household surveys that provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition"(NISR, 2015).
The observation period during the follow-up is 11 months for infancy and 12 up to 59 months after birth for under-five children.

3.4. Study population

The population that is especially focused on in this study are children with age below five in Burundi, Tanzania, and Rwanda as selected countries in the current study. It includes children who participated in the individual survey of DHS 2014 or later. All children born in the last five years have been included, while the other children have been excluded.

3.5. Sample size and Sampling techniques

The observations were retrospective data derived from the birth history of the mother. There were 13192 births in Burundi, 7856 births in Rwanda, and 10233 births in Tanzania within 5 years preceding the date of the interview.

As discussed is the data source section, the current study used data from three EAC countries collected by their corresponding national statistics offices. In all datasets used in the current study, a multi-stage stratified sampling was used during the selection of respondents (NISR, 2015; Burundi, 2017; TDHS 2015-16, 2015). The first stage involved the selection primary sampling units (PSU) from the frame list. A PSU is normally a geographically built area or part of the area;

named Enumeration Area (EA) which contains several households founded in the last population Census (Aliaga and Ren, 2006). The second stage involved the random selection of households within selected PSU from stage 1. In all stages, probability proportional to size principle was used to ensure the representativeness of sampled households across PSUs.

3.6. Study variables and measurements

3.6.1. Dependent variable

The dependent variable is survival time of the child measured in days. This variable indicates the life time in days that a child has survived from the date of birth. It was computed from the other DHS variables as follows: The survival time was computed for both children who were alive and for children died. The former was obtained by subtracting the date of their mothers' interview from the date of birth and the latter was obtained directly from the DHS as "Age at death".
Survival time was recorded in days for neonates, months for infancy, and years for children aged between 1 and 5 years old.

The age at death was initially coded as: 100 to indicate survival time in days, 200 to indicate survival time in months, and 300 to indicate survival time in years. Therefore, the last digits were used to indicate the number of days that a child has survived from 1 to 30, the same case for months from 2 to 23 and years from 2 to 5 in all countries. The researcher assumed that a month has 30 days and a year has 365 days whenever daily, monthly, or yearly estimates were need. (F Niragire, 2017).

3.6.2. Independent variable

The current study used the same variables for each country. This was useful in terms of results comparability. Table 1 displays the selected variables per their corresponding dimensions.

Table 1: Independent variables used for the current study

Codes for DHS	Labeling
Social-economic factors	
V106	High education(Mother's education)
V190	Wealth index
V025	Type of place of residence
Biological and maternal factors	
V212	Age of respondent at first birth
B11	Preceding birth interval
BORD	Birth order
V218	Number of living children
M4	Duration of Breastfeeding
Environmental factors	
V113	Source of drinking water
V116	Type of toilet facility
Demographic factors	
B4	Sex of child
V501	Marital status

3.6.3. Recoding of independent variables

Table 2 shows the measurement and how the researcher recoded independent variables included in the analysis. The recoding method helps to make variables usable along with the analysis, most of them are divided into 2 or more values.

Table 2:Measurement and recoding of covariates used for analysis

Covariates	How covariate is coded
SOCIAL ECONOMIC FACTORS	
Mother's education level (v106)	0=No education **/reference category** 1=Primary education 2=Second education 3=Higher education
Wealth index (v190)	0=Poor /reference category 1=Rich
Type of place of residence (v025)	1=Urban **/reference category** 2=Rural
BIOLOGICAL AND MATERNAL FACTORS	
age of respondent at 1st birth (v212)	1=7-17 **/reference category** 2=18-28 3=29-39 4=40-46
Preceding birth interval (b111)	1=Less than 1 year **/reference category** 2=Less than 2 years 3=Above 2 years
Birth order (bord)	1=First birth **/reference category** 2=Second birth 3=Third birth 4=Fourth and above
Number of living children (v218)	1= Children between 0-5 **/reference category** 2= Children between 6-10 3= Children between 11-14
Duration of breastfeeding(m4)	1=Ever/not current breastfeeding**/reference category** 2=Never breastfeeding 3=Still breastfeeding
ENVIRONMENTAL FACTORS	
Type of toilet facility(v116)	1=Flush toilet **/reference category** 2=Pit and traditional toilet 3=No toilet
Source of drinking water(v113)	1=Pipe water **/reference category** 2=Open well water
DEMOGRAPHIC FACTORS	
Sex of the child (b4)	1=Male **/reference category** 2=Female
Current marital status(v501)	0=Never married **/reference category** 1=Married

3.7. Methods of analysis

3.7.1. Survival Analysis

In the current study, the researcher used survival analysis to achieve the second and third objectives of the study. The survival analyses used are life tables and Kaplan-Meier method.

Kaplan-Meier method was used to represent graphically the survival probabilities of children to a period longer than a specific time t say a month, a year, or 5 years. It is denoted as:

$$\hat{S}(t) = \prod_{i=1}^{g}\left(\frac{n_i - d_i}{n_i}\right) \qquad (1)$$

Where:

- $\hat{S}(t)$ is the Kaplan-Meier estimator and it was used to estimate the survivor function in this study
- d_i represents the number of children who died and
- n_i represent the number of children living at the start

This method was used to estimate each country's child survival time. Having the country level survival rates, the researcher was able to make a comparison of child survival across different child' s age categories. This helped the researcher to achieve the first objective of the study which is "*To compare under-five child mortality for selected countries in EA and their determinants*". Also this method helped to estimate under-five child mortality. The mortality rates were computed for neonates, infancy, and under-five years old children for every country.

In this study, three assumptions were considered. Firstly, the researcher assumed that children that are censored have the same chances of survival as those that tend to be followed at any time. Second, we suggest that the chances of survival are equal for subjects recruited early and late in the study. Third, we are stating the event occurs at the specified time.
To achieve the second objective of this study (which is "*To identify the main determinants of child mortality and show the shape of child survival in EAC*.") both cox-proportional hazard model and frailty model were used as discussed in section 3.7.2 and section 3.7.3.

3.7.2. Univariate and Multivariate Analyses

To achieve the second objective of the current study which is "*To identify the main determinants of child mortality and show the shape of child survival in EAC*.", a combination of cox-proportional hazard and gamma frailty models were used.

cox-proportional hazard model

The cox-proportional hazard model is defined as:

$$h(t) = h_0(t) * e^{\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_r x_r}$$

Where

- $h(t)$ is the risk of death for child at time t (survival time for the child)
- $h_0(t)$ is a baseline hazard at time t (means all covariates at their respective reference levels)
- β_i are the regression coefficients
- $x_1, x_2, \ldots, x_r$ are selected variables in the current study
- $e^{\beta_i x_i}$ is the hazard ratio. If $\beta_i x_i$ is greater than 0 the hazard ratio will be greater than 1.

The dependent variable is the child's survival time. The hazard ratio for each variable in the model was estimated for each country. This was done by using both Univariate Cox proportional hazard regression models and multivariate cox proportional hazard model for each country. The Univariate cox proportional hazard model was used to select variables that have effect on child survival. Then after, all these variables found to be statistically associated with child survival by country were included in the reduced model. However, it was only limited to observed variables.

The determinants of child survival were selected based on the hazard ratios. That is: if the hazard ratio for a predictor is close to 1 then that predictor does not affect child survival. If the hazard ratio is less than 1, then the predictor is associated with improved child survival and if the hazard ratio is greater than 1, then the predictor is associated with low child survival.

One of the advantages of this model is that it does not require strong data distribution assumptions (Saroj et al., 2018).

This model consists of two parts: the underlying hazard function, often referred to as $h_0(t)$, explaining how the risk of an event (death) per unit of time changes over time at covariate baseline levels; and the effect variables explaining how the hazard differs in response to explanatory covariates (X is a vector of explanatory covariates and β is a vector of unknown regression parameters).

Gamma frailty model

The frailty model is an unobserved random proportionality factor that changes the hazard function of an individual, or related individuals (Angela & Uju, 2015). This model is used to check unobserved factors that lead to under-five child mortality and to introduce random effects, association, and unobserved heterogeneity into models.

The frailty model is defined as follow:

$$h(t/\alpha) = \alpha h_0(t) * e^{\beta x}$$

Where:

- ✓ α is some random positive quantity assumed to have a mean equal to 1 and variance θ.
- ✓ $h_0(t)$ represent the baseline hazard function
- ✓ $h(t) * e^{\beta x}$ denote the cox regression model

The frailty in the model is assumed to follow a gamma distribution g(α) are used in the survival analysis to account for the study population's unobserved heterogeneity or missing covariates. The concept is to suggest that different children have different frailties and that frailer children appear to be frailer than less frail children. As it follows the gamma distribution with mean equal to 1 and variance equal to θ, the gamma distribution is used for analysis to derive survival, density, and hazard function expressions of the closed-form.

The value of θ or variance of the frailty will be estimated to indicate that the frailty components have a contribution to the model. The parameter estimates in the Cox regression model would be changed since the frailty is included. Thus, to achieve this, the age of the mother was used to form clusters of children to be able to test the possible availability of non-observed factors associated to child survival. It was assumed children born to mothers with the same age group have the nearly the same risk of dying.

3.8. Model selection criteria (AIC)

The AIC is used as a means of models comparison. More specifically, it is used to evaluate the model training error. The reason why it can be used to compare the performance of models with assumption that in-sample and out of sample performance will be the same (Snipes & Taylor, 2014). AIC is computed as follows:

$$AIC = 2K - 2\ln(\hat{L})$$

Where: **K** in the number of model parameters and

$\hat{L}$ is the maximum value of the likelihood function for the model.

Therefore, the same analogy was used to evaluate first of all independence model performance but also to compare the models used in the current study. The low the AIC a model has, the better performance.

CHAPTER 4: DATA ANALYSIS AND RESULTS

4.1. Frequency distribution of covariates

The results of the univariate analysis are represented in Table 3. The same table shows that mother's education has an association with child survival, children who mostly died are those born from mother with no education with 6.06 percent in Burundi, 5.7 percent in Rwanda.

Around 6.48 percent of children born from mother with age at first birth between 7 and 17 died mostly compare to others and 6.89 percent of children died from mother with age between 29-39 in Burundi. In Rwanda, 5.23 percent and 6.97 percent of children deaths are associated with mothers age at first birth between 7-17 in Rwanda and Burundi respectively.

Since the preceding birth interval is low child death increases. The outcome percentages of children dying are 9.78 percent, 12.12 percent, and 11.96 percent for preceding birth interval less than 1 year in Burundi, Rwanda and Tanzania respectively. Children with the preceding birth interval of less than one year are considered as having a high risk of dying compared to others.

Duration of breastfeeding influences child survival. The percentage of children who never breastfeed is 58.25 percent in Burundi, 76.58 percent in Rwanda, and 56.22 percent in Tanzania which are very high. This shows that the duration of breastfeeding has a great influence on child survival. There is no death for those children who are still breastfeeding.

Table 3:The frequency distributions of child deaths according to selected covariates

covariates	Child status					
	Burundi		Rwanda		Tanzania	
	Alive(%)	Dead(%)	Alive(%)	Dead(%)	Alive(%)	Dead(%)
Mother's education level(v106)						
No education	5593(93.94)	361(**6.06**)	1076(94.3)	65(**5.7**)	2097(95.36)	102(4.64)
Primary	5218(94.51)	303(5.49)	5414(96.27)	210(3.73)	5839(94.64)	331(5.36)
Secondary	1536(96.73)	52(3.27)	869(97.53)	22(2.47)	1691(95.27)	84(4.73)
Higher	125(96.9)	4(3.1)	199(99.5)	1(0.5)	86(96.63)	3(3.37)
Wealth index						
Poor	7509(93.78)	498(6.22)	4804(95.79)	211(4.21)	6106(95.15)	311(4.85)
Rich	4963(95.72)	222(4.28)	2754(96.94)	87(3.06)	3607(94.52)	209(5.48)
Place of residence (v025)						
Urban	2035(95.67)	92(4.33)	1671(96.87)	54(3.13)	2243(93.77)	149(**6.23**)
Rural	10437(94.32)	628(5.68)	5887(96.02)	244(3.98)	7470(95.27)	371(4.73)
Age of respondent at first birth (v212)						
7-17	1904(93.52)	132(**6.48**)	598(94.77)	33(**5.23**)	2967(94.7)	166(5.3)
18-28	10118(94.8)	555(5.2)	6542(96.26)	254(3.74)	6558(95.07)	340(4.93)
29-39	446(93.11)	33(**6.89**)	417(97.43)	11(2.57)	187(93.03)	14(**6.97**)
40-46	4(100)	0(0)	1(100)	0(0)	1(100)	0(0)
Preceding birth interval (b111)						
Less than 1 years	166(90.22)	18(**9.78**)	58(87.88)	8(**12.12**)	81(88.04)	11(**11.96**)
Less than 2 years	1901(92.06)	164(7.94)	844(96.57)	30(3.43)	1691(94.95)	90(5.05)
Above 2 years	7998(95.45)	381(4.55)	4399(96.58)	156(3.42)	5675(95.55)	264(4.45)
Birth order (bord)						
first birth	2386(94.27)	145(5.73)	2219(95.56)	103(4.44)	2249(93.75)	150(**6.25**)
Second birth	2286(94.31)	138(5.69)	1776(97.26)	50(2.74)	1802(94.99)	95(5.01)
Third birth	2030(94.68)	114(5.32)	1173(96.94)	37(3.06)	1424(95.51)	67(4.49)
Fourth and above	5770(94.7)	323(5.3)	2390(95.68)	108(4.32)	4238(95.32)	208(4.68)
Number of living (v218)						
1-5	9958(93.98)	638(6.02)	6796(96.03)	281(3.97)	7652(94.45)	450(5.55)
6-10	2471(96.79)	82(3.21)	760(97.81)	17(2.19)	1979(96.63)	69(3.37)
11-14	43(100)	0(0)	2(100)	0(0)	82(98.8)	1(1.2)
Duration of breastfeeding(m4)						
Ever/not currently breastfeeding	6670(91.66)	607(8.34)	3675(94.57)	211(5.43)	6030(93.94)	389(6.06)
Never breastfeeding	81(41.75)	113(**58.25**)	26(23.42)	85(**76.58**)	102(43.78)	131(**56.22**)
Still breastfeeding	5721(100)	0(0)	3836(100)	0(0)	3581(100)	0(0)
Sex of the child (b4)						
Male	6287(94.19)	388(5.81)	3810(95.78)	168(4.22)	4852(94.16)	301(**5.84**)
Female	6185(94.91)	332(5.09)	3748(96.65)	130(3.35)	4861(95.69)	219(4.31)
Marital status (v501)						
Never married	388(95.33)	19(4.67)	664(95.82)	29(4.18)	461(92.57)	37(7.43)
Married	12084(94.52)	701(5.48)	6894(96.24)	269(3.76)	9252(95.04)	483(4.96)
Source of water drinking(v113)						
Pipe water	1229(96.17)	49(3.83)	2769(96.62)	97(3.38)	1722(95.03)	90(4.97)
Open well water	11243(94.37)	671(5.63)	4788(95.97)	201(4.03)	7991(94.89)	430(5.11)
Type of toilet facility (v116)						
Flush toilet	460(97.25)	13(2.75)	172(97.73)	4(2.27)	1186(94.2)	73(5.8)
Pit and traditional toilet	11663(94.59)	667(5.41)	6953(96.29)	268(3.71)	3000(94.73)	167(5.27)
No toilet	349(89.72)	40(**10.28**)	426(94.46)	25(5.54)	5527(95.18)	280(4.82)

4.2. Survival time of children in Rwanda, Burundi, and Tanzania

The survivor function (Figure 2) simply indicates the probability of child survival over time. The function is monotonically decreasing. This shows that, as time increases, the survival probability decreases. Because no one has experienced the event yet, the chance of surviving past time at the beginning of the study is one. If the time rises without limit, no one will ultimately survive, so the survivor curve has to fall to zero.

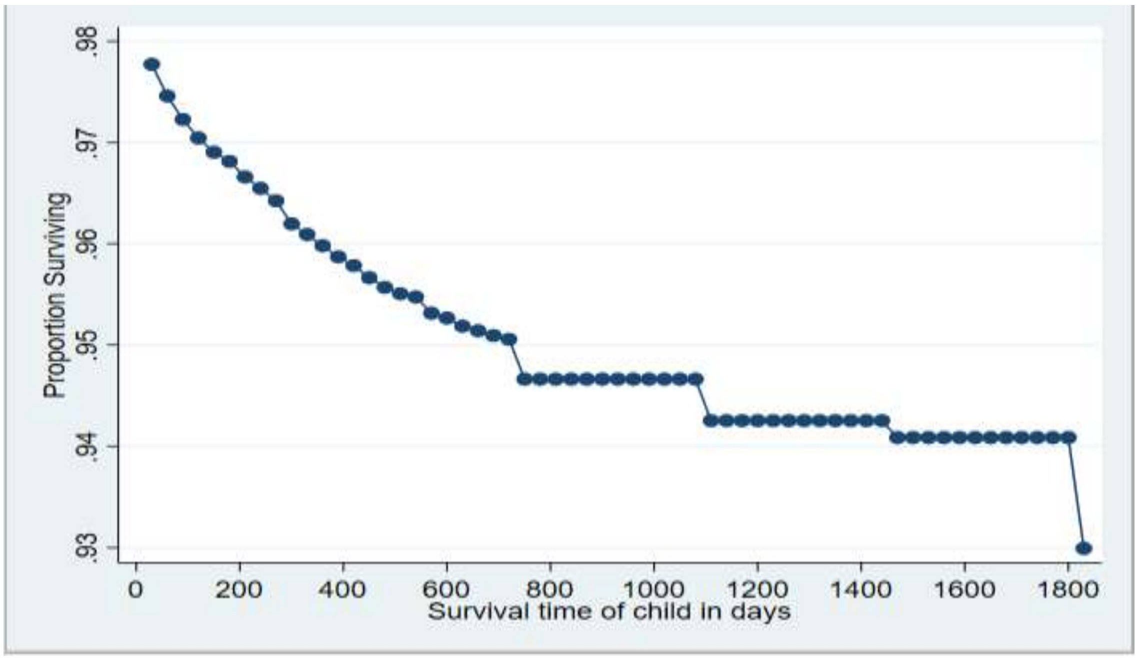

Figure 2:General picture of children survival in Rwanda, Burundi, and Tanzania

Figure 2 indicates average survival rates for children in Rwanda, Burundi, and Tanzania. The rate dropped quickly from 0-700 days, by looking at it. A significant number of children are dying in this interval because the chance of survival is steadily declining. Between the 700-800 days' interval and 100-1100 days' interval, the number of deaths increased dramatically as seen in the graph. Again, death numbers gradually decrease in 1400-1500days and 1600-1700days intervals. This shows that more children died between 0 and 700 days compared to other days so they are at high risk of dying in those days and children between 1600-1700 days are at low risk of dying relative to others as the curve drops steadily at 1600-1700 days as seen on the figure. The last drop is an explanation for a higher increase in mortality rates and a slow drop is an indicator of a decline in child mortality. It determines the current death rate in Rwanda of under-five of 49.38 deaths per 1000 births, in Burundi 76.90 deaths per 1000 births, and Tanzania 67.90 deaths per 1000 births as shown in Table 1. The probability of survival of under-five children in all countries is 0.94 or 94 percent, meaning the risk of dying is 6 percent

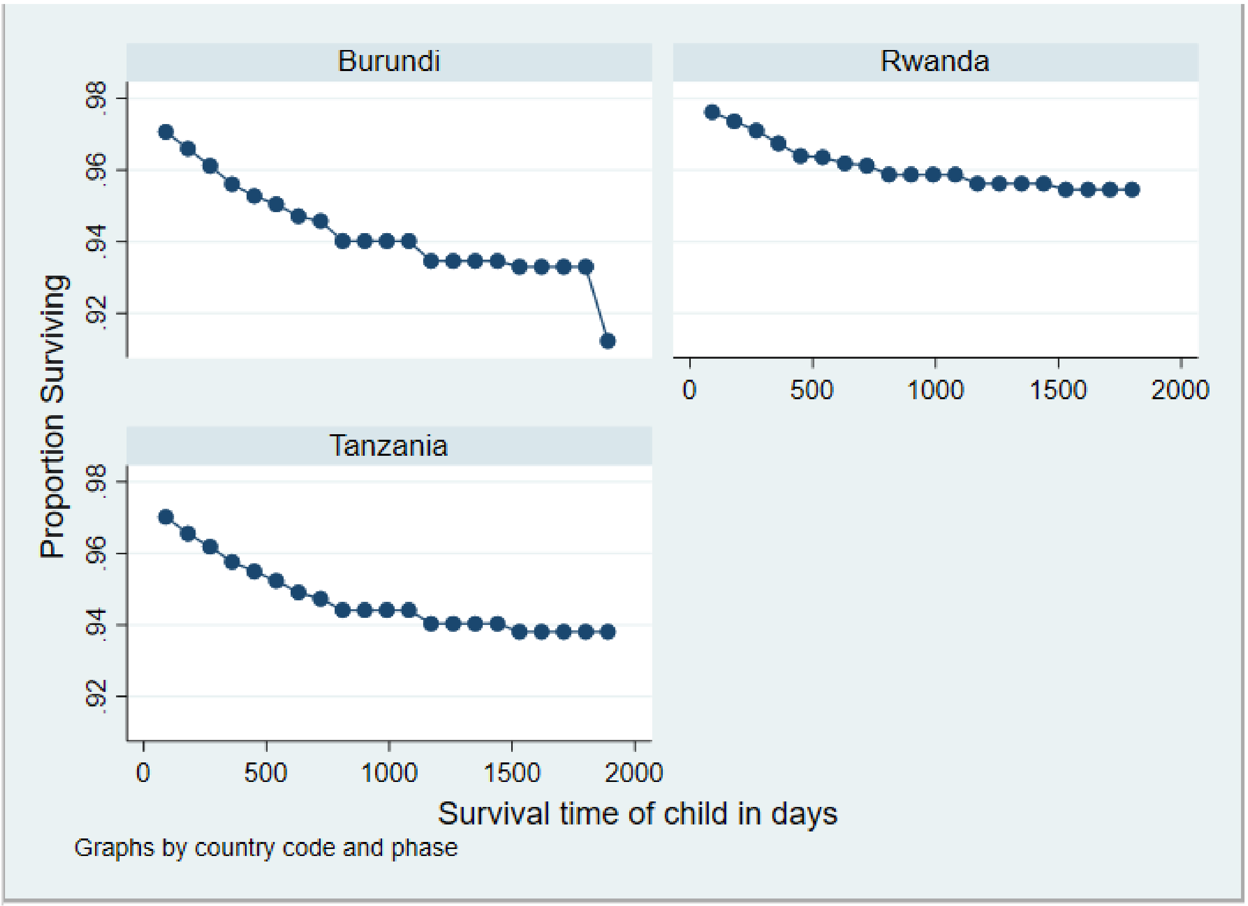

Figure 3: Survival pattern of under-five children by country in days

From Table 8 in appendix which helps to provide figure 2, the probability of surviving of children up to age five in the country is different where it appears that Rwanda has the highest survival rate of around 0.954 but Burundi with the lowest probability of survival of 0.912 and Tanzania with 0.938. Also, the chance of survival of children from day 0 to 100 days is different for Burundi, Rwanda, and Tanzania where they are around 0.968, 0.975, and 0.967 respectively.

4.3. Kaplan Meier estimator curves

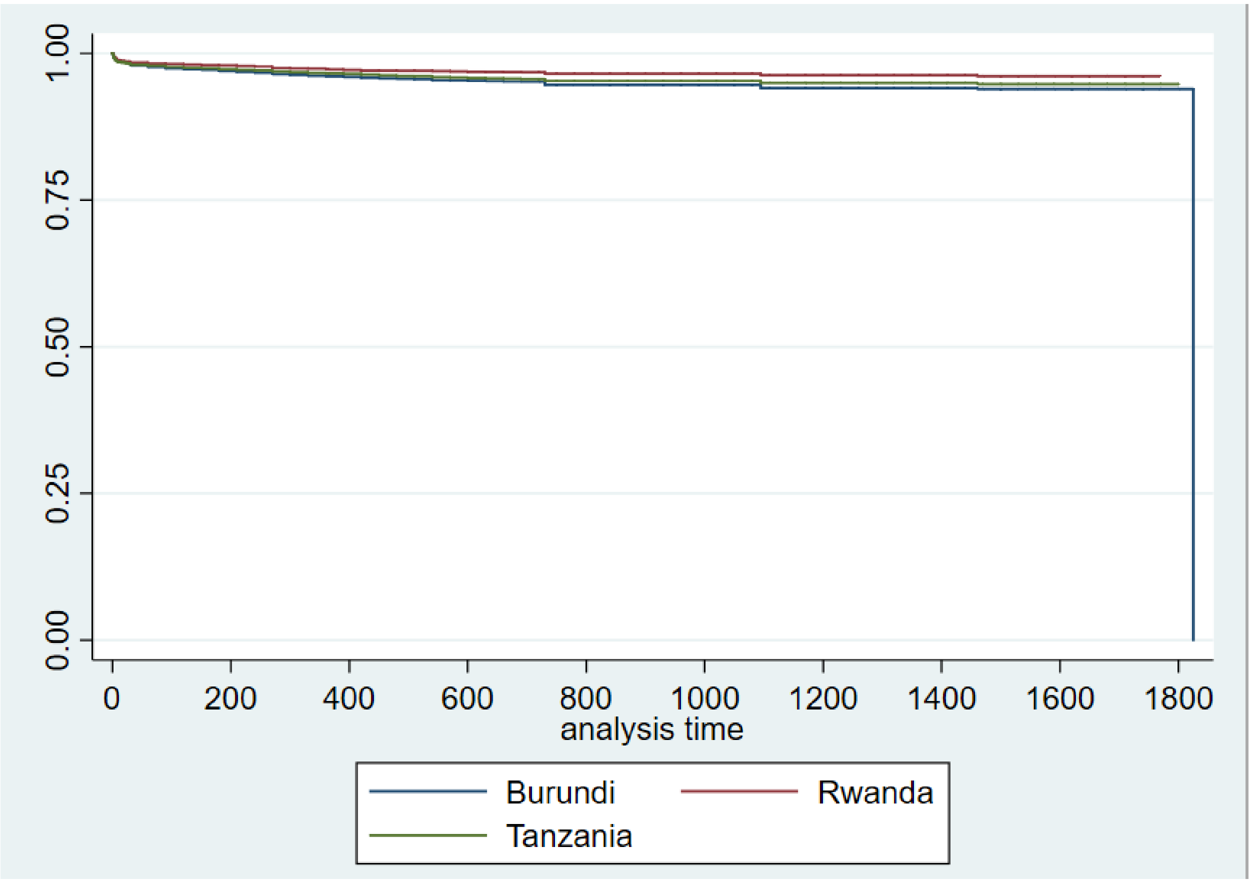

Figure 4: Child survival probability over time in days for Burundi, Rwanda, and Tanzania

As discussed in the earlier paragraph, figure 3 indicates the survival functions of 3 countries of East African community countries. The upper line is the survival function of under-five children of Rwanda and being at the upper indicates that those children have the highest survival probabilities. Unlike Rwanda, Burundi has the bottom survival function and it means that Burundi under-five children have the lowest survival probabilities compare to Rwanda and Tanzania. However, the survival probabilities decrease from up to bottom. Thus, Rwanda has the highest survival probability compare to others, this shows that the under-five child mortality rate of Rwanda is lower compare to Tanzania and Burundi's under-five child mortality rates. In this figure, the curves end at various points as this study period is different for the three countries. The curve for Burundi drops to 1825 days, this is because no children remain at the end of the study

4.4. Estimated under-five child mortality rate

The mortality rates of children are defined neonatal mortality rate as the probability of death within the first month of life, Postnatal mortality rate as the probability of death from the first month of life to the first birthday, infant mortality rate as the risk of dying between birth and first birthday, child mortality rate: the risk of death between the first and fifth birthdays; and under-five mortality rate as risk of death between birth and fifth birthday. All rates are explained as deaths per 1000 births apart from child mortality, expressed as deaths per 1000 living children up to their first birthdays.

Table 4: Neonates, Infancy, under-five mortality rates by Country

Rates	Rwanda	Burundi	Tanzania
Neonatal mortality	19.667	22.861	25.406
Post-neonatal mortality	13.105	24.041	17.761
Infant mortality	32.772	46.903	43.167
Child mortality	17.174	31.474	25.851
Under-five mortality	49.384	76.901	67.902

Based on Table 1 Among the three selected countries, Rwanda is the first country with a small rate of under-five child mortality of 49.38 deaths per 1000 births followed by Tanzania with 67.9 deaths per 1000 births, and lastly Burundi with 76.9 deaths per 1000 births as shown in the above Table. Many children deaths occur before celebrating their first birthday in all countries especially neonatal deaths are higher compare to postneonatal deaths. Neonatal rates are still high in Tanzania and Burundi (25.4 deaths per 1000 births and 22 deaths per 1000 births respectively) compare to Rwanda (19.66 deaths per 1000 births). Most deaths of children occur in the first month of life.

4.5. Univariate cox proportional hazard model

Univariate Cox regression allows us to describe the association between each independent variable and the dependent variable. This association would allow for a sound selection of variables that have a significant effect on Burundi, Rwanda, and Tanzania's under-five mortality. Significant variables will be involved in the last model of the analysis. The criteria used to determine the significance level of variables is 0.05, all variables are at all significant as their p-value is less than 0.05. Any variable with a p-value of less than 0.05 has an important influence on under-five child mortality.

Table 5:Univariate cox proportional hazard model of selected variables

Covariates	Burundi			Rwanda			Tanzania		
	B	**Ratio**	**P**	**B**	**Ratio**	**P**	**B**	**Ratio**	**P**
Mother's education level (V106)									
None		1			1			1	
Primary	-0.083	0.919	0.282	-0.40	0.665	**0.004**	0.166	1.181	0.141
secondary	-0.574	0.562	**0.000**	-0.79	0.449	**0.001**	0.063	1.065	0.665
Higher	-0.654	0.519	0.1931	-2.41	0.089	**0.016**	-0.27	0.759	0.639
Wealth index (V190)									
Poor		1			1			1	
Rich	-0.371	0.689	**0.004**	0.309	0.733	**0.015**	0.132	1.141	0.138
Place of residence (v025)									
Urban		1			1			1	
Rural	0.262	1.300	**0.018**	0.236	1.266	0.116	-0.28	0.750	**0.003**
Age of respondent at first birth (v212)									
7-17		1			1			1	
18-28	-0.213	-0.80	**0.027**	-0.35	0.701	**0.045**	-0.06	0.935	0.484
29-39	0.085	1.089	0.660	-0.71	0.487	**0.039**	0.277	1.319	0.320
40-46	-12.17	0.000	0.988	-11.3	0.000	0.992	-10.00	0.000	0.989
Preceding birth interval (B111)									
Less than 1 years		1			1			1	
Less than 2 years	-0.195	0.822	0.431	-1.342	0.261	**0.000**	-0.923	0.397	**0.003**
Above 2 years	-0.75	0.472	**0.001**	-1.32	0.266	**0.000**	-1.045	0.351	**0.000**
Birth order (bord)									
first birth		1						1	
Second birth	-0.009	0.990	0.938	-0.480	0.618	**0.005**	-0.243	0.783	0.062
Third birth	-0.057	0.944	0.648	-0.364	0.694	0.057	-0.356	0.700	**0.015**
Fourth and above	-0.064	0.937	0.522	-0.023	0.977	0.865	-0.327	0.720	**0.002**
Source of drinking water (V113)									
Pipe water		1			1			1	
Open well water	0.381	1.464	**0.009**	0.165	1.179	0.181	0.032	1.032	0.782
Type of toilet facility (v116)									
Flush toilet		1			1			1	
Pit& traditional toilet	0.674	1.962	**0.016**	0.502	1.652	0.318	-0.096	0.907	0.491
No toilet	1.344	3.836	**0.000**	0.917	2.503	0.088	-0.187	0.828	0.153
Sex of the child (b4)									
Male		1			1			1	
Female	-0.140	0.868	0.060	-0.232	0.792	**0.046**	-0.312	0.731	**0.000**
Marital status (v501)									
Never married		1			1			1	
Married	0.110	1.117	0.634	-0.152	0.858	0.436	-0.508	0.601	**0.002**
Number of living children (v218)									
1-5		1			1			1	
6-10	-0.665	0.513	**0.000**	-0.623	0.535	**0.012**	-0.545	0.579	**0.000**
11-14	-14.13	0.000	0.984	-11.06	0.000	0.989	-1.579	0.206	0.115

Duration of breastfeeding (m4)									
Ever/not currently		1			1				
Never breastfeeding	2.596	13.41	**0.000**	3.552	34.89	**0.000**	2.814	16.68	**0.000**
Still breastfeeding	-17.88	0.000	0.964	-18.87	0.000	0.984		0.000	0.973

Univariate cox proportional hazard model is done to each country. In Burundi, variables that have influence on child survival time are mother's education, wealth index, age of mother at first birth, preceding birth interval, source of drinking water, type of toilet facility, number of living children and duration of breastfeeding.

For Rwanda country, variables that have a significant impact on child survival time are mother's education, wealth index, age of the mother at first birth, preceding birth interval, birth order, sex of the child, number of living children and duration of breastfeeding.

Finally, in Tanzania, significant variables based on univariate analysis are place of residence, preceding birth interval, birth order, sex of the child, number of living children and duration of breastfeeding.

4.6. Multivariate Cox proportional hazard model and gamma frailty model

These models' purpose is to assess the impact of several factors on survival simultaneously. In other words, it helps us to analyze how defined variables influence the rate of occurrence of a particular event (e.g., death) at a given time point. This rate is generally referred to as the hazard rate.

Frailty models are extensions of the cox proportional hazards model (CPHM) better referred to as the Cox model, the most used model of survival study. In the study of survival in most health situation generally assumes a homogeneous population to be studied. It means that all individuals proposed for this study are exposed to the same risk in general, for example, risk of dying, risk of being infected by a disease (Wienke, 2014). Nevertheless, individuals differ greatly concerning background characteristics as well as the influence of various covariates variables. The population study cannot be considered to be similar in many situations but must be treated as a heterogeneous sample (individuals with various hazards). The Frailty Model is a theory of statistical modeling that seeks to allow for heterogeneity caused by unmeasured covariates (Shen, Farid, & Mcpeek, 2008).

Table 6:Multivarite Cox proportional hazard model and gamma frailty model results

COVARIATES	BURUNDI				RWANDA				TANZANIA			
	CPHM		FRAILTY		CPH		FRAILTY		CPHM		FRAILTY	
	HR	P	HR	P	HR	P	HR	P	HR	P	HR	P
Mother's education (V106)												
No education	1		1		1		1		1		1	
Primary	0.972	0.747	0.959	0.65	0.591	**0.001**	0.568	**0.000**	.	.	.	.
secondary	0.651	**0.022**	0.644	**0.045**	0.486	**0.041**	0.472	**0.042**	.	.	.	.
higher	0.589	0.291	0.581	0.36	0.000	0.995	.	.	.	.	.	.
Wealth index (V190)												
Poor	1		1		1		1		1		1	
Rich	0.833	**0.044**	0.841	0.100	0.760	0.113	0.811	0.23	.	.	.	.
Place of residence (v025)												
Urban	1		1		1		1		1		1	
rural	1.102	0.450	1.098	0.54	.	.	.	.	0.749	**0.013**	0.737	**0.012**
Age of respondent at first birth (v212)												
7-17	1		1		1		1		1		1	
18-28	0.777	**0.010**	0.800	**0.047**	0.849	0.479	0.989	0.96	.	.	.	.
29-39	1.299	0.209	1.203	0.450	0.402	0.145	0.456	0.230	.	.	.	.
40-46	0.733	1.000	.	.	.	.	.	.	.	.	.	.
Preceding birth interval (B111)												
Less than 1 years	1		1		1		1		1		1	
Less than 2 years	0.903	0.274	0.922	0.750	0.302	**0.003**	0.317	**0.000**	0.588	**0.000**	0.592	0.110
Above 2 years	0.530	**0.000**	0.537	**0.010**	0.309	**0.001**	0.335	**0.000**	0.536	**0.000**	0.531	**0.040**
Birth order (bord)												
first birth	1		1		1		1		1		1	
Second birth	.	.	.	.	0.504	**0.000**	0.399	**0.000**	0.751	**0.018**	0.752	0.072
Third birth	.	.	.	.	0.494	**0.000**	0.492	**0.001**	0.746	**0.030**	0.760	0.082
Fourth and above	.	.	.	.	.	.	.	.	1.000	1.000	.	.
Source of drinking water (V113)												
Pipe water	1		1		1		1		1		1	
Open well water	1.07	0.685	1.088	0.68	.	.	.	.	.	.	.	.

Type of toilet facility (v116)												
Flush toilet	1		1		1		1		1		1	
Pit& traditional toilet	1.336	**0.047**	1.340	0.450	.	.	.	.	.	.	.	.
No toilet	2.807	**0.000**	2.825	**0.015**	.	.	.	.	.	.	.	.
Sex of the child (b4)												
Male	1		1		1		1		1		1	
Female	.	.	.	.	0.953	0.745	0.941	0.68	0.745	**0.004**	0.744	**0.005**
Marital status(v501)												
Never married	1		1		1		1		1		1	
Married	.	.	.	.	.	.	.	.	.	.	.	.
Number of living children (v218)												
1-5	1		1		1		1		1		1	
6-10	0.473	**0.000**	0.428	**0.000**	0.315	**0.000**	0.264	**0.000**	0.490	**0.000**	0.437	**0.00**
11-14	0.000	0.996	.	.	0.000	0.999	.	.	0.123	**0.037**	0.080	**0.001**
Duration of breastfeeding (m4)												
Ever currently breastfeeding	1		1		1		1		1		1	
Never breastfeeding	14.92	**0.000**	14.67	**0.000**	31.76	**0.000**	33.83	**0.000**	15.21	**0.000**	15.06	**0.000**
Still breastfeeding	0.000	0.968	.	.	0.000	0.989	.	.	0.000	0.977	.	.
Frailty(p-value)				**0.029**				**0.000**				**0.004**
Variance of frailty			0.028				0.165				0.065	

As discussed in the methodology section and as shown in Table 7, looking to the values in the table, it looks that frailty model has small value of AIC compare to cox proportional hazard model. The result show that the good model for each country is the gamma frailty model

Table 7:Models comparison using AIC score

Country name	Cox proportional hazard model	Gamma frailty model
Burundi	9286.938	9273.43149
Rwanda	2771.189	2747.17082
Tanzania	5865.411	5852.89112

Based on table 6, significant variables that have an influence on child survival in all countries are: preceding, birth interval, number of living children in a family and duration of breastfeeding. Birth order has a significant influence on child survival especially in Rwanda and Tanzania but mother's education has an influence on child survival in Burundi and Rwanda. Place of residence and sex of the child are two variables associated with child survival in Tanzania. Type of toilet facility and mother's age at first birth have a significant influence on child survival in Burundi.

The gamma distribution follows with a mean equal to 1 we just need to measure its variance to completely estimate the levels of frailty. Frailty inclusion affects the estimator but there is a slight change in the values of parameters. The empty place on some categories of variables is due to missing values.

The variability among children in Burundi, Rwanda and Tanzania from the gamma frailty model is 0.028, 0.1652, and 0.065 respectively. This implies that there is frailty among specific children. There is a difference among these children but small, and their chance of survival decreases when exposed to these socio-economic, biological, and health, environmental, and demographic factors.

The education of mother as a variable has a significant effect on child survival in Burundi and Rwanda, no education group was taken as the reference group. Mother's education has an impact on Burundi and Rwanda. Burundian children born from mothers with secondary education level have a 36 percent chance of survival compare to children born from uneducated mothers, and lastly, in Rwanda, children born from mothers with a primary level of education have a 44 percent chance of surviving and children born to mothers with secondary education have 43percent chance of surviving compare to children born from uneducated mothers.

Also, the place of residence has an influence on child survival time in Tanzania. Urban were taken as the reference group. Based on the results from the Table 6, it shows that Tanzanian children from rural died at a rate of 73.75 percent compare to children from urban areas. This shows that children from rural have a 26 percent survival chance compare to children from urban.
Age of the mother at first birth has a significant influence on child survival in Burundi. Children born to mother with age between 18-28 at first birth have a low rate of 0.800 (p-value=0.047). Those children have 20 percent chance of surviving compare to children born to mothers with age between 7-17 at first birth.

In all countries, the preceding birth interval influences child survival, with the reference group preceding birth interval of less than 1 year. In Burundi, the preceding birth interval above 2 years has a major effect on child survival among where children with preceding birth intervals above 2 years have a 46 percent chance of survival compared to those with preceding birth interval less than 1 year. Rwandan children with a previous birth interval of less than 2 years have a 68 percent chance of survival and those with a preceding birth interval of more than 2 years have a 66 percent chance of survival compared with Rwandan children with a previous birth interval of less than 1 year. For the country of Tanzania, children above 2 years old have a 47 percent survival chance compared to those with preceding birth interval less than 1 year.

Birth order plays a significant role on child survival in Rwanda. It showed that second and third births in Rwanda. Birth order has low hazard ratio. In Rwanda, second birth has a 0.399 (p-value=0.000) hazard ratio which is low compare to the first birth. Also in the third birth has a 0.4923 (p-value=0.001) hazard ratio which is also low compare to the first birth.

Type of toilet facility has a significant influence on child survival in Burundi. Type of toilet facility has three categories which are: flush toilet, pit and traditional toilet, and no toilet. The first category (flush toilet) was taken as reference group. Toilet facility has a higher hazard ratio as its hazard ratio exceed one. Children born in families with no toilet are 2.825 times likely to die compared children born in family with flush toilet.

Sex of the child has an influence on child mortality in Tanzania only where female children in Tanzania has lower hazard ratio of 0.744. this rate shows that female Tanzanian children have 26.5percent chance of surviving compare to male children.

The number of living children variable where the number of living children between 1and 5 was taken as the reference group. It has an influence on child survivorship in all countries. In Burundi, the hazard rate is lower for those living children between 6-10 which is equal to 0.428 with a p-value of 0.000 compare to living children between one and five. In Rwanda, the number of living children between 6-10 have a lower hazard ratio of 0.264 with p-value of 0.000. This indicates that the children born in family with number of living children between 6-10 has 74 percent chance of surviving compared to children between 1-5. In Tanzania, living children between 6-10 have a 56 percent chance of surviving compared to those with living children between 1-5, and living children between 11-14 has a 92 percent chance of surviving compared to those living children between 1-5.

Breastfeeding as determinants of child mortality in all countries have shown that in Burundi children that never breastfeed are 14.67 times likely to die compared to those who were ever/currently breastfeed, in Rwandan children that never breastfeed are 33.83 times likely to die compared to those who were ever/currently breastfeed and lastly, in Tanzania, children that never breastfeed are 15.06 times likely to die compared to those who were ever/currently breastfeed (p-value =0.000).

CHAPTER 5: DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1. Discussion

The main goal of the study was to assess the main determinants of under-five child mortality in selected EAC countries (Burundi, Rwanda, and Tanzania). The first objective of the current study was to compare under-five child mortality rates in selected EAC countries and their determinants. As, expected the mortality rates among under-five children were found to be higher in Burundi, Tanzania, and Rwanda respectively as shown by Table 7. This is in line with each country mortality estimation done by their corresponding statistics offices. Although the never report the same rate for neonates, this study found confirmatory results with previous researches on the point that neonates and infancy are at higher risk compared to over infancy children. The same results were found in all selected EAC countries. This finding suggests a strong need for earlier child health care services. This idea was adopted by all selected EAC countries but the level of implementation is still unsatisfactory (NISR, 2015; Burundi, 2017; TDHS 2015-16, 2015).

These findings were supported by the Kaplan-Meier survival function that showed that in the selected countries newborns are at higher risks compared to closed to five years old. this study found that the median death age is 821 days in Rwanda, 791days in Burundi, 821 days in Tanzania. These levels are still unsatisfactory and more efforts is need to ensure a very chance of surviving for every newborn in the region.

The second objective of the study was to identify the main determinants of child survival and show the shape of child survival in EAC. The current study findings revealed that fewer number of living children in the family, longer period of breastfeeding, and increase in preceding birth interval are the common factors contributing to the survivorship of children among the selected countries. The same findings were found in (TDHS 2015-16, 2015) These factors have given attention since the last two decades by introducing sensitizing families about the use of family planning methods as one of the ways of limiting the number of children in family and then recognize the interests of long period breastfeeding which is believed to extend the birth intervals.

The current study found also that in Burundi type of toilet facility and age of the mother are the main specific determinants of child survival. This suggests that the improvement in hygienic practices and increased age at first birth could significantly improve child survival in the same country. This was also highlighted in (Malderen et al., 2019) the research by pointing out that that country's poverty level in return affects that country's child survival through what is called "Viscous circle of poverty".

On the other side, the difference in child survival among Tanzanians rural and urban areas was recognized. In the same way disproportionality of child survival was noticed among males and females' children in the country. This confirms the findings of (Ogbo et al., 2019) and thus agrees with the UN philosophy of living none behind.

As expected, the current study found no specific factors affecting child survival in Rwanda. The country has made a good progress in implementing WHO guidelines about child and mothers health. It is left with those factors that need a longer period to reach a desirable and satisfactory improvement in child survival. That include lowering number of children in families and ending poverty.

Source of drinking water and marital status do not have influence on child mortality. Source of water drinking on other hand has a significant influence on child survival as confirmed by the findings of (Ezeh, Agho, Dibley, Hall, & Page, 2014) that under-five children without access to improved water and sanitation facilities are at higher risk of death. Marital status has been remarked by (Hong, Ayad, Rutstein, & Ren, 2009) that children whose mothers are in a stable relationship are predicted to have lower risk of death than those whose mothers are not married.

Although this study achieved its objectives, there are some limitations could have allowed more analyses once not present. The main limitation was the possible under reported births and deaths in the compilation of historical data. In conversations with mothers, children who die shortly after birth may be ignored and this possibility of under reporting might be more noticeable if the event occurred back in time (TDHS 2015-16, 2015). Thus, the inclusion of such information might have influenced our findings in one way or another. The second limitation is the absence of data for children without mothers.

Therefore, future research should explore this area and assess any possible loss of useful information when such data are not used in the analyses.

5.2. Conclusion

The study main objective was to assess the main determinants of under-five child mortality in EAC countries and it has been achieved. To achieve this objective, the researcher pulled DHS data from three EAC members' states (Rwanda, Burundi, and Tanzania) from DHS program website.

Cox proportional hazard model and Gamma frailty model were used to estimate the likelihood of children survival within these countries given a set of predictors. To ensure the accuracy of model, the researcher used AIC to compare the performance of models. The best model was the gamma frailty model.

Based to the results in table 7, the determinants for under-five child mortality were seen that they are different in Burundi, Rwanda, and Tanzania. Factors such as preceding birth interval, number of living children, and duration of breastfeeding have association with child survival in all selected countries (Burundi, Rwanda, and Tanzania).

The determinant which is associated with child survival in Burundi and Rwanda is mother's education. Type of toilet facility and mother's age at first birth are associated with child survival in Burundi. Moreover, place of residence and sex of the child are associated with child survival in Tanzania.

In general, type of place of residence, preceding birth interval, birth order, number of living children, sex of the child, and duration of breast feeding are the potential determinants of child survival in Tanzania. In Rwanda, mother's education, preceding birth interval, birth order, number of living children, and duration of breast feeding are the country's specific factors affecting child survival. In the last country covered by the current study (Burundi), Mother's education level, age of the mother 's age at first birth, wealth index, type of toilet facility, preceding birth interval, number of living children, and duration of breast feeding affect the survivorship of children.

The current study concludes by recommending institutions and future researchers on what might be done for the current research to contribute to the realization of SDG 3.2 target of ensuring a maximum U5MR of 25 deaths per 1000 live births by 2030.

5.3. Recommendations

Based on the results of this study, the following recommendations were suggested:

Recommendation to DHS program

It is recommended that the DHS software collects and records childhood age at death in days than months to prevent the loss of any information for children who did not live up to one month and to make the DHS data more reliable.

To make the sample more representative, a variable that shows the birth history of the dead mother should be added to the DHS questionnaire. This is because the regular DHS questionnaire only uses a living mother, while children may have lost their mother. However, the data collection needs to contain information about their birth history.

Recommendation to Eastern African Community countries

The study recommends governments and program managers in the child health sector to implement new strategies to improve the situation for children under the age of five by increasing awareness about and enhancing factors that contribute to child mortality.

In all countries, infant mortality rates were higher during the first days of life (neonatal). Child survival policies and programs should be implemented, scaled up, or improved to reduce neonatal deaths since neonatal deaths will decrease, under-five mortality and child mortality also will decrease.

Eastern African Community could develop the different and strategies to reduce under-five child mortality since according to the study, factors that lead to child mortality are not the same in all countries.

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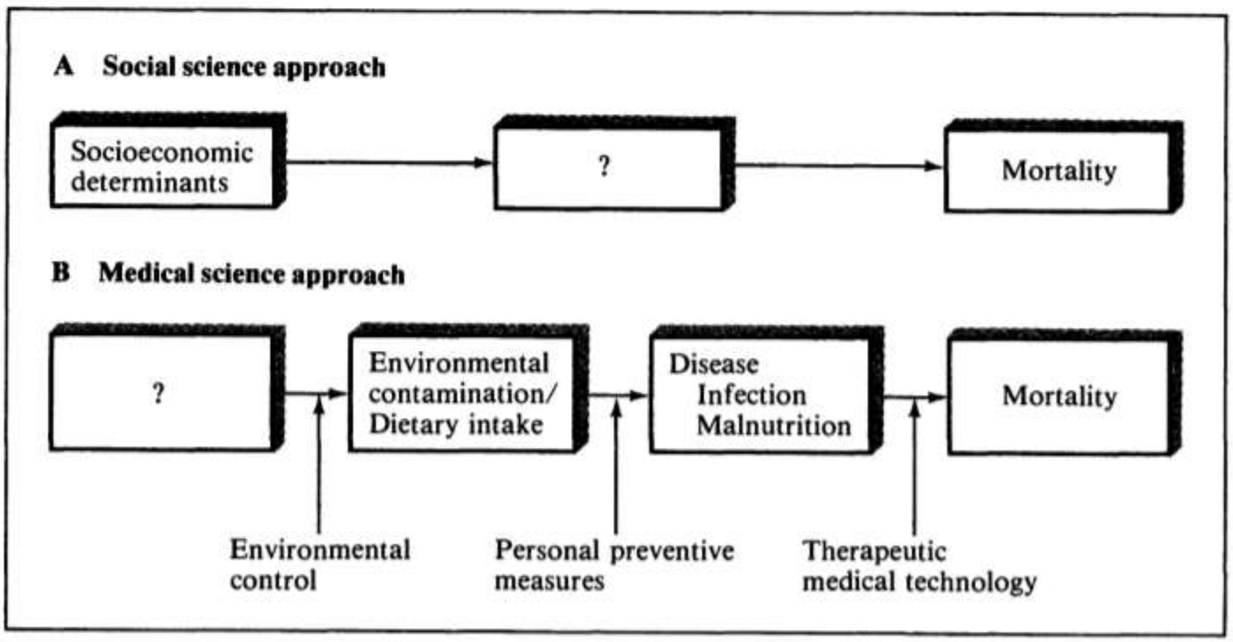
APPENDIX

Table 8:Life table for by country

Interval		Total	Deaths	Lost	Survival prob.	Error	[95% Conf. Int.]	
BURUNDI								
0	100	13192	407	755	0.9682	0.0015	0.9651	0.9711
100	200	12030	54	613	0.9638	0.0017	0.9604	0.9669
200	300	11363	59	716	0.9586	0.0018	0.9550	0.9620
300	400	10588	50	907	0.9539	0.0019	0.9500	0.9574
400	500	9631	29	695	0.9509	0.002	0.9469	0.9546
500	600	8907	28	643	0.9478	0.002	0.9436	0.9517
600	700	8236	18	845	0.9456	0.0021	0.9413	0.9496
700	800	7373	42	593	0.94	0.0023	0.9354	0.9443
800	900	6738	0	614	0.94	0.0023	0.9354	0.9443
900	1000	6124	0	811	0.94	0.0023	0.9354	0.9443
1000	1100	5313	28	509	0.9348	0.0025	0.9298	0.9394
1100	1200	4776	0	564	0.9348	0.0025	0.9298	0.9394
1200	1300	4212	0	809	0.9348	0.0025	0.9298	0.9394
1300	1400	3403	0	562	0.9348	0.0025	0.9298	0.9394
1400	1500	2841	4	606	0.9333	0.0026	0.9281	0.9382
1500	1600	2231	0	823	0.9333	0.0026	0.9281	0.9382
1600	1700	1408	0	681	0.9333	0.0026	0.9281	0.9382
1700	1800	727	0	638	0.9333	0.0026	0.9281	0.9382
1800	1900	89	1	88	0.9126	0.0207	0.8619	0.9452
RWANDA								
0	100	7856	188	443	0.9754	0.0018	0.9716	0.9786
100	200	7225	17	441	0.973	0.0019	0.9691	0.9764
200	300	6767	32	480	0.9682	0.002	0.9640	0.9720
300	400	6255	21	503	0.9649	0.0022	0.9604	0.9688
400	500	5731	8	383	0.9635	0.0022	0.9589	0.9675
500	600	5340	6	411	0.9623	0.0023	0.9577	0.9665
600	700	4923	6	493	0.9611	0.0023	0.9563	0.9654
700	800	4424	11	392	0.9586	0.0024	0.9536	0.9631
800	900	4021	0	389	0.9586	0.0024	0.9536	0.9631
900	1000	3632	0	505	0.9586	0.0024	0.9536	0.9631
1000	1100	3127	7	401	0.9563	0.0026	0.9510	0.9611
1100	1200	2719	0	376	0.9563	0.0026	0.9510	0.9611
1200	1300	2343	0	542	0.9563	0.0026	0.9510	0.9611
1300	1400	1801	0	396	0.9563	0.0026	0.9510	0.9611
1400	1500	1405	2	302	0.9548	0.0028	0.9490	0.9599

1500	1600	1101	0	413	0.9548	0.0028	0.9490	0.9599
1600	1700	688	0	356	0.9548	0.0028	0.9490	0.9599
1700	1800	332	0	332	0.9548	0.0028	0.9490	0.9599
TANZANIA								
0	100	10233	319	642	0.9678	0.0018	0.9642	0.9711
100	200	9272	39	494	0.9636	0.0019	0.9597	0.9672
200	300	8739	33	523	0.9599	0.002	0.9558	0.9636
300	400	8183	32	671	0.956	0.0021	0.9517	0.9599
400	500	7480	27	556	0.9524	0.0022	0.9479	0.9565
500	600	6897	17	587	0.9499	0.0023	0.9453	0.9542
600	700	6293	17	646	0.9472	0.0024	0.9424	0.9517
700	800	5630	18	497	0.9441	0.0025	0.9390	0.9487
800	900	5115	0	496	0.9441	0.0025	0.9390	0.9487
900	1000	4619	0	596	0.9441	0.0025	0.9390	0.9487
1000	1100	4023	14	455	0.9406	0.0026	0.9352	0.9455
1100	1200	3554	0	484	0.9406	0.0026	0.9352	0.9455
1200	1300	3070	0	600	0.9406	0.0026	0.9352	0.9455
1300	1400	2470	0	432	0.9406	0.0026	0.9352	0.9455
1400	1500	2038	4	462	0.9385	0.0028	0.9327	0.9438
1500	1600	1572	0	599	0.9385	0.0028	0.9327	0.9438
1600	1700	973	0	461	0.9385	0.0028	0.9327	0.9438
1700	1800	512	0	430	0.9385	0.0028	0.9327	0.9438
1800	1900	82	0	82	0.9385	0.0028	0.9327	0.9438

Figure 7: Conceptual framework developed by Mosley and Chen



Source: Mosley and Chen's conceptual framework

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