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SPATIAL ANALYSIS OF EMERGENCY OBSTETRIC CARE SERVICES FOR UPGRADING OF HEALTH FACILITIES: A CASE STUDY OF HOMA BAY COUNTY.

BY

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Declaration

I, Thuranira Nkatha Pamela hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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This project has been submitted for examination with my approval as university supervisor

Prof F. N. KARANJA 22.08.2022

Name of supervisor **Date**

Dedication

This work is a genuine dedication to God for his divine guidance, grace, protection and help through this research journey.

My sincere thanks goes to my husband Mr. Benard Mitto and our boys Ramy and Ray for great support and understanding throughout this project period. In addition, Mr. Benard being a GIS expert offered me great help in data synthesis and analysis.

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Abstract

Maternal Mortality is when an expectant woman dies during pregnancy, childbirth, or at least within a month of giving birth because of pregnancy management. Incidental or accidental deaths do not constitute Maternal Mortality. Unpredictable Obstetric problems (infection, severe bleeding, hypertension, and obstructed labor) remains top causes of death and disability for women. However, the most reliable mitigation to pregnancy right/correct, timely and effective emergency obstetric care for respective complication remains unknown. Therefore, the objective of this study is to use Geospatial Techniques to support the selection of the existing public health facilities to be upgraded (to EmOC using Homa Bay County as a case study), to ensure better provision of Emergency Obstetric Care.In the methodology, the facilities that met the EmOC functions standard were identified, these were 9 (7 BEmOC and 2 CEmOC). Their catchments were then determined at 10km using Voronoi Polygons in QGIS 3.4. Catchment populations were extracted and 7 facilities of the 9 existing EmOC facilities were found to serve more population than recommended by WHO, i.e., 100,000 people per health facility. In order to determine which health facilities would be upgraded to offer EmOC services, a 2-hour buffer was created around each facility (walking and motorized scenarios). Then a set of inclusion criteria (>10km from the existing BEmOC facility, > 500m from a road, at least 100 people/km square) was ran at 21 combinations and the list of recommended facilities for upgrading was arrived at. There was a need to upgrade 4 facilities to meet the desired 13. However, the two health centers (Pala Masogo and Sena) automatically qualified because they are Level 3. After the criteria of selection, the other two facilities that qualified for upgrading were Godbura Dispensary and Ponge Dispensary (Mbita).

Recommendations drawn from the findings were first, reporting in DHIS2 should be improved to ensure identification of EmOC signal functions at the health facility level is not a complex process. This would also ensure that there is data completeness and good quality. Secondly, the accessibility of BEmOC and CEmOC was determined using spatial analysis in Grasshopper, OSM, and QGIS. However, it can be achieved at once by use of Access MoD 5. Third, a simpler and more understandable feature picking method should be explored when choosing the best combination.

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LIST OF ABBREVIATIONS

API	Application Programming Interface
BEmOC	Basic Emergency Obstetric Care
CEmOC	Comprehensive Emergency Obstetric Care
DHIS2	District Health Information Software 2
ICDP	International Conference on Population and Development
ICMNCH	Improve Maternal, Newborn and Child Health
EPMM	Ending Preventable Maternal Mortality
EmOC	Emergency Obstetric Care
GIS	Geospatial Information System
HDX	Human Data Exchange
HIMs	Health Information Management System
KMFL	Kenya Master Health Facility
MDG	Millennium Development Goal
MDR	Multidrug-resistant
MMR	Maternal Mortality Rate
MOH	Ministry of Health
NMR	Neonatal Mortality Rate
OSM	Open Street Map
QGIS	Quantum Geo spatial information system
UHC	Universal Health Coverage
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
UNFPA	United Nation Fund for Population Activities
UTI	Urinary Tract Infection
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

Healthcare for all is one of the Kenya's Big Four Agenda. In Kenya, this has been embedded into the global objective on Universal Health Coverage (UHC); which is one of the sustainable development goals (SDGs) global target by the year 2030 (Roth et al., 2016). Access to health services is viewed in three dimensions; physical accessibility, financial affordability and services acceptability (quality of service), which are a prerequisite for Universal Health Coverage. Ensuring actual receipt of health services is what constitutes universal health coverage (Thaddeus and Maine, 1994).

The ability of all people and communities to use the promotive, preventive, curative, rehabilitative and palliative health services they need, of sufficient quality to be effective, with limited exposure of the user to financial hardship ,is what defines Universal health coverage (UHC) .Currently the countries with fully functional universal healthcare include but not limited to Austria, Czech Republic, France, Denmark, Croatia, Finland, Iceland, Germany, Greece, Italy Ireland, the Netherlands, Malta, Luxembourg, Moldova, Norway, Poland, Ukraine, Portugal, Romania, Serbia, Spain, Russia, Sweden, Switzerland, Turkey, and the United Kingdom.

In Kenya, this is inspired by the Kenya Vision 2030, whose aim is to transform Kenya into an industrializing, middle-income country while providing a high quality of life to all its citizens by the year 2030.

Maternal mortality, which means the demise of a female person while expectant or within 42 days of ending a pregnancy, without regard to the period and place of the pregnancy, from any reason associated to, or made worse by the gestation or its management but not from or incidental or accidental reasons (WHO, 2010), has been amongst leading causes of death amongst the women of childbearing age (Fournier and Dogba, 2009).

Approximately 10.7 million women perished due to obstetric hitches between 1990 and 2015. 99% of the deaths took place in developing countries out of which 66% of them happened in sub-Saharan Africa (SSA). In 2005, an estimated over half a million women perished from gestation and birth-related difficulties as reported by World Health Organization (WHO) and the recent majority cases are in Africa and Asia. Most of these losses occur during and soon after birth (WHO and UNICEF, 2009).

The Millennium Development Goal 5, a series of measurable health indicators for each target, which was agreed upon by 189 countries in the year 2000, had an aim to minimize maternal mortality by three quarters by the year 2015. Studies show that this is far from being achieved because Southern Asia and SSA contributed approximately 86% which translates to 254, 000 deaths of the estimated global maternal deaths in the year 2017. SSA accounted for approximately 66% (196, 000) of maternal deaths. To build up on the unachieved MDG 5, strategies were put in place as part of the sustainable development agenda three (2016 – 2030), to minimize world maternal death ratio to lower than 70 per 100 000 live births (WHO, 2019).

According to a report on maternal mortality released by UNFPA-United Nations Population Division, WHO, World Bank Group, and the UNICEF, in September 2019, there were about two hundred and ninety-five thousand maternal deaths in the year 2017 worldwide. This number reflects a 38% reduction, from 342 deaths to 211 deaths per 100,000 live births, since the year 2000, which is a mean reduction of just below 3% per year within that period. Well, this is below half the 6.4 percent yearly reduction rate required to achieve the SDG 3 of 70 maternal deaths per 100,000 live births by the year 2030.

Millennium Development Goal (MDG) 5 targeted at minimizing Global maternal deaths by two-thirds (2/3) by the year 2015. Since this had not been achieved by 2015, the MDG 5 translated to Sustainable Development Goal (SDG) 3 whose aim was to minimize world Maternal death Rate (MMR) to < 70 deaths per 100 000 live births & reduce Neonatal Mortality Rate (NMR) to at least 12 deaths per 1000 live births by the year 2030.

Fatal perinatal obstetric complications accounts for 15% of all pregnancies, which include obstructed labor, bleeding (hemorrhage), hypertension, infections, and complications of unsafe abortion (Bale et al, 2003)

Besides these, emergency traumas, and surgical processes, emergency obstetric conditions contribute greatly to this percentage. Maternal mortality can either be direct and indirect obstetric deaths.

1. **Direct obstetric deaths**: These results from obstetric complications of the pregnancy state (pregnancy, labor, and the puerperium). They mainly from omissions, interventions, incorrect treatments, or from combination of any of the above events.

2. **Indirect obstetric deaths**: These result from previous existing disease that developed during pregnancy, and which were not due to direct obstetric causes but were aggravated by physiologic effects of the pregnancy.

This section from here to where problem statement starts can be moved to literature review section

1.2 Problem Statement

For over a decade, Homabay County has been topping the list as one of the counties performing poorly in terms of Maternal care (Gatakaa, et al, 2019). It was discovered that Homabay has many health facilities offering maternal care, but the Mortality rate was still high.

Research has been done on different aspects to improve the maternal situation in the County whose main focus has been availability of healthcare workers as well as availability of drugs in the facilities (Moses, et al, 2021). Other scholars have focused on physical accessibility to the health facilities. They concluded that though it is possible to achieve effective and quality physical access to health facilities, the maternal death rates would still remain high due to various other factors such as poor financial status, unavailability of emergency services, high Malaria transmission, high HIV Prevalence, and unskilled birth attendance

In Kenya, and with HomaBay County as a sample, there exists many health facilities that could offer basic or comprehensive emergency care but are not currently recognized as EmOC facilities. This led to a decision to carry out this study by use of spatial evidence to recommend which heath facilities could be upgraded to EmOCto improve the status of Maternal Health in the County.

> "We have not identified an intervention whose effectiveness at reducing maternal mortality is strongly supported by the available evidence. We have seen a track record of programs being recommended without strong evidence and recommendations being changed over time in response to lack of progress." (GiveWell, 2009).

From the clause above, although many interventions exist at all levels of administration, the best and most reliable measure to counter maternal deaths would be provision of evidence-based interventions and one of them being possibly life-saving indicator functions of emergency obstetric care (EmOC). In addition, following a previous study in May 2019 that manifested

Homa Bay County, which is among top counties in Maternal Mortality, a decision to use Homa Bay as a case study was made.

Kenya, being among countries with a high rate of maternal deaths, it is clear that decision takers are unaware of the urgency and magnitude to which the life- saving emergency care is needed and where exactly to intervene. These facts informed this decision of the study to assess and analyze existence, accessibility, and functionality of EmOC services at County level and using spatially determined evidence, recommend which health facilities to upgrade to offer the EmOC services.

1.3 Objectives of the Study

1.3.1 Overall objective

The main objective of the study was to use Geospatial Techniques to analyse EmOC services to inform upgrading of Health Facilities (general health facilities toEmOC) using Homa Bay County as a case study.

1.3.2 Specific objectives.

The Specific Objectives were namely to:

1. Identify the number of (active) BEmOC and CEmOC facilities in the county based on WHO standards.
2. Map the (active) BEmOC and CEmOC facilities.
3. Analyze accessibility of BEmOC and CEmOC in terms of distance and time of Travel
4. Assess the suitability of health facilities for targeted EmOC services strengthening/upgrading to BEmOC and CEmOC.

1.4 Justification for the Study

This study can be used by the ministry of health at the county and national level in order to provide guidance on which Heath facilities to upgrade to EmOC based on spatial analysis evidence. The study on HomaBay County can also be used to inform such similar actions in other counties.This study can also inform evidence-based decision making by other actors who support the health agenda for example the non-governmental organizations and private investors.

1.5 Scope of work

This study covered Homabay County focusing on the routine data recorded in DHIS2 in reference to pregnant mothers from the year 2010 to June 2020. The research covered Public Hospitals run by the county Ministry of Health, in the interest of financial affordability to every expectant Mother.

Analysis was conducted in such a manner as to identify all the facilities that meet the EmOC functions standards and extracting population within the catchment areas for each facility. Statistics was used to arrive at the total population served by each facility and proportion of the birth giving/pregnant mothers out of the total population computed.

Since Homa Bay County had a population of less than 100,000 people, it was concluded that it has a gap in the EmOC facility services thus chosen for the next steps otherwise dropped from the investigation list.

1.6 Organization of the Report

Chapter 1 Gives background details of the topic of study in the introduction, it also states the problem addressed by the study and outlines the objective , justification and scope of the study. Finally, it outlines how the thesis will be organized.

Chapter 2 covers literature review highlighting past research in the field of maternal mortality and emergency care at global, regional, and country levels.

Chapter 3 highlights the study methodology used to in this study to form the basis of data analysis. A spatial approach to routine data was adopted to achieve the goal of recommending the health facilities to be strengthened and upgraded to offer comprehensive care.

Chapter 4 covers the results (maps, figures, tables and graphs) of the analysis carried out in the methodology and finally a discussion of each result in reference to the study objective.

Chapter 5 covers the conclusion and recommendation based on the results achieved. Here, the four health facilities that can be upgraded are stated and a recommendation done on the same.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Maternal deaths are health burden in the world, and worse in the developing and middle-income countries, Kenya included. Measures have been put in place to overcome this threat and Emergency Obstetric Care Services is among them. Since is among major causes of death, maternal deaths have stirred a great desire among researchers to want to find out more on its extent, effects on the economy, impact on as well as what has worked and what has failed. However, despite the huge quantity of research done and published about maternal deaths, number of deaths amongst women continue to rise at an unacceptable alarming rate. The solution, however, remains very elusive and difficult to measure even in its simplest way of quantifying the actual number of global maternal deaths as explained by (Graham et al., 2007).

As expected, despite the evident decline, the least developed countries lead in maternal deaths, estimated at 415 maternal deaths per 100, 000 live births with the lifetime risk as high as 1 in 37 for women of childbearing age (15 - 49) in sub-Saharan Africa (KDHS, 2014). Probability of a woman in developing countries to die from pregnancy complications stands at 97 times more than that of a woman in a developed country; example of a women of the mentioned age living in New Zealand or Australia (developed countries) would have a risk of just 1 in 7,800 (WHO et al., 2010).

Asia and Sub-Saharan Africa contributed about 86% translating to 254, 000 of the estimated global maternal deaths in the year 2017, with Southern Asia accounting for about 58, 000 translating to about 20% and South-Eastern Asia contributed over 16000 which is 5% of global maternal deaths while Sub-Saharan Africa alone accounted for about 196, 000 which makes 66% (Gabrysch et al., 2012). During this period (1990 – 2015), there have been notable regional and country-level trends in MMR. The greatest overall percentage reduction in its MMR by 59% (384 to 157 per 100,000 live births) was achieved by Sub-regions such as Southern Asia. This translated to an average yearly reduction rate of about 5.3%. Four other sub-regions approximately reduced their MMRs by half during this period: Europe at 53%, Eastern Asia achieved 50%, Central Asia at 52%, and Northern Africa closed with 54%. Besides its alarming high maternal death ratios, Sub-Saharan Africa as a region equally attained a remarkable reduction of about 38% from the year 2000. A relatively strange trend was noted during this period where sub-region of Northern America, though with a very with MMR of 12, had a rise in MMR of almost 52%, rising to from 12 to 18 in 2017. This was expected due to observed reduced MMR levels, changes in life expectancy, and improvements in data collection and/or disparities between subpopulations changes.

In Africa, maternal deaths stands among main public health delinquent, especially in SSA with estimates of over 1 maternal deaths in every 100 live births across African countries (Bale et al., 2003.

This translates to a very low annual reduction rate of about only 0.1 %. Kenya was one of the eleven countries that contributed to just about 65% of all global maternal mortality in the year 2008. It was also one of the twenty three sub-Saharan African countries that did not make sufficient progress towards MDG Five as stated by (Dixon, 2016).

Kenya had a MMR of 362/100,000 live births and a neonatal mortality of 22 per 1000 live births by the year 2019. This, according to different studies was mainly caused by lack of education, lack of effective health systems, socio-economic factors and many other external factors. Recently, there have been multiple efforts to reduce maternal deaths. Since 1987, WHO, UNFPA and The World Bank have been hosting the Safe Motherhood conference with the first one being held in Nairobi, Kenya. This conference sought to bring together international communities to look into how to reduce Maternal Mortality and Morbidity (McCarthy, 2010).

By the year 2015, the efforts of Safe Motherhood had borne fruits because the estimated MMR had decreased significantly (World Health Organization, 2017).Population and Development (ICPD) Conference in 1994 took place in Cairo Egypt on how to end maternal deaths. The landmark Nairobi Summit (ICPD25) followed 25 years later as a follow-up on progress on of alleviation of maternal mortality. WHO set country specific targets for the SDG 5 (WHO, 2015).

These targets were:

1. Countries with baseline MMR <420 in 2010 (the majority worldwide) should reduce their MMR by at least two thirds by 2030.
2. Countries with baseline MMR >420 in 2010 should not have an MMR greater than 140 by 2030.
3. At the sub national level, countries with baseline MMR of less than 10 as at 2010, should target to achieve equity in MMR.

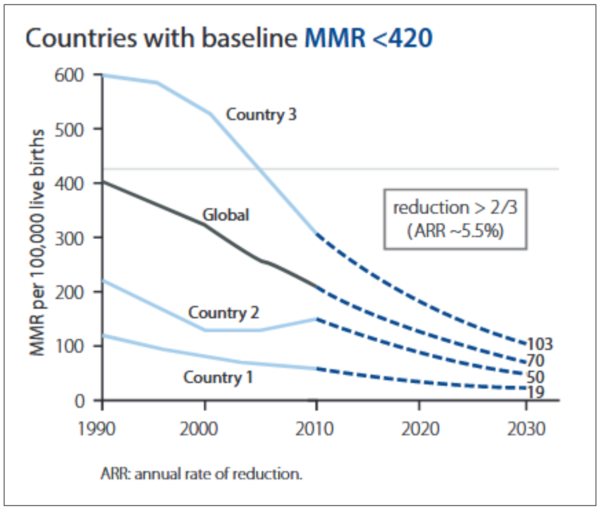


Figure 0.1: Countries with baseline MMR < 420 (WHO, 2015)

Post 2015, WHO came up with a roadmap towards achieving the SDG goal 5. They purposed to.

1. Ensure unequitable access to and quality of maternal, newborn, and reproductive health care.
2. Ensure UHC for all round maternal, newborn, and reproductive health care.
3. Strengthen health systems by collect high quality data on needs of girls and women in general.
4. Ensure accountability for improved quality of care and equity.

In November 2018, the second African Union International Conference was held in Nairobi, Kenya to discuss progress and re-strategizing on how to Improve Maternal, Newborn and Child Health (ICMNCH) (Options, 2018).

In Kenya even though maternal death rates have gone down in the past few years, pregnancy and childbirth related complications remain high and accounts for about one-fifth of deaths in women of childbearing age (362 deaths in every 100,000 live births). This is mainly contributed by about 40 percent (%) of these pregnant women who give birth outside a health facility, nor do they get assistance from skilled birth attendants. In addition to afore-mentioned measures, optimally staffed and equipped health facility that is able to provide emergency obstetric care services can mitigate maternal deaths. (Schroeder et al., 2015).

According to Dr. Gershim Asiki, an associate research scientist at the African Population for Health Research Center "Even 360 maternal deaths per 100,000 is already bad enough in the world scale and such figures cannot be ignored" (Kes, 2015).

To understand the background of this topic Google Scholar was searched, Lancet, Global Health, Medline, WHO, Embase, Directory of Open Access Journal (DOA), and PubMed; for existing literature associated with measurement of geographical assessment and access to hospital care in developing countries of Sub-Saharan Africa (SSA); from 2000 to 2018. Search terms used were: *"Geographic", OR "Emergency Obstetric care", "Maternal Mortality", OR "Spatial Access", OR "pregnancy complication" OR "EmOC Indicators" and "Health Facilities"*

AND

*Outcome * OR distribute * OR describe * OR evaluate* OR effect * OR perform* OR function * OR impact OR assess.*

2.2 Emergency Obstetric Care (EmOC)

Emergency Obstetric Care (EmOC) is a set of services provided by skilled health workers to save lives through averting deaths and disability in pregnant women and newborn (Raise, n.d.) In a life of any woman that has become pregnant, the process of labor and childbirth is the most common emergency they experience in their lifetime. These Emergency health situations contributes to about 45% of maternal deaths in developing countries. EmOC emphasizes on the identification, treatment and referral of women with obstetric conditions. It also assigns equal risk to all pregnant women. Antenatal care assists to keep a pregnant mother in proper health throughout the gestation, communicates to her about the state of progress, labor and childcare and how to detect any of the above stated emergency issues (Nmihi, 2015). For example, in case of pre-eclampsia (high blood pressure, weight gain, and stress on the kidney), regular blood pressure checks and checking presence of urine protein content, urinary tract infection (UTI) through urinalysis allows early detections that helps the normal growth of the baby in the womb (Medindia, 2015).

There are a set of recommended process that affects Maternal Health care programs on the Maternal Mortality. These are.

1. Number of Health Facilities providing essential Obstetric care per 500,000 people.
2. The ratio of Complicated Cases managed at EmOC facilities.
3. C-sections as a ratio of all births in the population.
4. Percentage of population within 2-hour travel time to the EmOC facility.
5. Ratio of all births in EmOC facilities.

What is the effort so far to alleviate maternal deaths in Kenya?

Most of efforts have been made on Predicting and preventing obstetric complications, i.e., Training traditional birth attendants; antenatal care; and Community mobilization.

Why are these efforts not still working?

Maternal deaths from complications can neither be predicted nor prevented since they are emergent. In other words, any pregnant woman from anywhere can develop complications at any given moment during pregnancy, during delivery, or during the postpartum period. However, these complications can be treated as they occur. For example, hemorrhage occurs anytime during pregnancy.

Research by (Baird, 2011) has also shown that many eclampsia cases can happen without any]# during or after delivery. Therefore, and because of this, it is necessary to be fully prepared to handle emergencies in pregnant mothers (WHO, 2012). Simply having enough EmOC (Emergency Obstetric Care) facilities is not good enough; their geographic distribution and utilization must be considered as well for efficient EmOC, there should be at-least five emergency obstetric care health facilities with ≥1 comprehensive for population of 100 000 people. BEmOC facilities should be located in such a way they can be accessed within a maximum travel time of two hours when walking or using motor vehicle.

Health facilities offering emergency obstetric care are categorized into two; those that offer "basic" emergency obstetric care (BEmOC) and "comprehensive"(CEmOC). WHO, in its handbook gave a list of signal functions that define the Basic and Comprehensive obstetric care in a pregnant woman. These signal functions are six for Basic and two additional ones for a comprehensive care. These are administration of parenteral antibiotics, getting rid of retained products (e.g., manual vacuum aspiration), uterotonic drugs administration (i.e., parenteral oxytocin), parenteral anticonvulsants administration for pre-eclampsia and eclampsia (i.e., magnesium sulphate), manual placenta removal, assisted vaginal delivery (e.g., vacuum extraction, forceps) for BEmOC. If a health facility has performed each of the first six functions in the last three months, then it qualifies to be a BEmOC. In addition to these six above, a comprehensive emergency obstetric care (CEmOC) facility includes; performance of surgery (e.g., caesarean section), and performance of blood transfusion (Paxton, Bailey, & Lobis, 2006).

BEmOC Signal Functions

1. Parenteral antibiotics administration.
2. Removal of retained products (e.g., manual vacuum aspiration).
3. Uterotonic drugs administration (i.e., parenteral oxytocin).
4. Parenteral anticonvulsants administration for pre-eclampsia and eclampsia (i.e., magnesium sulphate).
5. Manual removal of the placenta.
6. Perform assisted vaginal delivery.

CEmOC signal Functions

In addition to these six above, a comprehensive emergency obstetric care facility includes:

1. Performance of surgery (e.g., caesarean section); and
2. Performance of blood transfusion, [WHO, 2009].

Based on this, the following literature was found relevant to this study based on global, regional, and national level view.

2.2.1 Global Overview on Access to Maternal Health Facilities

As recent as the year 2008, the WHO estimated the maternal deaths to be at 358,000 globally. This approximation was computed using complete data from the civil registers for the regions where it was available, statistical modeling using country -level survey data, surveillance systems' data, census data, as well as registration of deaths data, where available (WHO, 2010). (Hogan et al., 2010) re-evaluated MM estimates was computed between 1980 and 2009.This was done by aggregating the "proportion of all female deaths that were attributable to maternal cause" from 6 important registers. The registers included data from censuses and surveys for deaths in the household; sibling history data from household surveys; and national and subnational population-based studies publications of MM. A model was then created to produce approximations of maternal mortality ratio (MMR) and maternal deaths annually between 1980 and 2008.Application of this model, (Hogan et al., 2010) approximated 342,900 maternal deaths world over in 2008.

Besides quantifying the recommended impact and process indicators by (Gottlieb and Lindmark, 2002), researchers are still grappling to qualify: why, how, when, and where women die during pregnancy and childbirth. Their Results indicate that high number of deaths of mothers happen at the final stages of gestation period, between the third trimester and the first post-partum week.

Hoj et al., (2003) states that the risk of women dying remains high for up to 6 months after child birth. This highlights the importance of skilled intra-partum and postpartum attendance. A mother can die due to direct or indirect causes. The direct causes are defined as obstetric complications of pregnancy, labor, and puerperium, or consequences of interventions related to combination of all the above.

Lovett et al,. (2002) noted that when different speeds are used for different road types, the travel times derived between a patient's address and GP's address are more realistic. Manongi et al., (2014), used self-reported speeds by local residents to measure the correlation between inpatient child mortality and hospital travel time, they assumed a fixed travel speed of 30 km/h for the buses. However, self-reported speeds are subjective and prone to computational errors, besides the results are often impossible to reproduce.

A 2006 literature review Khan et al, concluded hypertensive, diseases, hemorrhage, and infections as the major reasons for maternal deaths. The analysis by the author was however restricted by the fact that the data and the information collected was incomplete which is usually a main challenge in developing countries where causes of death are rarely recorded thus they were excluded from the study review (Khan et al., 2006). Data from Khan et al and WHO's 2000 maternal mortality approximations, was used by Ronsmans & Graham (2006) to make a regional comparison on causes of maternal mortality (Figure 2.2)

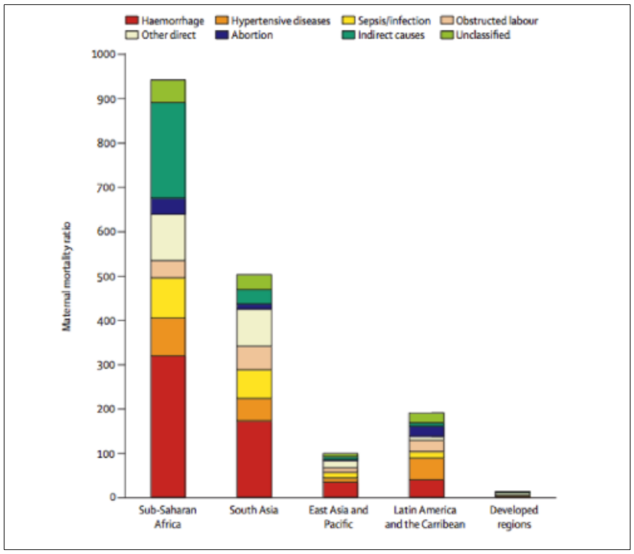


Figure 0.2: Maternal Mortality by cause, (Khan et al., 2006).

According to Lawn et al (2001), timely, appropriate, and quality medical care is a great obstacle that women with complicated labor face. These impediments are broken down into four delays, which are adapted from the original three types of delays as described by (Maine, 1997). Delay in a mother's decision to seek care, delay in diagonizing complications, delay in reaching a health facility due to lack of transportation or necessary resources, and delay in getting the necessary care at the facility.

2.2.2 Regional overview on Access to Maternal Health Facilities

Several studies have also been done on the accessibility and distribution of EmOC facilities in Africa. Chen et al. (2017) analyses the transportation schemes in relation to location of health facilities in Africa. Defining access to health care is very key for driving the emergency obstetric care motion. However, many countries in SSA have a paucity of information about the coverage of health care providers, which makes it very hard to measure accessibility gaps. In combination with population, distribution in a spatial domain to identify inequities would be very useful to decision makers.

Pearson & Shoo (2005) used Geo spatial Information Systems (GIS) to determine accessibility and usage of emergency obstetric services in Kenya, Uganda, Rwanda and Southern Sudan. She mapped the geographical distribution of these health facilities. She used data from provider and client interviews and focus group discussions and observations. A random and universal sampling method was used in selecting which health facilities were to be assessed. Local nurses and midwives were part of the data collection exercise. They discovered that the coverage of BEmOC ranged from zero to 1.1/500,000 population compared to the recommended level of 4/500,000. CEmOC services coverage ranged from 0.5-4.3/500,000 compared to the recommended 1/500,000. In their study, they noticed "oversupply" of CEmOC facilities but acute shortage of BEmOC facilities therefore sufficient life-saving services were available in urban areas and limited coverage in rural area.

Several models to measure accessibility to healthcare have also, been adopted over time. These often differ in their level of complexity as well as how they represent the reality on the ground (Luo et al 2009). Mostly, geographic accessibility models adopted are based on a component of network analysis, that uses the road segments lengths as well as the designated road speeds (depending on means of transport), to compute travel time along these different road segments.

2.2.3 National overview on Access to Maternal Health Facilities

Extensive literature also exists indicating that majority of maternal deaths in poor countries is likely go down if pregnant women had timely and access quality remedies for treating difficulties that arise throughout the gestation period, childbirth and postpartum care. Some of these studies are on the accessibility of the health facilities for timely deliveries, consistency in antenatal care, family planning, complications associated with pregnancy and much more. This revelation affirms the importance of emergency obstetric care (EmOC) in curbing an increase in maternal deaths (Echoka et al., 2013).

Ouma et al (2018), used a generic travel speed of 5 km/h by making assumptions that patients could either walk, be carried, or be transported using alternative means to the nearest road prior to obtaining motorized travel. He also focused on generating the first Pan-African Database geocoded database for the 48 countries and Islands in Africa. In his paper, however, he clearly stated that it was difficult to determine the exact services that were being offered in the health facilities of interest therefore the facilities with the exact EmOC functions could not be highlighted; rather the study was based on probability of facilities offering these services. Besides, this was done for the entire Africa.

Echoka et al (2013) in her cross-sectional study about theory versus reality of EmOC functionality at fine spatial units of Kenya argues that the basic understanding on emergency obstetric care (EmOC) is very narrow in Kenya, because limited facts and studies exist at subnational level. She further states that the EmOC process indicators have not been in cooperated into routine health information management system (HIMs) to record and track evolvement in interventions put in place for safe at either national or sub national levels in Kenya. In her conclusion she states, “In a country where maternal mortality is high, it means that decision takers are unacquainted of the level of necessity for care to save lives hence where to input interventions.

From this literature review, a conclusion was drawn that there is an inadequate number of research work that have underscored EmOC geographical assessment in Kenya at subnational or county level. From the little information available, completeness and quality of analysis are doubtful.

2.2.4 Review of BEmOC and CEmOC in relation to EmOC

EmOC, emergency obstetric care means functions necessary to save lives. EmOC can be classified as Basic EmOC (BEmOC) if they have performed seven signal functions (except cesarean section deliveries and blood transfusions) while Comprehensive EmOC (CEmOC) includes performance of all signal functions.

A literature review on obstacles to access and utilization of emergency obstetric care at health facilities in sub-Saharan Africa was done and it was concluded that there were factors affecting utilization of the EmOC services and other factors causing delays in accessing the EmOC services, (Ayele et al, 2018). Affecting utilization were factors like, social-economic factors, quality of EmOC and physical accessibility. While delays to accessing EmOC services were because of delayed seeking of EmOC services as well as delayed identification of EmOC health Facilities. Further research by (Echoka et al. (2013) was done on functionality and existence of emergency obstetric care services at the level of a district in Kenya: reported what is reported to exist versus what is existing. The objective of this study was to find out the actual presence and operation of EmOC services at the level of a district. This study revealed that strict application of WHO standards, no medical facility met EmOC requirements, given that aided delivery by forceps or vacuum was absent in any of the medical facilities. This was also so because reporting for routine data was very poor then. The conclusion to this study was that operations and existence gaps of EmOC services revealed may indicate the condition of health systems that contributes to the absence of efforts to improve maternal survival in Kenya. Latest publication on EmOC was Kenya Emergency Medical Care Policy 2020-2030 which was launched in July 2021 by Ministry of Health (MOH, 2021). It sought to find out stable funding, universal access to safe, high-quality, needs-based emergency care for all and effective governance as part of universal health coverage through policy formulation.

The two publications highlighted a great lack of knowledge around EmOC services and thus requirement for further studies that would influence implementation policies. The MOH publication being a very recent one also indicates a journey that is just beginning towards reliable EmOC services.

2.3 Challenges in Implementing EmOC services in Kenya

As noted, SSA constitutes more than half burden of maternal deaths globally. This indicates that a significant number of women are still facing challenges in accessing the necessary life-saving obstetric care.

More than 50 percent of pregnant women in Kenya are attended to by unskilled birth attendants/or at homes and this exposes them and their newborns to poor health outcomes especially when complications occur during delivery and postnatal period. Another challenge facing the Emergency care in Kenya is the low ratio of EmOC facilities to the size of population, which is at 2.7 facilities /500,000 people. This is low because it lies way below the WHO recommended minimum of 5 facilities /500,000 people. Besides, inequitable, and limited access to health services is another cause of poor emergency obstetric care across the country. Due to these and many more reasons, there is high maternal mortality in Kenya due to inaccessibility of Emergency Care at the right time for pregnant women.

2.4 Role of GIS Technologies in Analysis of EmOC services

In the year 2016, Panciera et al carried out a spatial cross-sectional study on EmOC health-seeking behavior from 39 poor urban clusters using GIS. They joined their geo-coded data of EmOC facilities to these clusters. They ran a Geo-statistical logistic regression model to quantify how time of travel determined delivery location (home or EmOC facility). The research mainly focused on urban set up of Sylhet town of Bangladesh where it was easy to notice effects of traffic congestion, high-cost implications on travel times to health facilities.

In their findings, they noticed that long time of travel to the closest EmOC facility was the key cause of inability to access emergency obstetric care in the poor settlements in urban areas of Sylhet. An increase in travel time to the nearest BEmOC or CEmOC facility by 5minutes, was associated with a 30 % reduction in the probability of delivery at an EmOC facility rather than delivery at home. They concluded that spatial evidence was the key tool to help the policy makers to strengthen the transport systems to EmOC facilities or shifting the facilities close to the poor to reduce the travel times in seeking emergency care during pregnancy.

Echoka et al. (2013) in her research, looked at a facility based cross-sectional study in Malindi District of Kenya. Her aim was to determine the spatial distribution of EmOC services at district level using GIS. They collected data from 40 health facilities that were offering maternity services especially caesarean section. 29 government owned facilities were assessed, 7 were private and 4 were owned by voluntary organizations. The ratio was 6.2 EmOC facilities to 500,000 people of EmOC facilities. However, the limitation to this study is that they did not use the strict WHO requirements since none of the facilities offered assisted delivery, by vacuum or forceps.

In his effort to inform policies in Mozambique on reducing maternal mortality, Beyes used GIS to understand the geographic impediment that pregnant women face when seeking care. He sought to embrace existing documented methodologies for determining geographic access to better care to explain why women bypass the nearest and most accessible facilities in search of Emergency Obstetric care.

They used various data sources and modelled them in GIS environment (ArcGIS V.10.3 software, Spatial Analyst, and Network Analyst extensions) to compute segments of patient's travel route to health care. The segments included; segment one, a woman would travel the longest distance in search of quality EmOC care in a preferred facility and segment 2: If the woman found out that the facility of preference did not offer her the required service, she would ask to be referred to the nearest facility that did have the service. Using these two segments, sum travel time to highest preferred care was determined.

The conclusion to this study indicated that a woman's decision to seek emergency Obstetric care was highly determined by quality of care. The challenge faced during this study was, modelling the travel times in different seasons and accounting for the delays that come with this variation.

2.5 Conceptual Framework

Figure 2.3 is a conceptual framework showing how various factors lead to maternal mortality as well as morbidity. It explains stages in the flow process leading to death or disability of an expectant woman or a mother right after she has given birth. These are Complications related to pregnancy where a woman may experience abnormal episodes of sickness during the period of pregnancy or childbirth.

These complications area an outcome of five sets of first-hand determinants: general health status of the pregnant woman; health-seeking behavior of the expectant woman, reproductive status of the expectant woman, accessibility of health services, other unknown determinants. Other distal factors include cultural and socioeconomic as well as environmental contributors.. A lot of literature revolved around the contributing factors to maternal mortality and mainly conclude that a woman's decision to seek emergency obstetric care was determined by quality of care she would receive. There was a gap in literature that looked into strengthening of emergency obstetric care as a way of curbing maternal mortality which is the question that this research seeks to answer.

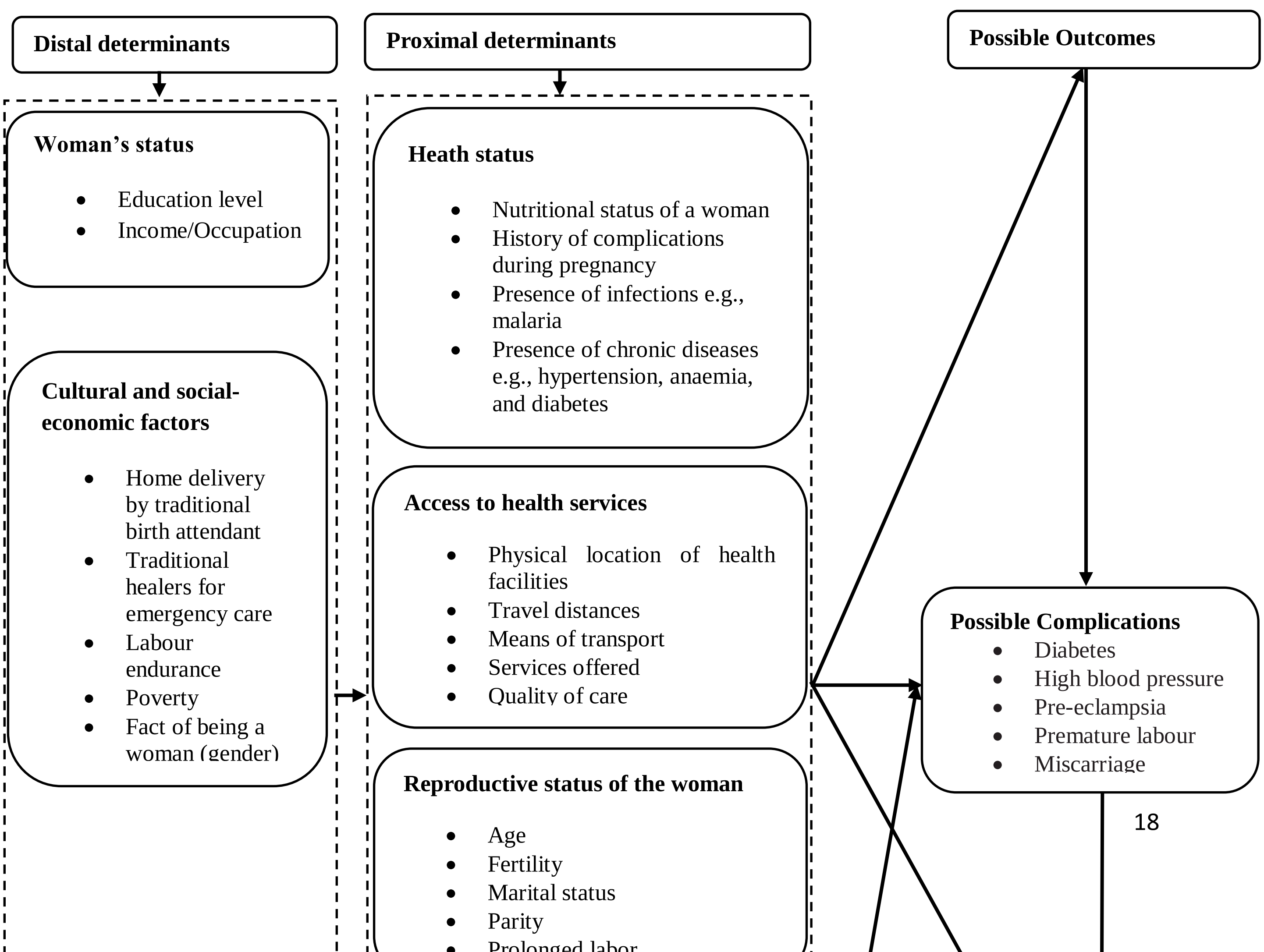


Figure 0.3:Conceptual Framework

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Area of Study

This Study was undertaken in Homa Bay County (figure 3.1). Homa Bay County is one of the forty-seven semi-autonomous governments (counties) in Kenya (Muray, 2010). It is in former Nyanza province between latitude 0^{o} 15' and 0^{o} 52' South, and longitudes 34^{o} and 35 ^{o} East. It covers an area of 4,267.1 Km^2 sand a population of 1,126,006 (2019 census), 540,288 males and 585,719 females. Its location is to the Southwestern of adjacent to the shores of Lake Victoria, neighboring Siaya County to the North. Kisii and Nyamira counties are to the East, Migori County located to the South and Republic of Uganda and Lake Victoria to the West. (Murray, 2010).

Homa Bay County headquarter is Homa Bay town. The county is politically divided into eight constituencies/ sub-counties namely, Rangwe, Homa Bay Town, Ndhiwa, Mbita, Suba, Kabondo/Kasipul, Kasipul, and Karachuonyo constituencies. Homa Bay County is further divided into 40 Electoral Wards, 86 Locations and 211 Sub-locations. The counties settlement patterns are greatly influenced by terrain, rain patterns, infrastructure development, availability of natural resources, proximity to urban centers, and security (Integrated & Plan, 2017).

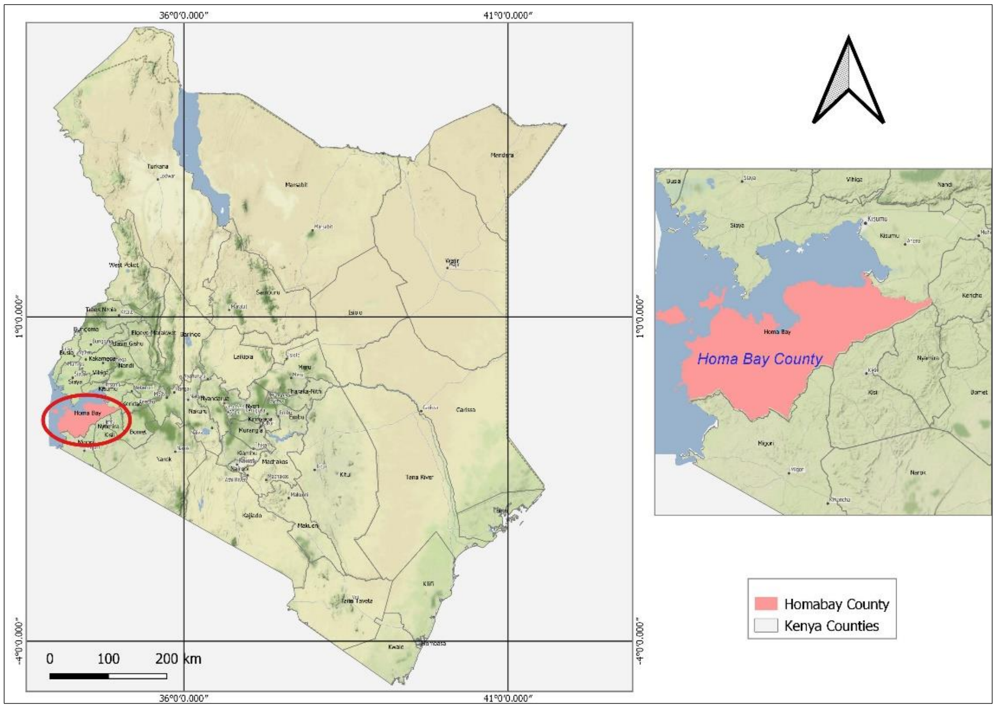


Figure 0.1: Homa Bay County

In Kenya, the health sector is made up of a public health system, which accounts for about 49% of all health institutions ran by national and devolved government Ministries of Health as well as parastatal organization has 147 public, 19 non-governmental, 28 faith-based and 32 private health facilities (Health Project, 2019, Ministry of Health, 2015).

Of all deliveries, 61.9 % of them happened in health facilities while trained health attendants attended to about 69.5 % of births in 2019 (Boah, Mahama, & Ayamga, 2018)….(Boah et. al., 2018)

In 2008, the maternal mortality stood at 577 deaths per 100,000 live births, which still exceeded the national maternal death rate, which stood at 414 deaths per 100,000 live births in the same year. The inflated rates of maternal is attributed to several factors some of which include: very low doctor to patient ratio as well as low nurse to patient ratios, demotivated health workers, lack of adequate emergency care and lack of adequate knowledge in the population among other factors.

3.2 Data sources and Tools.

As the global community moves to the Sustainable Development Goals, Africa towards agenda 2063 and Kenya towards Big Four Agenda, better use of frequent data is needed to ensure appropriate monitoring of progress toward maternal mortality and neonatal reduction targets. Data analysis, and visualization was done using Geographical Information Systems (GIS) and statistical methods, making it easier to understand and facilitate decision-making to adapt and improve programs and policies.

3.2.1 Data Sources

Combined data from a variety of sources in Table 3.1) and visually display ‘‘layers’’ of information will include the following.

Table 0.1: Datasets, their sources, and description.

Data	Source	Description
EmOC Indicators	DHIS2	Text data on conditions for EmOC facilities.
Health Facilities	DHIS2 and Kenya Ministry of Health Facility List (KMFL)	A list of health facilities in HomaBay County geocoded from google maps and Geo-names.
Population	World Pop	A 2020 raster surface of population density at 30m spatial resolution.
Administration Boundaries	HDX human data exchange	Shapefiles of Admin 0(Kenya limit), Admin 1(County boundaries) and admin 2(sub-county boundaries).

3.2.2 Tools

The following tools were used during this study

i. Quantum GIS (QGIS) software was used for spatial data analysis, geo-visualization,
ii. DHIS2 for extraction of signal functions
iii. Excel for tables and comparisons
iv. Graph hopper maps to model the travel times and distances.
v. Python for running permutations
vi. Microsoft Word for report writing.
vii. PowerPoint for presentation

3.2.3 Spatial Analysis Workflow

The Analysis workflow in this research was segmented as shown in figure 3.2

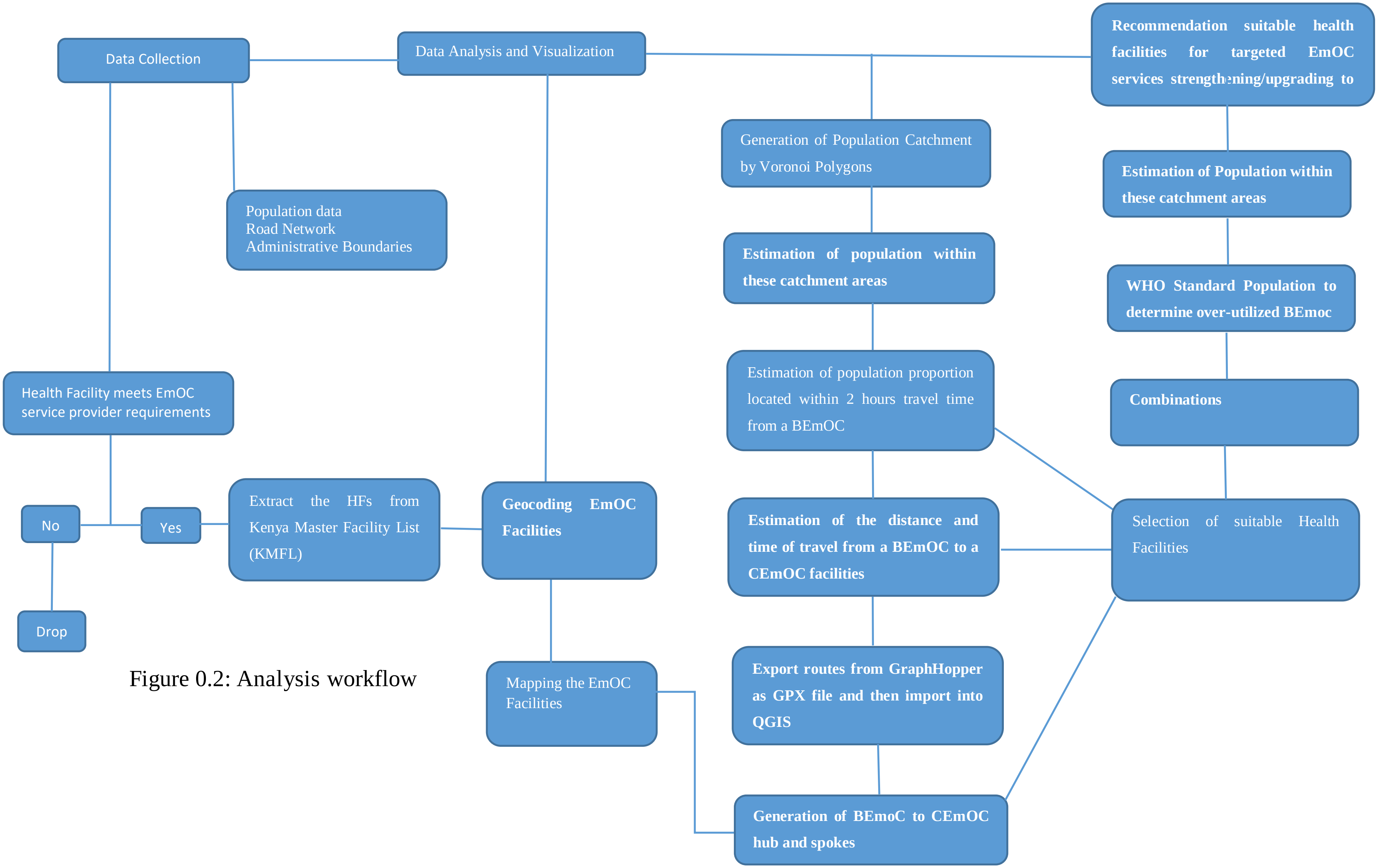


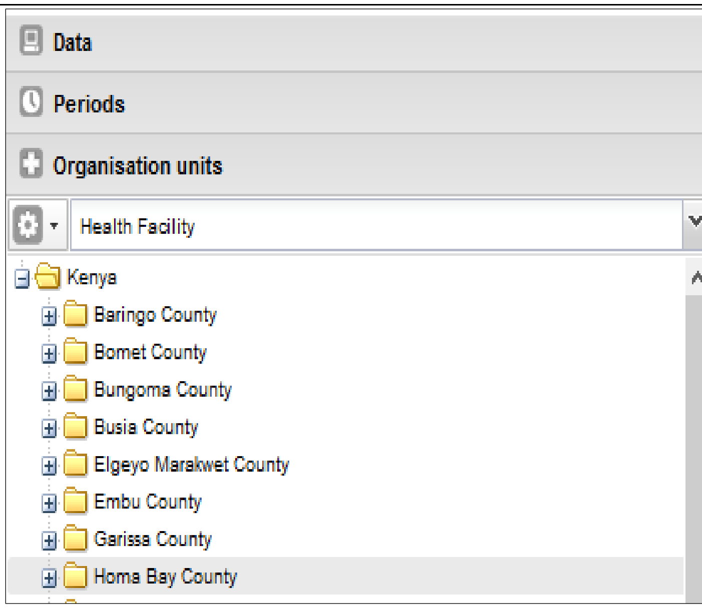
Figure 0.2: Analysis workflow

3.2.4 Data collection

A simple random strategy, a probability sampling technique was used to gather the required datasets. All the public health facilities that reported on DHIS2, 2010-2020, in Homabay County stood equal chances of being selected as a sample for this study. The advantages of this sampling method include, it presents minimal errors, and it is simple and free of bias.

The first stage involved determining and extracting the set of conditions (signal functions) that EmOC facilities must meet according to WHO handbook from DHIS2 Hospital level routine data (years, 2010 -2020*)*. Table 3.2 shows the signal functions and Table 3.3 shows the signal functions by hierarchical organization to the smallest level of data i.e., the health facility.

Table 0.2: WHO signal functions



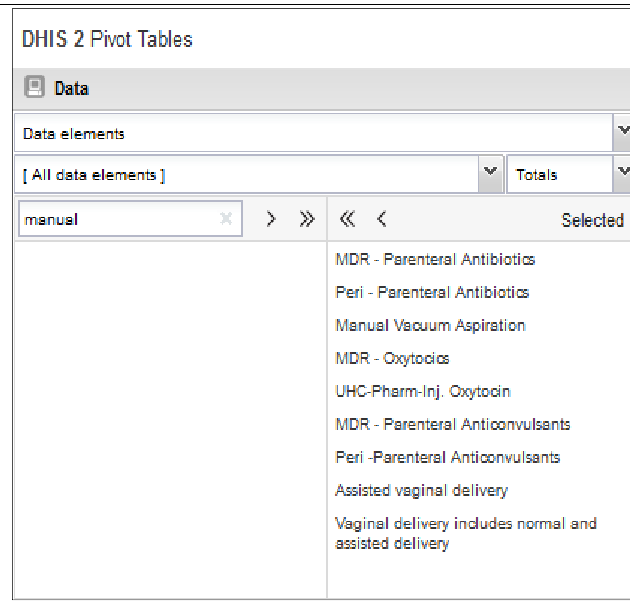
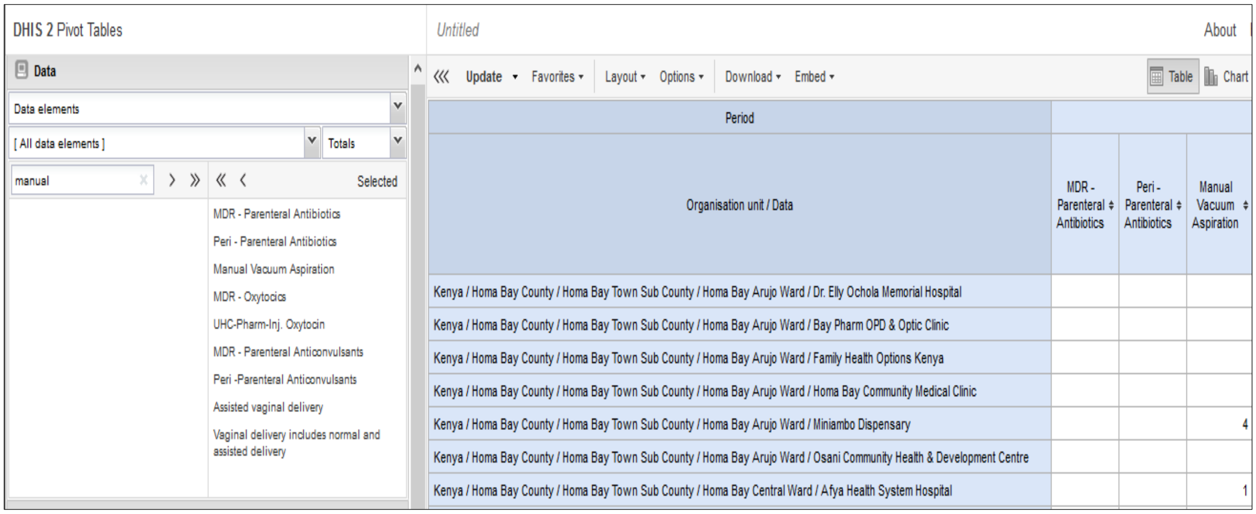


Table 0.3: Signal functions by hierarchical organization to the smallest level of data



The list of facilities that met these conditions were extracted from Kenya Master Heath Facility (KMFL).

Official Road Network was obtained from Open Street Map (OSMs). Terrain data was obtained from OSM at 30m spatial resolution within QGIS. Population data (year 2020) was obtained in roster format from World Pop. Finally, administrative boundaries data was obtained from Humanitarian Data Exchange (HDX) data exchange.

3.3 Data Analysis

3.3.1 Geocoding and mapping EmOC facilities

The health facilities of interest were then geocode using Geo-names, Google Earth and Google maps to assign coordinates to them. These (active) BEmOC and CEmOC facilities were then mapped as shown in Figure 4.1.

3.3.2 Estimation of proportion of expected deliveries within 2 hours travel time from a BEmOC to CEmOC.

Sabine et al. (2011) states that the recommended speed of patients to the health facilities, while walking and using motorcycles be 5 km/hr and 15 km/hr respectively. However, the speed of a pregnant woman when walking was estimated to be half, i.e., 2.5 km/hr and 7.5 km/hr respectively. EmOC facilities should be located so they can be accessed within a maximum of two hours. In Rural Homabay, motorized transport is rare, therefore, a geographic accessibility was computed (distance= speed x time) to be 5km and 30 km buffers respectively as shown in figure 4.

Zonal statistics tool was used to estimate population within the buffer regions, 881,003people for 30km buffer and 156,422 for 5km buffer.

Using, the two means of transport, the extracted population within 5 and 30 km buffers and the total Homabay county population as shown in Table 4.3 were used as the variables for computing the proportions of expected deliveries within 2hr travel time when walking and using motor vehicle.

Table 0.4: Parameters for computation of proportion of expected deliveries

Means of Transport	**Population within buffers**	**Total pop of Homabay County (2019)**
Motor Vehicle (30km)	881,003	1,300,000
Walking (5km)	156,422	1,300,000

According to DHIS2, the proportion of expected deliveries for HomaBay County, is at 3.3 of the total population. Therefore,

a. The proportion of expected deliveries within 2hr travel time = (**Population within buffers x 3.3) /100**

When walking, expected deliveries = (156,422x 3.3) / 100 =5,162

When using motor vehicle, expected deliveries = (881,003x 3.3) / 100 =29,073

b. The proportion of expected deliveries outside 2hr travel time = ((**Total pop of HomaBay County (2019) - Population within buffers) x 3.3) / 100**

When walking, expected deliveries = ((1,300,000 - 156,422) x 3.3)) /100 = 37,738

When using motor vehicle, expected deliveries = ((1,300,000 - 881,003) x 3.3)) /10 = 13,827

3.3.3 Estimation of the distance and time of travel from a BEmOC to a CEmOC.

This was conducted using Graph Hopper which is an open-source routing library and server written in Java to provide a web interface as shown in Figure 3.3. Maps as well as a routing API over HTTP. It can run on the Android, server, Raspberry Pi, and desktop. It calculates the ideal route to get from one place to another using publicly available map data from OpenStreetMap for different means of transport. The coordinates of the beginning point (BEmOC) and endpoint (CEmOC) were input and distance and time between the two were generated as shown in Figure 4.6.

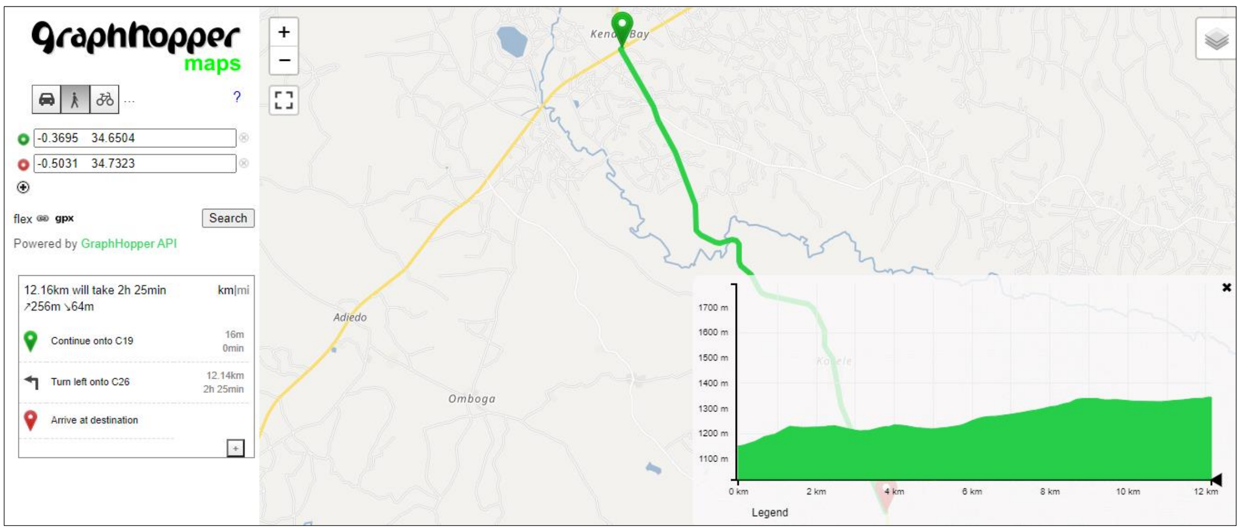


Figure 0.3: Graph hopper model for extracting distances and time of travel

The distances and time of travel extracted are as in Table 4.4

3.3.4 Generation of catchment by Voronoi Polygons and population extraction

After mapping the EmOC facilities, it was necessary to generate the health facility catchment areas that would be used in extracting the facility catchment population. This population was used in comparison to the standard WHO population that each health facility should serve. A choice to use by Voronoi polygons (these divides the geographic space into regions of influence based on facility locations) as the catchment was made because Voronoi diagram divides a 2-D plane with nÂ sites into n zones, one for each site, such that any point inside the zone is nearer to the site that owns the zone as compared to any other sites (Rezende, et al, 2000) as shown in

Figure 4.2. A 40% buffer extent was chosen as it covered the Area of Interest (AOI) most satisfactorily.

The Homabay population raster shown in Figure 4.3b was added into QGIS.This population raster was downloaded from WorldPop which combines AfriPop, AsiaPop and AmeriPop population and thus estimated at 60% accurate population source. Catchment populations corresponding to each of the existing (active) BEmOC and CEmOC facilities was extracted using the Voronoi polygons as the extents and sum of the total population as the Zonal Statistics' value. Zonal Statistics is a plugin in QGIS and ArcGIS, used to analyze the results of a thematic classification based on a vector polygon, in the sense that pixel values of a raster are aggregated based on the polygons of interest.

3.3.5 Comparison to WHO population standards

A comparison was drawn between the extracted populations for each health facility with the 100,000 people per facility, acceptable WHO standard as shown in Table 4.2. It was discovered that of all EmOC facilities only Kendu sub-district and Mbita subcounty hospitals served the expected and acceptable population.
Figure 0.4: Map of catchment populations

3.3.6 Determination of proportion of expected deliveries within 2hr travel time

It was necessary to determine the proportion of deliveries that were within two-hour travel time. This was also a qualification for strengthening the health facilities. The recommended speed of patients to the health facilities, while walking and using motorcycles be 5 km/hr and 15 km/hr respectively. However, the speed of a pregnant woman when walking was estimated to be half, i.e., 2.5 km/hr respectively. The location BEmOC facilities should be such that they can be accessed within a maximum of two hours. A geographic accessibility was computed (distance= speed x time) to be 5km and 30 km buffers respectively as shown in figure 4.4 (a).

Zonal statistics tool was used to estimate population within the buffer regions, 881,003people for 30km buffer and 156,422 for 5km buffer.
Using, the two means of transport, the extracted population within 5 and 30 km buffers and the total Homabay county population as shown in Table 4.3 were used as the variables for

computing the proportions of expected deliveries within 2hr travel time when walking and using motor vehicle as shown in figure 4.5 (b).

According to DHIS2, the proportion of expected deliveries for HomaBay County, is at 3.3 of the total population. Therefore,

a. The proportion of expected deliveries within 2hr travel time = (**Population within buffers x 3.3) /100**

   When walking, expected deliveries = (156,422x 3.3) / 100 =5,162
   When using motor vehicle, expected deliveries = (881,003x 3.3) / 100 =29,073

According to Figure 4.5, approximately, 18% (5,162) and 79.4% (29,073) of expected deliveries are within 2 hours to a BEmOC facility when walking and using a motor vehicle, respectively.

3.3.7 Extraction of distances and time of travel from BEmOC to CEmOC

Further to the analysis, it was necessary to determine the distance and time taken to travel from the BEmOC to CEmOC facilities. Distance and time were extracted from OSM and presented as shown in table 4.4.

Table 0.5: Distances and time of travel from BEmOC to CEmOC

3.3.8 Extraction of shortest route to a from BEmOC to CEmOC facility

The routes were exported from GraphHopper as GPX file, then loaded into QGIS as shown in Figures 4.7. Finally, these were visualized using Hub and Spoke model in QGIS as shown in figure 4.8. Hub and Spoke model is a form of transport topology optimization in which routes are organized as a series of "spokes" that connect outlying points (BEmOC) to a central "hub"(CEmOC).

3.3.9 Determination of number of potential health facilities for strengthening

All the public health facilities in Homabay County were used in identifying which were worth upgrading. There were nine existing EmOC facilities and to serve the entire population, the county should be having **13** EmOC facilities according to the following formula. According to WHO, 5 EmOC facilities (4 BEmOC and 1 CEmOC) should serve at least 500,000 people. Therefore, 5 EmOC facilities (4 BEmOC and 1 CEmOC) = 500,000 people, what about the total population of Homabay County (1,300,000)?

= (1,300,000 x 5)/ 500,000 = 13

Therefore, the need to upgrade 4 (13 expected– 9 existing) facilities to be EmOC

3.3.10 Suitable health facilities for targeted EmOC services strengthening

For efficient EmOC strengthening, the following set inclusion criteria should be met. Therefore, for any health facility to be upgraded to EmOC it should:

- Be able to serve at least 100 people/km square.
- Be serving more than 100,000 people
- Be at a distance >10km from existing BEmOC facility
- Be >500m from a road

Following this Criteria, nine health facilities came up from the entire list of government health facilities in Homabay County

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Identification of the gap and need for strengthening

This is in reference to objective 1 where the active EmOC facilities were determine, mapped, their catchment population extracted and compared to the expected WHO standards of how many people an EmOC facility should serve.

The results section in this report highlights the products of each stage from data collection, data analysis (spatial and statistical) to the final expected output. It is in 10 consecutive stages.

4.1.1.1 Extracted and mapped EmOC Facilities.

Table 0.1: list of the public health facilities that met the WHO signal functions.

County	Sub County	Ward	Health Facility	Type	Parenteral Antibiotics	Removal of Retained Product	Uterotonic Drugs	Parenteral Anticonvulsants	Manual Removal of Placenta	Assisted Vaginal Delivery	Blood Transfusion	Surgery
Homa Bay	Homa Bay Town	Homa Bay Central	Homa Bay County Teach. & Ref. Hosp.	CeMOC	54	602	16	1	602	10,160	718	4,658
Homa Bay	Kabondo Kasipul	Kabondo West	Kabondo Sub County Hospital	BeMOC	4	71	3	4	71	1,858		
Homa Bay	Karachuonyo	Kibiri	Kandiege Sub-District Hospital	BeMOC	3	29	2	2	29	2,331		
Homa Bay	Karachuonyo	Kendu Bay Town	Kendu Sub-District Hospital	BeMOC	5	95	60	1	95	4,266		
Homa Bay	Suba South	Gwassi North	Kisegi Sub-District Hospital	BeMOC	4	24	3	3	24	510		
Homa Bay	Suba South	Gwassi South	Magunga Level Iv Hospital	BeMOC	1	45	12	2	45	1,632		
Homa Bay	Homa Bay Town	Homa Bay East	Marindi Sub County Hospital	BeMOC	2	40	4	2	40	2,744		
Homa Bay	Mbita	Kasgunga	Mbita Sub-County Hospital	CeMOC	8	92	1	1	92	3,183	131	226
Homa Bay	Ndhiwa	Kanyamwa Kosewe	Ndhiwa Sub County Hospital	BeMOC	8	72	3	1	72	3,574		
Homa Bay	Suba South	Gwassi North	Nyandiwa Level Iv Hospital	BeMOC	3	12	2	5	12	795		
Homa Bay	Rachuonyo South	West Kasipul	Nyangiela Sub County Hospital	BeMOC	1	3	1	4	3	343		
Homa Bay	Mbita	Lambwe	Ogongo Sub-County Hospital	BeMOC	5	49	1	2	49	907		
Homa Bay	Rachuonyo South	West Kamagak	Rachuonyo District Hospital	CeMOC	10	148	9	2	148	8,100	362	1,436
Homa Bay	Rangwe	West Gem	Rangwe Sub-District Hospital	BeMOC	11	34	128	2	34	1,965		
Homa Bay	Mbita	Mfangano Island	Sena Health Centre	BeMOC	4	104	3	1	104	842		
Homa Bay	Suba South	Kaksingiri West	Suba Sub County Hospital	CeMOC	10	227	6	5	227	3,108	130	652
Homa Bay	Mbita	Rusinga Island	Tom Mboya Memorial Sub-C.Hosp.	BeMOC	4	9	2	3	9	678		

Highlighted in blue are the four EmOC facilities showing the number of times a signal function has been performed within the ten-year referenced period (2010-2010). These four health facilities have values on blood transfusion and surgery which are the extra signal functions that makes a health facility a CEmOC facility.

Highlighted in cream yellow color are the BEmOC facilities defined by presence of 6 signal functions performed within the ten-year referenced period (2010-2010).

Figure 4.1 shows the distribution of the geocoded EmOC facilities in HomaBay County.

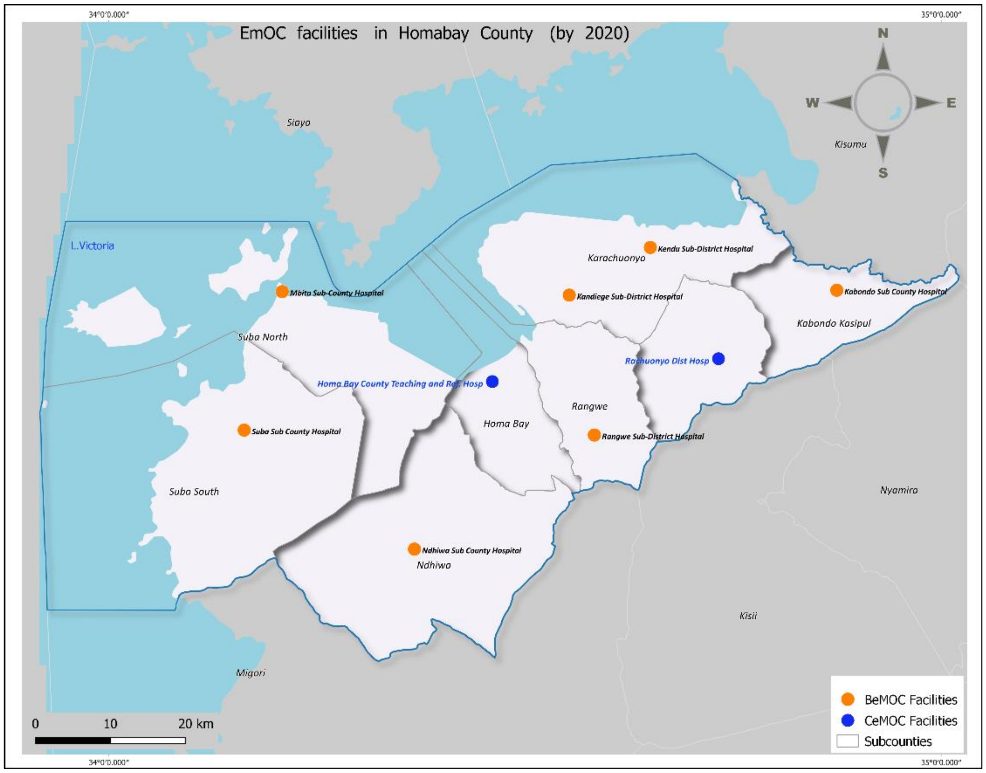


Figure 0.1: Map of Homabay EmOC facilities

The extracted EmOC health facilities were geocoded and mapped using QGIS as shown in figure 4-1. Each subcounty in Homabay County had atleast one EmOC health facility. The blue points are the CEmOC and orange are the BEmOC health facilities. In the map are also the neighboring counties of Homabay, to give a clearer picture of the county location. The purpose of the geographical representation of these health facilities was to visualize their location and also be used in catchment analysis as shown in figure 4.2.

4.1.1.2 Catchments by Voronoi Polygons

After mapping the EmOC facilities, it was necessary to generate the health facility catchment areas that would be used in extracting the facility catchment population. This population was used in comparison to the standard WHO population that each health facility should serve. A choice to use by Voronoi polygons (these divides the geographic space into regions of influence based on facility locations) as shown in Figure 4.2. A 40% buffer extent buffer was chosen as it covered the Area of Interest (AOI) most satisfactorily.

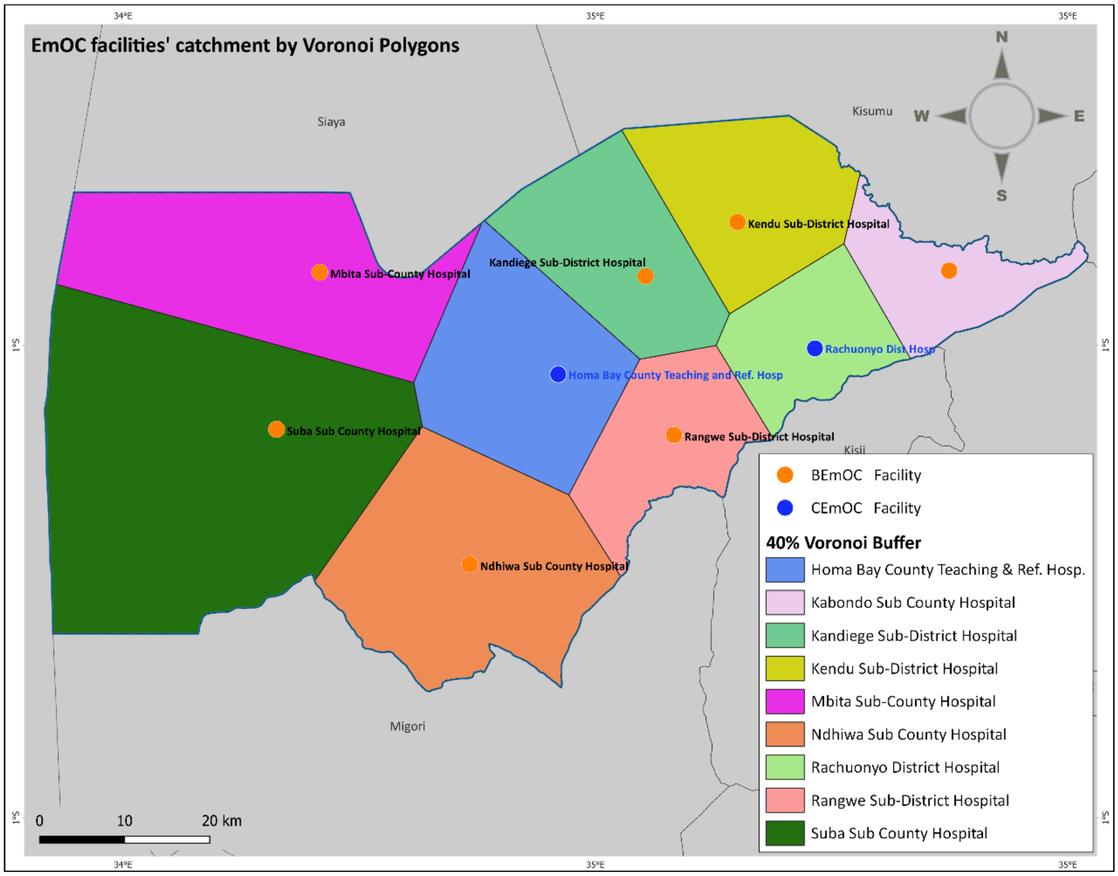
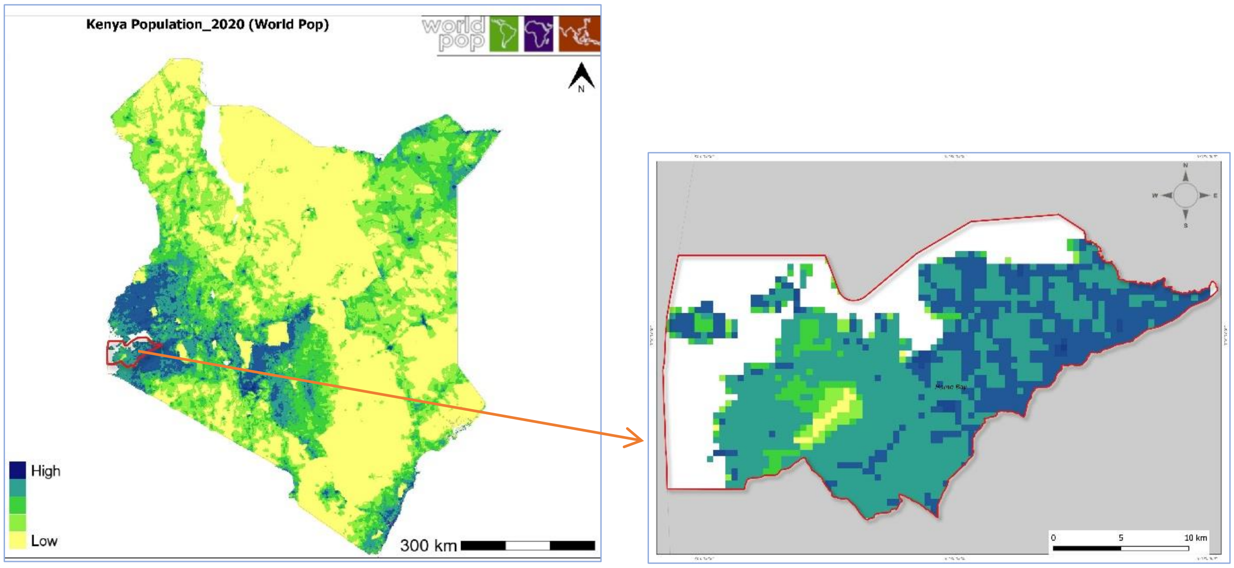


Figure 0.2: Voronoi polygons catchments

4.1.1.3 Extracted and mapped catchment population

The Homabay population raster shown in Figure 4.3b was added into QGIS.This population raster was downloaded from WorldPop which combines AfriPop, AsiaPop and AmeriPop population and thus estimated at 60% accurate population source. Catchment populations corresponding to each of the existing (active) BEmOC and CEmOC facilities was extracted using the Voronoi polygons as the extents and sum of the total population as the Zonal Statistics' value.



a *b*

Figure 0.3: Population Raster for Homabay county

4.1.1.4 Comparison to WHO population standards

A comparison was drawn between the extracted populations for each health facility with the 100,000 people per facility, acceptable WHO standard as shown in Table 4.2. It was discovered that of all EmOC facilities only Kendu sub-district and Mbita subcounty hospitals served the expected and acceptable population.

Table 0.2: Comparison to WHO population standards:

Health Facility	**Type**	**Catchment Pop.**	**WHO Standard Pop.**	**Gap from WHO (100,000)**
Kendu Sub-District Hospital	BEmOC	84,163	100,000	-15,837
Mbita Sub-County Hospital	BEmOC	74,787	100,000	-25,213
Ndhiwa Sub County Hospital	BEmOC	163,919	100,000	63,919
Homa Bay County Teaching & Ref. Hosp.	CEmOC	258,333	100,000	158,333
Rangwe Sub-District Hospital	BEmOC	129,078	100,000	29,078
Kandiege Sub-District Hospital	BEmOC	114,617	100,000	14,617
Suba Sub County Hospital	BEmOC	131,293	100,000	31,293
Rachuonyo District Hospital	CEmOC	145,215	100,000	45,215
Kabondo Sub County Hospital	BEmOC	110,005	100,000	10,005

(green)	(red)
Within WHO Standard	Exceeded WHO Standard

Figure 4.4 shows the extracted population equal or less than one hundred thousand as within acceptable WHO standards the vice versa.

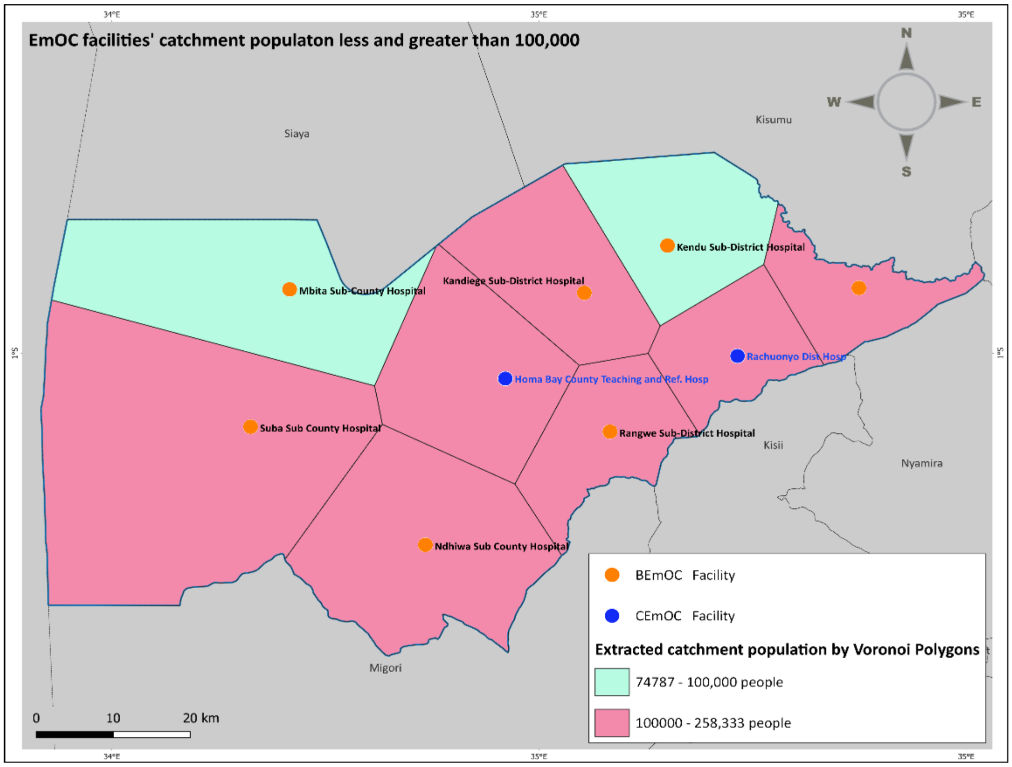


Figure 0.4: Map of catchment populations

Orange dots represent the BEmOC facilities while the blue dots represent the CEmOC facilities. The purple polygons are the catchments for the 7 health facilities that serves more than the recommended number of people i.e 100,000 per facility. The white polygons are catchments for the 2 health facilities that serve the recommended number of people.

4.1.1.5 Proportion of expected deliveries within 2hr travel time

It was necessary to determine the proportion of deliveries that were within two-hour travel time. This was also a qualification for strengthening the health facilities. The recommended speed of patients to the health facilities, while walking and using motorcycles be 5 km/hr and 15 km/hr respectively. However, the speed of a pregnant woman when walking was estimated to be half, i.e., 2.5 km/hr respectively. The location of BEmOC facilities should be such that they can be accessed within a maximum of two hours. A geographic accessibility was computed (distance= speed x time) to be 5km and 30 km buffers respectively as shown in figure 4.4 (a).

Zonal statistics tool was used to estimate population within the buffer regions, 881,003people for 30km buffer and 156,422 for 5km buffer.

Using, the two means of transport, the extracted population within 5 and 30 km buffers and the total Homabay county population as shown in Table 4.3 were used as the variables for computing the proportions of expected deliveries within 2hr travel time when walking and using motor vehicle as shown in figure 4.5 (b).

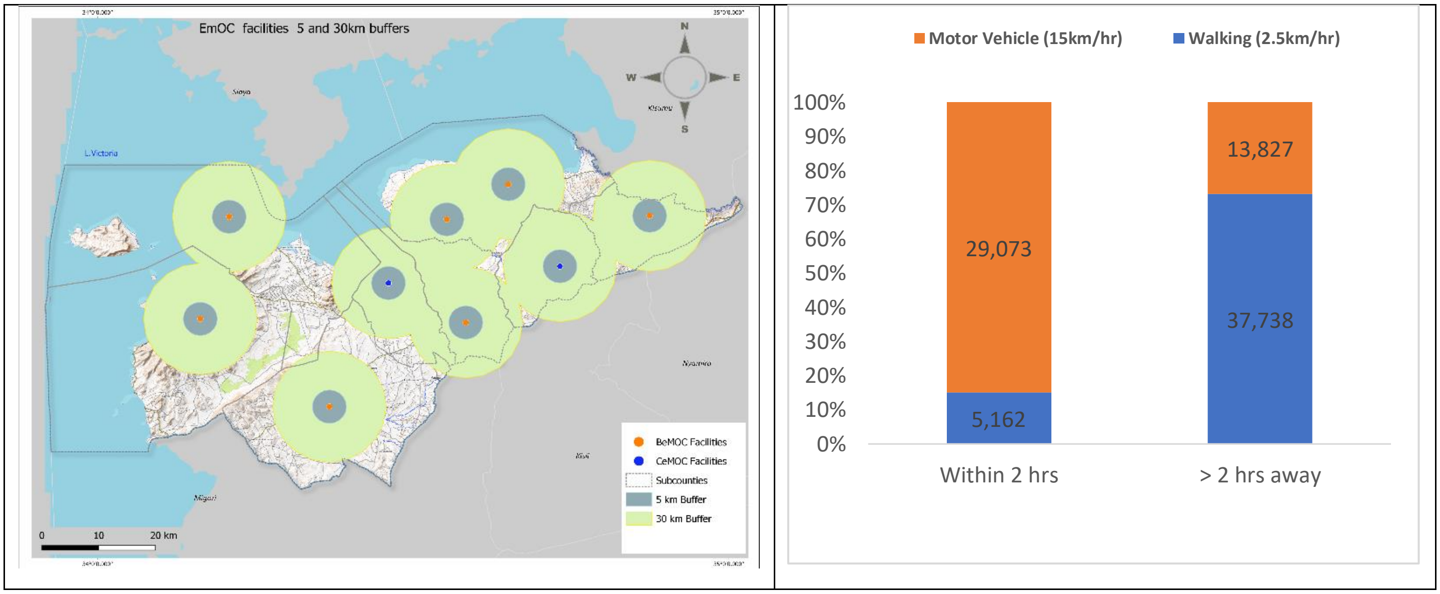


Figure 0.5: Buffers (a) and proportion (b) of expected deliveries within 2hr travel time

According to Figure 4.5, approximately18% (5,162) and 79.4% (29,073) of expected deliveries are within 2 hours to a BEmOC facility when walking and using a motor vehicle, respectively.

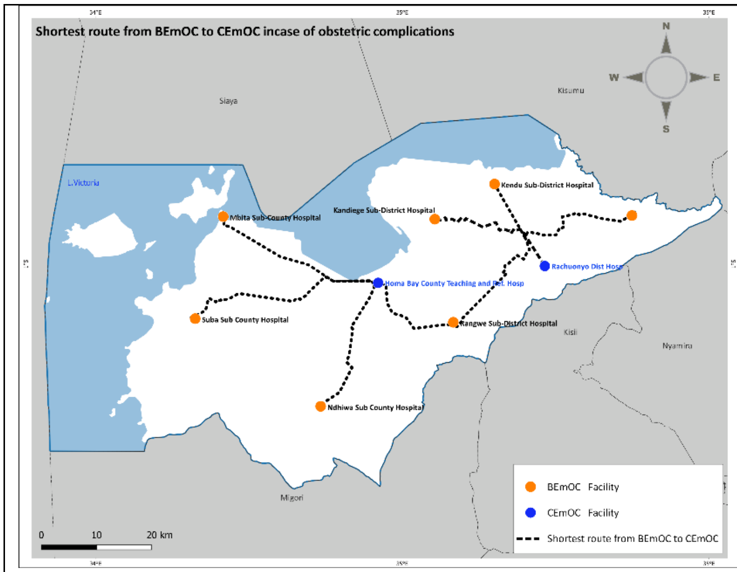
4.1.1.6 Extraction of distances and time of travel from BEmOC to CEmOC

Further to the analysis, it was necessary to determine the distance and time taken to travel from the BEmOC to CEmOC facilities. Distance and time were extracted from OSM and presented as shown in Table 4.3. Only three of the seven BEmOC health facilities are within 2-hour travel time to a CEmOC facility. Rangwe Sub-District Hospital to Homabay County Teaching and Referral Hospital, Kabondo Sub-County Hospital, Kandiege Sub-County Hospital, and Kendu Sub-District Hospital to Rachuonyo District Hospital.

Table 0.3:Distances and time of travel from BEmOC to CEmOC

From (BeMOC)	To (CeMOC)	Type	Distance (km)	Time
Mbita Sub-County Hospital	Homa Bay County Teaching & Ref. Hosp.	CeMOC	35.09	2h 21min
Ndhiwa Sub County Hospital		BeMOC	32.07	2h 7min
Suba Sub County Hospital		BeMOC	44.81	3h 32min
Rangwe Sub-District Hospital		BeMOC	22.13	1h 35min
Rangwe Sub-District Hospital	Rachuonyo District Hospital	CeMOC	49.3	3h 39min
Kabondo Sub County Hospital		BeMOC	27.22	1h 57min
Kandiege Sub-District Hospital		BeMOC	25.32	1h 50min
Kendu Sub-District Hospital		BeMOC	15.26	1hr 17min

Extraction of shortest route to a from BEmOC to CEmOC facility. The routes were exported from GraphHopper as GPX file, then loaded into QGIS as shown in Figures 4.6. Finally, these were visualized using Hub and Spoke model in QGIS as shown in figure 4.7.



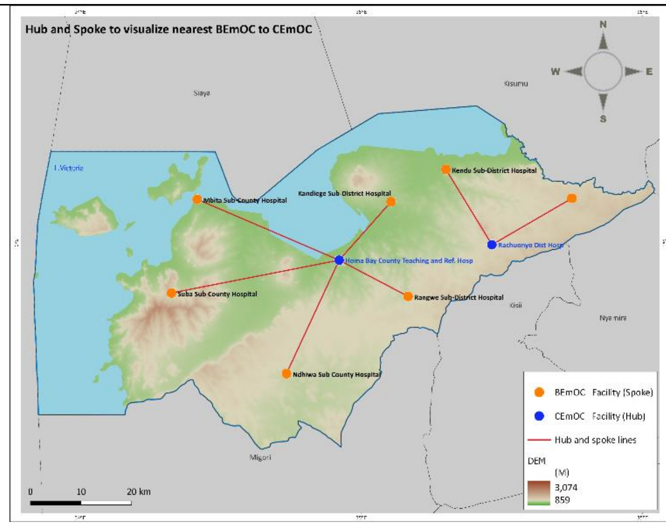


Figure 0.6: Shortest route to a CEmOC facility

Figure 0.7: Hub and Spoke showing the nearest CEmOC to BEmOCs

4.1.2 Determined number of potential health facilities for strengthening

For efficient EmOC strengthening, the following set inclusion criteria should be met. Therefore, for any health facility to be upgraded to EmOC it should:

- Be able to serve at least 100 people/km square.
- Be serving more than 100,000 people

- Be at a distance >10km from existing BEmOC facility
- Be >500m from a road

Following this Criteria, nine health facilities as shown in Table 4.4 came up from the entire list of one hundred and forty-seven government health facilities in Homabay County

Table 0.4: Potential facilities for Strengthening to EmOC

County	Sub County	Ward	Health_Facility	DHIS_Code	Population Per square km	Population = or > 100,000 people	>10km from BEmOC	> 500m from the road
Homa Bay	Ndhiwa-Kabuoch South	Pala Ward	Ponge Dispensary	14015	321	Yes	Yes	Yes
Homa Bay	Ndhiwa	Kwabwai	Kadhola Dispensary	16769	227	Yes	Yes	Yes
Homa Bay	Mbita	Kasgunga	Ang'iya Dispen/sary	13479	295	Yes	Yes	Yes
Homa Bay	Suba South	Gwassi South	Godbura Dispensary	13585	339	Yes	Yes	Yes
Homa Bay	Homa Bay Town	Homa Bay East	Pala Masogo Health Centre	19859	480	Yes	Yes	Yes
Homa Bay	Homa Bay Town	Homa Bay West	Kijawa Dispensary	16765	322	Yes	Yes	Yes
Homa Bay	Mbita	Gembe	Ponge Dispensary (Mbita)	14016	167	Yes	Yes	Yes
Homa Bay	Mbita	Mfangano Island	Soklo Dispensary	14095	164	Yes	Yes	Yes
Homa Bay	Mbita	Mfangano Island	Sena Health Centre	14075	225	Yes	Yes	Yes

Selection of 4 needed EmOC health facilities from the 7 potential health facilities

The two Health centers (Pala Masogo Health Centre and Sena Health Centre), by the fact that they offer better services, (level 3) than dispensaries (do not have in-patient facilities), qualified for the strengthening process. The seven dispensaries were taken through 21 combinations to select two extra most suitable facilities that yielded optimal ratio. This combination was a 7 (viable) combination 2 (needed) as in figure 4.8

$$ {}_nC_r = \frac{n!}{r!(n-r)!} \quad = \quad C(n,r) = ? $$

$$ C(n,r) = C(7,2) = \frac{7!}{(2!(7-2)!)} = \frac{7!}{2! \times 5!} = 21 $$

${}_nC_r$ = number of combinations

n = total number of objects in the set

r = number of choosing objects from the set

Figure 0.8: Combination computation (source: Byjus mathematics)

There were 7 Health Facilities from which 2 needed to be chosen for upgrading: Ponge Dispensary, Kadhola Dispensary, Ang'iya Dispensary, Godbura Dispensary, Kijawa Dispensary, Ponge Dispensary (Mbita), Soklo Dispensary

All their combinations with a sample size of 2 health facilities are as shown in Table 4.5:

Table 0.5 possible combinations of health facilities

Combination Number	**Combinations**
1	Ponge Dispensary + Kadhola Dispensary
2	Ponge Dispensary + Ang'iya Dispensary
3	Ponge Dispensary + Godbura Dispensary
4	Ponge Dispensary + Kijawa Dispensary
5	Ponge Dispensary + Ponge Dispensary (Mbita)
6	Ponge Dispensary + Soklo Dispensary
7	Kadhola Dispensary + Ang'iya Dispensary
8	Kadhola Dispensary + Godbura Dispensary
9	Kadhola Dispensary + Kijawa Dispensary
10	Kadhola Dispensary + Ponge Dispensary (Mbita)
11	Kadhola Dispensary + Soklo Dispensary
12	Ang'iya Dispensary + Godbura Dispensary
13	Ang'iya Dispensary + Kijawa Dispensary
14	Ang'iya Dispensary + Ponge Dispensary (Mbita)
15	Ang'iya Dispensary + Soklo Dispensary
16	Godbura Dispensary + Kijawa Dispensary
17	Godbura Dispensary + Ponge Dispensary (Mbita)
18	Godbura Dispensary + Soklo Dispensary
19	Kijawa Dispensary + Ponge Dispensary (Mbita)
20	Kijawa Dispensary + Soklo Dispensary
21	Ponge Dispensary (Mbita) + Soklo Dispensary

To select the most suitable combination, the existing EmOC facilities, the two selected health centers and each of the two combined health facilities in table 4.5 were mapped separately. These were twenty-one representations, each with thirteen health facilities. In every representation, there were two different sets of potential health facilities. Voronoi polygons were generated for each of the 21 sets and population extracted for each catchment. The set of thirteen that had population ranging around 100,000 or less people was chosen as the most suitable for upgrading. Combination number 17 was the most appropriate as shown in Table 4.6

Table 0.6: Most Suitable combination of health Facilities for strengthening

Combination number	Health Facility	Population after combination
17	Pala Masogo Health Centre	25,257
17	**Ponge Dispensary (Mbita)**	**36,842**
17	**Godbura Dispensary**	**65,025**
17	Sena Health Centre	86,376

Therefore, these two, Godbura Dispensary and Ponge Dispensary (Mbita), besides Pala Masogo and Sena health centers qualify for upgrading making a total of four as shown in Figure 4.8.

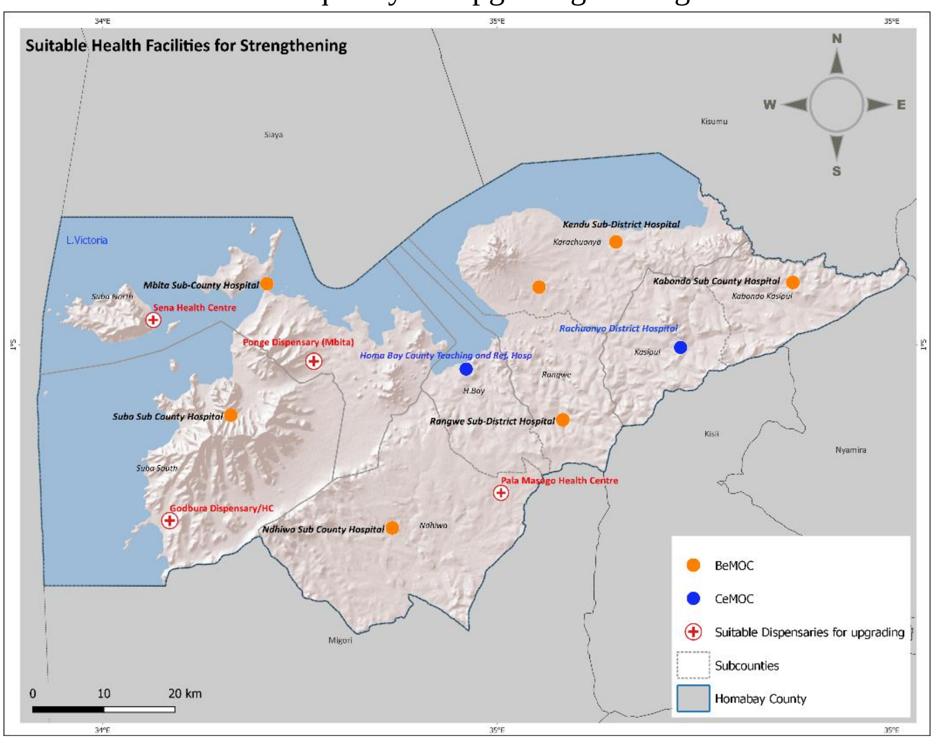


Figure 0.9: Health facilities selected for upgrading

4.2 Discussions of the results

Simply having enough EmOC facilities is not enough as their geographic distribution and utilization must also be considered. In this research, a gap was identified in that the county has only 9 EmOC facilities yet according to the WHO set standards, it should be having 13 EmOC facilities. Besides, it was discovered that only two of the existing EmOC facilities, served the required population of at least 100,000 people.

In addition to these, the existing EmOC health facility should be located such that it can be accessed within a maximum of two hours. However, only,18% (5,162) and 79.4% (29,073) of expected deliveries are within 2 hours to a BEmOC facility when walking and using a motor vehicle, respectively. This is a big gap because in relation to social economic and environmental factors, 18 % of pregnant women from the entire county population is a very small number of pregnant women who can easily access an EmOC facility in case of a complication. Besides, on extracting distance and time through the shortest rotes from existing BEmOC to a CEmOC facility, it was discovered that only three of the seven BEmOC health facilities are within 2-hour travel time to a CEmOC facility; Rangwe Sub-district Hospital to Homabay County Teaching and Referral Hospital, Kabondo Sub- County Hospital, Kandiege Sub- County Hospital, and Kendu Sub-district Hospital to Rachuonyo district Hospital.

Following this evidence of existence, it was necessary to determine which health facilities out of the one hundred and fourty-seven public health facilities currently in Homabay County. Following the selection criteria, 9 facilities qualified for strengthening to EmOC. However, only for were required to meet the basic minimum requirement. By the fact that a health center offers superior services to a dispensary, the two health centers, Pala Masogo and Sena, in the list, automatically qualified for strengthening. The remaining seven dispensaries were taken through twenty-one combinations to select the remaining two to meet the need of the four facilities. After the criteria of selection, the other two facilities that qualified for upgrading were Godbura Dispensary and Ponge Dispensary (Mbita), making a total of four.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS AND AREAS FOR FURTHER RESEACH

5.1 Conclusions

This study sought to determine if there are enough and accessible public health facilities within HomaBay County. Besides, it aimed at outlining if thery were, viable to serve as CEmOC facilities and yet this was not the case on the ground. It was discovered that several active EmOC facilities in the county was inadequate.

For such a study, three-month reference period is acceptable, but a ten-year period (2010 -2020) was adopted to take care of low patient volume which would result to one or more of the signal functions not being performed or reported in case a short period was adopted. This approach was chosen to take care of missing data and allow for comparisons across space and time.

Distances and time were extracted from GrassHopper application because it demands less data inputs (no land uses, DEMs, road networks and hydrographic network) therefore the error margins are minimal. Spatial and statistical analysis are useful tools in improvement of health care. In this report, the number of (active) BEmOC and CEmOC facilities in the county based on WHO standards were identified, geocoded, and mapped.

With reference to objective one, it was concluded that Homabay county has nine EmOC health facilities where seven are BEmOC and 2 are CEmOC. Subjecting this number to WHO requirements and the population of Homabay county (2019 census), this county is expected to have 13 EmOC facilities. There is therefore, need to upgrade four facilities to EmOC. The catchment population of these health facilities was extracted and compared to the WHO Standards. It was realized that only two EmOC facilities namely, Mbita Subcounty hospital and Kendu sub-district hospital met the requirement that a health facility should serve a maximum of 100,000 people. With reference to objective two, the map of the (active) BEmOC and CEmOC facilities showed the distribution of the existing EmOC facilities. Going by type, the CEmOC facilities were unevenly distributed as they are very close to each other and very far from some BEmOC facilities. The BEmOC facilities are also unevenly distributed creating an imbalance in coverage.

Objective three sought to analyze accessibility of BEmOC and CEmOC. Accessibility was determined in relation to distance and time taken to travel from a BEmOC to CEmOC facility as well as the ratio of pregnant women within two-hour travel time to an EmOC facility. Finally, after assessment of the existing gap, suitability of health facilities for targeted EmOC services strengthening/upgrading to BEmOC and CEmOC was carried out

5.2 Recommendations

1. Reporting in DHIS2 should be improved to ensure identification of EmOC signal functions at health facility level is not a complex process. This would also ensure that there is data completeness and good quality. Besides, this would enable analysis to be done at an interval of shorter period thus more reliable and useful results.
2. Accessibility of BEmOC and CEmOC was determined through calculation of distance and time taken to access the CEmOC from BEmOC by use of spatial analysis in Grasshopper, OSM and QGIS. However, it can be achieved at once by use of **Access MoD** 5 which is an open source WHO tool to model physical accessibility, referral times, and scaling up scenarios for public health facilities.
3. Catchment population was equally extracted using spatial means. From these combined requirements, a set of potential health facilities was achieved. Through statistical methods, combinations, the potential set was thinned to the four final health facilities that qualified for strengthening. This proved to be a complex strategy to achieve the objective of selecting the optimal facilities. Simpler method would be recommended.
4. There is need for an elaborate assessment of EmOC services in Homabay county for improvement.
5. Since the objectives of the study were achieved, it is recommended that Geo-statistical methods should be used for evidence-based decision making to improve EmOC referral services in all for the rest of the counties in bid to support the Kenya health referral strategy (2014-2018) (Ministry of Health, N.A.)
6. A more understandable feature picking method should be explored when choosing the best combination.

5.3 Areas for further Research

1. Impediments to access of EmOC facilities, such as patient`s ability to afford a specific means of transport, stock outs of necessary drugs, road condition, lack of available trained staff, or inadequate equipment and supplies should be included in future studies.
2. Future studies should also focus on separate set of criteria for strengthening BEmOC to CEmOC.
3. Besides, it would be important and informative to find out the effectiveness of healthcare care workers by cadres, towards improved emergency care.
4. Also, this kind of analysis can be carried out at loser administrative levels like sub counties and wards.
5. Research can also be done to find out effects of such studies on policy change and implementation.

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